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Quantitative Analysis on the Influence Factors of the Sustainable Water Resource Management Performance in Irrigation Areas: An Empirical Research from China

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Abstract: Performance evaluation and influence factors analysis are vital to the sustainable water resources management (SWRM) in irrigation areas. Based on the objectives and the implementation framework of modern integrated water resources management (IWRM), this research systematically developed an index system of the performances and their influence factors ones of the SWRM in irrigation areas. Using the method of multivariate regression combined with correlation analysis, this study estimated quantitatively the effect of multiple factors on the water resources management performances of irrigation areas in the Ganzhou District of Zhangye, Gansu, China. The results are presented below. The overall performance is mainly affected by management enabling environment and management institution with the regression coefficients of 0.0117 and 0.0235, respectively. The performance of ecological sustainability is mainly influenced by local economic development level and enable environment with the regression coefficients of 0.08642 and −0.0118, respectively. The performance of water use equity is mainly influenced by information publicity, administrators' education level and ordinary water users' participation level with the correlation coefficients of 0.637, 0.553 and 0.433, respectively. The performance of water use economic efficiency is mainly influenced by the management institutions and instruments with the regression coefficients of −0.07844 and 0.01808, respectively. In order to improve the overall performance of SWRM in irrigation areas, it is necessary to strengthen the public participation, improve the manager' ability and provide sufficient financial support on management organization.

Keywords: sustainable water resources management; integrated water resources management; impact factors of performance; quantitative analysis; irrigation areas

1. Introduction

Irrigation areas are the basic regional units for the water resources management in rural areas especially. In China, the irrigation areas not only gather a large amount of rural population and agricultural production but also consume a lot of water resources. Due to the highly intense exploitation and utilization of water resources for long time, the water environment problems have been extremely serious in irrigation areas in China and seriously threaten the sustainable economic and social development of rural areas [1–3]. Therefore, it is of great significance to strengthen the water resources management in the irrigation areas in order to achieve the sustainable utilization of limited water resources and development in China.

The performance evaluation and analysis on the influencing factors of water resources management are critical to SWRM, as they can provide useful information for improving the sustainable utilization of water resources [4,5]. While a large number of studies have begun to focus on this topic, the previous relative researches mainly focus on the performance evaluation of water resources management of the basins [6–10], districts [11–13] or the water project [14–16]. And few of them pay attention to the performance evaluation of water resources management at the irrigation area level. The existing research on influence factors of water management performance concentrates on exploring the relationship between some specific management tools and its performance. In particular, these tools can often include management policy [17–19], management organizations [20–24], irrigation schemes [25,26], technological investments and governance structures [27], while others mainly introduce and develop valid research methods [28,29]. Obviously, the results of these researches provide an important support to this research topic especially when the index systems of performance and its influence factors of the SWRM in irrigation area are developed.

The existing studies, however, have not systematically developed the performance index system and its influence factors of water resources management in irrigation areas based on a paradigm of SWRM. They therefore are not able to reveal fully the values and the restrictive factors of SWRM in irrigation areas. By far, IWRM has become a water management approach with wide international acceptance and has made an important contribution to sustainable development [30]. Based on the objectives and the implementation framework of IWRM, this research attempts to systematically build an index system of the performance and ones of its impact factors of SWRM in irrigation areas. By adopting the multiple regression method with the correlation analysis, we conduct a quantitative empirical research focusing on a typical irrigation area, Ganzhou, which is located in the middle reaches of the Heihe River in China. We aim to build a set of index systems for the comprehensive performance evaluation and the systematic analysis on the influencing factors of SWRM in the case area. The workflow of this research is shown as the Figure 1.

