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Investigation and Technical Evaluation of Sprinkle Irrigation in Shandong Province

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Abstract

This paper takes 30 hm^2 wheat sprinkling irrigation land of Yunguo Family Farm in Yanzhou, Shandong Province, China as a sample, and draws a conclusion by comparing it with other households (including individual and large households). The conclusions are as follows: wheat sprinkling irrigation has a remarkable water-saving effect and comparative revenue. Water saving efficiency can reach 61.54% and a comprehensive income-increase rate can reach 38.67%. The main factors of increasing income and incentives of saving irrigation by sprinkling irrigation ranks as the following: saving land consolidation and water monitoring labors (accounts for 62.50%), saving land area of wheat bed to increase production and income (accounts for 23.44%), saving water bills (accounts for 14.06%). The incentive effect of water saving is not obvious mainly because the water price is low. The main obstacles to the promotion of sprinkling irrigation by individual household are the uneconomical scale and the barriers of coordination of proxy irrigation. Other large household's (family farm) obstacles are mainly the instability of land tenure and mixed management. Suggestions on promoting sprinkling irrigation in wheat field: Accelerate land circulation and promote agricultural scale management to create basic scale conditions for spreading sprinkling irrigation; stabilizing farmland management rights as stabilizing farmland contractual rights, thus giving long-term business interests to all kinds of large household owners; guide the development of "scale + specialization" modern family farms; appropriate water saving subsidies should be given according to the positive externality of household water saving; confirm agricultural water rights to household and allow compensated transfer of "surplus water rights".

Keywords

Sprinkling Irrigation in Wheat Field, Comparative Revenue, Obstacle Factors, Promoting Strategy, Surplus Water Transfer

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1. Introduction

In China, the total amount of agricultural water in China is large, the comprehensive utilization ratio is low and the water resources are wasted seriously. Thus, agricultural water saving is of great significance to guarantee and promote the sustainable development of economy and society. There are many specific technical models for agricultural water saving, such as sprinkling irrigation in the field, drip irrigation, seepage irrigation, hardening of canal systems in water conveyance links, and pipeline transportation, etc. In reality, canal system hardening and pipeline water delivery in water conveyance links have been widely used. sprinkling irrigation (including micro-spraying), drip irrigation, and infiltration irrigation for gardening such as vegetables and orchards have been more common, but sprinkling irrigation for field crops, drip irrigation, Infiltration irrigation is still not used much (except for a few state-owned modern agricultural demonstration parks). The causes and countermeasures need further study.

In the past ten years, the economic research on the problems related to the water saving of irrigation by water-saving irrigation technology has gradually increased, which can be summarized into three research perspectives: first, the investigation and research on farmers' willingness to save water. The second is about farmers' water-saving behavior, and the third is about farmers' water-saving incentives.

In terms of farmers' willingness to save water, most of the research literature appeared after 2010. Zhu Lijuan, Xiang Huijuan [1] studied the willingness to adopt water-saving irrigation of farmers in Heilongjiang Reclamation area. The main conclusions were that the proportion of income of planting industry, government support, cultivated land area and the age of peasant household head of household had an effect on the water-saving willingness of farmers in turn. Huang Yuxiang, Han Wenting, *et al.* [2] studied the situation of 296 sample farmers in 10 counties (regions) of greenhouse crop-growing areas in Shaanxi Province. Through structural equation model analysis, it was concluded that farmers' cognition of water-saving irrigation, the degree of satisfaction with the existing irrigation methods, the way and intensity of policy subsidies, the cost of irrigation and the level of education have an effect on the willingness of farmers to adopt water-saving irrigation technology in turn. Yu'an [3] studied 311 samples of farmers in 16 counties (cities) of Zhejiang Province, and analyzed the age of farmers, government subsidies, villagers' mutual assistance, departmental business guidance, and types of information channels. Risk factors and income increasing factors have an important influence on farmers' willingness to adopt water-saving irrigation technology. Xu Lang and Tang Mengqin [4] studied the farmers' willingness to pay for water-saving irrigation technology in Mengyin County, Shandong Province. The conclusions are: farmers' age, income level, cultivated land area, and the degree of approval for the expected effect of water-saving technology. The degree of satisfaction with related

policies affected the willingness of farmers to pay for water-saving irrigation in turn, and the willingness to pay was RMB 4086 yuan per hectare. Li Mingwei and Wei Jinghong [5] studied the farmers' willingness to demand water-saving irrigation in two types of areas in Hebei Province. The main conclusions are: age of head of household, planting area of crops, irrigation cost, and the effect of water-saving irrigation on yield. The government's emphasis on water-saving irrigation is the main factor that affects farmers' willingness to demand water-saving irrigation. Wang Xiaohong and Yang Yanli [6] studied the situation of 326 sample farmers in 6 counties (districts) of Gansu Province. They considered that the main labor force of the family was educated for years, total household income, the proportion of agricultural income, the structure of agricultural planting, the area of cultivated land. There is a positive correlation between the economic subsidy of the government, the pricing method of irrigation water, the construction of water conservancy infrastructure, the degree of water resources shortage and the willingness of farmers to adopt water-saving irrigation technology. According to Wang Yuying [7], farmers' cognition is the core determinant factor that restricts farmers to adopt water-saving irrigation technology, and improving farmers' cognition level is conducive to promoting agricultural water-saving.

