The Comprehensive Evaluation of Rural Drinking Water Security in Yunnan Province

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Abstract

In view of the uncertainty and ambiguity of the rural drinking water security, the paper built the fuzzy matter-element model based on the entropy weight, combining entropy theory with fuzzy matter-element. And on that basis, in Yunnan province, for instance, the rating system was constructed with six indexes such as the proportion of people without guarantee of water and per capita water consumption; the results show that the state of rural drinking water security overall on low level in Yunnan provides the evidence of constructing rural drinking water security safeguard measure.

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Keywords: rural drinking water security; entropy theory; fuzzy matter-element; rating system;Yunnan province

1. Introduction

The development pattern in china, is urban and rural asymmetric for a long time. There are still 170 million people who live in rural areas across the country having the safe problem of drinking water which has not been solved as planned yet by 2010. As the rural drinking water security has proved to be a bottleneck to restrict rural development, it is inevitable to resolve the security issues of rural drinking water for new socialist countryside construction. And the theoretical basis to solve the problem is the scientific and reasonable evaluation methodology.

It is a vague definition of what circumstance the rural country water security is, and people have not
found an absolute standard. Now the evaluation methodology of rural drinking water include synthetical index method multiple-factor comprehensive evaluation method, attribute distinction method, fuzzy mathematical method, analytic hierarchy process (AHP), and information entropy method etc[1]. When we evaluate two adjacent security level of drinking water, however, it is difficult to accurately judge which level it belongs to and to confirm all factors’ weight objectively. Based on matter-element analysis and combining the fuzzy set and closeness degree, we introduced entropy method into the calculation of the weight to build the fuzzy matter-element model, which is applied to the comprehensive evaluation of rural drinking water safety in all districts of Yunnan Province.

2. Presentation of fuzzy matter-element model

2.1. Fuzzy matter-element

Given the name of the object M, it’s magnitude about characteristic C is v, regard the order triple R = (M, C, V) as basic element, matter-element for short. If the magnitude of v is fuzzy, so we call the matter-element R fuzzy matter-element. Generally we combined n-dimensional matter element of M things to compose the composite fuzzy matter-element. To a specific drinking water safety evaluation system, there are m evaluated objects, and each of them has n evaluation index. Now we use X to stand for composite fuzzy matter-element, and Mj represents the j-th evaluated object, Ci stands for the i-th evaluation index of the j-th evaluated object, denoted by [2]

\[
X_{mn} = \left\{\begin{array}{ll}
M_j \\
C_i \\
u(x_{ij})
\end{array}\right.
\]

(1)

Where: i=1, 2, ..., n; j=1, 2, ..., m.

2.2. Standard fuzzy matter-element and difference square composite fuzzy matter-element

As a result of each evaluation index value has positive and negative effects on fuzzy comprehensive evaluation results, it is should be co-rotating treatment before modeling.

\[
\mu_{ij} = \begin{cases}
\frac{x_{ij}}{\max x_{ij}} & \text{positive indexes} \\
\frac{x_{ij}}{\min x_{ij}} & \text{negative indexes}
\end{cases}
\]

(2)

Maximum or minimum evaluation of the object constructed a new standard fuzzy matter-element R0mn, here we take the maximum value 1.

\[
R_{0mn} = \left\{\begin{array}{ll}
M_0 \\
C_i \\
u(x_{0ij})
\end{array}\right.
\]

(3)

Let be

\[
\Delta_j = [u(x_{0j}) - u(x_{ij})]^2
\]

(4)

Construct difference square composite fuzzy matter-element, namely

\[
R_\Delta = \left\{\begin{array}{ll}
M_j \\
C_i \\
\Delta_j
\end{array}\right.
\]

(5)

2.3. Determining weights based on entropy method

According to the entropy theory and literature[3,4], calculate weight coefficient as follows:
(1) To construct the judgment matrix \([ R = (x_{ij})_{mn} \mid i=1, 2, \ldots, n; j=1, 2, \ldots, m]\) of N evaluation indexes of m objects.

(2) After normalization processing we obtain normalized judgment matrix B.

\[
b_{ij} = \frac{x_{ij} - x_{\min}}{x_{\max} - x_{\min}}
\]

Where: \(x_{\max}, x_{\min}\) represent different things respectively in the best and worst, of which bigger is better.

(3) M evaluation objects in n evaluation index which determine the evaluation index of entropy.

\[
H_i = \frac{1}{\ln m} \sum_{j=1}^{m} f_{ij} \ln f_{ij}
\]

\[
f_{ij} = \frac{1 + b_{ij}}{\sum_{j=1}^{m} (1 + b_{ij})}
\]

\[
i=1, 2, \ldots n; j=1, 2, \ldots, m
\]

2.4. The evaluation index of entropy \(W'\)

\[
W' = w_i \mid w_i \sum_{i=1}^{n} H_i = 1
\]

2.5. Euclid approach degree

This paper uses the M \((\cdot, +)\) algorithm for calculating the euclid approach degree \(\rho H_j\).

\[
\rho H_j = 1 - \sqrt{\sum_{i=1}^{n} w_i A_{ij}}
\]

Where : \(\rho H_j\) represent approach degree between the evaluation of the object and standard value.