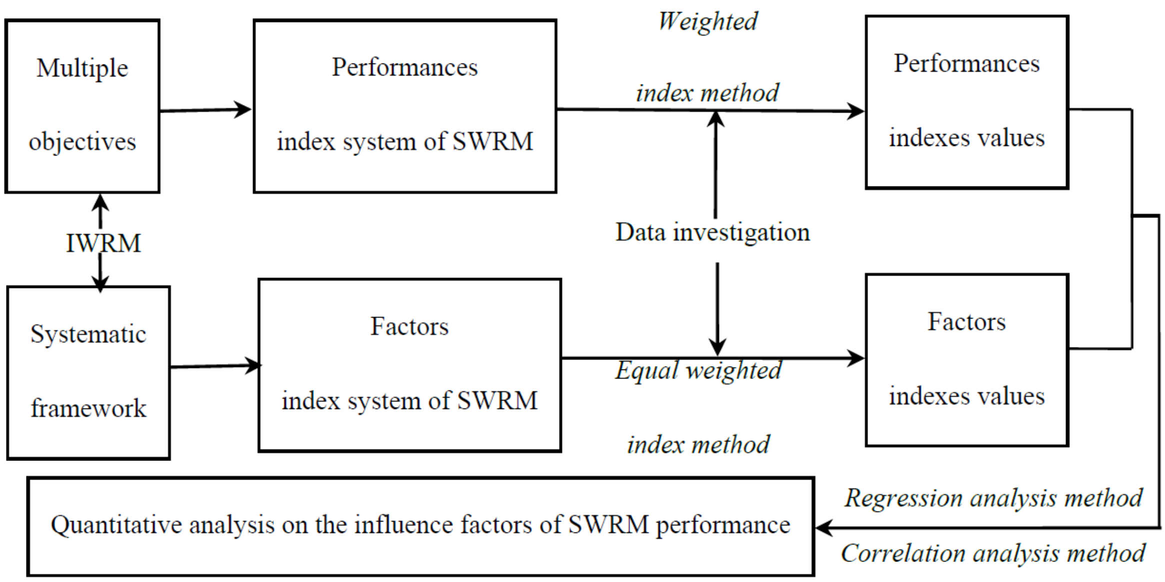

Figure 1. Flow chart of quantitative analysis of influence factors on the performance of SWRM.

The structure of this paper is organized as follows. Section 2 introduces a proposed index system of performance and its influence factors developed based on the multiple objectives and systematic implementation framework of IWRM. Section 3 describes the methodology by providing the accounting methods on the performance indexes and the values of the influence factor indicators. The modeling approach of the quantitative relationship between the performance and its influence factors is described in detail in this section too. Section 4 presents and explains the empirical results. Section 5 concludes and offers some policy recommendations.

2. Development of Index Systems

2.1. The Performance Index System

The concept of IWRM was originated in the early 1990s which has been regarded as a new paradigm of water resources management under the guidance of the sustainable development thoughts [31–33]. According to the research report from Global Water Partnership (GWP), IWRM is defined as "*a process that promotes coordinated development and management of water, land and related resources in order to not only maximize economic and social welfare but also ensure equity and sustainability*" [34]. Based on this definition, GWP gives further detailed explanations on IWRM principles. GWP argues that, to achieve SWRM, it is necessary to follow three important principles: *to maintain the sustainability of ecological environment*, that is, water resources should be used in the way of not undermining the key life support system and of not endangering the future generations' interests; *to guarantee the social equality*, i.e. to make sure that all people can get enough high-quality water resources and water security; *to strive for efficient utilization*, which means that water resources should be used efficiently as much as possible to maximize human's economic welfare. Obviously, SWRM has three types of objectives and thus its performance should contain, at least, three kinds of benefits such as environmental sustainability, economic efficiency and social equity [34].

In accordance with the three objectives of IWRM, the performance index system of the SWRM should include three dimensions, namely, *ecological sustainability*, *water use equity* and *water use efficiency*. Considering the fact that the realization of the three major objectives of SWRM is based on the sustainability of water management system and the improvement of its operational efficiency, *organizational efficiency* is taken herein as a key endogenous target of SWRM in irrigation areas. Concerning the characteristics of irrigation areas, the performance index system of SWRM is established, consisting of four indicator dimensions denoted as I_1–I_{15} (Table 1) in this research. Among these indicators, I_2 and I_6 are the negative indicators while the others are the positive ones.

Table 1. Performance index system of the SWRM in irrigation areas.

	Performance Indicators	Indicators Interpretation
Ecological sustainability (C1)	Natural vegetation coverage (I_1)	The rate of forestland and grassland area to total land area, reflecting the sustainability and goodness of ecological environment.
	Water resources exploitation coefficient (I_2)	The rate of the number of water withdrawal to total water resources amount, reflecting the potential of water resources amount and its sustainability.
	Dilution ratio of water (I_3)	The rate of total runoff in irrigation areas to the sewage discharge amount, reflecting the sustainability of water quality environment.
Water-use equity (C2)	Ratio of rural households using tap water (I_4)	The rate of the number of rural households using tap water to the total of rural households, reflecting the equity of domestic water accessibility.
	Ratio of rural households using clean water (I_5)	The rate of the number of rural households drinking hygiene-standard water to the total of rural households, reflecting the equity of domestic water quality.
	Ratio of water disputes among rural households (I_6)	The rate of the number of rural households disputing with others for production water to the total of rural households reflecting the injustice of water utilization.
	Ratio of households participating in meetings on water (I_7)	The rate of the number of rural households participating in meetings on water to the total of the rural households, reflecting the fairness of the water management process.
	Ratio of the rural households' opinions adopted (I_8)	The rate of the number of the farmers' opinions adopted to the total of farmer's opinion at the water meetings, reflecting the democracy of water resources management.
Water-use efficiency (C3)	Average irrigation amount per hectare (I_9)	The value of irrigation amount divided by the total effective irrigation area in an irrigation area, reflecting the efficiency of agricultural water utilization.
	Per capita domestic water consumption (I_{10})	The value of the domestic water consumption divided by the total population, reflecting the efficiency of domestic water consumption in irrigation areas.
	Agricultural output value of water per cubic meter (I_{11})	The value of total agricultural output value divided by total agricultural water consumption, reflecting the economic benefits of agricultural water consumption.

