Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2020.25253

188 (2020) 277–281
June

Impulse analysis process of rice growers participating in water conservancy and irrigation management and countermeasures and suggestions for agricultural scientific research units to play a guiding role – take the Qingan County of Heilongjiang Province as an example

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Received 30 June 2019; Accepted 20 December 2019

ABSTRACT

The water consumption of rice planting is large. Based on the limited water resources and the strong domestic rice demand, measures must be taken to make rational use of water resources. The effective way is for rice growers to participate in the management of water conservancy irrigation. In this study, the cooperative organization of water use between rice growers and water cooperation organization was used as a closed system to solve the stable relationship between them and the influence of water cooperative organization on irrigation management of rice growers.

Keywords: Water conservation; Irrigation management; Rice cultivation; Impulse process simulation

1. Survey site selection and sample description

Qingan County belongs to Suihua City, located at the intersection of Songnen Plain and Xiaoxing' an Mountains in central Heilongjiang Province. This county belongs to the low mountains and hills plain area, belongs to the cold temperate zone continental monsoon climate. This country is suitable for planting rice, where is the national green food base and the first-grade rice production base. In 2018, the rice planting area is about 1.55 million mu.

There are nine rivers in Qingan County, which are relatively rich in water resources, but the proportion of domestic agricultural water use is the highest in various industries, and the utilization rate of agricultural water resources is low. Meanwhile, a phenomenon of water waste can be seen everywhere. Moreover, the management level of agricultural irrigation technology lags, and water conservation has not been taken seriously. In recent years, with the rapid development of the local economy and society, the demand for water resources has soared, and the relative shortage of water resources has been highlighted [1–6]. Therefore, it is urgent to carry out water resources management. Under various water resources management modes, it is an effective way for rice growers to participate in water conservancy and irrigation management.

The main research area of this study is the Heping Irrigation District in Qingan County, which is a self-flowing water irrigation area. Heping irrigation district is one of the first irrigation districts to set up farmers' water cooperation organization in Heilongjiang Province. The regional water use cooperation organization has a good development and has certain representativeness. The irrigation area

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1944-3994/1944-3986

is effectively controlled by 2,626.67 hm², which belongs to medium-sized irrigation area. In this study, the field survey data were used to systematically analyze the participation of rice growers in the irrigation management impulse process in Heping irrigation district.

2. Model construction

This study is to determine the scope of a system, then to find the interactions between the elements within the system. The main aim is to predict and judge of evolution process and changing trend of one factor to other various elements in the system.

The research mainly uses v_1–v_8 to indicate the scale of the water-use cooperation organization, the completion rate of the project, the water utilization coefficient of the irrigation, the irrigation area, the average irrigation water consumption per unit area, the price of the irrigation water, the frequency of the water dispute, and the yield of the rice unit at the same time, consider these eight factors as a closed system [7–12].

In this system, $v_i(t)$ is used to represent the state value of v at t time, and a_{ij} is used to represent the influence coefficient of v_i on v_j at the next time. The relationship between the factors in the closed system is as follows: if the influence of v_i on v_j in the next stage is positive, it is represented by 1, and vice versa. If there is no effect, it is represented by 0. The formula is as follows:

$$A_{ij} = \begin{cases} 1, \text{ if } v_iv_j \text{ is positive} \\ -1, \text{ if } v_iv_j \text{ is negative} \\ 0, \text{ if } v_iv_j \text{ does not exist} \end{cases} \quad (1)$$

$$A = (a_{ij})_{8\times 8} = \begin{bmatrix} a_{11} & \cdots & a_{18} \\ \vdots & \ddots & \vdots \\ a_{11} & \cdots & a_{18} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 1 & 1 & -1 & -1 & -1 & 0 \\ 1 & 0 & 1 & 1 & -1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ -1 & 0 & 0 & -1 & 0 & 1 & 1 & 0 \\ -1 & 0 & 0 & -1 & -1 & 0 & 0 & 0 \\ -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (2)$$