In the aspect of farmers' water-saving behavior, the behavior characteristics and influencing factors of farmers adopting water-saving irrigation technology were studied. Han Qing [8] believes that water-saving irrigation technology has the characteristics of "quasi-public goods", and there is a general trend of community and farmers to provide it together. High or low water prices, government incentive policies and crop types (mainly food crops and cash crops) have an impact on the adoption of water-saving irrigation techniques by farmers. Xie Xiling [9] studied the influencing factors of water-saving irrigation techniques used by farmers in Xuwen County, Guangdong Province, including the age of farmers, the number of labor force, their education level, their land endowment and their ability to mobilize funds. The characteristics of farmers, such as knowledge and skills, are important factors. The comparative benefits of agriculture, the development of secondary and tertiary industries, and the environment of special agricultural industries are conducive to promoting farmers to adopt water-saving irrigation techniques. The backwardness of water conservancy infrastructure is the most important negative factor affecting farmers' water saving. Li Jia Yi, Li Tongsheng and Li Shukui [10] studied the effects of different agricultural technology environments on the adoption of water-saving irrigation techniques by farmers in semi-arid areas of the northwest: in high-tech areas, the national support policy is the main factor to encourage farmers to adopt water-saving irrigation technology. In the middle technical level area, training and natural conditions are the main influencing factors while in the low technical level area, the farmers' information convenience, natural conditions and farmers' risk awareness are the main influencing factors. Meng Lei [11] studied the

influencing factors of rice farmers adopting water-saving irrigation technology in Wuchang city of Heilongjiang province. Among them, the age of farmers was negative the education level of farmers rice planting area and the government incentive and support policies were positive correlation factors. Xu Lang, Liu Jinjin based on the survey data of Mengyin County, Shandong Province, concluded that farmers' cognition, income source and proportion, cultivated land area, government propaganda and water price are the important factors that affect farmers' adoption of water-saving irrigation technology. Zhang Xinhuan, Xiao Yanqiu, Yang Degang and Liu Yun ranked the driving forces of household water-saving irrigation in the following order: irrigation water price, cultivated land location, non-agricultural income proportion, farmland ownership, and farmers' understanding of water-saving irrigation. Gender of interviewee, irrigation water consumption, age of family members, area of cultivated land under management, etc. are also frequently tested. Ren Shizhou studied the influencing factors of sugarcane farmers adopting water-saving irrigation technology in Guangxi in order of villager demonstration, sugar mill influence, water fee, government influence, farmers' technical preference, sugarcane planting income, farmer's education level, whether village cadre and so on. In Da'an City, Jilin Province, the main influencing factors are farmers' age, education level, village cadres, farmland management scale, family income level, income increasing factor, risk factor, government policy, technical training and so on. Li Feng [12] thought that irrigation pattern, risk cognition, cultivated land characteristics and peasant household characteristics had a common effect on household irrigation behavior, using cooperative irrigation, the cultivated land was located at the end of the canal, and the family was rich. Farmers with a high level of education have a high degree of using saving irrigation technology.

Summing up existing studies, most "analyze the relevant factors (including the use of econometric model analysis) along the lines of investigating the willingness and behaviour of farmers (whether or not they have adopted water-saving irrigation techniques)," According to the main line of incentive suggestion, this paper investigates and analyzes the situation of farmers adopting water-saving irrigation in different areas. From the analysis of the "influencial factors" and the "incentive suggestions", there are obvious characteristics of periphery and marginalization. Although it has something to do with saving water in agriculture, the actual distance is still far away. In addition, there is almost no case study of practical water-saving irrigation. In view of this, the real case of farmers water-saving irrigation analysis and research is more valuable.

2. Research Method and Sample

This paper mainly uses the method of sample analysis and contrast to carry out the research. From 2015, the research group made investigations and survey at the annual crop irrigation season in Yanzhou District, Jining City, Shandong Province and several surrounding counties, cities, districts, such as Jinxiang

County, Jiaxiang County, and Wenshang County. More than 600 farmers were surveyed. Farmers' production and management (crop planting) can be divided into two categories: large-scale centralized management (growing large households and family farms) and small scale decentralized management. The cutoff value is 100 mu. The irrigation water use can be divided into three categories: large household sprinkling irrigation, large household border irrigation, and small house border irrigation.

