Evaluation of Water Resources Sustainable Utilization in Wuhan Based on the Model of SUDE

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Abstract. SUDE model is a systematic sustainable use model based on the view of the whole life cycle of water resources. The analysis of the model water resources has been divided into four stages according to the state of motion water resourcesat different times in its life cycle, namely the water supply stage ("S"),water use phase ("U"),water collection,treatment anddrainage stage("D") and water return to natural ecological (ecology) environment for dilution, degradation stage("E").on the analysis above,SUDE theoretical model of water system has been built and corresponding evaluation index systemhas therefore been established. Then, we use entropy weight TOPSIS method to evaluate thesustainability of water resource during 2013~2017 yearsin Wuhan, and finally the corresponding conclusions and suggestion have been drawn according to the result of evaluation in the paper.

Keywords: SUDE model, water resources, sustainability, entropy weight TOPSIS method

1. Introduction

Water system is not only the resource guarantee of a region's economic development, but also an important part of the natural ecological environment. The degree of its healthy and effective utilization is an important embodiment of the harmony between human society and nature, which directly affects the whole social and economic sustainability [1]. Therefore, it is an important element of sustainable development in a region.

The meaning of sustainable development is to meet the needs of the present generation and not to endanger the ability of future generations to meet their needs The sustainable use of water resources is defined as the whole process of supporting the coordinated development of population, resources, environment and economy and meeting the water needs of both within and between generations, while maintaining water sustainability and ecosystem integrity [2].

2. Relevant Literature Review

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The research of sustainable water resources utilization in management concept and quantitative evaluation have been carried out. Koop (2015), Kasim (2014) believed that the sustainable use of water resources could be implemented through the establishment of a reasonable management framework [3,4]. From the perspective of global water use Wada et al. (2014) believed that the main ways could be explored and to improve the sustainability of water resourcesthrough the reconstruction of the past and the prediction of the future [5]. From the point of view of European water usage, water footprint methods were applied to evaluate the sustainability of water resources by Vanham (2017) [6]. From the perspective of promoting water management in watersheds, the assessment methods to promote regional sustainability by improving the sustainability of watershed water management has been studied (Cortes, 2012) [7]. Singh (2020), Fard (2020), from the perspective of urban water management in developing countries, discussed the of water resources sustainability through case studies of cities in India and Iran [8,9].

The sustainable management and evaluation methods of water resources has been also explored by domestic scholars from different levels. LiShuang (2019), LiYunjie (2016), GuoLidan (2020) and ZhangQian (2019) analyzed and evaluated the sustainable use of water resources in watersheds, provinces and cities using water ecological footprint method [10-13]. SunYaru (2019) and Liu Li (2020) used cloud models to analyze and evaluate the water safety of Nanjing city and the water sustainability level and spatial heterogeneity of nine cities in the PearlRiver delta respectively [14,15]. ZuoQiting (2020) used TOPSIS method to analyze the of water resources carrying capacity in nine provinces of the Yellow River Basin [16], and AiYadi (2020) used AHP-entropy weight method to evaluate the degree of water resources development in Xi'an [17]. For the northern part of China, water comes from underground, unlike surface water, groundwater has its own characteristics. For this type of region, scholars also used different analytical methods to study. Dong Yi (2019) selected the Bossel index system to evaluate the underground in Lishu County, Jilin Province [18]. Wang Lei (2019) used the AHP method to evaluate the groundwater safety in Yanbian Prefecture and put forward the countermeasures and for sustainable utilization [19].

For the evaluation of sustainable use of water resources, scholars at home and abroad mainly focus on scarcity, safety and carrying capacity, but from a systematic point of view, the sustainability of water resources has been studied by time axis, and the research is still in frame stage [20], especially the lack of practical evaluation.In this paper, water resources are regarded as a system, and the evaluation model of sustainable utilization of water resources has been established, and Wuhan has been taken as an example to make an empirical analysis.

