Ecological Impact Assessment of Water Resources Utilization in Delingha City, Northwest Inland River Region

Wu Zhijun[1,2,3], Wang Yongqiang[1,2], Yan Bo[1,2*], Li Kai[1,2], and Huang Feng[3]

[1]Water Resources Department(International River Management Department), Changjiang River Scientific Research Institute, Wuhan 430010, China;
[2]Hubei Provincial Key Laboratory of Basin Water Resources and Ecological Environmental Sciences, Changjiang River Scientific Research Institute, Wuhan 430010, China
[3]College of Hydrology and Water Resources，Hohai University，Nanjing 210098，China

Abstract. In recent years, regional climate change and the intensification of human activities have made the problem of water shortage particularly prominent. It is of great significance to conduct in-depth research on the ecological environmental impact and evaluation methods caused by the use of regional water resources. Based on the characteristics and actual conditions of Delingha City in the northwest inland river region, this article established the Northwest in terms of water conservation, vegetation stability, soil conservation, and soil quality improvement in accordance. The ecological environment impact assessment index system of Delingha City in the inland river area is combined with the analytic hierarchy process and cloud theory model to establish an evaluation model. The purpose is to scientifically and reasonably evaluate the ecological environmental impact of Delingha City in the northwest inland river area. The results show that the overall impact on the ecological environment of Delingha City is the third level and is in a good state, in which water conservation and soil quality improvement are in a good state, and the other two criterion levels are in a normal state, and the annual precipitation accounts for a larger weight.

1 Introduction

The northwestern inland river region is one of the extremely fragile regions of China's ecological environment. The deterioration of its ecological environment has a great negative impact on the ecological environment and economic development of other regions(Lifeng Zhang et al., 2017). Therefore, the evaluation of the ecological environment of the inland river area in the northwest of the implementation of water resources is of great significance to the ecological protection and restoration of the inland river area in the northwest(J.P. Lv et al., 2018). Since the last century, the rapid development of cities and towns and the remarkable improvement of the level of science and technology have caused serious damage to the natural environment, and even more so that it has exceeded the renewal and restoration capabilities of nature (Frederick R et al., 2020). Evaluation methods have gradually changed from qualitative evaluation to a single ecosystem element index change, and then developed to a multi-level index evaluation system. In the existing research, Wu Huajun (Huajun Wu et al., 2006) used matter-element analysis to prove that this method is particularly suitable for evaluating the ecological environment quality of small towns in my country. Fu Aihong (Fu Aihong et al., 2009) and others used tomographic analysis to evaluate the ecosystem health of the Tarim River Basin. But so far, the model of the regional ecological environment impact assessment is not clear, and the method is relatively close to uniform. The evaluation methods are mostly fuzzy synthesis methods, back propagation (BP) neural network methods, system dynamics and other related methods. The BP neural network method has inconsistencies in the actual process. The fuzzy comprehensive evaluation method divides the fuzzy classification boundary of the index, but the calculated membership degree is easily disturbed by subjective conditions. The system dynamics method is to build a model around the problem. For the same problem, due to different models, the results will be very different. To sum up, although the existing quantitative evaluation methods and models can obtain the level of regional ecological environmental impact, they ignore the ambiguity of quantitative indicator description and the randomness of indicator value determination and grade division. Academician Li Deyi (Zhong Li et al., 2005) first proposed a cloud model that can consider both the fuzziness of evaluation and the randomness of evaluation, and it has been widely used in multi-attribute decision-making, analysis and evaluation. For example, Zhang Yang's (Yang Zhang et al., 2013)evaluation of the ecological security of land resources

*Corresponding author：[a]byanhhu@163.com; Tel.: +86-15850660117

in Hubei Province based on the normal cloud model. This study introduced the normal cloud model into the regional land resource ecological security assessment and evaluated the ecological security of land resources in Hubei Province(Kanga Idé Soumaila et al., 2019).

