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Evaluation on valley health based on set pair analysis and variable fuzzy set

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ABSTRACT

Evaluation on the valley health was donewith set pair analysis (SPA) making a relative membership function on variable fuzzy sets (VFS) in the paper. And evaluation indexes and connection number of evaluation grade were made with the SPA. And the valley health was evaluated with grade characteristics values of relative membership degree, which attached to 'classifying evaluation grade n' of Fuzzy set by calculating indicators' samples. And the evaluation results showed that the current health grade on the Zhang river was healthy, while ones on the Tangshan region in the Luan river sub-healthy.

KEYWORDS

Set pair analysis (SPA);
Variable fuzzy sets (VFS);
Valley health;
The Luan river.

INTRODUCTION

There were much more researches only considering set pair analysis (SPA) or variable fuzzy sets (VFS) now. While study were very limited, in which included both of them. Such as, the safety evaluation of earth rock dam, evaluation of stability of surrounding rock, Watershed Water Resources Security, the water environment quality of surface and river ecology health etc. were studied by some scholar[1-8]. And these researches were better combined with the SPA and the VFS, and they contributed to other relative researches. Based on the current researches and the actual situation of study sites, evaluation model on valley health based with the SPA and the VFS was done in the paper.

ASSESSMENT METHOD OF THE VALLEY HEALTH COUPLED WITH SPA AND VFS

Connection number

Connection number μ' could be made directly and indirectly. Uncertain coefficients i and j could be firstly done with reasonable method, then both of them were put into the formula of contact degree so as to get the connection number μ', when the direction method was adopted. On the basis of the theory of the SPA and existing research results, the value of the j was usually taken -1, so the μ' mainly depended on the value of the i.

The i could be directly gotten with empirical judgement method and average value method. And the main idea of the empirical judgement method was that the

FULL PAPER

value of the i could be taken, which should be based on variable characters of property from research object and researchers' purpose and experience, and made the scientific and rational value of the i. And value range of uncertain component coefficient was from -1 to 1. And empirical values usually taken were-1, -0.75, -0.5, -0.25, 0, 0.25, 0.5, 0.75, 1. While the major idea on the average value method was followed. Namely, it was assumed that difference degree of set pair was divided evenly by the uncertain component coefficient with referencing the definition of the connection degree. And the coefficient, the similar degree a in the formula of the connection degree kept at 1, and the coefficient j of the contrary degree were keeping at -1. Assumed that there were n grades, there were n-1 equal divisions between -1 and 1 by the uncertain component coefficient of differences, and points of the equal dividing value were the value of the uncertain component coefficient.

The indirect method ensuringμ'was that making the indictors of the research object as one set A1 and some grade standard Sk as another set Bk, and both of them constituted the set pairs H={Al, Bk}. Then their connection numberμ' was indirectly gotten with some formulas. In which xl was set the index value of the research object, and it was calculated with following equations.

In which there two cases. The first case was when the evaluation grade standard s1≤s2≤…≤sk, and the relative formulas were following.

$$\mu'_{A_1\sim B_1}=\begin{cases}1 & x_1\le s_1\\ 1-\dfrac{2(x_1-s_1)}{s_2-s_1} & s_1<x\le s_2\\ -1 & x_1>s_2\end{cases} \quad (1)$$

$$\mu'_{A_1\sim B_k}=\begin{cases}-1 & x_1\le s_{k-1}\\ 1-\dfrac{2(s_k-x_1)}{s_k-s_{k-1}} & s_{k-1}<x\le s_k\\ 1 & x_1=s_k\\ 1-\dfrac{2(x_1-s_k)}{s_{k+1}-s_k} & s_k<x_1\le s_{k+1}\\ -1 & x_1>s_{k+1}\end{cases} \quad k=2,3,\cdots,n-1 \quad (2)$$

$$\mu'_{A_1\sim B_k}=\begin{cases}1 & x_1\le s_{n-1}\\ 1-\dfrac{2(s_n-x_1)}{s_n-s_{n-1}} & s_{n-1}<x_1\le s_n\\ -1 & x_1>s_n\end{cases} \quad (3)$$