Table 1. *Cont.*

	Performance Indicators	Indicators Interpretation
Organizational efficiency (C4)	Ratio of the rural water user paying water fee actually (I_{12})	The rate of the number of water users paying water fee actually to the total who should pay, reflecting the administrative efficiency and sustainability of water management institutions.
	Rate of the water disputes resolved (I_{13})	The rate of the numbers of water disputes resolved effectively in irrigation areas to total water disputes, reflecting the administrative efficiency of water management institutions.
	Rate of the irrigation canal system with lining (I_{14})	The rate of the length of the irrigation canal with lining, to the total length of the irrigation canal system, reflecting the engineering construction efficiency of water administrative departments.
	Rate of the intact irrigation canal (I_{15})	The rate of the length of intact irrigation canal system to the total length of irrigation canal system, reflecting the engineering maintenance efficiency of water administrative departments.

Note: "C" refers to the performance dimension and "I" refers to the performance evaluating indicator.

2.2. The Influence Factors Index System

The objectives of SWRM are realized through the water resources management practices. The structural components of SWRM system, therefore, constitute the basic factors that affect the performance. In order to guide the practice of IWRM and to achieve the SWRM objectives, GWP proposed the general implementation framework and requirements for IWRM in three aspects: *the enabling environments*, *the institutional roles* and *the management instruments* [4]. *The enabling environment* provides goal-oriented policy, legislation guarantee and financial support; *the institutional roles* refer to the legitimate executing agency with well-defined power and responsibility, as well as its effective co-ordination mechanisms and; *the management instruments* offers the managers with a variety of effective and alternative tools. All of them are indispensable for the achievement of SWRM objectives.

According to the implementation frame and requirements of IWRM and considering the water resources management features of irrigation areas, the index system of performance impact factors consists of three types of indicators, at least, including *enabling environments*, *institutional roles*, *management instruments*. Considering the performance of water management may be affected by the local development level as an exogenous variable of the water resource management system, *social economic development level* in irrigation areas is also involved in the impact factors index system. Table 2 provides four types of factor indicators and their explanations.

Table 2. Factors index system of SWRM in irrigation areas.

Index Type	Influencing Factor Indicators	Index Explanation and Requirement
Enabled environment	Concerted management policy and legislation (D_1)	A series of policies and legislation should be established completely and concertedly for irrigation areas to realize the objectives of sustainable water management.
	Multiple subjects participation mechanism (D_2)	Water managers should include legally the representatives of the water, environment, agriculture sectors and rural water users.
	Executing willingness to legislation and policy (D_3)	The attitude of water resource managers to implement the water legislation and policies of irrigation areas, which should be positive.
	Investment coefficient on water conservancy (X_4)	The ratio of water conservancy investment accounting for GDP, which should be enough large to meet the need of water conservancy development in irrigation areas.
	Social investment rate on water conservancy (X_5)	The rate of farmers' investment on water conservancy which should be large enough to cover the shortage of government investment in irrigation areas.
Institutional roles	Farmer participation ratio in water user associations (X_6)	The ratio of number of the households participating in Water User Associations to total rural households, which should be one hundred percent at best.
	Representatives of ordinary farmer water users in water user associations (X_7)	The rate of representatives of ordinary water users in the water user association congress, which should be enough large in order to safeguard their interests.
	Responsibilities division of agencies (D_4)	The responsibilities of water authority and other relative government sectors should be clear and specific.
	Participation of the vulnerable groups (D_5)	A certain proportion of women and impoverished households should join water use association in irrigation areas.
	Democratic supervision mechanism (D_6)	There is an external supervisory institution that is democratically founded by water users for water management.

Table 2. *Cont.*

Index Type	Influencing Factor Indicators	Index Explanation and Requirement
	Farmer's information feedback mechanism (D_7)	The feedback channel of suggestions from the water user representatives should be established and be effective.
	Training of water professional managers and users (D_9)	Professional knowledge training of water managers should be implemented periodically.
	Educational level of water management personnel (X_{10})	Average schooling years of administrators in irrigation areas, which should be higher.
	Guarantee rate of operation expenses of WUA (X_{11})	The financial supply for the daily operation of water user association in irrigation areas should be enough.
Management instruments	Water resources supply and demand evaluation (D_7)	The monitoring and evaluation of water supply-demand should be implemented in terms of quantity and quality.
	Water conservancy objects impact assessment (D_8)	Social and environmental impacts assessment of water resources development projects should be implemented firmly
	Water utilization measurement (X_{12})	The rate of the number of water users whose water consumption is measured accurately to total water users.
	Information providence about water evaluation (D_9)	Releasing the data of water resources supply and demand as well as water diversion and water distribution to the public.
	Quota management system implementation (D_{10})	The water distribution should be strictly implemented in accordance with quota management principles.
	Popularity of highly efficient water-saving crops (X_{13})	The ratio of highly efficient water-saving crops areas to the total crops acreage.
	Reasonable water price and water charges (X_{14})	The ratio of water price and water charges to income of farmers, which should be high enough to stimulate water saving.
	Ratio of irrigation water trading (X_{15})	The proportion of irrigation water traded by the farmers to the total water saving amount
	Water-saving irrigation technology coverage(X_{16})	The ratio of water-saving irrigation area to effectively irrigated area, which should be 100% at best
	Water-saving technical training rate of farmers (X_{17})	The ratio of the farmers obtaining water saving technical training to the total farmers, which should be 100% at best.
Development level	Per capita net income of farmers (X_1)	The difference of the per capita income and expenses of famers, which should be the higher the better.
	Science and technology development level (X_2)	The number of agricultural sci-tech staff per 1000 employees in irrigation areas, which should be 1000 at best.
	Educational level of the population (X_3)	The ratio of employees with educational level of the middle school and the higher to total employees, which should be 100% at best.