3. Overview of the Study Area

Taking Wuhan as an example, this paper analyzes the sustainability of urban water system. Wuhan is the capital city of Hubei Province, known as the province of thousands of lakes, and the central city of central China.

Wuhan is located at the junction of the Yangtze River and the Han River and the eastern part of the Jianghan Plain. The landform belongs to the transition area of southeast Hubei hilly area from the eastern margin of the Han River Plain to the southern foot of Dabie Mountain. The north subtropical monsoon climate has the

following characteristics, perennial abundant rainfall, abundant heat, cold winter and hot summer, distinct four seasons.There are many lakes in the city, accounting for about one quarter of the city's land area and a surface area of 2117.6km^2.There are 165 rivers within the urban length above 5km, the surface area of 471.31km^2; 166 lakes listed in the protection list; the control area of the city is 867.07km2; 264 reservoirs with a total storage capacity of 875 million m^3.

With the increase of population, the acceleration of urbanization and the need of economic development, the water demand of cities increases greatly. At the same time, due to the instability of precipitation and the problems of surface water quality, there are still some problems in the supply, use and reuse of urban water system.

4. Data sources and Research Methods

4.1. Data Sources

The data in this paper are from China Statistical Yearbook [21], Hubei Statistical Yearbook [22], Wuhan Statistical Yearbook [23] and Wuhan Water Resources Bulletin [24].

4.2. Research Methods

4.2.1. Determination of Evaluation Models

SUDE model is a sustainable model based on the whole life cycle of water resources. The analysis of the model regards water medium as a natural resource, which is used by human society to meet the needs of normal residents, industrial production, fire protection and farmland irrigation, and the water after use is collected and treated by drainage pipe system according to the different degree of pollution. After reaching the drainage water quality index, this part of the water goes back to nature--into rivers, lakes and seas, or recharge groundwater. Therefore, water resources can be divided into four stages of life cycle, that is, resource supply stage ("S"), water use stage ("U"), water collection and treatment stage ("D") and water return to natural water ecological ("E") environment for dilution and degradation. SUDE model is established, as shown in figure 1.
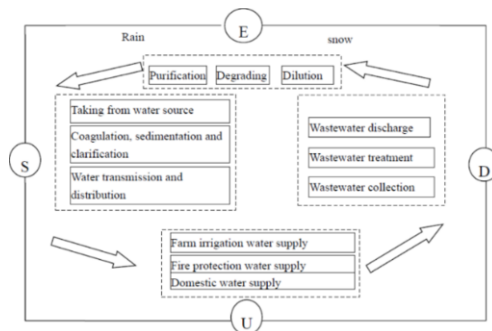

Figure1. The model of SUDE.

4.2.2 Determination of the Evaluation Method

The entropy weight TOPSIS method is the synthesis of entropy weight and TOPSIS method. Firstly, the method uses the amount of information carried by the evaluation index data, that is, the entropy weight method is used to give the index weight, and then the evaluation object is calculated and sorted by the TOPSIS method. On this basis, the optimal evaluation object is obtained. This evaluation method belongs to the objective evaluation method, which can make full use of the information of the data and effectively eliminate the influence between different indexes by the same trend and normalization of the original data.

The paper firstly assimilates and normalizes the original data to eliminate the influence between different indexes, then calculates the weight of each evaluation index in the SUDE model by entropy weight method, and then uses the TOPSIS to calculate the ranking of the evaluation objects.

5. Establishment of the Evaluation System and the Index Calculation

5.1. Establishment of the Evaluation System

Based on the above analysis, we can establish the evaluation indicators of SUDE, as shown in Table 1.

