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Can Property Rights Reform of China's Agricultural Water Facilities Improve the Quality of Facility Maintenance and Enhance Farmers' Water Conservation Behavior?—A Typical Case from Yunnan Province, China

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Abstract: Currently, China is facing the problems of chaotic governance of end-use agricultural water conservancy facilities and a serious waste of agricultural water. To address the above issues, China launched a pilot policy of reforming the property rights of agricultural water facilities in 2014. In this study, we obtained data from 328 farm households through a microscopic study of the pilot property rights reform in Yunnan Province. We found that the reform has resulted in two typical property rights models: "Multiple cooperative governance" and "Private contract governance". The impact of the reform on the maintenance quality of irrigation facilities and farmers' water-saving technology adoption behavior was empirically analyzed using the Oprobit and IV-Oprobit methods. The study found that: (1) the property rights reform significantly improved the quality of maintenance of facilities while promoting farmers' water-saving technology adoption behavior. (2) Heterogeneity analysis revealed that the degree of non-farming of farmers had a negative moderating effect on the quality of facility maintenance and a positive moderating effect on the adoption of water-saving technologies, and the physical health of farmers had a negative moderating effect on the quality of facility maintenance. (3) There was no significant difference in the quality of facility maintenance between the "Private contract model" and the "Multiple cooperative governance model", but the former had higher water supply capacity; in addition, farmers under the "Multiple cooperative governance model" mainly used drip irrigation technology, whereas farmers under the "Private contract governance model" mainly used sprinkler irrigation technology. The findings of this study provide Chinese experience in promoting the governance of agricultural water facilities and promoting the water-saving behavior of farmers.

Keywords: agricultural water facilities property rights reform; irrigation facilities maintenance quality; farmers' water conservation technology adoption; multiple cooperative governance model; private contracting governance model

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1. Introduction

Water scarcity is a major global resource and environmental issue today [1], and the current risks of climate change around the world are exacerbating the strain on freshwater resources [2]. In the 21st century of urbanization, economic development, and population growth, the world's demand for water resources is increasing at a rate of 1% per year [3]. The 2030 Agenda for Sustainable Development identifies water as the most important element of the global sustainable development goals. However, the continued depletion of water resources in water-intensive sectors such as agriculture poses a risk of unsustainable water resources. In many countries and regions, the serious destruction of agricultural water facilities and the confusion over the management of facilities has led to chaos in agricultural water use and the serious wastage of water resources [4]. To meet the challenges of agricultural water use, there is an urgent need for agricultural water management policy reform and exploration to reduce agricultural water wastage.

There are many ways to promote water conservation and effective agricultural water management. Currently, the most effective agricultural water management measures internationally are the implementation of water pricing policies [5,6], the enforcement of agricultural water rights [7,8], agricultural water-saving incentives [9], and the establishment of total factor cost pricing for agricultural water use [10]. However, current research on agricultural water management policies has mainly focused on the "water level", neglecting research into "property rights for agricultural water facilities". Agricultural water facilities are the means of transport for agricultural water, and it is the reasonable and effective operation of agricultural water facilities that is the key to enabling agricultural irrigation to proceed smoothly. However, the current problem of confusing property rights for agricultural water facilities is the very reason for the inefficiency of agricultural irrigation [4], so it is particularly important to study the reform of property rights for agricultural water facilities. Agricultural water facilities are part of rural public pond resources, and many scholars have conducted extensive research on the property rights of rural public pond resources over the past few decades [11]. However, property rights reform of agricultural water facilities is only just beginning to be explored in many developing countries and is a daunting task and challenge.

China is one of the 13 countries with the most severe water shortages in the world [12]. Water scarcity has become a bottleneck limiting China's development [13–15]. Agricultural irrigation water is the largest water-consuming sector in China, accounting for more than 60% of China's water use. However, China is a major country with extremely high water use in irrigated agriculture, with an effective agricultural water use coefficient of only 0.56 by 2021 [16], compared to 0.87, 0.80, and 0.73 in Israel, Australia, and France, respectively, as early as 2015 [17]. The main reasons for this phenomenon are, on the one hand, the confusion in China's agricultural water management policy, which has led to confusion in the water use behavior of Chinese farmers, and the extremely sloppy way in which water is used, such as diffuse irrigation, private well-drilling and pumping, and the stealing of water channels. On the other hand, China's agricultural water facilities suffer from a serious dilemma of unclear property rights, unclear management responsibilities, and confused governance [18,19]. This has resulted in China's small farmland water conservation facilities being used by people and left unmanaged, with field projects aging and falling into disrepair [20,21]. The adoption rate of water-saving technologies is extremely low. The above reasons have resulted in a waste of water resources in China's agriculture, which has constrained China's food production [22] and poses a great threat to China's food security.

In 2014, China introduced a policy to "carry out a pilot project to reform the property rights system and innovate the operation and management mechanism of farmland water conservancy facilities". The reform of the property rights of agricultural water conservancy facilities was launched in 100 pilot counties across the country. In an attempt to solve the chaotic governance of agricultural water conservancy facilities and promote water conservation among farmers by clarifying property rights and innovating the governance model of water conservancy facilities.

Scholars have conducted a number of studies on issues related to property rights for agricultural water facilities. Coase R's (1960) research concluded that clear property rights could produce better stewardship of public pond resources [23]. Ostrom E (1990) argued that agricultural water facilities, as typical rural public pond resources, under unclear property rights, rational, and profit-maximizing individuals would not act in the collective interest and would result in the inefficient operation of water facilities [11]. In the case of unclear property rights, it is easy to produce a "tragedy of the commons" in using irrigation facilities and excessive and uncontrolled use [24,25]. In addition, transferring the management of agricultural water facilities to farmers' associations or other private sectors is an effective way to solve rural water management problems [26] and has been successful in most countries [27]. Researchers also argue that the privatization of agricultural water rights offers the possibility of collecting water fees and setting water prices [28]; the scientific pricing of irrigation water raises the cost of irrigation and stimulates farmers' awareness of water conservation while being able to increase the adoption rate of water-saving technologies among farmers [27,29]. In China, the serious waste of agricultural water and insufficient adoption of water-saving technologies are related to the long-term low price of agricultural water [30–34].

Most of the current focus is on agricultural water facilities in the case of unclear property rights on the effectiveness of the operation and maintenance of facilities and farmers to save the water technology adoption impact. However, little research has been performed on the effects, such as water savings resulting from clarifying facility property rights after the reform of property rights for agricultural water facilities in China. Therefore, the two questions we now need to answer are: what impact does this reform policy have on the operation and maintenance of agricultural water facilities? Will it promote the adoption of water-saving technologies by farmers?

Based on this, this paper selects the most typical successful pilot county, Lu Liang County, Yunnan Province, China, to explore the impact of property rights reform of agricultural water facilities on the quality of facility maintenance and farmers' behavior in adopting water conservation technologies and to analyze the underlying governance logic behind the success of the reform. Compared with the existing studies, the contribution of this paper lies in the following two points. On the one hand, the study of the effects of property rights reform on agricultural water facilities in China fills a gap in previous studies. It provides new empirical evidence for achieving the effective governance of agricultural water facilities and promoting water conservation among farmers. On the other hand, The summary of typical property rights models is conducive to the replication of agricultural water facility governance models in other countries and regions according to local conditions.