Note: 'X' is a series of real variables of the influence factors and 'D' is a series of dummy variables of the influence factors.

3. Methodology

In this research, the regression analysis model in sociology recommended by Li [35] and Fan [36] are used to quantitatively analyze the influence of these factors in Section 2.2 on the performance of SWRM in irrigation areas. The overall comprehensive performance and the ones of four dimensions are regarded as the dependent variables and the factors influencing these performances are taken as the independent variables. Then five multiple linear regression models are established to analyze quantitatively the relationship between the performances and the influence factors. The accounting methods of the performance values and their influencing factors are shown in Sections 3.1 and 3.2, and the regression model is shown in Section 3.3.

3.1. Accounting Method of the Performance Index Values

The relative change index is used to indicate the values of performance indicators in this research. The index is of dynamics reflecting the changing value degree of performance indicators. The calculating method is shown as Formula (1) [37].

$$I_{ir} = \frac{|x_{ie} - x_{is}|}{x_{is}} \quad (1)$$

In the Formula (1), I_{ir}, is used to indicate the relative change index of the performance indicator I_i and x_{is} and x_{ie} are respectively the values of the performance indicator I_i at the beginning and the end of the study period. The relative change index method can not only reveal the performance of the sustainable water management but can also non-dimensionalize the performance indicator value.

The performance value calculation involves the synthesis of the values of multiple indicators but the importance of each indicator presents the differences of realizing the sustainable development of irrigation areas. Therefore, the integrated weighted index method is used to calculate the comprehensive performance and four dimension ones. The method is shown as the Formula (2).

$$I = \sum_{i=1}^{m} w_i I_{ir} \quad (2)$$

In the Formula (1), I, I_{ir} and w_i are indicated the performance values, the relative change index of the performance indicator I_i and its weight respectively.

In order to determine the index weights, Analytic Hierarchy Process (AHP) is adopted and the expert group scoring is used to overcome the unreasonable effect of the subjective factors arising from the personal experience and knowledge of evaluators [38]. In this research, we invited 15 experts on the water management from Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, to score the indicators. The weight values of performance indicators are shown in Figures 2 and 3.

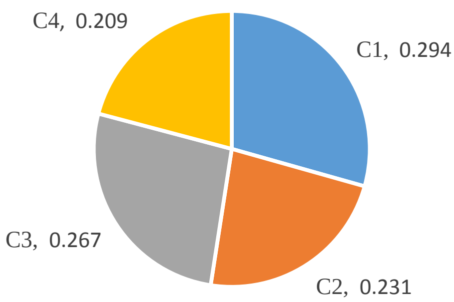

Figure 2. The weights of four performance dimensions.

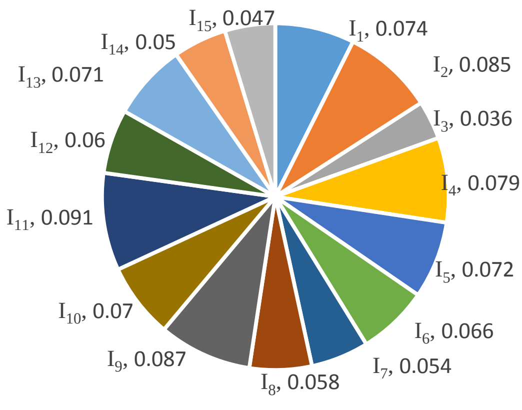

Figure 3. The weights of evaluating indicators.

3.2. Accounting Method of Influence Factors Index Values

Before analyzing the effect of the influencing factors on the water resources management performance, the indicator value of each influencing factor is quantitatively calculated. The values of the real variables are calculated using the relative method given in the right column Table 2. For example, the value of the indicator X_{12} can be obtained by computing *the ratio of the number of water users whose water consumption is measured accurately to total water users*. The values of dummy variables are signed according to the extent to which the implementation requirements in the right column of Table 2 are achieved. The scale of assigned values is in the range of 0–5. The value assigned is 0, if the requirement is not achieved completely. The value assigned is from 1 to 2, if the requirement is achieved a little. The value assigned is 3, if the requirement is achieved generally. The value assigned is 4 when the requirement is achieved quite well. The value assigned is 5 when the requirement is achieved very well. For instance, the value assigned D_{11} is five when the water distribution is strictly implemented in accordance with quota management principles.