This paper chooses the conceptual model of cloud theory, and selects the ecological environment evaluation indicators according to the principles of science, practicability and feasibility. Establish guidelines from four aspects: water conservation, soil conservation, vegetation stability, and soil quality improvement. Each criterion layer is further divided into specific indicators to select evaluation indicators that can comprehensively and fully reflect the ecological environmental impact of the study area, and analyze and evaluate the ecological impact of water resources utilization in the northwest inland river area.

2 Evaluation System

2.1. Evaluation index set

The main ecological problems in the northwest inland river area include ecological fragility, water conservation, water shortage caused by drought, desertification, vegetation degradation, and surface fragmentaunoff increase, and select ecological benefit evaluation indicators according to the principles of science, practicability and feasibility (Jinrui Yan et al., 2003)(Table 1).

Table 1 Ecological environment assessment index set

Target layer	Criterion layer	Index layer
Ecological environmental impact assessment subsection subsubsection	Water conservation	Annual rainfall、Annual evaporation、Groundwater mineralization
	Vegetation stability	Vegetation coverage、Vegetation destruction rate
	Soil conservation	Soil water content、Soil desertification area rate、Salinization area rate of irrigation area
	Soil quality improvement	Soil PH value、Soil salinity、Soil organic matter

2.2. Threshold determination

Refer to the relevant research results of the existing national ecological impact assessment index system and the actual situation of the study area to obtain the evaluation index threshold. The threshold value of the regional ecological impact is divided into four levels: Ⅰ (deteriorating state), Ⅱ (normal state), Ⅲ (good state), andⅣ(ideal state). The detailed ecological impact of Delingha City in the northwest inland river region is obtained. The specific classification standards and corresponding grades are shown in Table 2.

Table 2 Classification standard of ecological environment impact assessment in Delingha

Index layer	Evaluation standard			
	I	II	III	IV
Annual rainfall(mm)	<100	100-150	150-200	>200
Annual evaporation(mm)	>3000	2500-3000	2000-2500	<2000
Groundwater mineralization(g/L)	>50	10-50	3-10	<3
Vegetation coverage(%)	<20	20-40	40-60	>60
Vegetation destruction rate(%)	>1	0.7-1	0.4-0.7	<0.4
Soil water content(%)	<5	5-12	12-15	>15
Soil desertification area rate(%)	>70	40-70	10-40	<10
Salinization area rate of irrigation area(%)	>30	10-30	5-10	<5
Soil PH value	8.5-9	7.5-8.5	6.5-7.5	4.5-6.5
Soil salinity(g/kg)	>5	3-5	2-3	<2
Soil organic matter(%)	<0.6	0.6-2	2-4	>4

3 Evaluation model

3.1. AHP evaluation method

The analytic hierarchy process is a combination of qualitative and quantitative analysis methods (Juan Aguarón et al., 2021;Jayanthi Marappan et al., 2020). It models and quantifies the decision-making process of complex problems. It has the advantages of system and practicality, and the calculation results are clear and clear. There are several steps in using analytic hierarchy process to determine weight:

Normalize each column vector of matrix A to get

$$\overline{w}_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, j = 1,2,3,...n \tag{1}$$

Summing $\overline{w}_{ij}$ by line, we get

$$\overline{w}_{ij} = \sum_{j=1}^{n} \overline{w}_{ij}, i = 1,2,...,n \tag{2}$$

Normalize $\overline{w}_{ij}$ to get

$$w_i = \frac{\overline{w}_i}{\sum_{i=1}^{n} \overline{w}_i} \quad (3)$$

Calculate the largest characteristic root λ of the judgment matrix A, namely

$$\lambda = \frac{1}{n}\sum_{i=1}^{n}[\frac{(\mathrm{Aw})_i}{w_i}] \quad (4)$$

To check the consistency of the judgment matrix, calculate the CI first, and then calculate the CR.

$$CI = \frac{(\lambda - n)}{(n-1)} \quad (5)$$

$$CR = \frac{CI}{RI} \quad (6)$$

In the formula, CR is the random consistency ratio. When CR<0.1, the consistency of the judgment matrix is considered to be good, indicating that the index weight is reasonable. Otherwise, the index is compared again and the judgment matrix is adjusted until CR<0.1.

