RESEARCH OF REGION WATER SECURITY EVALUATION BY SET PAIR ANALYSIS

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Abstract The set pair analysis theory was applied in the water security evaluation due to the existing uncertain relationship in the system. Connection degree is used to describe this sort of uncertain problem. In the process, the indexes information of the region water security was reflected and the difficulty of weight allocation was avoided. The water security of Shandong province was evaluated by this method. The result was compared with what is got by fuzzy comprehensive evaluation and matter-element analysis. It proves that SPA analysis is simple and practical and can be a useful evaluating tool for region water security.

Key words Water Security; Set Pair Analysis; Evaluation; Connection Degree

1 INTRODUCTION

Water resources are fundamental natural resources and stratagem economic resources，hence water security is one of basic guaranteeing condition for existence and development of the region and country. Water security has been one important component of country security. On the first environment and development convention sponsored by UN in 1972, water crisis had been predicted to come after rock oil crisis and now it has appeared today, especially in the regions lack of water. On the water forum around world held in Stockholm in the August 2000, the theme was determined water security of the 21th century. After that conference, the researches concerning water security are getting more and more. The problem of water security has been one hot topic gradually, however, the holistic approach for that started later. Water security comprehensive evaluation approach is a important branch of water security. Xiajun et al.(2002) was the first one evaluating water security by the method of water resources carrying capacity. Water security evaluation model was built up according to multiple-layered and multiple-objective fuzzy optimality theory (Hanyu Ping, et al., 2004). Liru Zhong et al.(2005) analyzed water security condition of several provinces in China with matter-element analysis. Huang Qian et al.(2007) built up a modeling in light of entropy value theory and fuzzy matter-element theory to evaluate water security status of Shandong province located in the east of China. In previous water security evaluation, the solution of weight coefficient distribution are always under development. For instance, the approach of AHP to get a weight coefficient always have a limitation in which there are some subjective factors and unbelievable process to influence the facticity of evaluation result. And as a effective tool，set pair analysis(SPA) is able to avoid the trouble and therefore should be a simple and practical evaluation approach. Lu Min et al.(2006) once tried to evaluate the water security condition of some metropolises of Beijing, Shanghai and Tianjin in China utilizing SPA and gained a satisfactory results. The paper provides an application with SPA to analyze the region water security of Shandong

province.

2 SET ANALYSIS PAIR APPROACH

2.1 THE THEORY OF SPA

The conception of SPA was proposed originally by Chinese scholar Zhao Keqin in 1980's and the core theory is to deal with certain and uncertain relationship of system by dialectic analysis and mathematical treatment. SPA analyzes system problem from three aspects of the identity, the difference and the antagonism which are afflicted, influenced and restricted for each other and transformed in some condition. SPA is of an approach dealing with uncertain system problem. To research on a problem, SPA should firstly build up a set pair in the background and then undertake identical, different and antagonistic analysis aiming at characteristics of the two sets. After that, connection degree μ can be described quantitatively by.

2.2 CONCEPTION OF CONNECTION DEGREE

To a given set pair H=(A,B) composed by two sets, in the context of specific problem, all N.characteristics of set H are analyzed and S characteristics of those are in common for set A and B, P characteristics are antagonistic and the rest of characteristics which equals F=N-S-P are either in common nor antagonistic each other for set A and B. Then the connection degree is defined as follows:

$$\mu = \frac{S}{N} + \frac{F}{N} i + \frac{P}{N} j \qquad (1)$$

where μ is connection degree and $\frac{S}{N}$, $\frac{F}{N}$, $\frac{P}{N}$ are identity, difference and antagonism respectively. One can define $a = \frac{S}{N}$, $b = \frac{F}{N}$, $c = \frac{P}{N}$ and formula (1) can be transferred into the following one:

$$\mu = a + bi + cj \quad (a + b + c = 1) \qquad (2)$$

where i is coefficient of difference degree, $i \in [-1,1]$,and j is antagonism coefficient, j=-1. From formula (1) and (2), it is easily to be known that the connection degree formula simultaneously reflects the relation, influence and conversion of identity, difference and antagonism. If i equals 1, uncertainty degree converts into identity and if i is -1 uncertainty degree converts into antagonism degree. When i is given the value from the range between -1 and 1, it reflects the proportion of certainty and uncertainty. Connection degree is one of the key theory in SPA.

Based on the principle of SPA, i is given value theoretically from [-1,1]. However, to the same problem, one can give different value to i at different points of view or ideas. At present, there are several approaches of giving value. Because the paper provides assessment standards with threshold values, we only consider identity degree and antagonism degree and let i=0. Therefore, formula (1) and (2) convert into identiy-antagonism formula:

$$\mu'_{(A-B)} = \frac{S}{N} + \frac{P}{N} j = a + cj \qquad (3)$$

3 EVALUATION OF WATER SECURITY USING SPA

In this paper, provided water security system is synthesis system composing by life security, economy security, ecology and environment security, society security and management security，SPA is used in water security by building up a set pair of evaluation indexes and evaluating standards. If one evaluation index value falls in some evaluation grade, it's regarded as identical, whereas it is opposite.

Provided values of S indexes belonging to some grades and values of P indexes belonging to other grades in total N evaluation indexes, in light of formula (3) connection degree of water security

evaluation is built up, and the values of a , c and μ is analyzed. By the above steps, we can judge the water security condition.