3.3. Quantitative Regression Analysis Model

In this research, multiple regression analysis combined with the correlation analysis is adopted to reveal quantitatively the relationship between influential factors and performances. In the regression analysis, the performances of water management are the dependent values and the influential factors are the independent values. Given that there are only eight irrigation areas in the case region, eight samples can be used to regression analysis in this research. Obviously, the general regression analysis requirements are not met since the research sample size is limited and there are much more influencing factors [35]. As such, the equal-weighted composite index method is used to get a comprehensive value of each type of influencing factors in this study. The equal-weighted composite index method is shown as the Formula (3).

$$Z = \frac{1}{m}\sum_{i=1}^{m} X_{is} \tag{3}$$

In the Formula (3), Z is the comprehensive index of each type of influencing factors, m is the number of influential factors of each type and X_{is} is the standardized value of the influential factor X_i. In this research, X_{is} is obtained using the Formula (4).

$$X_{is} = \frac{X_i - \overline{X}_i}{S},\ (i = 1, 2, \ldots, 8) \tag{4}$$

In Formula (4), X_i refer to the indicator value, $\overline{X}_i$ is the mean value of X_i, S is the standard deviation and X_{is} is the standardized value of X_i.

Here, four comprehensive indexes of influencing factors can be obtained as follows: *social and economic development index* (denoted by Z_1), *enabling environment index* (denoted by Z_2), *institutional roles index* (denoted by Z_3) and *management instruments index* (denoted by Z_4). And then five regression analysis models are constructed to analyze quantitatively the relationships between these four kinds of influence factor indexes and five performance indexes including the *overall performance index* (denoted by Y_0), *ecological sustainability performance index* (denoted by Y_1), *water use equity performance index* (denoted by Y_2), *water-use efficiency performance index* (denoted by Y_3) and *management organization efficiency performance index* (denoted by Y_4). The models are shown as the Formula (5).

$$Y_{ji} = \beta_{0j} + \beta_{1j}Z_{1i} + \beta_{2j}Z_{2i} + \beta_{3j}Z_{3i} + \beta_{4j}Z_{4i} + \mu_{ji} \tag{5}$$

In the Formula (5), Y_{ji} refers to the overall performance or the dimension performance index of the item $j(j$ = 0, 1, 2, 3, 4) of the irrigation area $i(i$ =1, 2, . . . , 8). Z_{1i}, Z_{2i}, Z_{3i} and Z_{4i} refer to four influencing factors of the irrigation area i, respectively. β_{0j}, β_{1j}, β_{2j}, β_{3j} and β_{4j} represent respectively the regression constant and coefficients of corresponding models of the performance index of the evaluative dimension of the item j and μ_{ji} is the corresponding random error.

4. Empirical Research

4.1. Data Source

The Ganzhou District as the research case locates in the midstream of the Heihe Basin known as the second largest inland river basin in China. It is administrated by Zhangye City in Gansu province of China. There are eight large irrigation areas in this arid district. The research region and its eight large irrigation areas are shown in Figures 4 and 5, respectively. With the rapid economic development and population expansion in recent 30 years, all of these irrigation areas are confronted with severe water scarcity, ecological degradation and water conflicts. In 2002, Zhangye was issued as a pilot area of the water-saving society construction, and since then a series of reform measures for SWRM have been implemented in irrigation areas of Ganzhou, in particular.

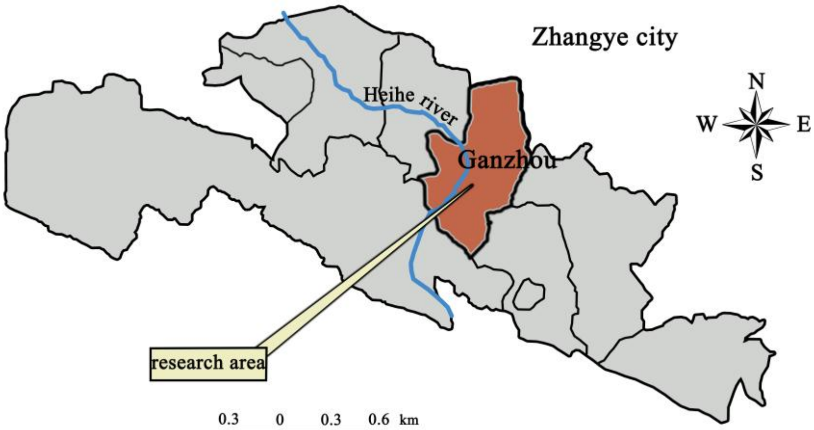

Figure 4. Location of the research area.

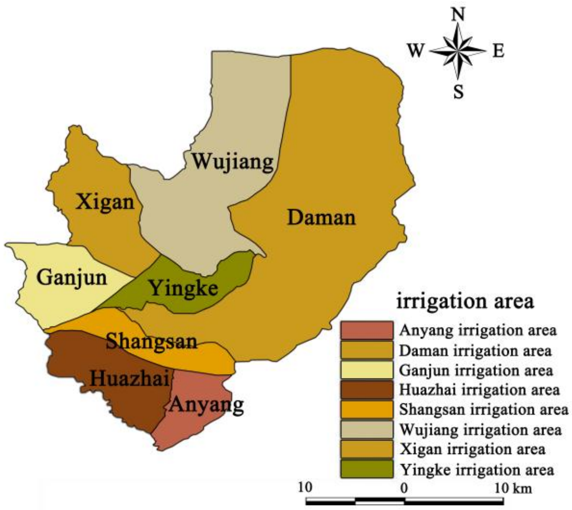

Figure 5. Eight irrigation areas in research area.