Let the influence between the factors in matrix $A = (a_{ij})$ be extremely different from that of ω_{ij}, and the matrix W. Get Eqs. (3) and (4):

$$p_i(t+1) = v_i(t) + p_i(t+1), i = 1,2,3,8,\ t = 0,1,2,3 \quad (3)$$

$$v_i(t + 1) = v_i(t) + p_i(t + 1),\ i = 1,2,3,8,\ t = 0,1,2,3 \quad (4)$$

Row vector: $V(t) = [v_1(t),v_2(t),v_3(t),\ldots,v_s(t)]$,
$P(t) = [p_1(t),p_2(t),p_3(t),\ldots,p_s(t)]$

According to Eqs. (3) and (4), get the Eqs. (5) and (6):

$$P(t+1) = P(t)W,\ t = 0,1,2,3 \quad (5)$$

$$V(t + 1) = V(t) + P(t + 1) \quad (6)$$

If only the system changes based on the initial state, get the Eq. (7)

$$V(t + 1) = V(t) + P(t + 1) \quad (7)$$

By means of Eqs. (1)–(6), the impulse $P(t + 1)$ received by each factor in the system at any time period from t to $t + 1$ can be calculated respectively, in order to grasp the changing trend of irrigation management system caused by the establishment of farmers' water cooperative organization (influence of impulse).

3. Data source and impulse process simulation

3.1. Data sources

It is mainly the data provided by the local water conservancy bureau. The time period is selected for the period from 2011 to 2018, with a total of 8 years. According to the basic data, calculate the average annual growth trend of each factor.

3.2. Simulation of impulse process

In the quantitative analysis of key factors, the annual growth rate of each factor for 8 years is used as the basis for quantitative analysis, as shown in Table 1.

On the basis of the relationship between the annual growth rate of each factor and the key factors in the adjacent matrix, the data of the annual growth rate are divided into pairs. The new data are used as the weighted value between the two factors, and the weight to replace the value of 0, 1, and –1 in matrix $A = a_{ij}$ ($a_{ij} = 0$, $w_{ij} = 0$). Thus, the corresponding adjacent matrix W. In the comparison between directed adjacent matrix W and A, it is found that there are positive and negative problems in the data after pairwise comparison of some factors.

4. Model analysis results and application

4.1. Volatility analysis of closed systems

If anyone of the factors in the system changes at $t = 0$, it can produce that any factor in the system does not change its numerical value at any time period, then the impulse process of this system is stable. While for the i and arbitrary t of the system, if $/p_i(t)/$ has a boundary, it is called impulse process impulse stability. If s is stable, then it is sure that this impulse process must be stable.

Let λ be a W nonzero characteristic root, then there is a necessary and sufficient condition for S impulse stability $/\lambda/ \leq 1$, and all of them are single roots. According to the data information of the directed connection matrix W_i, the

Table 1
Factors for Peace Index closed system of irrigation districts of water cooperation and rice planting farmers

Year	Organization size	Intact rate	Coefficient	Irrigation area	Water consumption	Water price	Frequency	Rice yield per unit
2011	1,441	40	39	2,550	53.34	2.6	54	7,128
2012	2,635	47	42	2,550	51.35	2.7	49	7,500
2013	3,024	53	50	2,580	50.20	2.72	45	7,510
2014	3,820	57	55	2,580	46.78	2.88	39	8,125
2015	4,615	62	62	2,600	46.21	4.10	36	8,800
2016	5,061	67	60	2,610	44.77	4.10	34	9,100
2017	6,009	71	68	2,620	43.35	4.10	33	9,380
2018	6,951	71	66	2,620	40.10	4.3	32	10,800
Average rise rate	25.2%	8.4%	8.1%	0.7%	–4%	7.5%	–7.6%	5.9%

characteristic roots of the matrix are obtained by MATLAB 2015b software. The characteristic roots of the matrix are λ = [1.5140 + 0.666i, 1.514 – 0.6663i, –0.8625 – 1.2243i, –0.8625 – 1.2243i, –1.4901, 0.0937 + 0.4619i, 0.0937 – 0.4619i, –0.0002]^T. It can be seen that the modulus of the characteristic roots is larger than 1. Evidence of instability in the closed system of the water partnership between rice growers and farmers.