4 APPLICATION

Considering of characteristics of water security and background of evaluated region, evaluation index system of water security was built. Twenty-three indexes including life security, economic security, ecological and environmental security, society security and management security was chosen and had a comprehensive evaluation by the means of SPA. After gaining the evaluation result, we would have a discussion about it comparing with the result in reference [5] by other means in the following subsection.

Table 1 Water security evaluation indexes and characteristic values of Shandong province

		Life security			Economic security				
	Evaluation index system	Quantity of water resources per capita (m^3)	Quality of drinking water (%)	Quantity of domestic water per capita (L)	GDP of per capita (Yuan)	Repeated utilization ratio of industrial water(%)	Crop amount of per capita (Kg)	Effective irrigation area(hm^2)	Industrial water amount of 10 thousand Yuan(m^3)
Threshold value of evaluation standard	Index value in the year of 2005	344	90.0	71	11618	62	377.0	0.05	16.0
	Extremely safe	1100	99.5	220	15000	90	530.0	0.07	5.0
	safe	875	97.5	180	13458	80	471.5	0.06	16.5
	Basically safe	625	94.5	140	10670	70	399.5	0.05	30.0
	unsafe	375	91.5	100	7882	60	360.0	0.04	43.5
	Extremely unsafe	225	88.5	60	5000	50	333.0	0.03	63.5

		Management security				Ecological and environmental security				
	Evaluation index system	Utilization coefficient of irrigation water	Utilization ratio of urban water pipe net(%)	Educational background structure of staff	Investment proportion of water moderniza-tion(%)	Water polluted ratio(%)	Quality of surface water(%)	Quality of underg ro-und water(%)	Quality of guest water (%)	Ratio of soil salinization (%)
Threshold value of evaluation standard	Index value in the year of 2005	0.55	80.00	0.60	1.00	0.44	70.0	100.0	95.0	1.0
	Extremely safe	0.80	97.00	0.95	6.00	1.00	98.0	98.0	95.0	0.5
	safe	0.70	93.35	0.85	4.75	4.35	82.5	92.5	82.5	2.5
	Basically safe	0.65	90.05	0.75	3.25	6.60	67.5	87.5	67.5	5.5
	unsafe	0.60	86.70	0.65	1.75	8.85	52.5	82.5	52.5	8.5
	Extremely unsafe	0.50	81.00	0.55	0.50	12.25	38.0	75.0	30.0	13.0

Continued

	Evaluation index system	Social security					
		Proportion of water disaster (%)	Ratio of drought disaster area (%)	Ratio of flood area (%)	Water investment proportion in GDP(%)	Urban flood control standard(%)	River flood control standard(%)
Threshold value of evaluation standard	Index value in the year of 2005	2.48	49.00	5.30	0.55	50	20
	Extremely safe	0.50	3.00	1.00	1.50	97	97
	safe	1.60	9.15	3.34	0.87	91	91
	Basically safe	2.80	17.45	5.51	0.61	83	83
	unsafe	4.30	25.80	8.17	0.34	75	75
	Extremely unsafe	5.50	34.00	13.00	0.15	65	65

According to the data in table 1, we can calculate the connection degree of life security, economic security, ecological and environmental security, society security and management security in water security system layer and those of Shandong province in the year of 2005, using formula (3). The calculation process was solved by program Matlab6.0. The result is showed in table 2.

Table 2 Water security evaluation connection degree of Shandong province in 2005

Grade System level	Extremely safe	safe	Basically safe	unsafe	Extremely unsafe
Life security	−1.0000	−1.0000	−1.0000	0.3333	0.3333
Economic security	−1.0000	−0.6000	−0.2000	−0.2000	−1.0000
Management security	−1.0000	−1.0000	−1.0000	−0.5000	1.0000
Ecological and environment security	−1.0000	−1.0000	−0.6000	−1.0000	−1.0000
Social security	−1.0000	−1.0000	0.0000	−1.0000	−1.0000
Water security of Shandong province in the year of 2005	−1.0000	−0.9130	−0.4783	−0.5652	−1.0000

5 ANALYSIS OF RESULT

From table 3, we see that the maximum value of connection degree of the water security grade is -0.4783. It indicates that the water security condition is basically safe which is the same as that evaluated by fuzzy comprehensive evaluation model and fuzzy matter-element model in reference[5]. Therefore, the SPA evaluation approach is reliable.

From the connection degree of every system layer, we can see that the life security including water quantity of per capita, quality of drinking water, quantity of domestic water of per capita was evaluated to be unsafe(0.3333) or extremely unsafe(0.3333), for water resources is in shortage in Shandong province. The management security including utilization coefficient of irrigation water, utilization ratio of urban water pipe net, educational background structure of management staff, investment ratio of water modernization is was evaluated to be unsafe(-0.5000), for the mode of using water now is extensive and wasted， and measures as well as implements of saving water is inadequate. Whereas, the economic security, ecological and environmental security and society security are rather better comparably and in the class of basically safe.

6 CONCLUSION

SPA analysis can be viewed as a method focusing on connection degree but it is differentiated from existing uncertainty approach e.g. classical probability theory, vagueness set or fuzzy set. With this approach, the information embedding in research problem can be dug by using

identity, difference, antagonism and connection degree. Many cases in different research domains prove that SPA analysis is simple, easily-mastered and reliable, and can be seen as one practical tool of evaluation and classification decision, especially in water security evaluation.

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