Given that the pilot initiative began in the case region since 2002, this paper selects the index data in 2002 as the initial year and terminal year of the water-saving society pilot construction to evaluate the performance dynamics of the water resource management in Ganzhou's irrigation areas. The data is mainly derived from the statistical yearbook [39] published by the government statistics department, and the comprehensive water conservancy reports of Zhangye and annual management reports of Ganzhou District provided by the local water department. The other data is from the questionnaires and in-depth interviews involving water administrative agencies, water users' associations and water users in the irrigation areas.

The data of influence factors are mainly obtained through questionnaire survey, with the respondents mainly being administrators of the water users associations, water administrative agencies, some data are acquired through investigating the rural households, and the data on regional development are mainly obtained from the literature [39]. The results show that, there are differences of the indicator values of the influencing factors except X_6, D_4, D_5, D_7 and D_8. So, these five independent variables are not included in the regression analysis.

The overall and four dimensions performance index values of eight irrigation areas in Ganzhou are given in the Appendix A of Table A1. And the values of influence factor indicators in the eight irrigation areas of Ganzhou are shown in the Appendix A of Table A2.

4.2. Results and Analysis

Before regression analysis, the correlation coefficients between the influencing factors indexes and the performance indexes of water resources management in the case areas are calculated first and shown in Table 3.

Table 3. Correlation coefficients between the performances and influence factors.

Influencing Factor Index	Correlation Coefficients				
	Y_1	Y_2	Y_3	Y_4	Y_0
X_1	0.307	−0.731 **	0.511	0.387	−0.243
X_2	0.089	−0.111	0.163	−0.391	−0.075
X_3	0.171	−0.697 *	0.643 *	0.194	0.011
D_1	−0.377	−0.129	0.648 *	0.024	−0.020
D_2	−0.330	−0.046	−0.003	0.688 *	0.288
D_3	−0.712 **	0.247	0.565	0.106	0.510
X_4	−0.312	0.217	−0.150	0.383	0.521
X_7	−0.485	0.443	0.067	0.235	0.705 **
D_6	−0.672 *	0.103	0.337	0.487	0.525
X_8	0.151	−0.235	−0.347	0.180	0.439
X_9	−0.374	0.099	0.102	0.643 *	0.729 **
X_{10}	0.023	0.553	−0.638 *	−0.450	−0.076
X_{11}	−0.677 *	0.192	0.202	0.759 **	0.951 **
X_{12}	0.300	0.003	−0.227	−0.233	−0.426
D_9	−0.669 *	0.637 *	0.220	−0.465	0.261
D_{10}	−0.379	0.445	0.103	−0.123	0.408
X_{13}	−0.298	−0.123	0.757 **	0.582	0.679 *
X_{14}	−0.690 *	0.109	0.661 *	0.660 *	0.846 **
X_{15}	−0.857 **	0.757 **	−0.128	−0.090	0.367
X_{16}	−0.406	0.454	0.673 *	0.274	0.596 *
X_{17}	−0.223	0.033	0.561	−0.102	0.012

Note: "*" and "**" indicate the significance tests at the levels of 0.1 and 0.05, respectively. "Y_i" refers to the performance index.

Using Limdep software, the regression analysis and testing of the models are carried out by Ordinary Least Square (OLS). The goodness of fit (R^2) of the regression models and the value of overall significance level (F) are both very low, which cannot meet the model analysis requirements. The models showed their heteroscedasticity when Goldfeld-Quat Variance Test is used [35]. After Weighted Least Squares (WLS) is utilized for correction, most of the goodness of fit (R^2) and significance level (F) are greatly improved, which can meet the model analysis requirements [35]. The regression coefficients and significance level of each model are listed in Table 4.

Table 4. Regression coefficients and its significance of influencing factors.

	Z_1	Z_2	Z_3	Z_4
(Y_0)	−0.00693 (0.134)	0.0117 * (0.087)	0.0235 ** (0.000)	−0.00629 (0.203)
(Y_1)	0.08642 ** (0.0220)	−0.01181 ** (0.0043)	−0.001949 (0.5863)	0.001341 (0.7000)
(Y_2)	−0.024828 (0.1406)	0.012048 (0.53886)	0.004004 (0.7427)	0.002173 (0.7717)
(Y_3)	0.01413 (0.1930)	0.03896 (0.9727)	−0.07844 * (0.0647)	0.01808 * (0.0966)
(Y_4)	0.0051 (0.3534)	0.01345 ** (0.0224)	0.0256 ** (0.0199)	0.0202 ** (0.0286)

Note: "*" and "**" indicate the significance tests at the level of 0.1 and 0.05, respectively. The figures in the brackets show the significance. "Y" and "Z" refer to the performance index and the influence factor index respectively.

Based on the results in Tables 3 and 4, we analyzed comprehensively the influence factors of the SWRM performance in the irrigation areas of Ganzhou.