3.2. Cloud model

The cloud model is a new mathematical model, which is characterized by the combination of normal distribution and membership function, and has wide versatility. Its three numerical characteristics are expected value (Ex), entropy (En) and super entropy (He). Ex is the score of the ecological environment impact assessment in Dari County, and En is the index level. The uncertainty and dispersion of each index are represented by He, which indicates the degree of correlation between the randomness and ambiguity of the index. The three characteristic value parameters (Ex, En, He) of each grade cloud are determined by the upper and lower boundary values of each evaluation index corresponding to its grade, which can be calculated by the corresponding characteristic value parameter value formula.

Since the median value of each level is the qualitative concept that best represents the level, the expected value is expressed as:

$$Ex_{ij} = \frac{(x_{ij}^1 + x_{ij}^2)}{2} \quad (7)$$

As the boundary of each level, x_{ij} belongs to both the upper level and the next level. Therefore, the membership of the boundary value to the upper and lower levels is equal, and the entropy value is obtained:

$$En_{ij} = \frac{(x_{ij}^1 - x_{ij}^2)}{6} \quad (8)$$

The size of He is generally obtained based on the entropy value and experience, which mainly reflects the thickness of the cloud layer. According to the size of En_{ij}, its value is determined through experience and experiments. Here we take 0.01:

$$He = T \quad (9)$$

According to the calculated characteristic parameter values of the three clouds and the actual evaluation index data after screening, the cloud model formula is used to determine the membership degree u_{ij} of the index i at the level j, forming a membership degree matrix $U=(u_{ij})_{n*m}$.

$$u = \exp\{-\frac{(x-Ex)^2}{2En'^2}\} \quad (10)$$

$$U=\begin{pmatrix} u_{11} & \cdots & u_{1j} \\ \vdots & \ddots & \vdots \\ u_{i1} & \cdots & u_{rj} \end{pmatrix} \quad (11)$$

Fuzzy transformation is performed between the weight set vector W and the membership degree matrix U of each evaluation object, and the fuzzy subset B on each evaluation standard is obtained. Combined with the principle of maximum membership degree, the grade with the largest membership degree is selected as the ecological environment impact assessment result.

$$B = W \times U \quad (12)$$

4 Case Analysis

4.1. Study area situation

Delingha City is located on the northeastern edge of the Qaidam Basin. The terrain in the territory is high in the north and low in the south. The terrain is a typical continental plateau climate, with an average annual rainfall of 140-190mm, strong solar radiation, sufficient sunshine, and 72% sunshine rate. Due to the high altitude, closed terrain, sparse rainfall, extremely dry climate, low temperature, windy sand, sparse desert vegetation, and fragile ecosystems in Delingha, once destroyed, it is difficult to recover in the short term. In recent years, the region's ecological construction has achieved remarkable results, and the ecological environment in some areas has been improved. However, the overall ecological environment is still very fragile. The conditions of land desertification, soil erosion, grassland degradation, wetland shrinking, and biodiversity reduction are still severe.

4.2. Ecological Environmental Impact Assessment of Delingha City in the Northwest Inland River Source Region

According to the specific calculation steps of the analytic hierarchy process described in section 3.1, the weight of each evaluation index is shown in Table 3.