1) Large Scale Sprinkling Irrigation Sample: Yunguo Family Farm

Large-scale sprinkling irrigation samples of Yunguo Family Farm which is located in Yanzhou District, Yanzhou Town, Jining city, Shandong Province in China. Of the more than 300 farmers in the surrounding counties, cities and districts that visited by the research group, whether large or small, only this household uses modern sprinkling irrigation technology to irrigate wheat and maize crops. The farm has 30 hm^2 of cultivated land (mainly contracted by other rural households in the village under the circulation lease, with a rent of 15,000 RMB per hectare per year). It mainly grows grain crops (winter wheat and corn are harvested twice a year), and agricultural production ranges from farming to harvesting and drying grains. The whole process of mechanization (including irrigation) was basically realized.

The irrigation methods of Yunguo Family farm all adopt self-walking moving sprinkling irrigation technology. The main sprinkling machinery is "JP85-300 coiling and disc irrigation machine", which is produced by Jiangsu Huayuan drainage and Irrigation Co., Ltd. The coil tube was extended by 300 meters (that is, the distance before and after the spray gun left the main engine for automatic walking irrigation was 300 meters), the width of one machine and two guns was 15 meters each, and the width of the whole machine was 30 meters. According to these parameters, the maximum area of one-way sprinkling irrigation is 9000 square meters, about 0.9 hm^2.

The two front sprinklings of the machine can walk along the base in the wheat field with the help of the retractive pull of the water conveyance pipe, thus completing the 30 meter sprinkling irrigation process with a single piece (one stroke). There is no need for infrastructure such as buried water pipelines (as long as the public water supply system can transport irrigation water to the ground). Therefore, in calculating the cost of sprinkling irrigation water, there is no need to consider the investment and labor input of underground pipeline facilities and their construction.

2) Large Scale Border Irrigation Sample: Surrounding Multiple Family Farms

The sample of large-scale border irrigation is a number of family farms around the country's family farms. Yanzhou District Happy Family Farm is located in Caohe Town, Hannan Village, where 24 hm^2 of cultivated land is managed, mainly growing grain crops (winter wheat and corn two seasons); the Shengjun Family Farm in Yutai County is located in Laozhai Town, Laobei Vil-

lage, Yutai County, with 28 hm^2 of cultivated land. Jiaxiang County Shuangfeng Family Farm is located in Shuangfeng Village, Wolongshan Town, Jiaxiang County, with 26.67 hm^2 of cultivated land. It mainly grows wheat, corn, and soybeans. Cotton and so on. 3 large scale management sample farmland irrigation all uses the surface border irrigation method. When farmland needs irrigation, The farmer pays the village committee to pay for the water intake index (radio frequency card), holds the card to the machine well room or the pump station in the Tianbian ground to open the machine well room or the pump station to open the water (this area is the well irrigation area), the irrigation water flows along the field edge Mao canal or the ground head hidden pipe flows into the wheat bed (jade) Irrigation is carried out in the gutter. In particular, the machinery well, well house and pumping station in this area are all invested in the national comprehensive agricultural development project or the small-scale irrigation and water conservancy construction or the modern agricultural industry technical system.

3) Scattered Small Household Border Irrigation Sample: Several Small Farmers Around

Scattered small household border irrigation samples are a number of small farmers around the country's family farm. The scattered farmers in Yanzhou area have an average cultivated land of 0.2 hm^2. The crops are wheat (corn), vegetables (garlic, onion, potato, yam), saplings and so on. Border irrigation is the main way to disperse small household farmland irrigation. The operation process of implementing farmland irrigation is the same as that of large scale furrow irrigation samples, that is, the village committee first buys the water index, and then holds the card to the machine well house and pumping station at the edge of the farmland to collect water by swiping cards irrigation.

3. Results

3.1. Benefit of Water Saving from Sprinkling Irrigation in Wheat Field

According to the statistics of family farms and surrounding farmers in Yunguo country for many years, the water consumption of sprinkling irrigation is 375 m^3/hm^2, the water consumption of surface border irrigation is 975 m^3/hm^2, the water saving efficiency of sprinkling irrigation is as high as 61.54% (saving 600 m^3/hm^2 water), and the total irrigation water of wheat in one season is 4 times. The total amount of water saved in sprinkling irrigation is 2400 m^3/hm^2. Yanzhou is plain well irrigated area, farmer irrigation does not need to pay water resources fee, irrigation water fee is mainly composed of pumping water and electricity, equivalent to water price of 0.25 RMB/m^3, according to this price, the water cost of wheat surface border irrigation 4 times in one season total 975 RMB/hm^2; Reel machine sprinkling irrigation requires secondary power pressurization, water consumption doubled, water price equivalent to 0.50 RMB/m^3, according to this price, a season of wheat sprinkling irrigation 4 water total wa-

ter cost 750.00 RMB/hm^2. Compared with border irrigation, sprinkling irrigation saves 225.00 RMB/hm^2 in water cost per season. The planting area of wheat in Yunguo family farm is 30 hm^2, and the total water cost saving of one-season wheat is RMB 6750.00. In order to clarify the contrast, the benefits of sprinkling irrigation water saving are listed in Table 1.