4.2.1. Analysis on the Influence Factors of Overall Performance

The regression coefficients of Z_2 and Z_3 pass significance tests at the levels of 0.05 and 0.1 respectively. And the coefficients are 0.0117 and 0.0235 respectively, which means that the *enabling environment* and *institutional role* factors have a significant positive effect on the overall comprehensive performance (Y_0) on a whole, and the effect of *institutional role* factors is slightly stronger than that of *enabling environment* factors in general. According to the correlation coefficients in Table 3, the institutional factors, such as the ratio of the representatives of ordinary water users in the congress of water user associations (X_7), the number of annual training sessions of the personals in management organizations (X_9) and guarantee rate of water users' association operation expenses (X_{11}), have positively affected the overall performance (Y_0). In addition, there is a highly significant positive correlation between the ratio of water consumption charges (X_{14}), popularity rate of highly efficient water-saving crops (X_{13}), the water-saving irrigation coverage (X_{16}) and the overall performance index (Y_0), which shows that these institutional factors also play an important role in the overall performance of water management in irrigation areas.

4.2.2. Analysis on the Influence Factors of Environment Performance

The coefficients of social-economic development factors index (Z_1) and enabling environment factors index (Z_2) pass the significance tests at the level of 0.05. The coefficient value (0.08642) of Z_1 indicates that the social-economic development level of the irrigation areas has a positive role in promoting the environmental performance of water resources management. However, the coefficient value (−0.01181) of Z_2 shows that the enabling environment factors including the policy, legislation and financial support have a slightly negative impact on the environmental performance. The correlation coefficients in Table 3 show that enhancing the irrigation technology and the peasants' educational level may be beneficial to promoting environmental sustainability. However, we find that the institutional factors and instrumental factors maybe have a certain negative impact on the environmental performance. According to the survey, the participants of water management in the research area mainly consist of the administrators of the water administrative agencies, administrative staff in township governments and water user representatives but lack the environmental protection staff, unfortunately. So, it is difficult to balance the relationship between ecological and agricultural water use through the water management. The ecological water demand is ignored seriously.

4.2.3. Analysis on the Influence Factors of Social Performance

Whether OLS or WLR regression analysis is adopted, the good fitness between each kind of influencing factor index and the social justice performance is very low. All of the regression coefficients do not pass the significance tests. However, according to the correlation coefficients of the factors theoretically relative to this performance, some factors may have direct effects on social justice performance. These factors include the water management information publicity (D_9), water administrators' educational level (X_{10}) and the ratio of the representatives of ordinary water users in the water user association congress in irrigation areas (X_7) with the correlation coefficients 0.637, 0.553 and 0.433, respectively. This shows that the information publicity and the public participation mechanism in irrigation water management may promote the water use equity. However, the other factors including the democratic supervision mechanism (D_6), information exchange and feedback (X_8), among others, have no stronger correlation with the performance, which indicates that these factors do not play their due roles in this performance.

4.2.4. Analysis on the Influence Factors of Economic Performance

As shown in Table 4, the institutional factors index (Z_3) and the management instrument factors (Z_4) pass the significance test at the significance level of 0.1, which shows that these two types of factors have a certain influence on the water use efficiency and economic benefits. The regression coefficients show that the water management instruments factors index (Z_4) significantly improve the economic performance of water management in irrigation areas, while the management system factors (Z_3) has a certain negative influence on this performance. By analyzing the correlation coefficients between all the influencing factors and the economic performance as shown in Table 3, the highly efficient water-saving crops' popularity rate (X_{13}), water-saving irrigation coverage (X_{16}) and the ratio of water charges in the agricultural production (X_{14}) have a strong positive correlation, with the correlation coefficients being 0.757, 0.661 and 0.673, respectively. This shows that the performance of water use efficiency and benefits has increased through by adopting the method of adjusting the planting structure, promoting efficient water-saving crops, popularizing water-saving technology and applying the economic lever of water charges.

4.2.5. Analysis on the Influence Factors of Organizational Performance

The coefficients of the enabling environment factors index (Z_2), the institutional roles factors index (Z_3) and management instruments factors index (Z_4) pass the significance tests at the level of 0.05. The coefficient values indicate that all of these three types of factors have positive influence on the management organizations efficiency (Y_4) on a whole. According to the correlation coefficients in Table 3, the management organizations performance has a significantly positive correlation with extensive participation mechanisms (D_2) with the correlation coefficient 0.688, the annual training sessions for water administrators (X_9) with the coefficient 0.659 and the expense guarantee rate of water user association operation (X_{11}) with the correlation coefficient 0.759. This means that the water resources management organization efficiency can be improved through stimulating the public and relevant organizations participation, strengthening the water management organizations capacity-building and improving the financial support for water user association in irrigation areas.

5. Conclusions and Recommendations

Irrigation areas are important geographic units in which large amounts of water resources are consumed and the use of water resources in these areas must be managed sustainably. It is significant to ascertain systematically the performance of the water resources management and its influential factors in irrigation areas. However, the previous research has not paid enough attention on the theme. In this research, we developed systematically the performance index system and its influencing factors index system suitable to irrigation areas. It provides basic index tools for evaluating and analyzing the SWRM of irrigation areas. In according with the multiple objectives of IWRM, the performance index system of SWRM consists of four indicator dimensions such as ecological sustainability, social equity, economic efficiency and operation efficiency of management organization. According to the implementation frame of IWRM, the influence factors index system includes four types of indicators including enabling environment, institution roles, management instruments and economic development level of irrigation areas.

