

Practice and research on water-saving water management model in Gaoyou irrigation district under South–North Water Transfer project situation

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Abstract. In order to meet the needs of the development of limited water supply in South – North Water Transfer Project, Gaoyou irrigation district, with the goal of realizing the modernization of irrigation district, keeps pace with the times, actively explores a new water-saving management model, reforms the water management system, and optimizes the dispatching of water sources, establishing scientific management system and good operation mechanism of irrigation district, realizing optimal allocation and efficient utilization of irrigation water resources in Irrigation district, and making irrigation district on the road of sustainable development of benign operation, significant water-saving benefits, irrigation benefits and social benefits have been achieved.

Keywords: Irrigation district; Water-saving type; Management; Gaoyou.

1. Introduction

Gaoyou irrigation district is a national large-scale irrigation district, located in the lower reaches of the Huai River, the upper section of the South-North Water Transfer Project east line project, Grand Canal water for artesian irrigation. The total designed area is 632,000 mu, the effective irrigation area is 589,000 mu, the soil is mainly clay loam, the soil is fertile. Gaoyou irrigation area is short of water resources, complex engineering water system, long water transmission lines, large channel section. In addition, agricultural industrial structure is single, led to the excessive concentration of water use during irrigation period. As the South-North Water Transfer Project water supply has been completed, the distribution of water resources has decreased, and the contradiction of water shortage is still obvious at the peak of water use. In order to meet the demand of limited water supply under the new situation, in addition to taking engineering measures to save water, it is of great significance to improve the management measures and study the water-saving management mode.

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2. Management practice of water-saving water consumption pattern

Over the years, in order to ensure the normal delivery of water from the South-North Water Transfer Project, the provincial and municipal governments have strengthened the management of the amount of water in the canal and implemented total control and quantitative supply. In order to adapt to efficient irrigation area agriculture development and the needs of the modernization of water-saving irrigation construction, Gaoyou irrigation district actively organizes and implements the irrigation district renewal matching and the water-saving reconstruction project. At the same time, according to the requirement of the “two reforms and one improvement” carried out the

research and practice of "water-saving water management model", the reform of water management system and operation mechanism, innovation of irrigation water supply system, Remarkable achievements have been made in saving water, improving irrigation benefits and improving economic and social benefits.

2.1 Reforming the Water Management System

Because the engineering front line is long, the management energy is scattered. In the past years, the decentralized management of water rights and the self-regulation of water quantity by the four management stations set up in main channels have resulted in extensive water management, poor implementation of water use plans and serious water waste. During the period of limited water supply by the South-North Water Transfer Project, the water level of the canal often fell easily, but rose slowly. Gaoyou irrigation district actively carries out the reform of water supply management system, adopts the practice of "Water rights general management, piecemeal regulation," and standardizes the management of water supply allocation [1]. The irrigation district is responsible for the management of water use along the canal gates, exercising the right of water allocation to the heads of the main canals, the township water stations along the line are responsible for water management below the tributaries, and the village groups and water supply brokers are responsible for supervision to the bucket canal head, up to field head. After the unified management of water rights was implemented, the responsibility and power of water management in the Gaoyou irrigation district were clearly defined, which fundamentally changed the chaotic situation of water use in the past with no organization, no discipline, and free control, straighten out the relationship between water supply and management, strengthen the management function.

2.2 Implement Channel Grouping and Rotation Irrigation

Opening of diversion culvert gate along the Grand Canal in Gaoyou Irrigation district , generally managed in the way of continuous irrigation of main canal and rotation irrigation of branch canal according to the water consumption plan handed down by higher authorities. When the South-North Water Transfer Project diverted water to the north, it was emphasized that the water level of the Grand Canal should be ensured, and the discharge distributed by the higher authorities was often not a constant, as a result, the water level of the main canal and the following channels is unstable and the water utilization efficiency is poor. In order to change this situation, the Gaoyou irrigation district has developed irrigation schemes and water consumption plans (take the irrigation water meter of Gaoyou irrigation district in 2018 phase I as an example, as shown in fig.1) , by adopting the practice of "Water right control, grouping rotation irrigation, regular water supply and systematic water saving", the sluice along the Grand Canal river adopted "grouping rotation irrigation and regular water supply", which effectively guaranteed the water level stability of the main channel and all levels of the channel, and promoted the water saving of irrigation area [2].