3.2. Labor Income from Sprinkling Irrigation in Wheat Field

Compared with surface border irrigation, wheat fields with sprinkler irrigation do not need ridging and strict leveling (border irrigation requires leveling the land so that the flow of water is smooth), Saving 15.0 working days per hectare of land consolidation (including carryover and leveling land), calculating 50 yuan per day according to the local average work value, saving land consolidation labor cost 750 yuan/hm^2. The total cost of land consolidation of 30 hm^2 wheat was saved 22,500 yuan. This is a huge cost savings!

In addition, compared with border irrigation, sprinkler irrigation can save irrigation nursing time. The coil machine needs one person to take care of sprinkler irrigation, the average working efficiency is 0.2 hm^2 (0.6255 work days/hm^2) per hour, 2 person shifts (10 hours per person) irrigate 4 hm^2 a day, and 30 hm^2 wheat irrigation water takes 150 h. This is equivalent to 18.75 working days (8 hours per working day, 7.5 days of natural days), and 75 working days are required for 4 times water irrigation of wheat in one season. According to the local average work value, the cost of irrigation and nursing labor is 3750 yuan. The general efficiency of border irrigation is "0.067 hm^2 per person per hour" (1.875 workdays/hm^2), 450 hours for wheat irrigated with the same area of 30 hm^2, and 1800 hours for irrigation of 4 times water per season. Equivalent to 225 working days (refer to sprinkler irrigation, 7 days of irrigation, 8 hours per person per day, 8 people at the same time), irrigation care labor costs 11,250 yuan. Compared with border irrigation, 30 hm^2 wheat sprinkler irrigation saved 7500 yuan in labor cost. Comprehensive land preparation and irrigation care two items, sprinkler irrigation total savings in labor costs of 30,000.00 yuan. In order to clarify the contrast, the benefits of sprinkler irrigation are listed in Table 2.

3.3. Land Saving (Yield Increase) Income from Sprinkling Irrigation in Wheat Fields

Compared with border irrigation, the wheat field with sprinkler irrigation does not need furrow ridge, saves the furrow area and increases wheat yield by 10%. The average yield of local wheat is 7500 kg /hm^2, and the yield of wheat is 750 kg/hm^2 per hectare in Yunguo Family Farm. In 2017, the price of wheat increased by 1875.00 yuan per hectare, the total sales income of 30 hm^2 wheat increased by 56,250.00 yuan, and the net income per hectare of wheat increased by 375.00 yuan per hectare after deducting the comprehensive cost of wheat production. 30 hm^2 wheat added up to a net income of 11,250.00 yuan.

Table 1. Water-saving income from sprinkling irrigation in the wheat field of Yunguo family farm.

Irrigation type	Primary irrigation water consumption (m^3/hm^2)	Annual irrigation times of wheat	30 hm^2 of water used for the whole year (m^3)	Irrigation water price (RMB)	Irrigation water charges and savings (RMB)
Moving sprinkling irrigation	375	4	45,000	0.50	22,500.00
Surface border irrigation	975	4	117,000	0.25	29,250.00
Sprinkling irrigation saving	600	4	7200	—	6750.00

Data Source: survey of Family Farm Development in Shandong Province (2018).

Table 2. Labour savings from sprinkling irrigation in wheat fields (Yunguo family farm).

Irrigation type	Land preparation labor and its costs			Monitoring labor and fees			Total amount of labor cost saved by sprinkling irrigation in 30 hm^2 wheat field (RMB)
	Work efficiency (working day/hm^2)	30 hm^2 of labour (working day)	Labor costs (RMB)	Work efficiency (working day/hm^2)	30 hm^2 4 times of Irrigation monitoring labor force (working Day)	Labor costs (RMB)	
Moving sprinkling irrigation	0	0	0.00	0.6255	75.0	3750.00	3750.00
Surface border irrigation	15	450	22,500.00	1.875	225.0	11,250.00	33,750.00
Sprinkling irrigation saving	15	450	22,500.00	1.2498	150.0	7500.00	30,000.00

Data Source: survey of Family Farm Development in Shandong Province (2018).

3.4. Comprehensive Comparative Benefits of Sprinkling Irrigation in Wheat Fields

Compared with border irrigation, the new income of 30 hm^2 wheat sprinkling irrigation is 48,000.00 RMB for Yunguo Family farm.