The results of this empirical research are as follows. The overall performance of water resources management in irrigation areas is mainly affected by the management implementation environment and institutional roles factors such as the ordinary farmers' participation, the water administrators' ability improvement, water user association operation expenses guarantee and so on. The performance of ecological sustainability is mainly affected positively by the social-economic development and enabling environment factors of SWRM in irrigation areas but the water management system design and capital investment play a restrictive role in this performance due to the excessive emphasis on the economic benefits and the lack of environmental protection. The social equity performance is mainly impacted by the information disclosure, the water administrators' educational level and the ordinary farmers' participation in water management. The popularity of the highly efficient water-saving crops and water-saving irrigation technologies and the economic level of water charges play an important role in increasing the economic benefits of water resources management in irrigation areas. The financial support for the farmers' water user association, the training of water administrators and the public participation have the significant positive effect on the operation efficiency of management organization.

Based on the results, we provide several policy recommendations for water resources management in irrigation areas. In order to improve the overall performance, it is necessary to strengthen public participation, improve the manager's ability and provide sufficient financial support for the management organization. For improving environmental performance, it is most important to strengthen the legislation that is designed for water environmental protection, water environment monitoring and the participation of environmental protection departments. In order to improve the social equity performance, it is of more significance to strengthen the participation of water users, establish the management supervision mechanism, as well as to improve the water administrators' educational level. For enhancing the economic benefit performance, it is needed to strengthen the rural household water utilization level, such as popularizing the water saving technology and changing the planting structure. In order to increase the water management organization's efficiency, a variety of channels should be used including financial support, personnel training, public participation and so on.

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Appendix A

Table A1. Overall and four dimensions indexes of the eight irrigation areas in Ganzhou district.

Irrigation Areas	Ecological Sustainability Index	Water Use Social Equity Index	Water Use Efficiency Index	Management Operation Efficiency Index	Overall Performance Index
Daman	0.031	0.120	0.042	0.083	0.281
Yingke	0.038	0.086	0.063	0.041	0.228
Wujiang	0.048	0.093	0.025	0.073	0.239
Yigan	0.034	0.114	0.072	0.026	0.247
Ganjun	0.022	0.091	0.086	0.069	0.268
Shangsan	0.031	0.082	0.077	0.107	0.297
Anyang	0.012	0.191	0.030	0.049	0.282
Huazhai	0.043	0.114	0.036	0.032	0.255

Table A2. Standardized values of influence factor indicators of the eight irrigation areas in Ganzhou district.

Influence Factor Indicators	Irrigation Areas							
	Daman	Yingke	Wujiang	Xigan	Ganjun	Shangsan	Anyang	Huazhai
X_1	0.571	0.840	0.529	0.430	0.414	0.426	−1.634	−1.575
X_2	−0.416	0.571	0.200	0.324	0.817	1.311	−1.527	−1.280
X_3	−0.551	0.975	1.144	1.229	0.127	−0.975	−1.144	−0.805
D_1	1.049	−0.150	−0.150	1.049	1.049	−0.150	−1.348	−1.348
D_2	0.354	0.354	0.354	0.354	0.354	−2.475	0.354	0.354
D_3	−0.540	−0.540	1.620	−0.540	1.620	−0.540	−0.540	−0.540
X_4	−0.900	−0.346	1.869	−0.346	−0.267	−0.425	1.236	−0.821
X_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X_6	−0.581	0.675	0.518	0.675	−0.581	0.675	0.675	−2.057
X_7	1.480	−0.461	0.509	1.286	−0.461	−0.461	−0.461	−1.431
D_4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D_6	0.725	0.725	−1.208	−1.208	0.725	0.725	0.725	−1.208
X_8	1.348	−0.449	0.150	0.150	−1.049	0.749	−1.648	0.749
X_9	−0.661	1.984	−0.661	−0.661	−0.661	0.661	−0.661	0.661
X_{10}	−0.883	0.896	0.489	−0.629	1.659	−0.273	−1.392	0.133
X_{11}	−1.347	0.527	−1.113	0.762	1.230	−0.644	0.996	−0.410
D_7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D_8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X_{12}	1.273	1.273	0.075	0.674	−1.423	−0.824	−0.374	−0.674
D_9	0.354	1.768	−1.061	−1.061	0.354	0.354	−1.061	0.354
D_{10}	0.382	1.146	−0.382	−0.382	−1.909	−0.382	1.146	0.382
X_{13}	1.438	0.214	−0.275	−1.499	1.193	−1.010	−0.275	0.214
X_{14}	0.242	−0.835	−0.404	0.027	1.104	1.750	−1.050	−0.835
X_{15}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X_{16}	−2.042	−0.212	0.441	0.964	0.310	−0.735	0.964	0.310
X_{17}	−1.142	1.033	−0.417	−1.142	−0.562	−0.127	1.323	1.033

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