2.3 Formulate Irrigation Cycle of Branch Canal at All Levels

Irrigation districts formulate irrigation systems for canals at all levels, adhere to the scientific water distribution principle of "rapid flow irrigation, high water long-distance delivery and grouped round irrigation," and formulate the main channel water source scheduling scheme according to the water consumption plan issued by the superior department (monthly total water consumption or daily flow) and different water source conditions and water demand for crop growth. According to the water dispatching plan formulated by the four management offices in the irrigated area, irrigation line and terrain characteristics of the field, the water resource allocation plan in the main canal is adjusted and improved. On the premise of stabilizing the water level of the main canal, the irrigation water plan is decomposed into each branch canal. After years of practice, the irrigation cycle is stable, and the scheduling operation is in order (Map of irrigation water use in branches below The Main Canal of Touzha in January 2018, as shown in fig.2).

Group	Name of culvert sluice	Water usage time (hours)		Rotational irrigation cycle																													
				(Four days, 96 hours)																													
		Irrigation	Stop	June																													
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
One group	Che Luo hole	57	39	24		15		24		15		24		15		24		15		24		15		24		15		24		15		24	
	Zi Yin sluice	67	29	9	14			9	14			9	14			9	14			9	14			9	14			9	14			9	
Two group	Nan Guan hole	62	34		4	14			4	14			4	14			4	14			4	14			4	14			4	14			
	Ba LiSong hole	57	39		23		14		23		14		23		14		23		14		23		14		23		14		23		14		23
Three group	Tou sluice	57	39	14		23		14		23		14		23		14		23		14		23		14		23		14		23		14	
Four group	Zhou San hole	56	40		15		23		15		23		15		23		15		23		15		23		15		23		15		23		15
	Jie Shou sluice	55	41		15		22		15		22		15		22		15		22		15		22		15		22		15		22		15
	Che Luo sluice	54	42		17		23		17		23		17		23		17		23		17		23		17		23		17		23		17

Figure 1. Application effect irrigation water meter for Gaoyou irrigation district (2018.1).

Group	Name of culvert sluice	Water usage time (hours)		Rotational irrigation cycle																																
				(Four days, 96 hours)																																
		June																																		
		Irrigation	Stop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30			
One group	Che Luo hole	57	39	24		15		24		15		24		15		24		15		24		15		24		15		24		15		24				
	Zi Yin sluice	67	29		9	14			9	14			9	14			9	14			9	14			9	14			9	14			9			
Two group	Nan Guan hole	62	34			4	14			4	14			4	14			4	14			4	14			4	14			4	14			4		
	Ba LiSong hole	57	39			23		14		23		14		23		14		23		14		23		14		23		14		23		14		23		
Three group	Tou sluice	57	39		14		23		14		23		14		23		14		23		14		23		14		23		14		23		14		23	
Four group	Zhou San hole	56	40			15		23		15		23		15		23		15		23		15		23		15		23		15		23		15		23
	Jie Shou sluice	55	41			15		22		15		22		15		22		15		22		15		22		15		22		15		22		15		22
	Che Luo sluice	54	42			17		23		17		23		17		23		17		23		17		23		17		23		17		23		17		23

Figure 2. Stage table of irrigation water used in branch canal(2018.1).