2. Policy Background and Analytical Framework

In this section, we first sort out and summarize the promotion of the pilot policy of agricultural water conservancy facilities reform in China; on this basis, we analyze the specific system of a typical pilot in Yunnan; and finally, we present the theoretical analysis framework of this paper.

2.1. China's Agricultural Water Conservancy Facilities Property Rights Reform Pilot Policy Promotion

In 2014, the Ministry of Water Resources, the Ministry of Finance, and the Development and Reform Commission of China jointly released the "Pilot policy for reforming property rights of agricultural water facilities" in the country's 100 pilot counties to carry out reform and exploration. The policy's primary purpose is to promote clear property rights and property rights transfer of facilities, innovation in the mode of operation and management of water conservancy facilities, and promote agricultural water conservation.

By the end of the 100 pilot reform period in 2018, the post-2018 period entered a phase of deepening reform and pilot experience promotion. This study summarizes the compilation of government research reports, and 100 reform pilot counties acceptance information found that the reform mainly formed two property rights models, (1) the form of centralized property rights: that is, the ownership, operation, revenue, and supervision of farmland water conservancy facilities are owned by one subject; (2) the form of separated property rights; that is, ownership, operation, revenue, and supervision rights under two or more subjects.

2.2. Analysis of the Institutional Presentation and Governance Model of a Typical Reform Pilot in Lu Liang County, Yunnan, China

2.2.1. Selection of Typical Case Pilot and System Presentation

Lu Liang County in Yunnan is the only one of the 100 pilots in the country that has formed the above two typical forms of property rights, and both models have been successful. Therefore, the 2018 China agricultural water facility reform governance model promotion field conference was held here, and Vice Premier Hu Chunhua attended the conference. This study adopts the principle of theoretical sampling, which requires the selection of typical areas that are more suitable for answering the research questions as research objects [35]. This paper focuses on whether the reform of farmland water property rights can improve the quality of maintenance of facilities and promote farmers' water-saving technology adoption behavior, with special emphasis on the "what" and "how" questions [35,36]. Therefore, the Lu Liang reform pilot in Yunnan is a typical case that is ideal for answering the research questions in this paper.

Since 2014, the reform in Luliang County, Yunnan Province, has been carried out mainly in "A Village" and "B Village" in C Township, with the following specific reform policies (Table 1): On the one hand, clarify the property rights of agricultural water conservancy facilities (ownership, operation, revenue, supervision). On the other hand, a clear irrigation system, water pricing system, and management and care system have been formulated based on clear property rights.

Table 1. Brief description of two models of reform pilot in Lu Liang County, Yunnan, China.

Form of property rights		The form of centralized property rights	The form of separated property rights
Model Name		"Multiple Cooperative Governance" Model	"Private Contract Governance" Model
Grassroots governance organization		Village Committee + Cooperative + Sub-district Water Stewards	Cooperative + Contractor
Reform time		2014	2014
The main form of the model	Property Rights System	Clarify that the ownership, management, and revenue rights of agricultural water conservancy facilities all belong to the village committee on behalf of the village collective.	The cooperatives own ownership and supervisory rights, and management and revenue rights are owned by the contractor.
	Water use and tariff system	"Water quota management": total water consumption control, charge according to the planting area (ranging from 200–250 RMB/0.07 Hectares according to the difficulty of water distribution in the plot).	"Measured water price": Charge at 0.79 RMB/m^3.
	Management system	The village committee is under unified leadership and entrusts the management to water cooperatives. The democratically elected sub-district water managers are responsible for maintaining irrigation facilities and providing irrigation services to farmers, whereas the cooperatives issue salaries to the water managers and supervise their work.	Private management: The contractor is solely responsible for the operation and maintenance of irrigation facilities and provides professional irrigation services for farmers.
	Irrigation system	Centralized water release system: the number and timing of unified water releases by the village committee, 7–12 times a season.	On-demand water supply system: release water at any time according to the needs of water users, unlimited times, and volume.

Note: Summary based on field research interviews.

However, these two neighboring villages have spontaneously developed two very different patterns of property rights and very different institutional rules (Table 1). According to the research, "A Village" is mainly in the form of "integrated property rights"; "B Village" is mainly in "the form of separated property rights". Based on the institutional differences between the two forms of property rights in these two villages, this study summarizes them as the "Multiple Cooperative Governance Model" and "Private Contract Governance Model".

2.2.2. Analysis of the Governance Logic of the Yunnan Case Pilot

In this study, based on in-depth field interviews and research with leaders of the Yunnan Lu Liang county water conservancy bureau, owners of agricultural water conservancy facilities in reformed villages, water managers, and farmers, we summarize and analyze the intrinsic governance logic of the two models as follows.

1 The governance logic of the "Multiple cooperative governance model";

The "Multiple Cooperative Governance Model" is a top-down governance method of "Village Committee + Cooperative + Rural Competent Person + Farmers" under clear property rights (Figure 1). The village committee owns all the property rights of the agricultural water conservancy facilities, and the water conservancy cooperative performs the operation rights as a village collective. Water cooperatives organize farmers to democratically elect "capable rural people" from each district to serve as sub-district water managers, who are responsible for the operation and maintenance of agricultural water facilities and provide irrigation services to farmers. The cooperative gives the water steward a salary incentive while supervising their performance assessment. The ease of access to water for farmers, the timeliness of the water supply, and the quality of facility maintenance are the criteria used to evaluate the performance of water stewards.

Under this model, the village council has an absolute voice. To facilitate unified management, promote equitable water use, and reduce farmers' planting risks, village committees have developed a centralized irrigation system, implemented a water pricing system that charges fees based on the area of cultivated land, and uniformly promoted water-saving irrigation technologies that they consider to be more water efficient (Table 1).

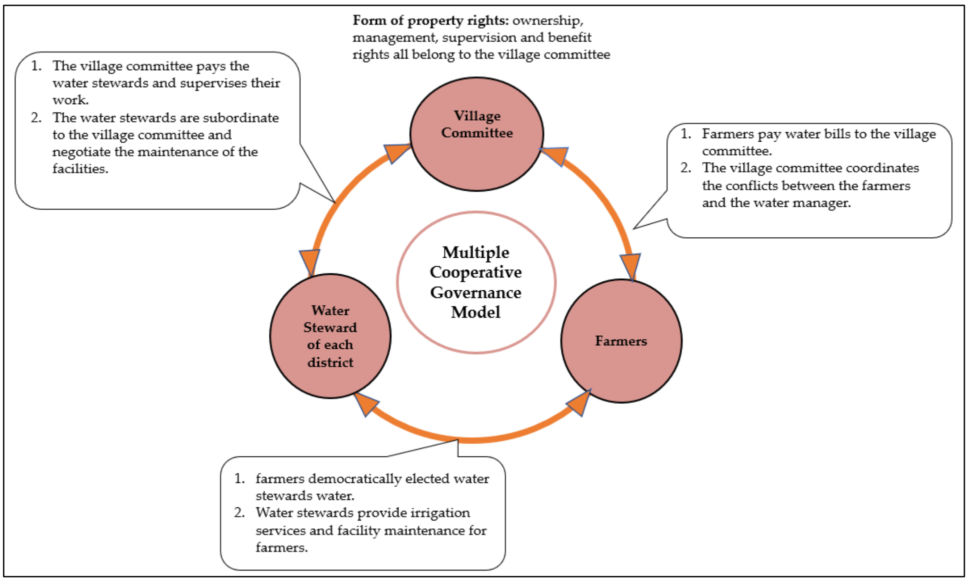

Figure 1. Governance logic diagram of the "multiple cooperative governance" model.