Table 1. Water system sustainability evaluation index system based on SUDE.

the first	the Second		the third		the Second	the third
		S1	Total volume of water resources (10^8m^3)	+		0.0927
		S2	Total volume of water supply (10^8m^3)	-		0.0430
		S3	Transit Water volume (10^8m^3)	+	0.2434	0.0275
	S	S4	The percentage of water quality standards in the first-level water functional area (%)	+		0.0383
		S5	Length of the water supply pipe network(km)	+		0.0419
		U1	Water consumption volume of ten thousandyuan GDP (10^8m^3)	-		0.0307
		U2	Water consumption volume of farmland irrigation per mu area (m^3)	-		0.0651
		U3	Water consumption volume of the industrial added value of ten thousand yuan (m^3)	-	0.1968	0.0273
	U	U4	Domestic water consumption volume of urban residents per person per day (*l*)	-		0.0396
		U5	The percentage of water supply population in central areas (%)	+		0.0341
		D1	The average volume sewage discharge per person per year (10^4m^3)	-		0.0281
		D2	Total volumesewage discharge of industrial wastewater (10^4m^3)	-		0.0330
		D3	Total volume of COD discharge in the industrial wastewater (m3)	-		0.0623
		D4	Total volume of Ammonia nitrogen discharge in the industrial wastewater (m^3)	-		0.0542
		D5	Total volume of urban domestic sewage discharge (10^4m^3)	-		0.0515
S U D E	D	D6	Total volume of COD discharge of urban domestic sewage (m^3)	-	0.4144	0.0334
		D7	Total volume of Ammonia nitrogen discharge in the urban domestic sewage (m^3)	-		0.0312
		D8	The percentage of industrial water reuse (%)	+		0.0617
		D9	Thepercentage of centralized treatment of urban domestic sewage (%)	+		0.0277
		D10	Length of the drainage pipe (km)	+		0.0312
		E1	Investment in ecological construction and protection completed within the year (10^4yuan)	+		0.0266
		E2	The average area of park green space occupied by per person (10^4ha)	+		0.0330
	E	E3	Greening coverage rate in built-up areas	+	0.1454	0.0227
		E4	Length of the levee	+		0.0413
		E5	Direct economic loss value of geological disasters	-		0.0218

5.2. TheIndex Calculation

The steps for the calculation are as follows.

(1) Establish a matrix composed of the original index data

Establish an original index data matrix that indicates the number of samples as "m", evaluation index is "n", as follows:

$$X = \begin{bmatrix} X_{11} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{m1} & \cdots & X_{mn} \end{bmatrix} \tag{1}$$

(2) Assimilation and normalization processing of data

1)The positive and negative Indicators are assimilated to obtain the matrix X'_{ij}

The positive Indicators: $x'_{ij} = \frac{(X_j - X_{min})}{(X_{max} - X_{min})}$ (2)

The negative Indicators: $x'_{ij} = \frac{(X_{max} - X_j)}{(X_{max} - X_{min})}$ (3)

In the formula above, X_{max} is the maximum of the j indicator and X_{min} is the minimum of the j indicator.

2)The data matrix is normalized to obtain a standardized matrix consisting of processed data, namely

$$Z_{ij} = \frac{x'_{ij}}{\sqrt{\Sigma(x'_{ij})^2}} \tag{4}$$

$$Z = \begin{bmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{m1} & \cdots & z_{mn} \end{bmatrix} \tag{5}$$

(3) Determination of the weights of the index data in the matrix

The weight of the index data is determined using the entropy weight method.

1) After the normalization of the matrix X'_{ij}, a dimensionless treatment is performed to obtain the matrix P_{ij}

$$P_{ij} = \frac{x'_{ij}}{\Sigma_{i=1}^m x'_{ij}} \tag{6}$$

2)

$$e_j = \frac{-1}{\ln m} \Sigma_{i=1}^m P_{ij} \times \ln P_{ij} \tag{7}$$

$$d_j = 1 - e_j \tag{8}$$

$$W_j = \frac{d_j}{\Sigma_{j=1}^n d_j} \tag{9}$$

$$3)\ Z_{ij}{}^* = W_j \times Z_{ij} \tag{10}$$

(4) Calculating the optimal solution $Z_J{}^{*+}$ And the worst solution $Z_J{}^{*-}$