2.4 Scientific Calculation of Water Allotment

In Gaoyou irrigated area, the crops are mainly rice, and the rotation irrigation period of irrigation water is generally divided into four stages, namely, planting period, greening period, copying period and yellow ripening period. The upper and lower limits of irrigation water layer were designed according to the growth cycle of rice to control the irrigation water consumption. During the planting period, the water surface layer of paddy field was controlled at 10 and 30mm according to the water demand of young seedlings. During the greening period, the surface water layer is generally between 20 and 30mm, which is conducive to the tillering of live trees [3]. From August to yellow ripening, the range of water layer variation is generally controlled within the range of -30 and 30mm (Water meter for wheel irrigation in Gaoyou irrigation area, as shown in tab.1).

Table 1. Water meter for wheel irrigation in Gaoyou irrigation area.

Rice Growth Period	Irrigated Water Layer(mm)		Allocation Water Purpose of Rice at Different Growth Stages
	Maximum water layer above field surface	Lowest water depth below field surface	
Transplanting period	10-30		Shallow planting
Turn green	20-30		Promoting tillering
Tillers	20	20	Deep roots
Anaphase tillers	0	45	Control ineffective tillers
Jointing stage	0	30	Thickenning straw
Booting stage	10	25	Keep the water needs
Heading stage	20	30	Nutrient uptake
Grain filling stage	30	25	Keep the water needs
Yellow ripening stage	0	30	Prevent dumping

The irrigation period of 96 hours (4 days) in planting period, 144 hours (6 days) in tillering period and 168 hours (7 days) after sunning the fields, which is called “467” irrigation system. From late May to late June, the growing period of rice is in the early stage of transplanting and tilling, the water is highly concentrated and the water consumption is large, but the speed of water running in the field is fast, and the period of water use should not be long, the growth of rice is in the tillering jointing and early booting stage, the speed of field running water is slow, and the time of irrigation is relatively longer, after the late of August, the growing stage of rice is in the stage of flowering, filling and yellow ripening, the speed of field running water is slow, in order to meet the requirement of crop water use, the water requirement for pest control is large, but the fluctuation range of water layer is large(Water allocation scheme for Gaoyou irrigation district, as shown in tab.2). According to Li Kunlin and others study on water balance model of paddy field and improvement of period irrigation system in“Stage irrigation” in Gaoyou irrigation area, it is shown that “467” irrigation system under different typical precipitation years can effectively reduce irrigation frequency and irrigation quota, in addition to saving irrigation water, time and economic costs are saved [4].

Table 2. Water allocation scheme for Gaoyou irrigation district.

Water supply period	Number of rotation irrigation groups	Cycle of rotation irrigation (hour)	Water supply time	Water cut off time	Gate opening frequency (%)	Design inlet flow (m ³ /s)	Actual incoming flow (m ³ /s)
6.1-7.10	4	96	57	39	62	159	90
7.11-8.5	6	144	60	84	50	159	75
8.6-9.30	6	168	60	108	50	159	70

2.5 Implement Accurate Measurement

Gaoyou irrigation district through the implementation of different irrigation cycle system, to achieve scientific allocation, rational allocation of irrigation water [5]. Before irrigation each year, the Gaoyou irrigation district, according to the water use plan issued by the province and the city,

formulates the agricultural water use index decomposition table of each township in the irrigation district (take Longqiu town as an example, as shown in tab.3) , and carries on the concrete and definite water use index of each township. At the same time, according to the total amount of water used, the demand of irrigation water and the popularization and application of water-saving technology, the amount of water used per mu in each village is determined, the farmers are given irrigation water distribution cards [6], and the total amount of water used is controlled. The electromagnetic flowmeter with high precision is installed at the outlet of the small irrigation pump station to measure the total quantity of water supply [7], so as to further enhance farmers understand of the total quantity of irrigation water, and advocate farmers to use water scientifically and save water.

Table 3. Decomposition table of agricultural water use index of Long qiu town in 2018.

