

# Evaluation system of water ecological civilization of irrigation area in China

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**Abstract.** Irrigation area is an important carrier, and also has a pivotal role in the construction of water ecological civilization in China, as well as worldwide. This work extracted the five basic characteristics of water ecological civilization of irrigated area, namely "resource saving, efficient production, ecological nature, beautiful environment, and civilized consciousness". Further, based on the frequency analysis of indicators related to the evaluation of irrigation area, we proposed the evaluation system of water ecological civilization of irrigated area. Taking an irrigation district of Huaian City, Jiangsu Province, China as an example, we carried out the case evaluation in use of the fuzzy comprehensive evaluation method. Thus, we provide the theoretical and technical reference for the construction and assessment of water ecological civilization of irrigation district to both China and abroad.

## 1. Introduction

As the source of life, water resource is also the control element of the ecosystem. Water conservancy construction, in some way, can be regarded as the core of ecological civilization. Early in 2012, China vigorously put forward that, from the aspects of resource conservation and ecological environmental protection, the country should speed up water conservancy construction and strengthen water management. In 2014, China again stressed the need to develop and improve the laws and regulations of ecological compensation, water pollution control, and marine environmental protection. Later, the new water management concept "water-saving priority, spatial equilibrium, system governance, handed force" was determined, so as to pointing out the direction of how to accelerate the development of water reform.

As an important grain-producing district, irrigation area becomes a vital carrier of water ecological civilization-due to its large proportion of water use in the whole society. In recent years, considering the modes such as "irrigation modernization", "ecological irrigation", "water-saving and ecology irrigation area", some scholars and managers analyzed the content, features and theoretical basis of the corresponding irrigated area. Further, they put forward the main technical systems and evaluation system. Some also carried out the relevant practice and pilot studies for ecological construction of irrigation area[2-8]. All of the above research can be used to guide and reference the construction of water ecological civilization of irrigated area. However, at present, the theory, ideas, and practice are still relatively weak. It is very hard to make an interpretation or evaluation of water ecological civilization of irrigation area. Therefore, from both a theoretical and practical point of view, the



construction of water ecological civilization of irrigation area in China is still in its infancy, and needs to strengthen the relevant research and practice.

## **2. Construction of evaluation system**

### *2.1. The first-level index*

Index, as the core of evaluation system, is the basis for the evaluation of construction of water ecological civilization in irrigation area. It should follow the principles of comprehensive, representative, and operational feasibility. Based on the background process of water ecological civilization, and related guidelines and objectives from "suggestions on accelerating the construction of water ecological civilization" by Ministry of Water Resources in China, the paper summarized the characteristic of water ecological civilization in irrigation area, as well as the basic evaluation criteria layer—resource saving, efficient production, ecological nature, beautiful environment and civilized consciousness. The specific meanings are as follows:

Resource saving—Corollary, water-saving transformation, universal resource conservation awareness, and efficient technology should be widely promoted. Many aspects, such as irrigation planning, design, construction and management processes, should all focus on high efficient use on soil and water resources and energy conservation. Efficient production—Irrigation area should set goals of both high yield and low cost, focusing on maximizing the overall efficiency. Ecological nature—Water conservancy project in irrigation area should be in harmony with the ecological environment. Ecological engineering and near-natural construction methods should be applied. Irrigated ecosystem can get the restoration and maintain homeostasis. Soil erosion and water environment have been effectively controlled. Agricultural non-point source pollution has been effectively regulated, so as to achieve restoration and protection of biodiversity. Beautiful environment—Environment in the irrigation district should be nice and clean. Irrigation and drainage canals, and rivers, should be kept in good condition. Hydraulic engineering should be in harmony with the surrounding environment and have a certain aesthetic value within the landscape. It would be better if they can reflect the local cultural characteristics of water. Civilized consciousness—awareness of resource conservation has been widely popularized. Concept of water ecological civilization is deeply rooted among people. Irrigated farmers are happy and satisfied with the participation in the irrigation area planning, design, construction and management.

### *2.2. The secondary-level index*

In reference to a number of relevant pieces of literature on irrigated area assessment, ecological civilization, modernization and regulations about water, agriculture, environment, ecology in China, the frequency analysis of related indicators were carried out. Indicators which received relatively high frequency were then selected from the five aspects—"resource saving, efficient production, ecological nature, beautiful environment and civilized consciousness". The Specific indicators system is shown in Table 1, including 5 first-level and 18 secondary-level indicators, in which 15 are quantitative and 3 are qualitative.