(5) Calculating the distance between the evaluation object and the optimal solution $D_i{}^+$; calculating the distance between the evaluation object and the worst solution $D_i{}^-$, and then determining the comprehensive index C_i

$$D_i{}^+ = \sqrt{\sum_{j=1}^{n}\left(Z_{ij}^{*+} - Zij\right)^2} \tag{11}$$

$$D_i{}^- = \sqrt{\sum_{j=1}^{n}\left(Z_{ij}^{*-} - Zij\right)^2} \tag{12}$$

$$C_{i=}\frac{D_i^-}{D_i^+ + D_i^-} \tag{13}$$

Computing the value of C_i, the comprehensive index of each evaluation object. And judge the order of the scheme according to the size of its value. Then, combined with the evaluation level standard (As shown in Table 2), the evaluation object, namely,the level of the sustainable utilization of the water resources can be obtained. We also could find the change of water utilization of Wuhan water resources (as shown in figure 2).

Table 2. The evaluation level standard of the sustainable utilization of the water resources.

closeness	[0,0.2]	(0.2,0.4]	(0.4,0.6]	(0.6,0.8]	(0.8,1.0]
	Weak	Relatively weak	Medium level	Relativelystrong	strong
the evaluation level standard					
	V	IV	III	II	I

6. Analysis of the Evaluation Results of the Sustainable Utilization of Water Resources

According to the sample data of 2013~2017, the sustainable utilization level of Wuhan water system is calculated. Thecalculation results including the weight of indicatorsand the level of the sustainable utilization are shown in Table 1and 3 respectively. According to the calculation results, the sustainable utilization level of the water system in Wuhan is showing a good development trend, and the sustainable utilization capacity is gradually improved. Among them, the water system sustainable utilization comprehensive indexesof 2013 and 2014 were 0.3194 and 0.3455, respectively, which were at the lower level. While the subsequent index of 2015 year reached 0.4319, rising to the medium level. The indexes of 2016 and 2017 were divided into 0.6657 and 0.6147, respectively, showing that the sustainable utilization of water resources in Wuhan has entered a good level of development.

Table 3. The level of the sustainable utilization of Wuhan water resources (2013~2017).

	d_i^+	d_i^-	c_i	level
2013	0.1583	0.0574	0.2660	IV
2014	0.1515	0.0482	0.2414	IV
2015	0.1273	0.0618	0.3332	III
2016	0.0613	0.1492	0.7088	II
2017	0.1083	0.1220	0.5296	III
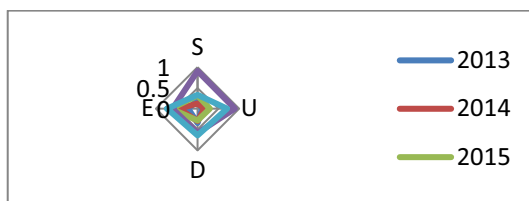
Figure2. the Change of water utilization of Wuhan water resources (2013~2017).

(1) Analysis the four subsystems of the SUDE (As shown in Table 4), the development index of the subsystem S ranged from the lower level of 2013~2015 years, continuously increasing thereafter, especially in 2016 year, reaching the peak. The main reasons of the index increasing depends on the increasing of the total volume of water resources and the transit water volume. That year had 29.4% more rainfall than in the past year and the volume of rainfall in that year was 46.2% more than the multi-year average. In 2017 year, the volume of rainfall year was 6.7% less than the annual average, and water supply levels declined at the sametime.

Table 4. Sustainable utilization index value of SUDE system and its subsystem of Wuhan (2013~2017).

	S	U	D	E
2013	0.2088	0.1072	0.3445	0.2229
2014	0.1269	0.1660	0.2958	0.4438
2015	0.3199	0.2967	0.2827	0.6340
2016	0.9077	0.8975	0.5815	0.5999
2017	0.3344	0.7109	0.6393	0.7307

(2) The value of development index of the subsystem U of SUDE was in the [0,0.2] interval with a low level of sustainable development in 2013 year, and was in the interval of (0.2,0.4] with a relatively low level of in 2014 and 2015 year. After 2016, it showed a highlevel of development trend. Relatively speaking, the level of urbanization in 2013~2015 was not very high, so the demand for domestic water consumption volume of urban residents per person per day was relatively low. But at the same time, due to the lack of science and technology level and the lack of water-saving consciousness, the number of agricultural mu average irrigation water and industrial 10,000 yuan added value water in this period remained high. But at the same time, due to the low level of science and technology and the lack of water-saving consciousness, both Water consumption volume of farmland irrigation per mu area and Water consumption volume of the industrial added value of ten thousand yuanin this period remained high.