While the second case was when the evaluation grade standard s1≥s2≥…≥sk, and the relative formulas were following.

$$\mu'_{A_1\sim B_1}=\begin{cases}1 & x_1\ge s_1\\ 1-\dfrac{2(x_1-s_1)}{s_2-s_1} & s_1>x\ge s_2\\ -1 & x_1<s_2\end{cases} \quad (4)$$

$$\mu'_{A_1\sim B_k}=\begin{cases}-1 & x_1\ge s_{k-1}\\ 1-\dfrac{2(s_k-x_1)}{s_k-s_{k-1}} & s_{k-1}>x\ge s_k\\ 1 & x_1=s_k\\ 1-\dfrac{2(x_1-s_k)}{s_{k+1}-s_k} & s_k>x_1\ge s_{k+1}\\ -1 & x_1<s_{k+1}\end{cases} \quad k=2,3,\cdots,n-1 \quad (5)$$

$$\mu'_{A_1\sim B_k}=\begin{cases}1 & x_1\ge s_{n-1}\\ 1-\dfrac{2(s_n-x_1)}{s_n-s_{n-1}} & s_{n-1}>x_1\ge s_n\\ -1 & x_1<s_n\end{cases} \quad (6)$$

Evaluation procedure

Furthermore, the valley health would be evaluated with the assessment model of the SPA and the VFS (SPA-VFS). And its evaluation procedure was as follow.

The first step was to constitute the evaluation index system. The valley health factorswere analyzed systematically based on the existing research results and consulting experts, and the evaluation system of the valley health was constituted combined with influencing the valley health and safety factors, such as driving force, pressure, state and response. Then the evaluation index system of the valley health was made with the scientific, systematical, representative and feasible principles, and it was x1,x2,…xm, in which the m was the number of the evaluation indexes.

The second one was to make the evaluation grade standard. In which there were several aspects considered comprehensively, such as the characters of valley system, the physical meaning of the evaluation indexes, and the sustainability in nature, social and economy etc. Furthermore, the evaluation grade standard of the valley health sk was set, in which k was equal to 1,2,…ÿn or n-1 and n represent the number of the evaluation grade.

The third was to calculate the connection number $\mu'_{A_i\sim B_k}$ between the evaluation index xl and the evaluation grade standard sk with the method making the connection number in the set pairs analysis, based on the

evaluation index system and the evaluation grade standard. In which two sets Al and Bk were set respectively, and l was equal to 1,2,…, m, while k was 1,2,…,k.

The forth was to calculate the comprehensive connection number $\bar{\mu}_k$ between the samples and the evaluation standard grade k, in which

$$\bar{\mu}_k = \sum_{l=1}^{m} w_l \mu'_{A_l \sim B_k} \quad (k = 1,2,\cdots,n) \qquad (7)$$

In which wl was weight of the evaluation l, and the value of the comprehensive connection number $\bar{\mu}_k \in [-1, 1]$.

The fifth was to calculate the membership vk, in which the evaluation indexes subordinated to the evaluation standard grade k of the fuzzy set. If there existed much more opposition between the evaluation and the evaluation grade k, $\bar{\mu}_k$ would be close to 1. And the evaluation index would not tend to the evaluation standard grade k. If the identity between the evaluation index and the evaluation grade k was much more, $\bar{\mu}_k$ would be also close to 1. While the evaluation index was to tend to the evaluation standard grade k. consequently, the comprehensive connection number $\bar{\mu}_k$ was a relative difference degree of the evaluation grade k from the fuzzy sets. And its relative membership degree could be done, as following.

$$v_k = 0.5 + 0.5\bar{\mu}_k \quad (k = 1,2,\cdots,n) \qquad (8)$$

The sixth to judge the valley health grade h. If the grade character was set as judging samples' health grade h, so as to avoid distortion caused by fuzzy pattern recognition with the principle of the maximum membership degree, and improve grade judging precision

$$h = \sum_{k=1}^{n} k \left(\frac{v_k}{\sum_{j=1}^{n} v_k} \right) = \sum_{k=1}^{n} k v'_k \qquad (9)$$

