The Evaluation Method Study for Water Resources Sustainable Utilization in Arid Areas

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Abstract—**The water resources carrying capacity is an important component of natural resource carrying capacity in sustained development process. And the evaluation of sustainable development is crucial to the social development. So ,This article from the water, social, economic, ecological environment subsystems, set up the evaluation model through combination of entropy theory and projection pursuit, evaluate the sustainable development of water resources. The Evaluation results show that water resources sustainable development tends to benign trend. The evaluation method is reliable and reasonable. The evaluatiaon results can afford scientific basis for water resources sustainable development and it is proved that EV-PP model is effective new method. Finally, the article brings forwards suggestions to improve the water resources sustainable development. It can provide decision-making for water resources sustainable utilization.**

Index Terms—**EV-PP model; evaluation index; sustainable utilization; Manas River basin**

I. Introduction

Manas River Basin located in the hinterland of the Eurasian continent, total basin area is 2.655×104km2，the population is 0.984 million. It is not only the most abundant inland water basin in the northern slope of Tianshan Mountains, but also the core of the regional economic zone of the northern slope of Tianshan Mountains. The basin is a typical continental arid climate, with the scarce precipitation and large evaporation; the annual average water is 27.83×108m3. Because of water shortage and temporal and spatial distribution imbalance of water resources, the basin has serious problems such as soil salinization, desertification and grassland degradation. The ecological environment is deteriorating. So, it's necessary to get the status of the basin water resources and make a scientific evaluation of water resources carrying capacity in and then use the limited water resources rationally.

The water resources carrying capacity originated from ecological study initially. It regarded as an index of human socio-economic activities, having a crucial influence to the region's developmen[1]t. The evaluation of water resources carrying capacity has become an important basis for the basin's sustainable development, especially in arid and semi-arid regions. The evaluation methods include principal component analysis, analytic hierarchical analysis, fuzzy comprehensive evaluation, the gray system theory, matter element analysis, artificial neural network, and projection pursuit model and so on. These methods have their applicable conditions and limitations [2]. Zhao Yumei (2008) applied principal component analysis to evaluate the water carrying capacity in Shanxi Province[3]; Zhang Yu (2007) applied fuzzy comprehensive evaluation method to analysis water resources situation of Yan'an City[4]; Xiao-Yu Yuan (2004) applied Grey theory to Huaihe River Basin in china[5]; Dai Tiansheng (2009) combined fuzzy analytic hierarchy model and projection pursuit to analyse water resources sustainable utilization[6].

In allusion to the water resources evaluation problem which due to many factors, this article introduces the entropy theory and projection pursuit, get the results of the weighted sum of two evaluation methods. We call it EV-PP model and It is a new method to evaluate the water resources sustainable utilization. Then take the Manas River Basin which in arid inland and shortage of water resources as the study area, applied EV-PP model to the water resources sustainable evaluation, provide basis for water resources decision making.

II. EV-PP Model

A. Euclidean Approach Degree

Approach degree indicates how close between the evaluation sample and the standard sample, the bigger, the closer. Euclidean approach degree is one of many formulas which used to calculate the approach degree. Take into consideration of the comprehensive evaluation, algorithm *M* (·,+) is used to calculate the ρH_j, that is first multiplication then addition.

$$\rho H_j = 1 - \sqrt{\sum_{j=1}^{n} w_i \cdot \Delta_{ij}} \tag{1}$$

In the formula, ρH_j (j= 1, 2,…, m) is the approach between the evaluation sample and the standard sample, the bigger the closer, and vice versa. On the basis of that, we get Euclidean approach degree Complex Fuzzy Matter Element $R_{\rho H}$[10], that is:

$$R_{\rho H} = \begin{vmatrix} & M_1 & M_2 & \cdots & M_m \\ \rho H_j & \rho H_1 & \rho H_2 & \cdots & \rho H_m \end{vmatrix} \tag{2}$$

Because Euclidean approach degree means the approach between the evaluation sample and the standard sample, so we can use the approach value to sort water resources carrying capacity of the sample.

B. Entropy Value Method

The entropy can be applied to evaluate the degree of

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order and their effectiveness for system information, viz. through determination matrix posed by evaluation index values to confirm index weight. it eliminates the factitious disturbance, so that the evaluation result is more logical[7-8].