Definitely, it is necessary to consider the depreciation cost and the operating cost of the machine in order to calculate the actual comparative income of the coil moving sprinkling irrigation (the main cost of use is electricity, which has been accounted for in the sprinkling irrigation price, so it is no longer repeated calculation here; The other use costs are mainly minor maintenance, which requires about 500.00 RMB a year. The purchase price of the JP85-300 roll disk irrigation machine is 60,000 RMB. According to the 10-year depreciation rate, the annual depreciation is 6000.00 RMB, and according to wheat, corn is divided into two seasons at 4:2 (wheat irrigates 4 water). Corn irrigation 2 water), wheat share sprinkling depreciation cost 4000.00 RMB, plus small maintenance cost 500.00 RMB, the total is 4500.00 RMB, after deducting the cost of sprinkling irrigation income is 43,500.00 RMB, average 1450.00 RMB/hm^2. The net income per mu of local border irrigation wheat is generally 3750.00 RMB/hm^2, and the increased range of sprinkling irrigation is about 38.67%.

3.5. Comparative Income Composition and Main Incentive Factors of Sprinkling Irrigation in Wheat Field

Since the depreciation and maintenance costs of the mobile sprinkling irrigation machine are common costs, they should be prorated among the various addi-

tional income items, so the comparative benefit composition of the mobile sprinkling irrigation should not be taken into account when calculating the composition of the comparative income of the mobile sprinkling irrigation. Only the internal composition of the $48,000.00 yuan increase can be calculated, as shown in Table 3.

From the data in Table 3, we can see that the comparative income of moving sprinkling irrigation mainly comes from saving labor (62.50% of the two items), especially saving land preparation (46.875% of the single item), then increasing the yield of land saving (23.438%), while the income of saving water ranks last (14.062%). The reason for this situation is very much related to the low water and grain prices, because water and food prices are low, even if more water is saved and more grain is increased, it will not show more benefits.

According to the order of comparative income composition of moving sprinkling irrigation in Table 3, we can also draw the corresponding conclusion: saving labor is the first incentive factor of sprinkling irrigation in winter wheat field, followed by saving land to increase production, and finally saving water cost.

4. Discussion

4.1. Obstacle Factors of Sprinkling Irrigation

According to the previous analysis, sprinkling irrigation in wheat fields has a very obvious water-saving effect (water saving 61.54%) and comparative income, so why not use it by the surrounding farmers (including retail and large households)? What are the obstacles to the spread of sprinkling irrigation? Visit the farmers to give the corresponding answer.

4.1.1. Barriers to the Spread of Retail Sprinkling Irrigation: Technical Adaptability, Economies of Scale and Barriers to Collaboration

The one-off investment of the coiled disk type mobile sprinkling irrigation machine is large, and the small investment is tens of thousands of RMB, and more than 100 thousand RMB. The general retail investors are unable to buy it. In use, they should also have a small scale of operation for one household, resulting in "uneconomical scale". It is difficult to implement sprinkling irrigation of wheat field (including self-purchase equipment, etc.). The local household average cultivated land is 0.2 hm^2, even if it is no longer divided into pieces (2 - 3 pieces in fact), it is not suitable for the sprinkling irrigation operation of the moving sprinkling machine.

Table 3. Composition of comparative income for moving sprinkling irrigation.

Revenue item	Water saving income	Land preparation and labor saving income	Monitor water and labor saving income	Land saving yield	Total
Unit area income (RMB/hm^2)	225.00	750.00	250.00	375.00	1600.00
Total farm income (RMB)	6750.00	22,500.00	7500.00	11,250.00	48,000
Revenue share (%)	14.062	46.875	15.625	23.438	100.00

Data Source: survey of Family Farm Development in Shandong Province (2018).

In the light of the concrete situation of "uneconomical scale" of individual sprinkling irrigation, we have proposed several schemes of implementing sprinkling irrigation in the process of visiting farmers, all of which have not been fully approved by farmers.

The first is the "large household irrigation system". That is to say, large households with coil irrigation machines such as Yunguo Farm implement sprinkling irrigation for peripheral retail wheat fields, and the price of sprinkling irrigation services is determined through consultation between the two sides. Practice has proved that, because farmland irrigation is very agricultural, the farm has 30 hm^2 of wheat, and the irrigation time of water alone takes 7.5 days. The best time for irrigation and drought resistance in local farmland is generally 7 - 10 days, waiting for the farm to irrigate its own wheat field after it has been irrigated. The best time to fight drought in the surrounding wheat fields has often been mistaken, and the actual agricultural efficiency will be affected.

The second is the "professional generation irrigation system". That is, specialized organizations (professional households or even companies) can purchase sprinkling irrigation machinery to provide specialized sprinkling irrigation services to farmers, and large operators such as Yunguo farms can also purchase sprinkling irrigation machinery to irrigate their own farmland at the same time. For the surrounding farmers to provide specialized sprinkling irrigation services. Due to the lack of practical cases to verify the technical and economic feasibility of "professional substitute irrigation", we still use the technical and economic parameters of wheat field sprinkling irrigation to do a simple analysis. The consolidated analytical data are shown in Table 4.