4.2. Impulse process of closed systems organized by rice growers and water cooperation organization in cooperation with water use

In this study, we used an impulse process model which is used to study the evolution process of each factor in the system when there was a sudden increase in the size of the water cooperative, and the volatility of each factor in the system is analyzed. It is assumed that the influence of the expansion of the scale of farmers' water cooperative organization on the factors in the closed system will appear in the next period, that is, if $P_0 = V_0$ = [10,000,000], $P(t)$ and $V(t)$ can be obtained according to the definition of Eqs. (5)–(7). The specific data run results were shown in Tables 2 and 3.

4.3. Results and interpretation of impulse process

The results of the impulse process of the closed system composed of the rice planting house and the farmers' water cooperative organization show that at the initial stage t = 0–4, the increase of the scale of the farmer's water cooperation organization has an adverse effect on the average water consumption of the unit area of the irrigation area and the water price of the irrigation water, and the main performance is that the data symbol is negative. That is to say, in the initial stage of the formation of the farmer's water cooperation organization, the increase of the members of the water cooperation organization has not played an important role in saving the irrigation water for the rice planting households and reducing the water cost. However, with the increase of the farmers' water cooperation organization, the utilization coefficient of irrigation water in the irrigation area is increased rapidly, and the water dispute incidence in the irrigation area is reduced obviously. When t = 0~5, the influence of the scale of the farmer's water cooperative organization on the key factors, V_2–V_8, is not significant, and the effect of the expansion of the scale of the farmer's water-use cooperative organization on the key factors V_2–V_8 is enhanced over time (t = 0~4), which means that over time, The farmers' water cooperative organization in the management of irrigation is gradually beginning to have an impact on it.

From influence degree, when t = 8, the biggest influence of V_1 scale on V_2 is 13.8256, followed by 7.5817 on V_3, which indicates that the increase of farmers' water cooperative organization has a higher influence on the completion rate of irrigation project and the coefficient of irrigation water use. In principle, the increase of the membership of the water cooperative organization will play a good role in promoting the completion rate and irrigation water utilization coefficient of the last canal system project in the irrigation area, but the results of the model analysis are the opposite. According to the most reliable explanation of the survey information, the internal governance mechanism of the farmers' water cooperative organization is not perfect. The incentive mechanism of reward and punishment is insufficient. Under the condition of a large increase in membership, the completion rate of the last canal system project has not been improved, and the water consumption rate of irrigation is still high. At the point of t = 8, the influence of the expansion of the V_1 scale on V_6 is also as high as 4.7045. It shows that the increase of farmers' water use cooperative organization membership will promote the price of irrigation water for water users. In the actual investigation, the size of V_6 is mainly affected by government pricing, and the running Peasant Water Cooperation Organization does not have the right to fix a price to agricultural water and to collect water charges. Water prices will gradually move towards cost price, appear to rise. It can be seen from Table 3 that the symbol of V_5 is always "–" at $0 \le t \le 7$, which indicates that the expansion of the scale of farmers' water use cooperative organization has a good influence on the reduction of the average water consumption per unit area of internal members. However, at t = 8, V_5 = 2.5847, it shows that the role of farmers' water cooperative organizations will be limited and even harm the interests of water users by relying solely on the expansion of the scale of the organization and the lack of effective internal operation mechanism and good external coordination

Table 2
Closed system of impulse user cooperation and farmers' water organization

t	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
0	1.000	0	0	0	0	0	0	0
1	0	0.3331	0.3176	0.0281	–0.1591	–0.2901	0.2942	0
2	2.9995	–0.3336	0.3176	0.1114	–0.1587	0.0019	0.0019	0.2261
3	0.9807	1.3298	0.6334	0.1396	–0.4778	0.0014	1.7649	–0.2268
4	2.9785	–2.0105	1.5772	0.2494	–1.1065	0.2987	0.8795	0.9031
5	1.8812	1.3247	–0.9698	0.3315	–0.4689	–0.2849	1.4625	–1.3652
6	–0.1235	–3.0457	1.8579	0.0189	–0.2896	2.0544	3.1885	0.8999
7	–19.4124	–2.3339	–2.9289	–0.1289	–0.5855	–0.2959	–0.3725	–2.0681
8	–10.2829	–9.0898	–8.3757	–1.1197	5.8289	3.2189	–8.1508	–1.5847