In which $v'_k = v_k / \sum_{k=1}^{K} v_j \quad (k = 1,2,...,K)$ was relatively normalized membership degree, h was the weighted mean of grades. Considering the constitution of the membership degree had a randomness in the field of the fuzzy mathematics. If its value was not suitable, information on intermediate value would had a great loss. Hence, the evaluation grade of the samples could be judged with confidence criterion on recognition on the ordered evaluation set with the membership degree.

$$h_k = (r_1 + r_2 + ... + r_n) > \lambda \text{ k=1,2,3…,n} \qquad (10)$$

In which λ was confidence coefficient. Generally, its taking value interval was between 0.5 and 0.7 instead of other variable range. If λ was over the taking value interval, the evaluation results would be much more conservative. If λ was less than the taking value interval, the dependability of the evaluation results would decrease. It was taken as 0.5 in the paper.

A CASE STUDY WITH THE SPA-VFS MODEL ON THE VALLEY HEALTH

Comprehensive connection number between evaluation indexes and grade standard

The connection number could be ensured with formulas from the first one to the sixth oneabove mentioned, on the calculation method of the connection number, and the connection number between evaluation indexes and grade standard could be calculated, and the results was shown in TABLE 1.

TABLE 1 : Connection number between indexes and grade standard in the evaluation system on the valley health

Connection number	Tangshan region in the Luan river				
	B1	B2	B3	B4	B5
D	-1.00	-0.43	0.39	-0.97	-1.00
P	-1.00	-0.34	-0.47	-0.59	-0.43
S	-0.56	-0.67	-0.25	-0.52	-1.00
R	-0.74	-0.57	-0.08	-0.62	-1.00
Connection number	**The Zhang river**				
	B1	B2	B3	B4	B5
D	-1.00	0.29	-0.94	-0.35	-1.00
P	-0.52	-0.62	0.01	-0.88	-1.00
S	-0.32	-0.53	-0.76	-0.44	-0.96
R	-1.00	-0.63	-0.69	-0.33	-0.35

Comprehensive connection number between evaluation sample and assessment standards

The comprehensive connection number among standard sub-system, the general evaluation purpose and the evaluation standards, were calculated based on the above comprehensive weight. And the results were shown, as following.

System grade on the valley health evaluation and calculation of membership degree

The value of the comprehensive connection number was put into the eighth formula, and the relative

FULL PAPER

membership degree of the evaluation grade standard to the evaluation samples was calculated. To further ensure their grade characteristics, the relative membership degree calculated was normalized. And the results were shown in TABLE 3.

TABLE 2 : Comprehensive connection number of rule hierarchy and object ones in the assessment system on the river basin

Connection number	Tangshan region in the Luan river				
	B1	B2	B3	B4	B5
C1	-1.00	-0.32	0.30	-0.97	-1.00
C2	-0.34	0.06	0.04	-0.27	-0.34
C3	-0.19	-0.29	-0.14	-0.05	-0.33
C4	-0.30	-0.48	-0.21	-0.10	-0.55
A	-0.80	-0.55	-0.17	-0.60	-0.84
Connection number	**The Zhang river**				
	B1	**B2**	**B3**	**B4**	**B5**
C1	-1.00	0.32	-0.94	-0.38	-1.00
C2	-0.06	-0.06	-0.22	-0.34	-0.34
C3	-0.38	-0.09	-0.29	0.06	-0.29
C4	-0.55	-0.36	-0.41	-0.07	-0.25
A	-0.55	-0.45	-0.58	-0.54	-0.88

TABLE 3 : Grade membership of rule hierarchy and object ones in the healthy evaluation system on the river basin