2. Governance logic of the "Private contracting governance model";
3. The "Private contract governance model" is a "market-based" approach to governance under the privatization of management and revenue rights. In this model, the cooperative has the ownership and supervision of the agricultural water conservancy facilities, and the contractor has the right to operate and earn income (Figure 2). The contractor is solely responsible for the operation and maintenance of agricultural water facilities and governance while providing irrigation services to farmers. At the

same time, the contractor has the power to make rules, and the "contractor" plays the role of a rational economic person in institutional rule-making. As a result, they develop institutional rules that favor maximizing its returns. Because the contractor's interest is motivated by collecting water fees, and the amount of water used by farmers determines the contractor's revenue, they want farmers to use as much water as possible, so they develop a water tariff system with metered water prices and an irrigation rule that provides irrigation services based on farmers' irrigation needs at all times (Table 1).

4. Thus, in this model, contractors are driven by profit to improve the governance of agricultural water facilities and provide farmers with professional-based irrigation services. However, the contractor does not uniformly promote more water-efficient technologies in this model. Instead, they prefer farmers to use relatively water-intensive irrigation technologies. This is because the more water the farmer uses, the more profit the contractor makes.

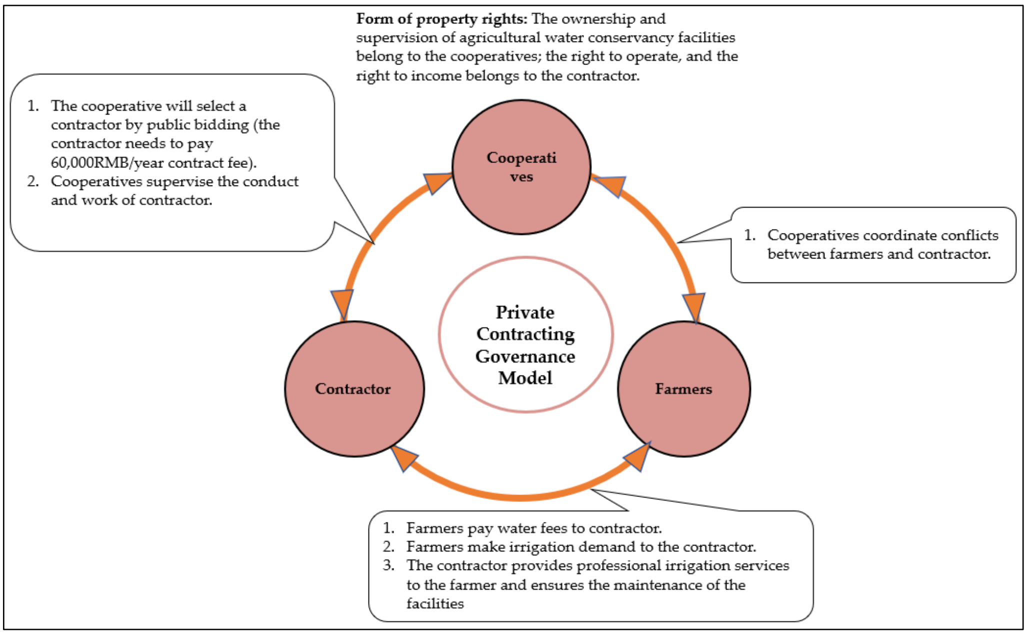

Figure 2. Governance logic diagram of the "Private contracting governance model".

2.3. Case-Based Theoretical Analysis Framework

What is the impact of these reform policies and institutional rules on the quality of maintenance of agricultural water facilities? Are they effective in increasing farmers' adoption behavior of water-saving technologies? How would the two models differ regarding the quality of facility maintenance and farmers' adoption of water-saving technologies? Based on these questions and in conjunction with existing research, the following theoretical framework is proposed for this study (Figure 3):

1. After the clarification of property rights, the development of a water pricing system makes farmland water conservancy facilities profitable private products, and property owners, as rational economic people, will maintain farmland water conservancy facilities in order to sustainably obtain the benefits of water levies, which is likely to improve the quality of facility maintenance [28,37].
2. On the other hand, the introduction of water tariffs after the clarification of property rights raises the irrigation costs of farmers. As rational economic agents, farmers are likely to adopt water-saving technologies to save on irrigation costs [29,31,38,39].
3. The "Multiple cooperative governance model" and the "Private contract governance model" have very different forms of property rights and institutional rules. These differences in institutional rules are likely to lead to differences in the quality of main-

tenance of agricultural water facilities and the adoption of water-saving technologies by farmers [40,41].

Based on the above theoretical derivation, the following research hypothesis are proposed in this study:

Hypothesis 1: *Agricultural water facilities reform areas have a higher quality of maintenance of agricultural water facilities compared to non-reform areas.*

Hypothesis 2: *The reform of property rights of agricultural water facilities can promote farmers' behavior in adopting water-saving technologies.*

Hypothesis 3: *The "Multiple cooperative governance model" and the "Private contract governance model" will lead to differences in the quality of maintenance of agricultural water facilities and farmers' technical behavior in water conservation due to differences in internal institutional rules.*