## **3. Evaluation method**

### *3.1. Choice of method*

Evaluation system of water ecological civilization irrigation has the following comprehensive characteristics: layered, fuzzy, gray and a certain degree of subjectivity. This paper, considering the adaption, recommends selecting the fuzzy comprehensive evaluation method [22] for the current work.

### *3.2. Level delineated*

In the fuzzy evaluation, it is necessary to select the appropriate fuzzy operator. Evaluation process of water ecological civilization in irrigation area needs to consider the overall factors comprehensively. It

will be relatively accurate to calculate through weighted average. In this paper, we take the operator type of weighted average.

The evaluation sets are respectively given a score of 5, 4, 3, 2 or 1, from good to bad, thus building a model in view of the fuzzy analytic hierarchy process. The evaluation results are represented by a number from 1 to 5—Score>4(Category I), 3<Score<4(Category II), Score<3(Category III).

#### 4. Case evaluation of water ecological civilization in irrigation area

##### 4.1. Overview of irrigation area

The irrigation area is located in Huai'an City, Jiangsu Province, China, mainly relying on the water of Yangtze River and Huai River for irrigation. Due to the large water leakage, ecological lining through the backbone water channel was carried out in irrigation area. Sprinkling, pipes and other water-saving projects and technical measures were promoted. Some arable land also needs pumping for irrigation. With a relatively good infrastructure and natural condition, the agricultural production in this irrigation area maintained well, as well as the overall environment. Ditches and roads were mostly green. Irrigation management organizations, which were divided into four agencies, have a strict system.

##### 4.2. Index weight and situation evaluation

Using AHP[1], index weights in each level are fingered out. Considering the core research subject and the length restrictions of the article, interviews, questions, matrix and weight calculation process are not shown in this paper. It should be noted that the index weight to all the levels of the evaluation system is not the same. They will make a corresponding change with different irrigation districts in different natural and geographical conditions. Specific weights were calculated in the AHP process and are shown in table 1. The evaluation involves a wide range of factors, most of which can be quantified through surveys, measurements and calculations. Some indicators are difficult to express mathematically; qualitative description is necessary at this time. Evaluation situations were primarily from the planning report, water-saving transformation planning report, Huaian yearbooks and administration statistics in irrigation areas. Concrete results are shown in table 1.

**Table 1.** Evaluation system of water ecological civilization in irrigation area.

First-level index	Weights	Secondary-level index	Weights	Value	Comment
resource saving	0.141	water use efficiency of			
		irrigation[9]	0.303	0.6	excellent
		area ratio of water-saving			
		irrigation project	0.233	0.58	excellent
		ratio of high standard			
		farmland[10]	0.280	50.2%	good
		average device efficiency of			
		pumping station[11]	0.184	56%	medium
		water productivity[12]	0.357	1.53	good
		grain yield per mu	0.386	468.2	medium
efficient production	0.283	agricultural input-output			
		ratio[13]	0.257	0.17	medium

		roads and canals greening			
		rate[15]	0.253	83%	good
		ecological revetment rate	0.266	79%	good
		loss control rate[16]	0.195	74%	medium
		quality compliance rate of			
		irrigation water[17]	0.178	69%	medium
		intensity of chemical			
ecological nature[14]	0.283	fertilizer[18]	0.108	267	bad
		compliance rate of village			
		environment	0.388	86%	medium
		irrigation building			
		ornamental[19]	0.313	/	good
		comprehensive utilization of			
beautiful environment	0.166	crop stalks[20]	0.299	58%	inferior
		awareness penetration of			
		water management and			
		ecological civilization	0.363	/	medium
		resource conservation			
		awareness of irrigation			
		farmers	0.298	68%	medium
civilized		integral satisfaction of			
consciousness[21]	0.126	Irrigation farmers	0.339	/	medium

According to the steps of the fuzzy comprehensive evaluation method, evaluation matrix of index was calculated.