1) Build evaluation index of Matrix R = (xij)mn (i = 1,2, ..., n; j = 1,2, ..., m);

2) Normalize the index value matrix:

Efficiency index: Xij = 0.1 + (Xij-Xjmin) / d; (3)

Cost-based index: Xij = 0.1 + (Xjmax-Xij) / d; (4)

D is stage difference: d = (Xjmax-Xjmin) (1-0.1) -1. (5)

Where, Xjmax, Xjmin is the maximum and minimum value of the jth index.

3) Confirm the entropy of evaluation index:

$$H_i = -\frac{1}{\ln m}\left[\sum_{j=1}^{m} f_{ij} \ln f_{ij}\right] \tag{6}$$

$$f_{ij} = \frac{1+b_{ij}}{\sum_{j=1}^{m}(1+b_{ij})} \tag{7}$$

i= 1,2,…,n ; j= 1,2,…,m

4) Calculate the entropy wight W:

$$\text{wi}=\frac{1-H_i}{n-\sum_{i=1}^{n} H_i}, \text{and} \sum_{j=1}^{m} w_i = 1 \tag{8}$$

5) Calculatethe comprehensive evaluation exponent.

The weight of each index by the normalized value and accumulate, then get the evaluation exponent ZEV.

Projection Pursuit Model

Projection pursuit is a statistical method for the multi-factor complex problem. The basic idea is the high-dimensional data to low-dimensional space (1 ~ 3-D) for projection, through the spread of low-dimensional projection data structures to study the characteristics of high-dimensional data. The evaluation of water resources carrying capacity is based on the evaluation standard, distinguish evaluation samples for class discrimination or a combination, so we can use index classification to construct the objective function, that is, the one-dimensional space between-class distance s (a) and within-class density d (a) at the same time to achieve maximum value. Construct the objective function Q (a) as follows [9]:

$$Q(a) = s(a) \bullet d(a). \tag{9}$$

Through the sample projection characteristic values, the between-class distance s (a) is calculated. The larger of s (a), the sample spread more.

$$s(a) = \left[\sum_{i=1}^{n}(z_i - z_0)^2 / n\right]^{1/2} \tag{10}$$

where,

$$z_i = \sum_{j=1}^{m} a_j x_{ij} (i = 1 \cdots n) \tag{11}$$

And define the zij = ajxij, zij is the i sample j index projection components; xij is index value non-dimensional treatment

z = (z1, z2 ... zn) is vector of projection characteristic values;

z_0 is the mean projection characteristic values z_i.

Within-class density

$$d(a) = \sum_{i=1}^{n}\sum_{k=1}^{n} f(r_{ik}) I(R - r_{ik}) \tag{12}$$

Where, $r_{ik} = | z_i - z_k |$ (k = 1 ... n),is the projection characteristic values distance; R for the density window width, related the data features; Studies have shown that max (r_{ik}) + m / 2 ≤ R ≤ 2m, is usually preferable to R = m; Density function f (r_{ik}) decrease with the increase of r_{ik}, where to take f (r_{ik}) = R-r_{ik}; I (R-r_{ik}) is the unit step function, when R> r_{ik}, then I (R-r_{ik}) = 1, contrary to 0. The greater of d (a), the classification salience is more.

Based on genetic algorithm optimization to calculate "a", then calculate projection characteristic values z_i.

C. Ev-Pp Model Evaluation Exponent

The two models' results are not comparable directly, so standardized the evaluation results and then combined them. Standardized formula as follows:

$$Z = \frac{Z - Z_{\min}}{Z_{\max} - Z_{\min}} \tag{13}$$

Comprehensive evaluation exponent:

$$Z_i = \lambda Z_{pp} + (1-\lambda) Z_{EV} \tag{14}$$

where, λ ∈ [0, 1] as weight, it can be determined by the experts; Zpp and ZEV were normalized value form projection pursuit model and entropy method; Zi is comprehensive evaluation exponent for the combination.

III. WATER RESOURCES SUTAINABLE UTILIZATION EVALUATION INDEX SYSTEM

According to the consultation form experts and the international and the domestic authoritative about sustainable development related index value, we get the index system and the standard value of the water resources carrying capacity. The combination of subjective and objective can be used to determine the weight, first use AHP method for the various subsystems, the entropy method used to determine the weights of different evaluation index systems in the various subsystems, and then we get the weight of each evaluation index for water resources carrying capacity in Manas River Basin.

In this paper, we form the characteristics of water resources in the basin, guided by integrity, dynamic development, regional characteristic, layer level, maneuverability principle, consult national Water resources evaluation system standard, through expert advice and then establish the water resources evaluation index system form water resources, social development, economic development, environment four subsystems.