In Table 4 (the cost data of sprinkling irrigation and border irrigation are derived from the previous correlation analysis), we simulate the scattered farmers to pay the surrogate irrigation fee to the large irrigation household according to the cost price of their own border irrigation, so the total benefit of the simulated 30 hm^2 wheat substitute irrigation is 32,250.00 RMB. The average value is 1075.00 RMB/hm^2. However, visit farmer knows, actual operation exists "collaboration obstacle". In the process of sprinkling irrigation, there are two wheels walking in the wheat field, which will inevitably crush some of the wheat seedlings and cause a certain yield loss, and the wide width of this machine will cover the wheat fields of several farmers at a time. In this way, very few farmers are willing to give their own wheat fields for mechanical compaction for other farmers to irrigate normally, and there are "coordination obstacles" among farmers here, which lead to the failure of irrigation service. In addition, on the same large area of land, some people agree to substitute irrigation, while others do not agree to substitute irrigation. However, the wheat fields that do not agree to substitute irrigation are just inserted into the wheat fields that agree to substitute irrigation, so that substitute irrigation cannot be implemented. This is a much more obvious "collaboration barrier".

Table 4. Technical and economic benefit analysis of "special substitute irrigation system".

Indicator item		Water rent	Water-monitoring labor fees	Depreciation and maintenance of machinery	Total cost
Sprinkling irrigation cost	Unit area cost (RMB /hm^2)	750.00	125.00	150.00	1025.00
	30 hm^2 total (RMB)	22,500.00	3750.00	4500.00	30,750.00
Border irrigation cost	Unit area cost (RMB/hm^2)	975.00	1125.00	0.00	2100.00
	30 hm^2 total (RMB)	29,250.00	33,750.00	0.00	63,000.00
Substitute irrigation income	Unit area cost (RMB/hm^2)	225.00	1000.00	−150.00	1075.00
	30 hm^2 total (RMB)	6750.00	30,000.00	−4500.00	32,250.00

Source: survey of Family Farm Development in Shandong Province (2018).

The third is the cooperative irrigation system. That is, many farmers jointly set up irrigation cooperatives, raise funds to purchase sprinkling irrigation machinery, and provide sprinkling irrigation services for cooperative members. The results of peasant household visit and questionnaire survey show that there are still various "cooperative obstacles" in the operation of cooperative generation irrigation system. First, it is difficult to carry out the purchase of sprinkling irrigation machinery by raising funds because of the inconsistency of payment intention among households; second, it is difficult for the farmers who agree to raise funds to do not connect with each other; third, they agree to purchase the land but they do not agree that the sprinkling machine should walk on their own wheat fields, so it is difficult to implement. Fourth, none of the first three problems exist but lack of "leader organization", which makes it difficult to implement (according to the wishes of 60 farmers who visited and participated in the questionnaire, none of them "would like to lead the organization", generally speaking, It takes a certain amount of time and energy or even funds to negotiate household action, which is in fact an additional cost payment. Various kinds of cooperation barriers have destroyed the practical feasibility of cooperative irrigation.

4.1.2. Extension Obstacles of Large-Scale Sprinkling Irrigation: Unstable Land Power and Hybrid Operation

As the same family farm and large-scale operators, why other large households do not use sprinkling irrigation technology? It is found that there are two kinds of barriers to sprinkling irrigation in other family farms and large scale farmers except the farm in China: one is the short time limit and the lack of stability of farmland management right; the other is the variety of farm management content.

The Happy family farm, which is not far from the Yunguo family farm, operates and sublets 24 hm^2 of wheat, which is technically suitable for the single machine operation of a jp85-300 type coil and disk sprinkling irrigation machine. However, the farm has been using surface border irrigation instead of buying

machine sprinkling irrigation. The operational barrier here is that the area's arable land has been planned for non-agricultural occupation, and land contractors are waiting for land compensation without signing long-term lease contracts with existing farmers, most of which are only three years old. Such unstable land management rights undermine the incentive of land subcontractors (existing farmers) to invest in long-term operations, including the purchase of sprinkling machinery. The lack of long-term stability of farmland management right is the main obstacle to the spread of sprinkling irrigation.

There are also several large family farms in Yanzhou's neighboring counties and districts. Although they are not in the same county as Yunguo Farm, they belong to Jining City, and the land management conditions are also very similar, including Qufu's Qinfeng Family Farm. Jiaxiang County Shuangfeng Family Farm and Liangshan County are all like family farms. From the perspective of diversified operation and adaptation to the market, they have planted a variety of crops, such as grain, wheat, corn, vegetables, and miscellaneous grains. Although the cultivated land is continuous and has a large enough area, however, Because of the many and miscellaneous management projects, it is impossible to mechanize sprinkling irrigation and can only be ground border irrigation.

4.2. Countermeasures and Suggestions for Advancing Sprinkling Irrigation

In order to popularize sprinkling irrigation technology and promote agricultural water saving, we must find ways to overcome the relevant obstacles and create suitable conditions for farmers to choose and adopt sprinkling irrigation technology.