Towns	Area of cultivated land (Mu)							Ten thousand cubic meters
	Plantation Industry			Farming	Forestry fruit industry	Facility	Other	
	subtotal	rice wheat	upland crops					
Long qiu	37259	35484	1775	31500	400	1620	480	2993.3

2.6 Strengthen Publicity of Irrigation System

To promote farmers' awareness of water-saving irrigation, the Gaoyou irrigation district has published the "rice water-saving irrigation production management profile", which is distributed to water user associations and farmers to guide them in water-saving irrigation and scientific farming [8]. More than 2,500 "Open letters" were issued and distributed to households in the Gaoyou irrigation district to ensure proper implementation of the water supply system. The water timetable will be issued to each village group in time, so that the people use water "Early know," change the past irrigation water supply around agriculture, agricultural water subject to irrigation scheduling arrangements. In order to strictly implement the system of "Early know" water use, Gaoyou irrigation district has developed a cloud platform of intelligent irrigation district, which can realize the readability of hydraulic conditions, the visualization of scenes, the measurement of water volume, the remote control of facilities and the monitoring of environment, so as to precisely regulate water level and water volume [9].

3. Benefit analysis

The trial implementation of water-saving management model in Gaoyou irrigation district has achieved benefits in the following four aspects.

3.1 Maintain the Normal Order of Water Use

Due to the implementation of all levels of channels and culverts on time operation, strict implementation of planned water use, determine water supply time, irrigation water level has been stable. By increasing the publicity of water use system and establishing strict rules and regulations of water use management, the masses have a new understanding of water use service, have a sense of trust in water use plan, and form a good water use management order. Gaoyou irrigation district has made full use of irrigation benefits by providing fair, high quality and efficient irrigation and drainage services to rural farmers through the implementation of planned water use, water conservation and scientific water use[10].

3.2 The Irrigation Efficiency Has Been Improved Obviously

After adopting the rotation irrigation method, the total water consumption and the time of water consumption are greatly reduced, and the efficiency of water supply is obviously improved because of the optimization of the dispatching scheme. After the gate is opened, the water level in the

channels at all levels is relatively stable, and the effect of large-stream Rapid Irrigation and high-water far delivery is realized. The guaranteed rate of self-irrigation is obviously improved, the total station of water supplement and the consumption of social water supplement power in irrigation district are obviously reduced. Since the reform of the water supply system, the irrigation guaranteed rate in the irrigation area increases from 67.5% to 75.25%, among which, the irrigation guaranteed rate in Cheluo irrigation area increases from 68% to 76%, the irrigation guaranteed rate in Nanguan irrigation area increases from 75% to 86%, the irrigation guaranteed rate in Touzha irrigation area increases from 65% to 72%, the irrigation guaranteed rate in Zhoushan irrigation area increases from 62% to 67% (as shown in fig.3). The accumulative self-irrigation area was expanded by 30,500 mu, among which, the self-irrigation area was expanded by 7000 mu in Cheluo, 6000 mu in Nanguan, 8000 mu in Touzha ,9,500 mu in Zhoushan (as shown in fig.4). A total of 316,000 mu of irrigated area has been improved, including 78,200 mu of irrigated area in Cheluo irrigation district, 62,400 mu of irrigated area in Nanguan irrigation district, 73,500 mu of irrigated area in Touzha irrigation district,102,000 mu of irrigated area in Zhoushan irrigation district (as shown in fig.5). Irrigation benefits are very obvious (as shown in tab.4, irrigation benefits analysis table of Gaoyou irrigation area in 2018 for details).

Table 4. Irrigation benefit analysis table of Gaoyou irrigation district in 2018(ten thousand mu).