Evaluation grade		Tangshan region in the Luan river				
		B1	B2	B3	B4	B5
Relative membership degree	C1	0	0.34	0.65	0.01	0
	C2	0.5	0.67	0.82	0.51	0.5
	C3	0.75	0.83	0.91	0.75	0.75
	C4	0.88	0.92	0.96	0.88	0.88
	A	0.94	0.96	0.98	0.94	0.94
Normalized membership degree	C1	0	0.34	0.65	0.01	0
	C2	0.16	0.26	0.25	0.18	0.16
	C3	0.2	0.18	0.21	0.24	0.17
	C4	0.21	0.15	0.23	0.27	0.13
	A	0.1	0.22	0.41	0.19	0.08
Evaluation grade		**The Zhang river**				
		B1	**B2**	**B3**	**B4**	**B5**
Relative membership degree	C1	0	0.66	0.03	0.31	0
	C2	0.47	0.47	0.39	0.33	0.33
	C3	0.31	0.45	0.36	0.53	0.36
	C4	0.23	0.32	0.29	0.46	0.37
	A	0.23	0.27	0.21	0.23	0.06
Normalized membership degree	C1	0	0.66	0.03	0.31	0
	C2	0.24	0.24	0.2	0.17	0.17
	C3	0.15	0.23	0.18	0.26	0.18
	C4	0.13	0.19	0.18	0.28	0.22
	A	0.23	0.27	0.21	0.23	0.06

Comprehensive evaluation on the valley health system

The relative membership degree calculated was put into the ninth formula, and the grade characteristics of sub-systems and the evaluation aim was made. And the valley health system was evaluated with the accessibility between them and the values of the evaluation grade k. Meanwhile, the grade of the evaluation aim was judged with the confidence criterion in the tenth formula. And the evaluation results were shown in TABLE 4.

TABLE 4 : Comprehensive evaluation results on valley health in subsystems

Study sites	Tangshan region in Luan river		
grading method	grade characteristics	evaluation grade	confidence criterion
driving force	2.68	3	3
pressure	2.92	3	3
state	2.99	3	3
Response	2.97	3	3
system comprehensive evaluation	2.93	3	3
study sites	**The Zhang river**		
grading method	**Grade characteristics**	**Evaluation grade**	**Confidence criterion**
driving force	2.65	3	2
pressure	2.79	3	3
state	3.08	3	3
response	3.26	3	3
system comprehensive evaluation	2.63	3	2

The results indicated that the evaluation results kept basically with the different methods, but there existed some certain difference, when the valley health was evaluated comprehensively with SPA-VFS model.

It was in Tangshan region in the Luan river that its health grade had a same result. Namely, the system and sub-system evaluation results were both sub-healthy. Similarly, the evaluation results on the sub-systems of pressure, state, response in the Zhang river was also sub-healthy. While the assessment result of driving subsystem with the confidence criterion was health, the same tothe objective comprehensive evaluation. However, it

was sub-health when the average value method was adopted. The health grade of the Zhang rive was healthy when the evaluation results based on the confidence criterion was adopted. And the comprehensive evaluation result on the subsystem of the driving force was health, while the one on the subsystem of pressure, state and response were all sub-healthy.

Generally, the comprehensive evaluation result in the study site was sub-healthy. It showed that the state of the valley heath was between healthy and unhealthy in current year. If the pressure on the valley health in the future would increase or no positive measures were made, its state would be worse than ever underconsidering the subsystems and the actual valley situation,

The above evaluation results indicated the actual situation of the subsystems in current year. Though the evaluation result of the pressure subsystem was health, its trend was close to subsystem. And it was similar to the one of the state subsystem. Especially, there was no active response to the current state. If there was no change, the valley health in the future would be worse.

CONCLUSIONS

The valuation on the valley health was done by SPA making a relative membership function on VFS in the paper. And the evaluation indicators and the connection number of the evaluation grade were built with the SPA. And the valley health was evaluated with grade characteristics values of the relative membership degree, which subordinated to the classifying evaluation grade n of fuzzy set by calculating indicators' samples. And the evaluation results indicated that the current health grade on the Zhang river was healthy, while ones on the Tangshan region in the Luan river sub-healthy.

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