

Vulnerability Assessment of Water Environmental System in Beijing-Tianjin-Hebei (BTH) Region

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Abstract—Rapid population growth and increased economic activity impose an urgent challenge on the sustainability of water environmental system in Beijing - Tianjin - Hebei (BTH) region. Water environmental system is a complex uncertain system under change which is of vulnerability. But water environmental system vulnerability research is relatively weak. In this study, we present a multifunctional hierarchy indicator system for the performance evaluation of water environmental vulnerability (WEV). This paper constructed the assessment index system of water environment system based on PSR model which contained 24 indicators considering social-economy conditions and situation of water resources. Weights were calculated by the method of analytic hierarchy process (AHP) and entropy, and fuzzy set pair analysis assessment method (FSPAAM) was applied to evaluate the degree of vulnerability in the Beijing - Tianjin - Hebei region. The vulnerability degree in Beijing was from III to II, while in Tianjin was mostly III (except IV in 2013), and in Hebei was all III. Finally, we make some suggestions for water environmental management in BTH.

Keywords—Water environment vulnerability; Beijing - Tianjin - hebei; Assessment; Indicator system; Fuzzy set pair analysis

I. INTRODUCTION

Water environmental system plays a significant role in regional sustainable development. The influencing factors to water environmental vulnerability are various. These factors influence each other and constitute a system which has the features of hierarchy, uncertainty and complexity [1]. So, the assessment of water environmental vulnerability is the process of multiple objective decision-makings, in which mathematics model needs to be established to provide scientific basis for the sustainable water environmental management. General assessment methods included fuzzy set theory, artificial neural network model, analytic hierarchy

process and so on [2-4]. Those assessment methods have some difficulties for assessing complex uncertain water resources system vulnerability rationally. Set pair analysis (SPA) theory was proposed by Keqin Zhao in 1989[5, 6]. The theory has advantage to deal with uncertainties compared with other models. Therefore, to solve the above uncertain complexity assessment problems of water environmental vulnerability, we first establish a hierarchy indicator system for the performance assessment of water environmental vulnerability (WEV) based on the Pressure-State-Response (PSR) model. And then we build an fuzzy set pair analysis assessment method (FSPAAM) for assessing water environmental vulnerability, in which weights are determined by the analytic hierarchy process (AHP) and entropy method, and the assessment degrees are determined by the fuzzy set pair analysis (SPA) theory. Finally, FSPAAM is used to assess the degree of water environmental vulnerability in Beijing, Tianjin and Hebei region.

II. FUZZY SET PAIR ANALYSIS ASSESSMENT METHOD (FSPAAM) FOR WEV ASSESSMENT

We propose a multiple criteria decision making method on water environmental vulnerability (WEV) assessment. It includes the assessment indicator system and assessment criteria. The index system was established with 24 indicators based on Pressure-State-Response (PSR) model. The indicators are shown in Table 1. The construction of assessment index system is divided into four steps. First, select appropriate indices based on the PSR model. Second, the degree of water environmental vulnerability can be divided into 5 grades: lowest (1), lower (2), middle (3), higher (4), highest (5). Finally, we gave an assessment method for WEV. In this study, we gave a fuzzy set pair analysis assessment method (FSPAAM) for WEV assessment. Weights were calculated by the method of

analytic hierarchy process (AHP) and entropy. And fuzzy set pair analysis assessment method (FSPAAM) was applied to evaluate the degree of vulnerability in Beijing, Tianjin and Hebei (BTH) regions. Figure 1 shows the basic flow path in the process of fuzzy set pair analysis assessment method (FSPAAM) for WEV assessment.

TABLE I. THE ASSESSMENT INDICATOR SYSTEM

Pressure index	State index	Response index
No.1 Amount of water resources per unit area	No.8 Emission concentration of $\text{NH}_3\text{-N}$	No.16 The capacity of Industrial wastewater treatment
No.2 Utilization ratio of water resources	No.9 Emission concentration of COD	No.17 Proportion of agricultural water-saving irrigation area
No.3 Ten-thousand yuan GDP water consumption	No.10 Green coverage rate	No.18 Proportion of ecological water
No.4 The discharge of domestic sewage per person	No.11 Consumption of daily water per person	No.19 Proportion of water and soil erosion control area
No.5 Average annual precipitation	No.12 The average person possession of water	No.20 Environment investment ration
No.6 Floods affected area ratio	No.13 Wetland area ratio	No.21 Industrial water recycling rate
No.7 Proportion of agricultural water use	No.14 Population density	No.22 Urban sewage treatment rate
	No.15 Per capita GDP	No.23 The capacity of sewage treatment
		No.24 The sound level of the legal system