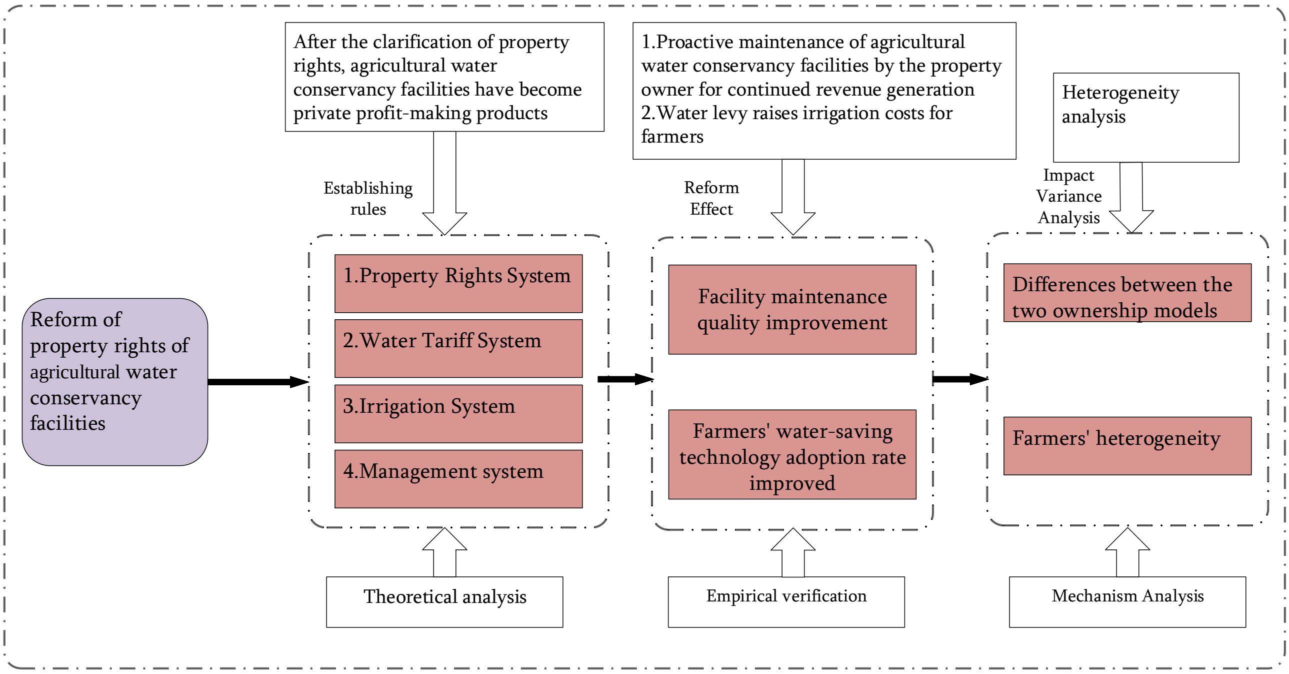

Figure 3. Theoretical analysis framework.

3. Data and Methods

3.1. Data Source

The research data were mainly obtained from an in-depth field study conducted by this research team in June and July 2021 in Luliang County, Yunnan Province (Figure 4). The control group's data came from a questionnaire survey of farmers in the reform area. In addition, four non-reform villages were randomly selected as reference groups in other townships in Lu Liang County. For the accuracy of the study, local farmers growing the main irrigated crop of spring potatoes were used as the study population, and, finally, 328 farmers' micro-study data were obtained. Of these, 208 were in the reform area (108 in the Multiple cooperative governance model and 100 in the Private contract governance model); 120 were in the non-reform area.

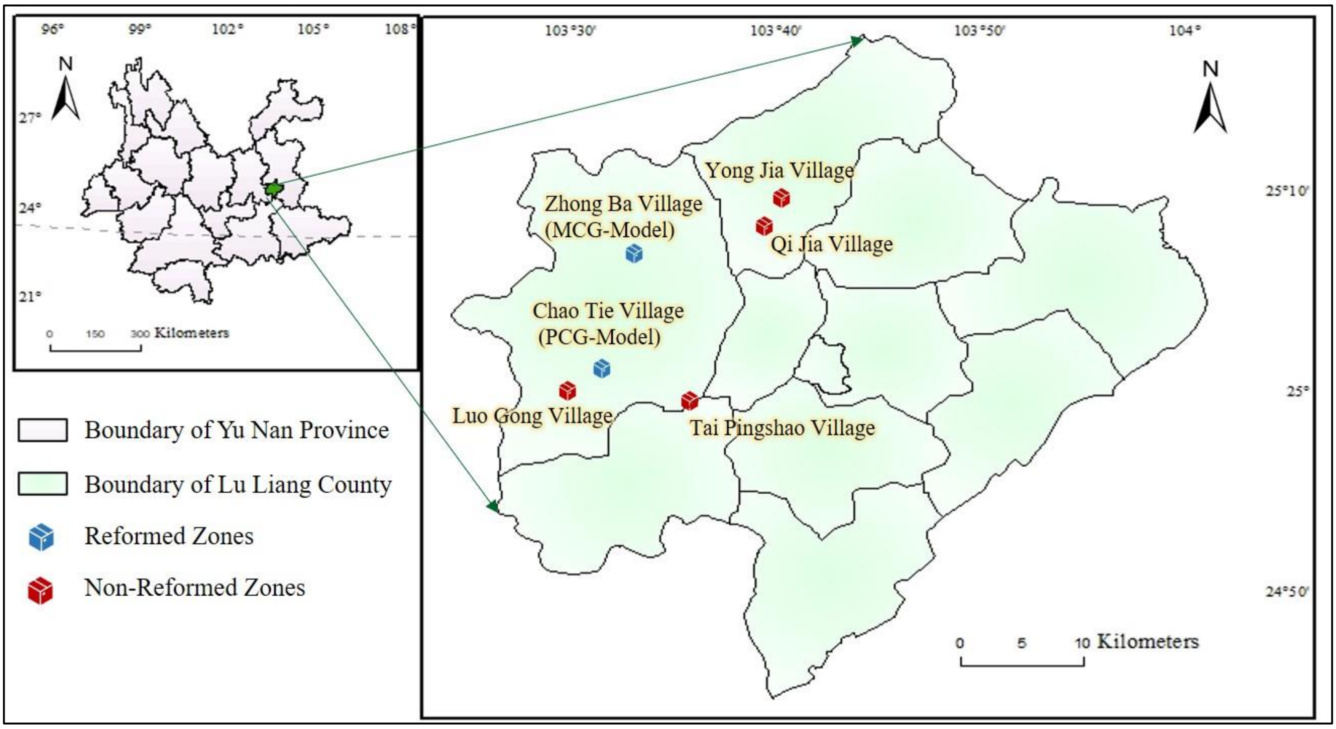

Figure 4. Microdata field study areas for this study. Note: In the picture, MCG-Model is the abbreviation for "Multiple Cooperative Governance Model" in the diagram; PCG-Model is the abbreviation for "Private Contract Governance Model".

3.2. Variable Setting and Descriptive Statistics

1. Dependent variables: quality of maintenance of agricultural water facilities, farmers' water-saving technology adoption behavior, and water-saving technology adoption categories.

Among them, the quality of facility maintenance refers to the comprehensive evaluation of farm households on the maintenance of agricultural water facilities in the village (1 = very poor; 2 poor; 3 = fair; 4 = better; 5 = very good). The farmers' adoption of water-saving technology variable is whether they adopt water-saving technology (0 = no adoption; 1 = adoption). The "water-saving technology adoption category variable" is mainly the dependent variable used to analyze the differences in water-saving technology adoption between "the two models". According to the field research, it was found that local farmers only adopt two water-saving technologies, drip irrigation and sprinkler irrigation, so this variable was set to (0 = no adoption; 1 = adoption of sprinkler technology; 2 = adoption of drip technology).

In this study, the specific descriptive statistics of the dependent variables are shown in Table 2, from which we can see that the average quality of facility maintenance in the whole sample, reformed areas, and non-reformed areas are 3.4, 3.9, and 2.7, respectively. The quality of facility maintenance in the reformed areas is significantly higher than in the non-reformed areas. The quality of facility maintenance is slightly higher in the "Private contract governance model" than in the "Multiple cooperative governance model".

From the point of view of farmers' water-saving technology adoption, the average adoption rate of farmers' water-saving technology in the full sample, reform area, and non-reform area is 76%, 95%, and 42%, and the adoption rate of farmers' water-saving technology in the reform area is 53 percentage points higher than that in the non-reform area. Regarding specific technology adoption categories, drip irrigation adoption was 33%; sprinkler adoption was 38%. However, the adoption of water-saving technologies by farmers in the two property rights models was very different. Under the "Multiple cooperative governance model", 88% of the farmers mainly adopted drip irrigation. Under the "Private contract governance model", 95% of the farmers mainly used sprinkler irrigation.