Based on that construct approach degree composite fuzzy matter-element \(R_{\rho H}\):

\[
R_{\rho H} = \begin{bmatrix}
M_1 & M_2 & \ldots & M_m
\end{bmatrix}
\]

3. Application example

3.1. Impact factors selection

Base on the rural drinking water safety and health evaluation index system which issued by Ministry of Water Resources and Ministry of Health, and an evaluation and assessment report of the rural drinking water safety in Yunnan province[5] (Yunan Provincial Institute for Water Resources Research), this paper selected six representative indexes which include population proportion of water non-guarantee, per capita water consumption, population proportion of surface water pollution, the rate of water quality reaching standard, the popularizing rate of running water and population proportion of no water facility.

3.2. Model calculation

According to table 1 basic data, we have built the fuzzy matter-element evaluation model by using theory method above. Detail procedure as follows:

First step: establish composite matter-element matrix.
Second step: constructing difference square matter-element matrix by formula (2)–(5).

Third step: determining weights based on entropy method. Constructing normalized judgment matrix B.

\[
X_{mn} = \begin{bmatrix}
  M_1 & M_2 & \ldots & M_{15} & M_{16} \\
  C_1 & 4.121 & 0.503 & \ldots & 24.228 & 1.433 \\
  C_2 & 54.0 & 48.2 & \ldots & 48.8 & 56.0 \\
  C_3 & 14.507 & 14.915 & \ldots & 14.693 & 18.202 \\
  C_4 & 55.201 & 14.172 & \ldots & 21.662 & 14.804 \\
  C_5 & 11.904 & 47.371 & \ldots & 18.404 & 39.201 \\
\end{bmatrix}
\]

\[
R_X = \begin{bmatrix}
  M_1 & M_2 & \ldots & M_{15} & M_{16} \\
  C_1 & 0.049 & 0.400 & \ldots & 0 & 0.885 \\
  C_2 & 0.717 & 0.640 & \ldots & 0.124 & 0.066 \\
  C_3 & 0.367 & 0.356 & \ldots & 0.314 & 0.207 \\
  C_4 & 0.923 & 0.237 & \ldots & 0.407 & 0.566 \\
  C_5 & 0.949 & 0.238 & \ldots & 0.445 & 0.085 \\
\end{bmatrix}
\]

Calculating entropies by formula (7)–(8). \( H_i = (0.9923, 0.9927, 0.9967, 0.9937, 0.9935, 0.9946)^T \) \( i=(1,2,\ldots,6) \) and \( w_i = (0.2109, 0.2000, 0.0904, 0.126, 0.1780, 0.1479)^T \) \( i=(1,2,\ldots,6) \)

Fourth step: calculating euclid approach degree by formula (10).

\[
R_{\text{eff}} = \begin{bmatrix}
  \rho H_1 & 0.743 & 0.581 & 0.859 & 0.662 & 0.569 & 0.711 & 0.559 & 0.617 \\
  \rho H_2 & 0.743 & 0.581 & 0.859 & 0.662 & 0.569 & 0.711 & 0.559 & 0.617 \\
  \rho H_3 & 0.374 & 0.567 & 0.600 & 0.572 & 0.536 & 0.831 & 0.498 & 0.494 \\
\end{bmatrix}
\]

By sorting of approach degree, in various regions of Yunan province rural drinking water safety degree from high to low as follows: Yuxi, Dehong, Kunming, Baoshan, Wenshan, Diqing, Honghe, Qujing, Banna, Puer, Chuxiong, Lijiang, Dali, Nuijiang, Lincang and Zhaotong.

According to the reckoning above, we adopt hundred-mark system to grade the rural drinking water security state in Yunnan province and, the results are divided into 5 grades (extremely safety, safety, basic safety, unsafety, extremely unsafety) which corresponds to the range of scores were \([ 90,100], [ 80,90), [ 60,80), [ 40,60), [ 0,40)\). Through the calculation result that Yuxi and Dehong are in the safety range, kunming , wenshan , baoshan , diqing and honghe are in the basic safety range, the rest are not safe especially zhaotong.

4. Conclusion

A fuzzy matter element model is constructed based on fuzzy matter-element theory, euclid approach degree and information entropy. The results showed that evaluation results are close to actual situation of yunnan province, proving the rationality of the model.

On the basis of the evaluation results, degree of rural drinking water safety in Yunnan Province is low, regional difference is marked. Most of cities are in state of danger. Generally, degree of rural drinking water safety always has a close connection with local quantity of water resource and economic growth situation. The results can be a proof to make a decision about rural drinking water safeguard system construction this stage in Yunnan.

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