For example, calculation process of resource saving evaluation matrix is as follows:

$$B_1 = A_1 \bullet R_1 = [0.303 \quad 0.233 \quad 0.280 \quad 0.184] \bullet \begin{bmatrix} 0.8 & 0.2 & 0 & 0 & 0 \\ 0.8 & 0.2 & 0 & 0 & 0 \\ 0.15 & 0.7 & 0.15 & 0 & 0 \\ 0 & 0.15 & 0.7 & 0.15 & 0 \end{bmatrix}$$

$$= [0.471 \quad 0.331 \quad 0.129 \quad 0.028 \quad 0]$$

Similarly, the comprehensive evaluation matrix of irrigation area can be drawn:

$$R = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \end{bmatrix} = \begin{bmatrix} 0.471 & 0.331 & 0.129 & 0.028 & 0 \\ 0.054 & 0.346 & 0.504 & 0.096 & 0 \\ 0.078 & 0.419 & 0.355 & 0.132 & 0.016 \\ 0.047 & 0.277 & 0.319 & 0.118 & 0.239 \\ 0 & 0.150 & 0.700 & 0.150 & 0 \end{bmatrix}$$

$$B = A \bullet R = [0.141 \quad 0.283 \quad 0.283 \quad 0.166 \quad 0.126] \bullet$$

$$\begin{bmatrix} 0.624 & 0.274 & 0.088 & 0.014 & 0 \\ 0.045 & 0.313 & 0.537 & 0.105 & 0 \\ 0.096 & 0.493 & 0.311 & 0.091 & 0.010 \\ 0.035 & 0.258 & 0.506 & 0.183 & 0.018 \\ 0 & 0.150 & 0.700 & 0.150 & 0 \end{bmatrix}$$

$$= [0.112 \quad 0.329 \quad 0.403 \quad 0.107 \quad 0.044]$$

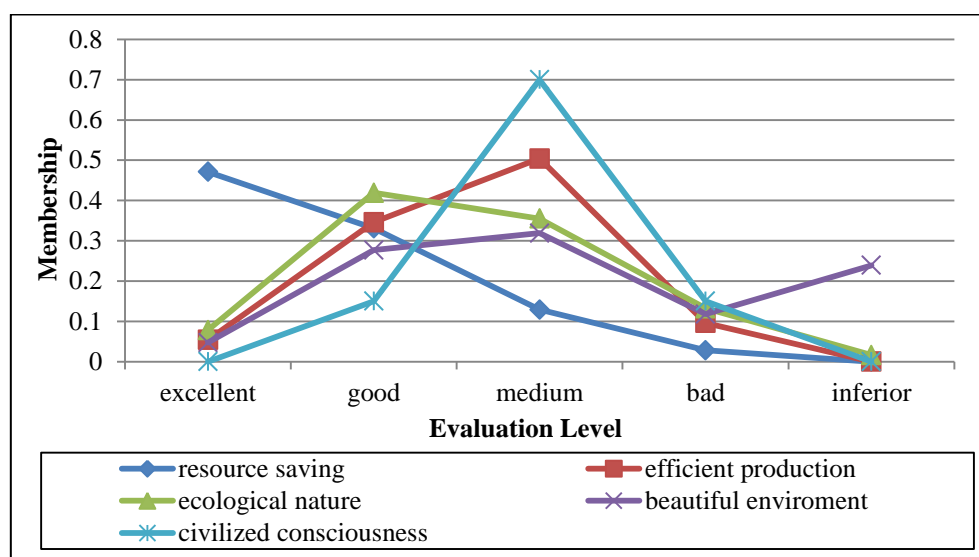
To quantify the results of the evaluation,

$$W = B \bullet Q = [0.112 \quad 0.329 \quad 0.403 \quad 0.107 \quad 0.044] \bullet [5 \quad 4 \quad 3 \quad 2 \quad 1]^T = 3.34$$

#### 4.3. Results analysis

Comprehensive evaluation score of the irrigation area is 3.34, which belongs within Category II. Essentially, it basically met the evaluation criteria-the construction and management substantially satisfied the requirements of water ecological civilization in irrigation area, but still needs to be improved in some aspects.