Table 2. Model variable settings and basic statistical results.

Variable Name	Variable Meaning	Full Sample (Mean)	Reform Zone (Mean)	Non-Reform Zone (Mean)	Multi-Cooperative Governance Model (Mean)	Private Contract Governance Model (Mean)
Dependent Variables						
Quality of maintenance	1 = very poor; 2 poorer; 3 = fair; 4 = better; 5 = very good	3.43	3.86	2.68	3.81	3.90
Adoption of water-saving technologies	Use = 1; No use = 0	0.76	0.95	0.43	0.94	0.97
Water-saving technology adoption category	0 = no; 1 = sprinkler; 2 = drip	1.03	1.39	0.40	1.82	1.04
Core independent variable						
Reform of property rights of agricultural water conservancy facilities	Reformed area = 1; Non-reformed area = 0	0.63	1	0	1	1
Control variables						
Planting income	Continuous variable (10,000 RMB)	9.33	11.00	6.20	8.00	14.00
Scale of operation	Continuous variable (0.067 hectares)	21.61	23.60	18.17	16.22	29.80
Distance to the county	Continuous variable (km)	15.09	14.82	15.55	14.44	15.14
Ln (Facility maintenance cost)	Continuous variable (RMB)	189.24	200.79	169.33	187.26	212.26
Ln (Cost of irrigation) per 0.067 hectares	Continuous variable (RMB)	255.88	289.83	197.04	268.65	307.64
Age	Continuous variable (year)	48.58	47.13	51.11	47.97	46.42
Education	Continuous variable (years)	7.60	7.67	7.47	7.33	7.97
Village cadres or not	Yes = 1; 0 = No	0.11	0.10	0.13	0.10	0.11
Water manager or not	Yes = 1; 0 = No	0.11	0.15	0.04	0.23	0.09
Farming experience	Continuous variable (years)	27.61	26.27	29.94	26.71	25.90
The policy factor	whether farmers have received information on reform policies Yes = 1; 0 = No	0.58	0.83	0.16	0.78	0.87
Perception of temperature changes	1 = lower; 2 = no change; 3 = higher	2.97	2.97	2.98	2.98	2.93
Perception of precipitation change	1 = lower; 2 = no change; 3 = higher	1.06	1.08	1.03	1.04	1.11
Perception of water scarcity	1 = decrease; 2 = no change; 3 = increase	0.53	0.44	0.68	0.60	0.31

2. Core independent variable: reform of property rights of agricultural water facilities.

The core content has been given in the theory section of this study (0 = no reform; 1 = reform). Reform here means that the property rights of agricultural water facilities are clarified, but it also includes developing a series of water pricing systems, management and care systems, and irrigation systems.

3. Control variables

In this study, with reference to other related studies, the control variables selected were mainly household characteristics, farmers' personal characteristics, farmers' perceptions of climate, and policies [19,41,42]. Among them, household characteristics mainly include total annual household income, the scale of operation, facility maintenance cost, cost of irrigation per 0.067 hectares, and distance from the county. The personal characteristics of farmers mainly include education, age, farming experience, and whether they are village cadres and water manager or not. Farmers' perceptions of climate mainly include perceptions of temperature and precipitation, and perceptions of whether there will be water shortages in the future. The policy factor is mainly whether farmers have received information on reform policies.

The selection and assignment of specific variables for descriptive statistics for the remaining variables are shown in Table 2.

3.3. Model Setting

Discrete data with non-continuous dependent variables are usually encountered in research problems. For discrete dependent variables, the OProbit model [43–45] and ordered logit are commonly used in various studies to analyze such problems [46,47]. However, due to the limitation of the intertemporal correlation problem of unobservable factors in alternative forms of Logit, Oprobit does not have this problem to a large extent. Therefore, the Oprobit model is more suitable for analyzing the behavioral decision problem of economic agents' behavior. Considering that the dependent variable in this study belongs to this type of data, the Oprobit model is more suitable for this study.

3.3.1. Oprobit Model

The Oprobit model is an extension of the Probit model, specifically for the case where the dependent variable is categorically ordered data. The basic form of the model is as follows:

1. Model 1: Model of the impact of property rights reform of agricultural water facilities on the quality of facility maintenance.

$$FM_i = \alpha_0 + \alpha_1 WST_i + \alpha_2 X_i + \varepsilon_i \tag{1}$$

where FM_i denotes the maintenance quality of agricultural water facilities, WST_i is the core independent variable (reform of property rights of agricultural water conservancy facilities), X_i is the control variable, and ε_i is the random disturbance term. α_0 is the constant term, and other parameters are regression coefficients.

2. Model 2: Model of the impact of property rights reform of agricultural water facilities on farmers' adoption behavior of water-saving technologies.

$$WST0_i = \beta_0 + \beta_1 WST_i + \beta_1 H_i + \delta_i \tag{2}$$

where $WST0_i$ denotes farmers' water-saving technology adoption behavior, WST_i is the core independent variable, H_i is the control variable, δ_i is the random disturbance term, β_0 is the constant term, and other parameters are regression coefficients.

3.3.2. IV-Oprobit Model

Although the reform of property rights of water conservancy facilities belongs to the national macro policy and is an exogenous variable, the selection of pilot villages for the reform may be influenced by other objective or subjective factors. Thus, the selection of pilot villages is likely not to be strictly exogenous [48–51]. Therefore, the core explanatory variables of this study are likely to have endogeneity problems. Additionally, such an endogeneity problem can lead to inaccurate model estimation results.

To effectively address the endogeneity problem, this paper introduces instrumental variables in the Oprobit model [52]. Combined with previous scholars' research on rural agricultural policy pilots in China, and also based on interviews with relevant leaders and personnel of the Water Resources Bureau in Lu Liang County, Yunnan Province. The factors affecting the selection of reform pilot villages are likely natural topographic conditions and pre-existing water conservancy conditions; therefore, based on the existing studies, the following two variables were selected as instrumental variables in this study [53].

Instrumental variable 1: "The topographic condition of the largest plot of the farmer" was selected as the instrumental variable for the reform of the property rights of agricultural water facilities to affect the quality of maintenance of the facilities.

Instrumental variable 2: "The distance between the largest plot of the farmer and the nearest irrigation canal" was selected as an instrumental variable for the reform of property rights of agricultural water facilities to influence farmers' adoption behavior of water-saving technologies.

The above variables were chosen as instrumental variables because, based on our field interviews, we found that local leaders are working to ensure more successful policy implementation, and villages with better rural irrigation conditions and better arable land topographic conditions will be selected for reform. At the same time, these two variables can reflect the topographical conditions and the original irrigation conditions of the villages to some extent, and they are exogenous; they meet the basic requirements of correlation and the exogeneity of the instrumental variables.

3.3.3. Two-Step Estimation Method of IV-Oprobit Model

In this paper, the Heckman two-step method is used to estimate the model's parameters.

In the first stage, the endogenous explanatory variables were subjected to Oprobit regression on the instrumental and exogenous explanatory variables, respectively, to obtain the fitted values $(c\hat{e}v_i)$ of the latent variable cev_i:

$$c\hat{e}v_i = \gamma z_i + \delta x_i + \omega_i \tag{3}$$

where $c\hat{e}v_i$ is the fitted value of the variable, x_i is the control variable, and z_i are the instrumental variables (IV1: The topographic condition of the largest plot of the farmer; IV2: The distance between the largest plot of the farmer and the nearest irrigation canal).