4.2.1. Speeding up Farmland Transfer, Promoting Scale Management, Creating Basic Scale Conditions for Popularization of Sprinkling Irrigation

The case study shows that scale management is the basic condition for the application of roll disk type mobile sprinkling irrigation. One of the main obstacles to the spread of individual sprinkling irrigation is the uneconomical scale. Therefore, promoting agricultural scale management should be the first consideration to promote the application of sprinkling irrigation technology. In order to realize the agricultural scale management effectively, the academic circles have formed an academic consensus and put forward a lot of policy suggestions on agricultural scale management based on the premise of agricultural land circulation and speeding up the agricultural land transfer. For example, non-agricultural economy is developed to solve the problem that some farmers are reluctant to give up farmland, to make sure the right of farmland to protect the land rights and interests of abandoned farmers, to improve the mechanism of farmland transfer to provide convenience for the transfer of agricultural land, and so on.

4.2.2. To Stabilize the Right to Operate Agricultural Land as to Stabilize the Right to Contract Agricultural Land, and to Endow All Kinds of Large Business Operators with Long-Term Operating Rights and Interests That They Can Expect

The one-time purchase investment of the coiled disk type mobile sprinkling irrigation machine is relatively large. From the perspective of investment allocation, it takes a long time to share, which requires a long-term and stable farmland management right to be guaranteed, otherwise, The management behavior of farmer household also can short-term change. At present, in order to stabilize farmers' land contract rights, we have formed a mature and effective system. For example, the number of years of land contracting has been extended from the original 15 years to 30 years. It can also be extended (the Ministry of Agriculture's experiment in Zaozhuang, Shandong Province, for a contract period of 70 years), but the lease term for the new management rights formed after the land transfer has not yet been specified. Appropriate regulations should be made according to the specific use of land after the transfer, for example, small-scale temporary land can be transferred for a shorter period of time, and large-scale family farm land should be transferred for a sufficiently long period of time. It, in theory, can be consistent with the duration of the establishment of the right to contract.

4.2.3. Guiding the Development of "Large-Scale Specialization" of Modern Family Farms

Many family farms have quickly achieved a small scale to a large scale of expansion through land circulation, and the area of cultivated land managed by a single household can reach hundreds of mu. However, most family farms have also expanded their scope of operation while expanding their scale of operation. There are as many as 3 - 5 kinds of business projects, and their main decision-making considerations are to spread risks and create economies of scope. However, the effects of economies of scale have been affected, and many have been transformed into "large and complete" in the new form. Small-scale development nature and low-modernization characteristic of family farm should be improved. Local agricultural authorities can view farm management training and economic support (local government policy support projects for family farms such as model family farms, standardized family farms, etc.), To improve farmers' cognition of family farm scale economy and guide family farm to develop towards" scale specialization" modern family farm.

4.2.4. Appropriate Water Saving Subsidy for the Positive Externalities of Farmers' Water Saving

Agricultural water saving has obvious positive externalities, because they left the saved water resources in nature (in Yanzhou and its surrounding well irrigation area, manifested as remaining underground) and kept the groundwater level. The externality of saving water by a water user is closely related to the price of water. When the water price is very high, the personal benefit of water saving

(mainly the saving of personal water cost) is more obvious, the externality is not very prominent, but when the water price is very low, the individual benefit of saving water is not very obvious. The social benefit (positive externality) is more prominent; under the condition of zero water price, the whole income is social benefit, which has special externality, which is equivalent to saving the use of public goods.

Yanzhou's agricultural water is priced at 0.25 RMB/m^3. In fact, Yanzhou only charges electricity for water from the well, but not for the real water. Compared with local non-farm water, the irrigation water price of 0.25 RMB/m^3 is only 1.25 RMB/m^3 (excluding sewage treatment fee) for local urban residents. The industrial water price of 1.50 RMB/m^3 is 16.37%, and the operating service water price of 2.40 RMB/m^3 is 10.42%. In this kind of price comparison, the benefit of agricultural water saving is mainly shown as social income. If farmers are allowed to transfer the amount of water saved by them to industrial or business service industries for use, agricultural water users can earn 1.25 to 2.15 RMB in economic benefits for each 1 m^3 saved (not considering urban life and industry for the time being). In fact, the existing water-saving farmers give up completely, and these benefits intangibly melt into the public domain of social income, which has obvious externality.

Economic compensation should be given to the positive externalities of water saving in agriculture. The standard of compensation can be up to 2.15 RMB/m^3 (operating service water price minus agricultural water price), 1.25 RMB/m^3 (industrial water price minus agricultural water price), as low as 1.0 RMB/m^3 (urban resident living water price minus agricultural water price), or to the above standard. Look for a discount. Rough judgment, because agriculture has public welfare, urban residents living water price is also a public water price, according to the standard of 1.0 RMB/m^3 compensation water-saving farmers, or reasonable.