IV. CASE STUDY

A. Evaluation Index Original Value and Evaluation standard

TABLE I. WATER RESOURCES ORIGINAL VALUE AND EVALUATION STANDARD AFTER NORMALIZED

subsystems	*Evaluation index*	*Index value*			*Classification standard*		
		2000year	2010year	2020year	V_1	V_2	V_3
water resources subsystem	water resources per person	0.7343	0.9744	1.0000	0.1000	0.2828	0.4656
	water utilization rate	0.1000	0.1022	0.1269	0.7758	0.8879	1.0000
	water resources per unit area	0.1000	0.3190	0.3423	0.1011	0.5505	1.0000
social subsystem	growth rate of population	0.4330	0.3776	0.7923	0.1000	0.5500	1.0000
	urbanization rate	0.5797	0.6919	0.9613	0.1000	0.5500	1.0000
	water resources used in living	0.4963	0.3511	0.1000	0.2045	0.6022	1.0000
economic subsystem	water of ten thousand industrial production value	0.1000	0.5930	0.3661	0.7261	0.4130	0.1000
	repetition rate of industry	0.5140	0.6760	0.8200	0.1000	0.5500	1.0000
	per capita GDP	0.1000	0.3930	1.0000	0.1047	0.2667	0.4287
	water efficiency of irrigation	0.4600	0.5050	0.5725	0.1000	0.5500	1.0000
	tertiary industry proportion of GDP	0.2170	0.3490	0.4000	0.1000	0.5500	1.0000
environment subsystem	grass coverage	0.1000	0.1439	0.1800	0.2944	0.6472	1.0000
	environment water rate	0.5794	0.8318	1.0000	0.1000	0.2262	0.3523
	sewage treatment rate	0.1000	0.8364	1.0000	0.4273	0.6318	0.8364

By formula (3), (4), we get the normalized data form water resources original value and the evaluation standard in Table I.

For each classification standard, V3 stage is well, the water resources still has large potential, the supply situation is optimistic. V1 stage stands for poor, the water resources close to its saturation value and should take appropriate countermeasure, or it will limit the social and economic development. V2 stage is between V3 stage and V3 stage, water resources utilization potential has been a considerable scale, the water supply can satisfy the basin's economic development in a certain degree.

B. Approach Degree Calculation

First, Establish of composite fuzzy matter-element. To determine the compound matter element of the six scheme form three different level years and three grade. Then according to the weight of evaluation index, calculation Euclidean approach degree,

$$\rho H_j = \begin{bmatrix} & year2000 & year2010 & year2020 & V_1 & V_2 & V_3 \\ \rho H_j & 0.2637 & 0.3255 & 0.3709 & 0.3216 & 0.4892 & 0.7966 \end{bmatrix}$$

C. EV model Evaluation Exponent

Through Entropy calculation to calculate the weight of four sub-systems, then the subsystem weight capacity by index weight in each subsystem to get the combined weights.The combined weight of each index by the normalized value and accumulate, then get the evaluation exponent ZEV.

Z_{EV}= (0.2510 , 0.4194 , 0.4727 , 0.4408 , 0.6170 , 0.7932)

D. Pp Model Evaluation Exponent

Based on the index value of the water resources carrying capacity grading standards, establish the projection pursuit model, where n = 3, m = 6. Through the calculation, we get the optimal projection direction vector,

a= (0.5078, -0.5369, 0.0012, -0.0006, 0.1253, -0.0994, -0.0130, 0.1660, 0.3648, 0.0459, 0.0267, 0.0003, 0.4900, 0.1567);

Projection characteristic value z_{pp}= (0.4112, 0.8589, 1.2148, 0.1857, 0.5934, 1.0011)

E. Ev-Pp Comprehensive Evaluation Exponent

Through formula (11), we get the standardization value of evaluation exponent. Taking $\lambda = 0.5$, obtained comprehensive evaluation exponent. Z_i = (0.1096, 0.4824, 0.7044, 0.1750, 0.5356, 0.8962)

F. Results Analysis

From TABLE 3, the water resources sustainable utilization potential in Manas River basin trends to benign trend. In 2000, the level of water resources sustainable utilization was weak; the potential of water resources is small. But with water-saving irrigation and industrial structural adjustment measures, the sustainable development of water resources has improved in 2010 and 2020. In the four evaluation models, EV model and PP model are relatively objective. The information obtained by the data may deviate from the actual results and lead to erroneous classification. The EV-PP model counteracts the error of two parts in a certain extent. And the method is also more scientific in theoretical analysis.