In the second stage, an Oprobit regression will be performed on the fitted values of the potential variables, residuals, and exogenous explanatory variables.

4. Results

4.1. Rationalization of Instrumental Variables

The empirical results begin with a test and analysis of the plausibility of the instrumental variables. The first is the strength test of the instrumental variables. The second is the validity test of the instrumental variables. A typical rule for testing weak instrumental variables is to require the F-statistic of the first-stage regression to be greater than 10, and then the weak instrumental variable problem can be avoided. The first test revealed that the two instrumental variables were significantly correlated with the core explanatory variables. Secondly, the results of the one-stage regression of the instrumental variable "topographic conditions of the largest plot of the farmer" (Table 3), the F-statistics of model 3 (model 3 is a model that includes only the core independent variables after using instrumental variables) and model 4 (model 4 is a model with all control variables added to model 3) were 116.58 and 21.83, respectively, which are significantly larger than 10, indicating that the instrumental variable is better. The results of the first-stage regression of the instrumental variable "distance of the largest plot of the farmer from the nearest irrigation canal" are shown in Table 4. The F-statistics for model 3 and model 4 are 177.32 and 13.09, respectively, both of which are significantly larger than 10, indicating that it passed the weak instrumental variable test. Finally, this study passed the Sargan test and did not reject the original hypothesis that the instrumental variables and residuals are not correlated, indicating that the instrumental variables selected are appropriate.

Table 3. Regression results of the impact of the reform of property rights of agricultural water facilities on the quality of facility maintenance.

Model	Oprobit		IV-Oprobit	
	Model(1)	**Model(2)**	**Model(3)**	**Model(4)**
Dependent variable	Quality of facility maintenance	Quality of facility maintenance	Quality of facility maintenance	Quality of facility maintenance
Reform of property rights of agricultural water conservancy facilities	1.277 *** (−9.67)	1.244 *** (6.67)	1.598 *** (3.31)	2.379 *** (2.61)
Age		0.008 (0.63)		0.013 (0.99)
Education		0.029 (1.34)		0.041 * (1.79)
Whether village cadres		0.214 (1.32)		0.270 (1.47)
Whether water steward		0.326 (1.20)		0.249 (0.18)
Ln (cultivation income)		−0.262 ** (−1.09)		−0.116 (−1.84)
Scale of operation		0.001 (0.20)		0.002 (0.73)
Farming experience		0.002 (0.18)		−0.001 (−0.11)
Perception of reform policy promotion		0.249 * (1.67)		−0.357 (−0.83)
Distance to the county		0.006 (0.31)		0.017 (0.89)
Awareness of future water scarcity		0.416 *** (−2.81)		−0.356 *** (−1.28)
Awareness of temperature changes		−0.089 (−0.26)		−0.217 (−0.67)
Perception of precipitation changes		−0.311 * (−1.66)		−0.393 ** (−2.06)
Facility maintenance costs		0.000 ** (2.21)		0.000 ** (2.23)
Ln (cost of irrigation per 0.067) hectares)		−0.162 (−1.43)		−0.354 ** (−1.97)
First-stage F-value			116.58	21.83
R^2	0.101	0.131	0.263	0.321
Sample size	328	328	328	328

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4. Regression results of the impact of the reform of property rights of agricultural water facilities on farmers' adoption behavior of water-saving technologies.

Model	Oprobit		IV-Oprobit	
	Model(1)	**Model(2)**	**Model(3)**	**Model(4)**
Dependent Variable	Water-saving technology adoption	Water-saving technology adoption	Water-saving technology adoption	Water-saving technology adoption
Reform of property rights of agricultural water conservancy facilities	1.853 *** (−9.86)	1.693 *** (6.12)	0.568 *** (5.67)	0.515 *** (3.72)
Farmers' individual characteristics	—	Controlled	—	Controlled
Farm household characteristics	—	Controlled	—	Controlled
Farmers' perceptions of policies	—	Controlled	—	Controlled
Farmers' perceptions of climate change	—	Controlled	—	Controlled
First-stage F-value			177.32	13.09
R^2	0.326	0.411	0.352	0.402
Sample size	328	328	328	328

Note: *** $p < 0.01$.

4.2. The Impact of the Reform of Property Rights of Agricultural Water Conservancy Facilities on the Quality of Maintenance of Facilities

The regression results are shown in Table 3; model 1 is the baseline regression model with only the core independent variable, model 2 is the baseline model with all control variables added to model 1, and model 3 and model 4 are the regression models with instrumental variables. From the model setup, the joint significance of the whole model is high, which indicates that the model setup is reasonable. From the regression results, the core explanatory variables are significant in models 1–2, and after overcoming the potential endogeneity, the core independent variables remain significant in models 3–4, indicating that the reform of the property rights of agricultural water facilities significantly improves the quality of maintenance of agricultural water facilities. Hypothesis 1 is verified.

4.3. Impact of the Reform of Property Rights of Agricultural Water Conservancy Facilities on Farmers' Water Conservation Technology Adoption Behavior

The regression results are shown in Table 4; among them, model 1 is only the core independent variable benchmark regression model, model 2 is the benchmark model after adding all control variables, and model 3 and model 4 are instrumental variable regression models, where all control variables are one-to-one, as in the previous section, and control variables are omitted from Table 4 in this section due to space limitations. From the model setting, the joint significance of the whole model is high, which indicates that the model setting is more reasonable. From the regression results, in models (1–2), the core explanatory variables are all significant at the 1% level, and after overcoming the potential endogeneity, the core independent variables remain significant in model (3–4), which indicates that the reform of the property rights of agricultural water facilities significantly enhances the adoption behavior of water-saving technologies among farmers. Hypothesis 2 is tested.

4.4. Heterogeneity Analysis

According to existing studies, it has been found that the degree of non-farming and the physical health of the farmer are likely to influence the behavior and subjective awareness of agricultural operators [19,20]. In addition to this, the different ownership patterns in this study are likely to lead to differences in the quality of facility maintenance and the types of water-saving technologies adopted by farmers.

Therefore, this study analyzes the heterogeneity in three aspects: the difference between two property rights development models, the degree of non-farming of farm households, and the physical health of farm households. The meanings of specific indicators and descriptive statistics are shown in Table 5.

Table 5. Meaning of indicators and descriptive statistics of heterogeneity analysis.

Heterogeneity Analysis Variables	Indicator Meaning	Full Samples	Reformed Area	Non-Reformed Area
		Mean Value	Mean Value	Mean Value
Property Rights Models	1 = Multiple cooperative governance model; 0 = Private contracting governance model	0.29	0.52	0
Degree of non-farming of farming households	Percentage of non-farm income of farm households	0.23	0.20	0.27
Physical health condition	1 = very healthy ~ 5 = very unhealthy	1.11	1.10	1.13

4.4.1. Heterogeneity of Different Property Rights Models

1. Impact of different proprietary models on the effectiveness of facility operation and maintenance

The empirical results show that there is no significant difference in the quality of facility maintenance between the two models (Table 6). This indicates that after the reform of the property rights of agricultural water conservancy facilities, both models promote the quality of facility maintenance, making both models achieve efficient operation of the facilities.