Scope of water supply	Irrigation guaranteed rate (%)		Expansion of self irrigation area	Improve of self irrigation area
	<i>original</i>	<i>now</i>		
CheLuo irrigation district	68	76	0.7	7.82
NanGuan irrigation district	75	86	0.6	6.24
TouZha irrigation district	65	72	0.8	7.35
ZhouSan irrigation district	62	67	0.95	10.2
Total	67.5	72.25	3.05	31.6

■ Irrigation guarantee rate (%) original ■ Irrigation guarantee rate (%) now

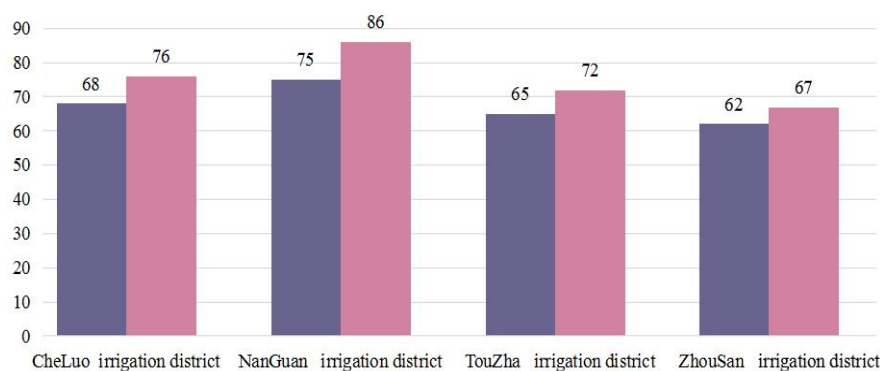


Figure 3. Comparison chart of irrigation guaranteed rate in Gaoyou irrigation area.

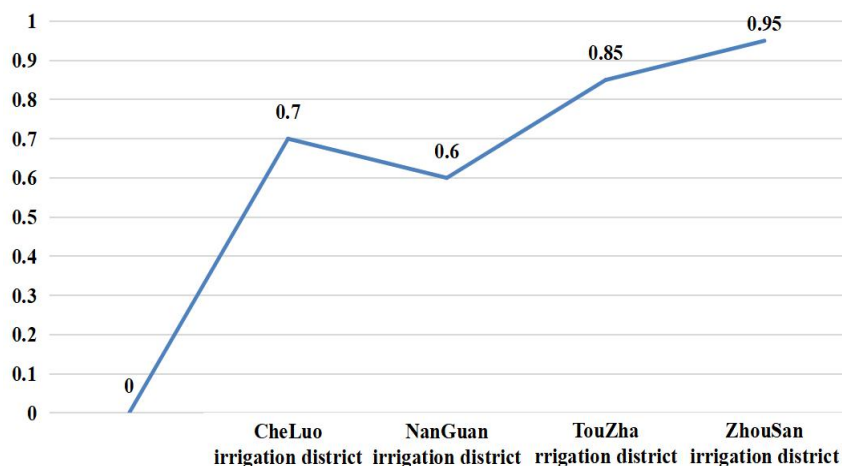


Figure 4. Increase self irrigation area(ten thousand mu).

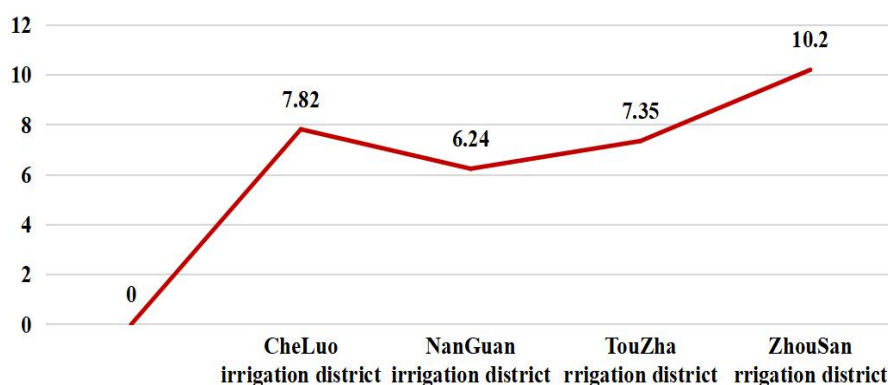


Figure 5. Improve of self irrigation area(ten thousand mu).