TABLE II WEIGHTS OF INDEX VALUE

Subsystem	Weight	Index value	weight	combined weights
water resources subsystem	0.3292	water resources per person	0.0453	0.0149
		water utilization rate	0.9093	0.2993
		water resources per unit area	0.0453	0.0149
social subsystem	0.2207	growth rate of population	0.3337	0.0737
		urbanization rate	0.3273	0.0722
		water resources used in living	0.3390	0.0748
economic subsystem	0.1807	water of ten thousand industrial production value	0.7338	0.1326
		repetition rate of industry	0.0642	0.0116
		per capita GDP	0.0699	0.0126
		water efficiency of irrigation	0.0669	0.0121
		tertiary industry proportion of GDP	0.0652	0.0118
environment subsystem	0.2695	grass coverage	0.3275	0.0883
		environment water rate	0.3269	0.0881
		sewage treatment rate	0.3456	0.0931

TABLE III EVALUATION EXPONENT OF THREE EVALUATION MODEL

Model	*2000year*		*2010year*		*2020year*		V_1	V_2	V_3
	evaluation exponent	stage	evaluation exponent	stage	evaluation exponent	stage			
EAD	0.2637	V1	0.3255	V1-V2	0.3709	V1-V2	0.3216	0.4892	0.7966
EV	0.2510	V1	0.4194	V1-V2	0.4727	V1-V2	0.4408	0.6170	0.7932
PP	0.4112	V1~V2	0.8589	V2-V3	1.2148	V3	0.1857	0.5934	1.0011
EV-PP	0.1096	V1	0.4824	V2-V3	0.7044	V2-V3	0.1750	0.5356	0.8962

V. CONCLUSIONS

1) In evaluation method, this paper combined entropy method and projection pursuit theory. Although the results are only a relative numerical score and can not delegate absolute levels of water sustainable utilization. We can see that the sustainable development of water resources is the benign direction in recent years.

2) The example shows that the model is reliable and reasonable. The results can be applied to evaluate water resources development and utilization. The EV-PP model can provide the scientific basis for water resources evaluation and it is an effective new method.

3) In order to achieve the goal of water resources sustainable development, we suggested the following measures: the government should focus on reducing agricultural water, the implementation of water-saving irrigation technologies, the development of water-saving industry and salty water using in the future. Through the implementation of measures, we can mitigate the supply and demand contradiction of water resources and enhanced the water resources sustainable level greatly.

REFERENCES

[1] Peng kun-Quan, Zhang Ping, in: Projection Pursuit of water environmental quality and evaluation，Environmental Science and Technology, 2007, 20(1): 59-62

[2] Liu Heng, Geng Lei-hua, Chen Xiao-Yan. in: Indicators for evaluating sustainable utilization of regional water resources. Advances In Water Science, 2003,14 (3) :265-270

[3] ZHAO Yu-mei, Zhao Xian-Gui, Dong Lin-Lin. in:Dynamics of water resources carrying capacity in Shaanxi Province. System Sciences and Comprehensive Studies in Agriculture,, 2008,24 (1) :95-98

[4] ZHANG Xing-yu, Analysis of Regional Water Resources Carrying Capacity - in Yan'an City. Shanxi: Northwestern University, 2007: 30-47

[5] YUAN Xiao-Yu, in: Multi-objective Decision Grey Relation Projection Method in the Water Resources Carrying Capacity Analysis. Jiangsu Water Resources, 2004

[6] DAI Tians-heng, Sun shao-rong, in: Evaluation of the Sustainablity of Water Resource System Based on FAHP-PP Model, Resources and Environment in the Yangtze Basin, 2009,18(5): 421-425

[7] WANG Shun-jiu, Yang Zhi-feng, Ding jing, in: Projection pursuit method of comprehensive evaluationon groundwater resources carrying capacity in Guanzhong plain, Resources Science, 2006,14(1):173-175

[8] ZHANG xin-li, DING Jing, LI Zuo-yong, in: Application of new projection pursuit algorithm in assessing water quality. China Environmental Science, 2001, 12(3):356-360.

[9] Friedman JH, Tukey JW. A projection pursuit algorithmfor exploratory data analysis[J]. IEEE Trans on Computer, 1974, C-23(9): 881-890.

[10] Fu Qiang, Ju-Liang Jin, Liang Chuan. Accelerating genetic algorithm based on real projection pursuit model to rice irrigation system optimization [J]. Journal of Hydraulic Engineering, 2002, (10) :39-45