Table 6. Regression results for heterogeneity of ownership patterns.

Model	**Oprobit**	**Oprobit**
	Model(1)	**Model(1)**
Variables	Quality of facility maintenance	Water-saving technology adoption categories
Property Rights Model	0.147 (−0.8)	2.207 *** (−8.59)
Farmers' individual characteristics	Controlled	Controlled
Farm household characteristics	Controlled	Controlled
Farmers' perceptions of policies	Controlled	Controlled
Farmers' perceptions of climate change	Controlled	Controlled
R^2	0.115	0.377
N	208	208

Note: *** $p < 0.01$.

2. Differences in the types of water-saving technologies adopted by farmers under different models of pro-property rights models

However, the empirical results show that farmers under different property rights models have very different choices in the type of water-saving technologies they adopt (Table 6). This further confirms the results of the descriptive statistics that farmers under the "Multiple cooperative governance model" are more willing to adopt drip irrigation technology; in contrast, farmers under the "Private contract governance model" are more willing to adopt sprinkler irrigation technology.

The inherent reason for this difference is that under the "Private contract governance model", the contractor does not promote water-saving technologies uniformly, and the farmer has the autonomy to choose which water-saving technologies to use. As rational economic people, farmers end up generally using sprinkler irrigation because it is less expensive to install and easier to use (based on the results of in-depth field interviews, it was found that local sprinklers do not need to be replaced for 4–5 years after being installed once, but drip irrigators must be replaced annually).

4.4.2. Heterogeneity in the Degree of Non-Farming of Farm Households

1. Moderating effect of the degree of non-agriculturalization on the quality of facility maintenance

Model 1 in Table 7 shows the regression results after adding the moderating variable "degree of farm household de-farming" to the baseline model. The results show that the degree of non-agriculturalization of farm households negatively modifies the maintenance quality of the facilities affected by property rights reform. According to the calculation, the specific regulation effect is shown in Figure 5. From the figure, it can be seen that the marginal effect of the reform of property rights of agricultural water facilities on the maintenance quality of facilities in the reformed areas decreases with the increase in the degree of non-farming of farm households. It ceases to be significant when the non-farming level of farm households exceeds 70%.

From an economic point of view, a higher degree of non-farming of farm households represents a higher share of non-farming income of farm households in household income, and this means that agricultural production is no longer the main economic source for farm households (it could be an increase in off-farm income due to an increase in part-time work or an increase in the proportion of time spent working outside the home by farm households). Additionally, at this point, the higher the degree of non-agriculture, the higher the opportunity cost for farmers to participate in the maintenance of agricultural water conservancy facilities. Therefore, the higher the degree of non-agriculturalization, the lower the motivation of farmers to participate in the maintenance of agricultural water facilities, and the less they care about the quality of maintenance of their village facilities.

Table 7. Heterogeneity regression results of the degree of non-farming of farm households.

Model	**Oprobit**	
	Model(1)	**Model(3)**
Dependent variable	Quality of facility maintenance	Farmers' water-saving technology adoption
Property Rights Reform	1.304 ***	1.214 ***
	(6.09)	(3.85)
Property rights reform × degree of non-farming of farm households	−1.157 ***	1.670 ***
	(−2.45)	(1.89)
Farmers' individual characteristics	Controlled	Controlled
Farm household characteristics	Controlled	Controlled
Farmers' perceptions of policies	Controlled	Controlled
Farmers' perceptions of climate change	Controlled	Controlled
R^2	0.173	0.423
N	328	328

Note: *** $p < 0.01$.

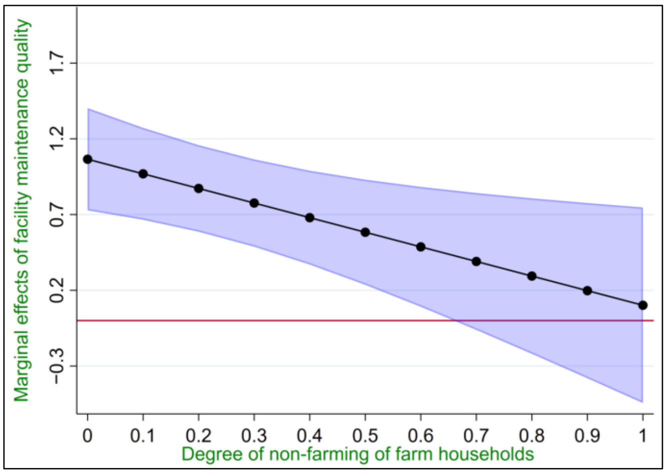

Figure 5. Moderating effect of the degree of non-farming of farm households on the quality of facility maintenance. Note: The black line in the figure indicates the moderating effect of the degree of non-farming of farm households on the quality of facility maintenance affected by property rights reform. The blue area represents the 95% confidence interval. The red line in the figure represents the significance level.

The above analysis of heterogeneity between the models shows that the differences in farmers' adoption of water-saving technologies between the two models proposed in Hypothesis 3 are verified. However, there was no difference between the two models in terms of the quality of maintenance of agricultural water facilities, which improved under both models.

2. Moderating effects of the degree of non-farming on farmers' water-saving technology adoption behavior

Model 2 in Table 7 shows the regression results after adding the moderating variable "degree of non-farming of farm households" to the baseline model. The results show that the degree of non-farming of farm households has a positive moderating effect on the property rights reform affecting the adoption behavior of farm households for water-saving technologies. According to the calculation, the specific moderating effect is shown in Figure 6. The figure shows that the marginal effect of property rights reform on farmers' water-saving technology adoption behavior in the reformed areas increases with the degree of farmers' non-farming.

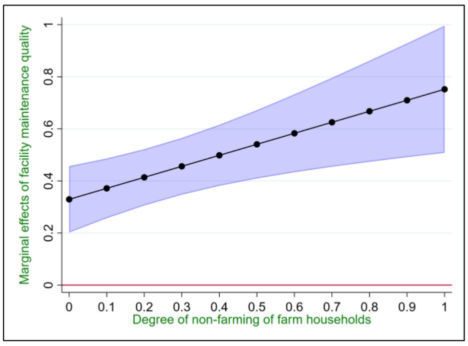

Figure 6. Moderating effect of the degree of non-farming of farm households on the adoption behavior of water-saving technologies. (Note: The black dashed line in the figure represents the moderating effect of the degree of farm household de-farming on the adoption behavior of farmers' water-saving technologies influenced by property rights reform. The blue area represents the 95% confidence interval. The red line in the figure represents the significance level.).

From an economic point of view, the higher the degree of non-farming of farm households, the higher the opportunity cost of labor participation in irrigated agriculture. Therefore, the higher the level of non-agriculturalization of farmers, the more willing farmers are to adopt water-saving technologies as an alternative to other labor-intensive irrigation methods, thus saving irrigation labor time for non-agricultural operations or part-time operations. Therefore, the higher the level of non-agriculturalization, the more farmers are willing to adopt water-saving irrigation technologies.