However, the evaluation result does not reflect the grade of the first-level index, nor explain the shortcomings of the status quo in the irrigation area. Membership, namely the level of related special subjection, can offer a more accurate way to the evaluation results. Thus, this work further analysed the degree of membership of the first-level indicator, reaching the evaluation results of the five first-level indicators. According to the principle of membership matrix, the maximum membership degree is the evaluation situation of the index. Memberships of the first-level index are shown in figure 1. The evaluation levels are excellent, medium, good, medium and medium, respectively. Analysis results show that in this irrigation area, resource saving rates the best, followed by the ecological nature. Efficient production, beautiful environment and civilized consciousness are relatively weak, and still need some targeted measures to improve the building standard, thus fully realizing the water ecological civilization in irrigation area.



**Figure 1.** Membership of the first-level index.

## 5. Conclusion

Construction evaluation is the most important content of water ecological civilization in irrigation area in China. This paper presented an appropriate evaluation system, as well as the comprehensive method. Further, an irrigation area in Huaian City was taken as an example to be evaluated, providing a specific and feasible theoretical basis for the assessment of water ecological civilization in irrigation area. It should be noted that the weights of indexes at all levels are not the same. With constant development, irrigated conditions and infrastructure are also changing, as is the evaluation system. Only through change will they meet the new requirements of different periods. In addition, the construction of water ecological civilization in irrigation district is a research blend of many disciplines including ecological economics, ecological ethics, landscape ecology and water conservancy projects. Therefore, it needs interdisciplinary study of thinking in order to achieve better research results.

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## References

- [1] Jiang G 2005 *Fuzzy AHP synthetical appraise method and application* Tianjin University
- [2] Jiang K P 2004 Construction thinking of ecological irrigation area-in use of ecological civilization to promote the sustainable development of irrigation district *China Rural Water Conservancy and Hydropower* 4-10
- [3] Tang X J 2007 Water resources situation, current problems and countermeasures of Dujiangyan irrigation area *Proc. of the 3rd Youth Science and Technology Forum of China Water Conservancy Institute*
- [4] Gu B J 2006 *Construction principle and key technology of ecological irrigation district* Hohai University
- [5] Zhang Z Z 2010 Study on ecological irrigation area and its healthy development *Modern High*

- Efficiency Water Saving Agriculture and Construction of Ecological Irrigation District*
- [6] Zhang Z Y 2006 Brief analysis on construction of ecological irrigation district in China *Academic annual meeting of China Water Conservancy Society*
  - [7] Fang Y X 2011 Fuzzy comprehensive evaluation model and its application of eco-system's health in irrigation district *Journal of Agricultural Engineering* **27** 199-205
  - [8] Yang P L 2009 Theory and technology of construction on ecological irrigation district *China Water Resources* 32-35
  - [9] Li Y N 2003 Study on water use efficiency in irrigation *China Rural Water Conservancy and Hydropower* 23-26
  - [10] Shen M 2012 Research on classification of provincial high standard farmland—Taking Guangdong Province as an example *China Land Science* **26** 28-33
  - [11] Zhang R T 1996 Research on conversion method of device efficiency of pumping station *Pump Technology* 27-31
  - [12] Li Y H 2001 Calculation method and application of water productivity *China Water Resources* 65-66
  - [13] Xie K J 1992 Investigation on agricultural input-output ratio of Xigangzi Town *Journal of Hei River* 40-42
  - [14] Jin D G 2004 Theory and practice of natural ecological engineering *Proc. of International Ecological City Construction*
  - [15] Xie X H 2008 Research of levee greening and management in Weishan Irrigation District *Shandong Water Resources* 52-53
  - [16] Liu J G 2008 Research on comprehensive evaluation system of loss control rate *Journal of Yangtze River Academy* **25** 82-85
  - [17] Zhao J R 2008 *Influence of irrigation water quality to Soil* Northwest A&F University
  - [18] Yu Y X 2009 Trends and countermeasures of fertilizer pollution in China *Proc. of China Sustainable Development Academy*
  - [19] Zhong S M 2004 Research on combination between practicality and appreciation of buildings *Building Development Orientation*
  - [20] Zhang K 2012 Comprehensive utilization of crop stalks will be increased—Interpretation of the implementation of comprehensive utilization of crops in 12th Five-Year *New Rural Technology* 49-50
  - [21] Zhuo Y 2007 Critical thinking of how to promote civil's sense of ecological civilization *Marx Doctrine and Reality* 106-111
  - [22] Jin J L 2004 Fuzzy comprehensive evaluation model based on AHP *Journal of Hydraulic Engineering* 65-70