3.3 The Waste of Water is Reduced and The Water Consumption is Saved

The water distribution scheme was optimized after the wheel irrigation system was implemented along the culvert gate along the Grand Canal River. The water use time was reduced by nearly 40% during peak period, 58% during normal growth period and 64% during grouting maturity period. The time of water supply is shortened, the time of water cut-off is prolonged, the farmers' consciousness of self-participation in water management is further strengthened, and the field water conservation measures keep pace with each other, thus greatly promoting water conservation in irrigation areas. By shortening the irrigation time, increasing the water cut-off time and controlling the water level of the field and the ground water, a great deal of water resources are saved under the premise of guaranteeing the irrigation quality and the irrigation effect [11]. The total amount of irrigation water decreased from 623.21 cubic meters per mu in 2011 to 576.52 cubic meters in 2018, and the net amount of irrigation water decreased from 390.66 cubic meters per mu in 2011 to 355.69 cubic meters in 2018 (comparison chart of irrigation water consumption, as shown in fig.6).

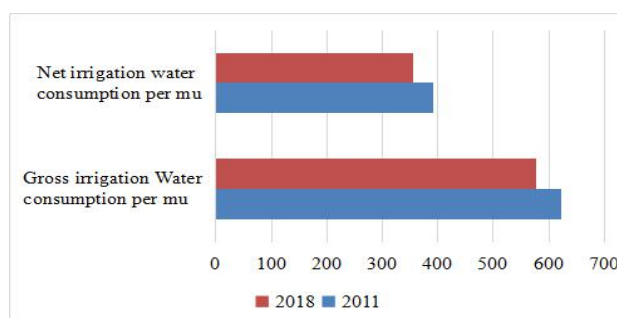


Figure 6. Comparison chart of irrigation water consumption.

3.4 The Burden on Farmers was Lightened and the Social Benefit was Improved

Since the completion of Ziyang trunk canal, 12 units have been used in the peak water period every year, and nearly 30 water-lifting outlets have been set up along the main canal. Through strengthening the means of water allocation, promoting high water level rotation irrigation, reducing the time of irrigation water use, raising the water level of the main channel above 20 cm on average, thus reducing the area of water lifting from the original 25% to 12% , and saving 30 ~ 50 yuan per mu of water pumping cost [12], the burden of farmers has been effectively reduced, promoting a large number of rural labor transfer. The Irrigation District Water filling station has not been powered on for more than 10 years, with the total amount of water saved annually reaching more than 45 million cubic meters. Taking 2018 as an example, the irrigation district can save 54.21 tons of diesel fuel for water replenishment and reduce the direct cost by 352,400 yuan(irrigation efficiency table of Gaoyou irrigation district in 2018, as shown in tab.5) , the social benefit is very remarkable.

Table 5. Irrigation efficiency table of Gaoyou irrigation district in 2018.

Scope of water supply	Main canal water level up (cm)	Filling water station		Annual average savings water consumption (ten thousand cubic meters)
		Save diesel (t)	Reduce the cost of water (Ten thousand yuan)	
CheLuo irrigation district	20	8.22	5.34	1152
NanGuan irrigation district	25	7.44	4.84	936
TouZha irrigation district	20	18.31	11.9	893
ZhouSan irrigation district	20~30	20.24	13.16	1528
Total	20~25	54.21	35.24	4509

4. Conclusion

Through the reform of water use system, the Gaoyou irrigation district has explored and practiced water-saving water use management system, and adopted measures such as “Intensive water transfer, physiological water distribution, regular water supply and systematic water saving,” the utility model reduces the invalid water use, realizes the source water saving of the diversion sluice tunnel, has changed the traditional way in the past of using water, creates a good social water saving atmosphere, and also provides a guarantee for the normal water supply of the South–North Water Transfer Project.

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