Especially after 2016, the proportion of water supply population in the central urban area increased, both the sanitary conditions of the whole society and the water supply efficiency of the water system were improved, which ensured that the relative levels of the subsystem U in both 2016 and 2017 year were higher.

(3) In the subsequent system D, the discharge volume of industrial wastewater and urban domestic sewage, COD and ammonia nitrogen emissions, although repeated but

showed an overall downward trend, indicating the improvement of drainage water quality, which is quite friendly to the environmental system. However,as the important indexes, which were reflected in the industrial and domestic sewage treatment capacity——the percentage of industrial water reuse and the percentage of centralized treatment of urban domestic sewage,were continuously improved, which depends on the increase of Wuhan municipal government investment in the environmental foundation such as drainage pipe network and the enhancement of the supervision of the sewage treatment level of industrial enterprises and sewage treatment plants.

(4) Similar to the system D, the sustainable level of subsystem E increased year by year after experiencing lower levels in 2013. The investment of ecological construction and protection by Wuhan Municipal Government ensured the improvement and development of ecological aspects such as the average area of park green space occupied by per person, greening coverage rate in built-up areas and the length of the levee. And at the same time, the sustainability of the whole ecological subsystem E has been also ensured.

The sustainable development trend of SUDE analyzed abovehasbe shown in figure 3.
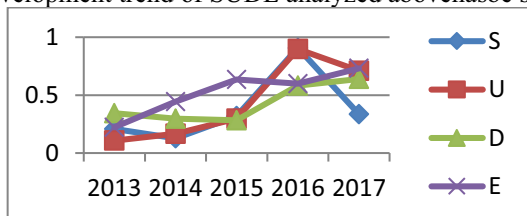

Figure 3. Sustainable development trend of SUDE subsystem in Wuhan (2013~2017).

7. Conclusion and Suggestions

(1) Compared with the previous evaluation index system, the urban water system based on SUDE model can analyze the problems from the system perspective, help to identify and select some important relevant factors which belong not only to the aspects of technology but also to the aspects of technology management, and better reflect the internal connection between the elements of the urban water system. In addition, the selection of indicators also considers the operability and reliability of data collection.

(2) Efforts should be strengthened continuously to ensure the supply quality of water resources. In particular, we should not rely on the endowment of water resources, efforts should be made to improve the compliance rate of the first-level water functional zones and strengthen the construction of the water supply pipe network.

(3) Improve the efficiency of water use, increase the promotion of agricultural irrigation technology, and continuously strengthen water saving publicity among urban residents, improve the awareness of water saving, while ensuring that the quality of living standards not decline. The total amount of water would be appropriately reduced,so as to reduce the pressure of urban water supply.

(4) Continue to strengthen supervision, especially for the supervision of drainage points near surface water, strengthen enterprise regular inspection and sampling inspection, so as to ensure the normal operation of sewage treatment facilities, which can not only improve the circulation rate of water treatment to reduce the volume of sewage water, but also reduce the water quality of sewage water, to achieve the dual control goal of quality and quantity.

(5) Increase investment in ecological construction. While nature gives us water resources through rainfall, it also threatens us with possible disasters such as floods. Withpreventing disasters in the bud, increasing ecological protective efforts, increasing the protection and construction of green space and wetlands, improving the runoffcoefficient of drainage to improve the natural water storage capacity, we could relieve the transportation and discharge pressure of the artificial drainage system, so as to ensure that the city passes safely during the onceinacentury flood disaster.

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