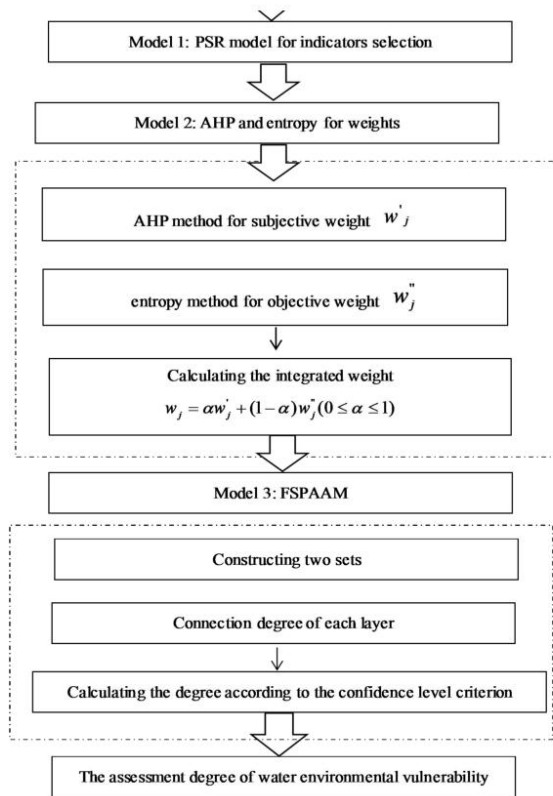


Figure 1. Fuzzy set pair analysis assessment method (FSPAAM) for WEV assessment

III. CASE STUDY

In this study, we use Beijing-Tianjin-Hebei (BTH) region as a case. BTH is the nation's political, economic and cultural center in China. With the rapid increase of population, the acceleration of urbanization and the rapid

development of economy and society, the water environment become more and more severe, especially during the past decades. And the same time, precipitation is one of the most important factors related with climate and water environment system. All the data are from The Editorial Board of The Blog of China Environment, China Statistical Yearbook, and the National Climate Center (NCC) of the China Meteorological Administration (CMA) in this study. Table 2 gives the grades of vulnerability in Beijing, Tianjin and Hebei by using the above fuzzy set pair analysis assessment method (FSPAAM).

TABLE II. THE GRADES OF VULNERABILITY IN BEIJING, TIANJIN AND HEBEI

Time	Beijing	Tianjin	Hebei
2010	3	3	3
2011	3	3	3
2012	2	3	3
2013	2	4	3
2014	2	3	3

Table 2 shows the grades of vulnerability in Beijing, Tianjin and Hebei was getting better. To be specific, the degree of vulnerability in Beijing was from III (middle) to II(lower),while in Tianjin was III(middle)mostly (except IV in 2013),and in Hebei was all III(middle). It reflects that the situation of water environment in Beijing shows a trend of improvement, while the grades in Tianjin and Hebei remain stable. In order to improve the situation, it is necessary to build a water-saving society, develop unconventional water resources and strengthen the protection of water environmental system.

IV. CONCLUSION

In this study, we present a hierarchy indicator system for the assessment of water environment vulnerability. We gave a fuzzy set pair analysis assessment method (FSPAAM) for WEV assessment. Weights were calculated by the method of analytic hierarchy process (AHP) and entropy. And fuzzy set pair analysis assessment method (FSPAAM) was applied to evaluate the degree of vulnerability in Beijing, Tianjin and Hebei (BTH) regions. And the main conclusions are as follows:

(1) The degree of vulnerability in Beijing was from III to II, while in Tianjin was III mostly (except IV in 2013), and in Hebei was all III.

(2) Compared with present situation, the degree of vulnerability in Beijing-Tianjin-Hebei Region was getting better due to efficient measures like decline in water consumption.

(3) For further improvements, it is necessary to build a water-saving society, develop unconventional water resources and impel the integration of water environment protection in the three regions.

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