Table 3 Weight of each indicator

Index layer	Unit	Weights
Annual rainfall	mm	0.3017
Annual evaporation	mm	0.0659
Groundwater mineralization	g/L	0.1151
Vegetation coverage	%	0.1978
Vegetation destruction rate	%	0.0494
Soil water content	%	0.0277
Soil desertification area rate	%	0.1046
Salinization area rate of irrigation area	%	0.0439
Soil PH value	-	0.0292
Soil salinity	g/kg	0.0184
Soil organic matter	%	0.0463

Table 4 Cloud model of each index of regional ecological environment

Evaluation index	Membership			
	I	II	III	IV
C1	(50,16.6,0.01)	(125,8.3,0.01)	(175,8.3,0.01)	(225,8.3,0.01)
C2	(3250,83.3,0.01)	(2750,83.3,0.01)	(2250,83.3,0.01)	(1000,333.3,0.01)
C3	(75,8.3,0.01)	(30,6.6,0.01)	(6.5,1.2,0.01)	(1.5,0.5,0.01)
C4	(10,3.3,0.01)	(30,3.3,0.01)	(50,3.3,0.01)	(70,3.3,0.01)
C5	(1.1,0.05,0.01)	(0.85,0.05,0.01)	(0.55,0.05,0.01)	(0.2,0.07,0.01)
C6	(2.5,0.83,0.01)	(8.5,1.17,0.01)	(13.5,0.5,0.01)	(17.5,0.83,0.01)
C7	(85,5,0.01)	(65,5,0.01)	(25,5,0.01)	(5,1.6,0.01)
C8	(35,1.6,0.01)	(20,3.3,0.01)	(7.5,0.8,0.01)	(2.5,1.6,0.01)
C9	(8.75,0.08,0.01)	(8,0.17,0.01)	(7,0.17,0.01)	(5.5,0.33,0.01)
C10	(6,0.33,0.01)	(4,0.33,0.01)	(2.5,0.16,0.01)	(1,0.33,0.01)
C11	(0.3,0.05,0.01)	(1.3,0.23,0.01)	(3,0.33,0.01)	(5,0.33,0.01)

Using the obtained relevant index data, combined with the forward cloud generator, calculate the cloud certainty of each index to form a membership matrix. Table 5 shows the membership degree matrix composed of cloud certainty of each index in Delingha, the inland river source area of northwestern China.

Table 5 Membership of the evaluation index cloud model

Evaluation index	Membership			
	I	II	III	IV
C1	0	0	0.99	0
C2	0.2	0	0	0
C3	0	0	0.06	0
C4	0	0.6	0	0
C5	0.3	0	0	0
C6	0	0	0.5	0
C7	0	0	0.02	0
C8	0	0.4	0	0
C9	0	0	0.25	0
C10	0	0	0.99	0
C11	0	0.007	0.02	0

According to the formula $B = W * R$, the subordination degree of the comprehensive evaluation of the four-level ecological environment in Delingha is calculated. According to the maximum value determination method, the evaluation grade is "good" (Table 6). The evaluation results of Delingha City using the cloud model are basically consistent with the actual situation, indicating that the evaluation model is reasonable.

Table 6 The membership degree of normal cloud model evaluation index in Delingha

Area	Membership				Grade
	I	II	III	IV	
Delingha County	0.03	0.14	0.35	0	III
Water conservation	0.02	0	0.31	0	III
Vegetation stability	0.01	0.12	0	0	II
Soil conservation	0	0.02	0.02	0	II

Soil quality improvement	0	0	0.02	0	III

5 Conclusions

This article evaluates the ecological environment impact of Delingha City. The evaluation results directly reflect the ecological environment, and the following conclusions are drawn.

(1) According to the use of cloud theory to establish a cloud evaluation model, the ecological environmental impact of the rational use of water resources in Delingha City in the northwest inland river area belongs to the membership vector R=(0.03,0.14,0.35,0) of each level. It can be seen that the region belongs to the maximum degree of membership of each level of impact is 0.35, so the overall impact on the ecological environment is the third level, that is, the ecological environment is good.

(2) From the perspective of the criterion level, water conservation and soil quality improvement are in good condition. The other two criterion levels are in a normal state. The weight of annual precipitation has a greater impact on the evaluation results. In general, the ecological environment problems in the region, Not too serious. Through a series of ecological projects such as increasing water resources and restoring vegetation, all other problems can be solved except for the slowing down of desertification.

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