Table 3
Closed system momentum user cooperation and farmers' water organization

t	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8
0	1.000	0	0	0	0	0	0	0
1	1.0000	0.3331	0.3176	0.0281	–0.1591	–0.2901	0.2942	0
2	3.9995	–0.0007	0.6344	0.1393	–0.3172	–0.2869	0.2959	0.2267
3	4.9807	1.3298	1.2672	0.2789	–0.7947	–0.2869	2.0609	–0.0005
4	7.9589	–0.6814	2.8443	0.5279	–1.9011	0.0118	2.9401	0.9031
5	9.8403	0.6439	1.8748	0.8597	–2.3699	–0.2727	4.4029	–0.4628
6	9.7169	–2.4017	3.7323	0.8777	–2.6589	1.7816	7.5908	0.4374
7	–9.6955	–4.7358	0.7939	0.7493	–3.2441	1.4859	7.2189	–1.6307
8	–19.9783	–13.8257	–7.5819	–0.3705	2.5849	4.7046	–0.9325	–3.2156

mechanism. From the influence on V_8, there is a deviation from the prediction relationship, which is because the promotion of V_8 is not only affected by irrigation water, but also affected by soil fertility, planting technology, planting varieties and soil fertility. The results of model analysis show that the effect of V_1 on V_4 is the least, which indicates that the increase of water cooperative organization membership has no significant effect on the impulse of irrigation area.

It shows that the scale expansion of farmers' water cooperative organization is faster than that of irrigation area, that is to say, there are problems in the statistical standard of the number of members counted by the water cooperative organization at present. Take the number of people in the administrative village covered by the association as the number of members.

5. Conclusion and recommendation

According to the conclusion of the analysis, it can be seen that maintaining the stability of the cooperative organization system between rice growers, giving full play to the role of farmers' water cooperative organizations in irrigation management, and giving full play to the main role of rice growers in the construction of small-scale water conservancy projects in rural areas, in addition to the need for the government to increase policies, funds, propaganda, guidance and service, increase the training of rice growers, pay attention to encouraging rice growers, and improve their participation. This study believes that attention should be paid to the establishment and innovation of the operating mechanism of farmers' water cooperative organizations:

- To establish an effective internal operation mechanism. In this paper, eight factors, such as the scale of farmers' water cooperative organization and the completion rate of the irrigation project, are involved in the vital interests of water users and the key factors affecting their enthusiasm to participate in irrigation management. However, the closed system composed of these factors is unstable, the important reason is that the increase of the scale of farmers' water cooperative organization has not improved the effectiveness of the original irrigation management, that is, the development of various factors within the organization is not coordinated. According to the results of actual investigation and data analysis, it is shown that the property right, input, governance, decision-making, incentive, and restraint mechanism of farmers' water use cooperative organization, that is, the internal governance mechanism, affect the water users and the water users. The stability of farmers' water cooperation and the decisive and fundamental factors of their own utility. Therefore, it is necessary to standardize the internal operation mechanism of farmers' water cooperative organization and ensure its function through the mechanism regulation.

- To establish a good external coordination mechanism. Through the impulse process model and operation results, it is found that the eight factors related to water users and farmers' water cooperation organizations are not only affected by the coordination relationship of internal factors but also affected by government policies, the degree of recognition and support of farmers' water cooperation organizations and the degree of adaptation of farmers' water cooperation organizations to the market. Therefore, if the external coordination mechanism is not handled well, it will directly affect the development of the internal operation mechanism, and even the operation of the whole system. It is necessary to establish a good external coordination mechanism and adjust the development orientation and planning of farmers' water cooperative organizations in due course.
- To give full play to the leading role of the agricultural water conservancy scientific research unit. The research and development of water-saving key equipment and major products of modern agriculture, the establishment of the technology innovation system of water-saving agriculture, the promotion of the technical level of water-saving agriculture, the rapid development of the water-saving agriculture industry, the research, and development of the modern water-saving agricultural technology system and the new products are given.

Acknowledgement

Be funded by: Research on transformation model innovation of research findings in agricultural scientific research institutions in Heilongjiang Province (GC16D114). Science and technology innovation project of gain high yield (2018YFD0300107-6). Postdoctoral program in Heilongjiang Province (2016). Doctoral research start-up fund project in Heilongjiang Academy of Agricultural Sciences (2015). Influencing factors and optimizing countermeasures study of diversification of soybean import sources in China based on the background of trade friction (19JYB022).

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