5. Discussion on the Additional Incentive Factors

With the help of the actual investigation data, this paper reveals the composition of the comparative income of wheat sprinkler irrigation in the family farm of Yunguo country, and finds out the new incentive factors for the farmer to carry out the sprinkler irrigation, which is beyond our general understanding of the sprinkler irrigation incentive, so it is necessary to make some additional discussions.

1) Sprinkler irrigation is of great significance in saving labor. Sprinkler irrigation in wheat fields can save a large amount of land consolidation and water viewing labor costs. This incentive factor is rarely found. It reminds us that sprinkler irrigation in wheat fields is a kind of labor-saving technological progress (general technological progress is divided into three types: labor-saving technological progress, capital-saving technological progress and labor-saving and capital-saving neutral technological progress). With the constant increase of

labor factor price in our country (this is an inevitable trend), the technological progress of labor saving should be paid more attention to. Moreover, according to the operators of the country's farm, the same labor force can take care of several sprinkler irrigation machines at the same time. If there is more arable land that can be operated in parallel, if there are several sprinkler machines working at the same time, save the amount of labor to see the water will be more obvious, but also worthy of attention.

2) The determination and circulation of farmers' water right is a new incentive which can be considered. Previously, we have mentioned that farmers' water saving has a positive externality, which should be compensated. The situation would not be the same if we had changed a system of water rights and determined the rights of irrigation water to farmers in accordance with the conventional needs of agricultural production. The externality of household water-saving can be avoided and new water-saving incentives will sprout. The key to this system is to allow farmers to transfer their surplus water rights through the market. Referring to the existing non-agricultural water prices in the Jining region, if the State Farm can transfer 72,000 m^3 of sprinkler irrigation surplus water resources directly (or through the supervision of government agencies) to industrial and commercial enterprises, The water-saving income from the farm will be a very significant figure: 10,800 - 172,800 yuan. Even if you take into account other fees to give a certain discount, the balance is not a small number. This is a very worthwhile water-saving incentive.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Zhu, L.J. and Xiang, H.J. (2011) Farmers in the Main Grain Production Areas Using Water-Saving Irrigation Will Analysis. *Agricultural Resources and Regionalization in China*, **32**, 17-21.

[2] Huang, Y.X., Han, W.T., Zhou, L., Liu, W.S. and Liu, J.D. (2012) Cognition of Farmers' Water-Saving Irrigation Technology and Its Influencing Factors. *Journal of Agricultural Engineering*, **28**, 113-120.

[3] Yu, A. (2012) Willingness and Influencing Factors of Farmers' Water Saving Irrigation Technology. Master Thesis, Zhejiang University, Hangzhou.

[4] Xu, L. and Tang, M.Q. (2015) Research on Farmers' Willingness to Pay for Using Water-Saving Irrigation Technology—Based on the Analysis of Investigation Data in Mengyin County. *Water Saving Irrigation*, No. 1, 86-89.

[5] Li, M.W., *et al.* (2010) Analysis of Farmers' Demand for Operating Water-Saving

Irrigation Projects and Their Influencing Factors: Based on the Investigation of Farmers in Hebei Province. *China Rural Water Conservancy and Hydropower*, No. 2, 64-69.

[6] Wang, X.H. and Yang, Y.L. (2012) An Analysis of the Factors Influencing Farmers' Willingness to Adopt Water-Saving Irrigation Techniques in Gansu Province. *Xinjiang Agriculture and Reclamation Economy*, No. 11, 15-19.

[7] Wang, Y.Y. (2013) Significance and Approach of Improving Farmers' Understanding of Water-Saving Irrigation Technology. *Qinghai Agroforestry Science and Technology*, No. 2, 98-99.

[8] Han, Q. (2013) Economic Analysis of the Application of Agricultural Water Saving Irrigation Technology. Ph.D. Thesis, Agricultural University of China, Beijing.

[9] Xie, X.L. (2014) Research on Influencing Factors and Countermeasures of Farmers Adopting Water-Saving Irrigation Technology. Master Thesis, Huazhong Agricultural University, Wuhan.

[10] Li, J.Y., *et al.* (2014) Behavior Analysis of Farmers' Technique in Agricultural Technology Diffusion Environment Area: Taking the Water-Saving Irrigation Technology in Arid and Semi-Arid Area of Northwest China as an Example. *Water and Soil Conservation Bulletin*, No. 5, 201-205+236.

[11] Meng, L. (2016) Study on the Influencing Factors of Rice Water Saving Irrigation in Wuchang City. Master Thesis, Northeast Agricultural University, Heilongjiang.

[12] Li, F. (2015) Analysis on Influencing Factors of Farmers' Behavior of Water-Saving Irrigation Technology-Based on Investigation Data of Mengyin County. Shandong Province. *China Rural Watch*, No. 6, 45-51.