4.4.3. Heterogeneity of Farmers' Physical Health Status

Table 8 shows the results of the regression with the addition of the moderating variable "farmer's physical condition" to the baseline model. "The poorer the health status of farmers" has a negative moderating effect on the quality of facility maintenance; however, the moderating effect on the adoption behavior of water-saving technologies is not significant.

The results of model 1 in Table 8 shows that the poorer the health of the farmer, the more negative the effect of property rights reform on the quality of maintenance of the facilities. According to the calculation, the specific regulation effect is shown in Figure 7; the moderating effect after "3 = unhealthy" was not significant. This negative moderating effect is easily explained: the deterioration of farmers' health represents disease on the one hand and increasing age on the other. Increasing illness and age will reduce the ability of farmers to work. This weakens their ability to maintain agricultural water facilities and reduces their attention to facility maintenance.

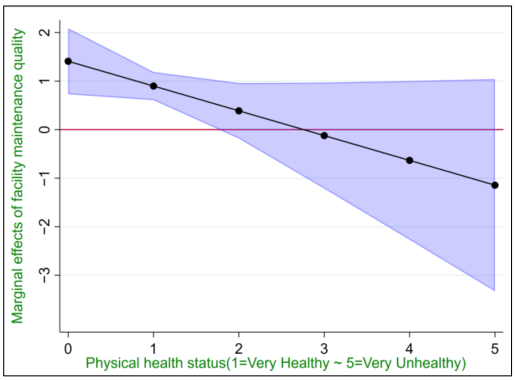

Figure 7. Moderating effect of farmers' physical health status on the quality of facility maintenance. Note: The black line in the figure represents the moderating effect of "farmers' health and physical condition" on the quality of property rights reform affecting facility maintenance. The blue area represents the 95% confidence interval. The red line in the figure represents the significance level.

Table 8. Regression results of heterogeneity analysis of farmers' physical health status.

Model	Oprobit	
	Model(1)	**Model(3)**
Dependent variable	Quality of facility maintenance	Farmers' water-saving technology adoption
Property rights Reform	1.681 ***	−2.341
	(3.95)	(−0.02)
Property rights reform × farmers' physical health status	−0.581 *	−0.058
	(−1.68)	(−0.16)
Farmers' individual characteristics	Controlled	Controlled
Farm household characteristics	Controlled	Controlled
Farmers' perceptions of policies	Controlled	Controlled
Farmers' perceptions of climate change	Controlled	Controlled
R^2	0.179	0.416
N	328	328

Notes: * $p < 0.1$, *** $p < 0.01$.

4.5. Robustness Analysis

4.5.1. Robustness Analysis of the Impact of Property Rights Reform of Agricultural Water Facilities on the Quality of Facility Maintenance and Water Conservation Technology Adoption Behavior

This section takes a robustness test using a replacement model and replacement variables [50]. The Oprobit model was replaced by OLS estimation; the variable "water supply capacity of the facility (number of irrigation delays by the farmer: a higher number of delays means that the facility is less capable of supplying water)" was used to replace the quality of facility maintenance (Table 9). Model 1 and model 2 in Table 9 show the robust analysis of the reformed property rights of agricultural water facilities on the quality of facility maintenance. After changing the estimation method and variable, the results remain robust, with a significant improvement in the quality of facility maintenance in the reformed areas, along with a significant reduction in the number of irrigation delays by farmers.

Table 9. Regression results of robustness analysis of the effect of property rights reform of agricultural water facilities on the quality of facility maintenance and water-saving technology adoption behavior.

Model	OLS		
	Model(1)	**Model(3)**	**Model(4)**
Dependent variable	Quality of facility maintenance	Number of irrigation delays for farmers	Farmers' water-saving technology adoption
Property Rights Reform	1.079 ***	−1.110 ***	0.475 ***
	(−6.91)	(−3.50)	(−8.32)
Farmers' individual characteristics	Controlled	Controlled	Controlled
Farm household characteristics	Controlled	Controlled	Controlled
Farmers' perceptions of policies	Controlled	Controlled	Controlled
Farmers' perceptions of climate change	Controlled	Controlled	Controlled
R^2	0.286	0.126	0.365
N	328	328	328

Notes: *** $p < 0.01$.

Model 3 in Table 9 presents the robustness analysis of the impact of the property rights reform of agricultural water facilities on the adoption of water-saving technologies. The results remain robust after changing the estimation method, indicating that the reform of property rights of agricultural water facilities can robustly promote farmers' adoption behavior of water-saving technologies.

4.5.2. Robustness Analysis of Different Property Rights Models Affecting the Quality of Facility Maintenance and Adoption of Water-Saving Technologies by Farmers

This section also uses a replacement model and replacement variables for robustness analysis. The Oprobit model was replaced by OLS estimation; the variable "water supply capacity of the facility (number of irrigation delays by the farmer)" was used to replace the quality of facility maintenance (Table 10). Model 1 and model 2 in Table 10 show the robustness analysis of different property rights models affecting the quality of facility maintenance. The results of model 1 are robust after replacing the estimation method, indicating no difference in facility maintenance quality between the two models. However, the results of model 2 after replacing the variables are not robust, with a higher number of irrigation delays for farmers under the "Multiple cooperative governance model" than the "Private contract governance model". This means that the "Private contracting model" has a higher water supply capacity than the "Multiple cooperative governance model", resulting in fewer irrigation delays for farmers. This is not difficult to explain: on the one hand, it is because the number of irrigation delays here represents the good or bad quality of facility maintenance; on the other hand, it also represents the different modes of management, institutional rules, and the ability to operate the system of water facilities. In the second part of this study, we analyzed the governance logic of the two models. (1) As the "Private contract governance model" uses a metered water price, an irrigation system that provides irrigation anytime according to the farmers' needs is preferable. Therefore, the contractor's interest is motivated by the farmers' water consumption, so the contractor will try not to delay every drop of water needed by the farmers for irrigation and try to ensure the capacity of the facility and reduce the number of irrigation delays for the farmers. (2) On the contrary, in the "Multiple cooperative governance model", a water pricing system is adopted that charges for water according to the area planted, and an irrigation system that provides irrigation to farmers with a fixed number of releases and hours is preferred. Under this system, the cooperatives do not have the incentive to release water to farmers at any time because it does not increase the cooperative's revenue by releasing more water or releasing water on time. Therefore, the water supply capacity of the "Multiple cooperative governance model" is weaker, and farmers passively receive irrigation leading to more delays in irrigation for farmers.

Table 10. Robustness analysis regression results of different property rights models on the quality of facility maintenance and adoption of water-saving technologies.

Model	**OLS**		
	Model(1)	**Model(3)**	**Model(4)**
Dependent variable	Quality of facility maintenance	Number of irrigation delays for farmers	Farmers' water-saving technology adoption
Property Rights Models	−0.101	0.681 ***	0.817 ***
	(−0.67)	(−3.62)	(−12.16)
Farmers' individual characteristics	Controlled	Controlled	Controlled
Farm household characteristics	Controlled	Controlled	Controlled
Farmers' perceptions of policies	Controlled	Controlled	Controlled
Farmers' perceptions of climate change	Controlled	Controlled	Controlled
R^2	0.286	0.126	0.365
N	328	328	328

Notes: *** $p < 0.01$.

Model 3 in Table 10 shows the robustness analysis of different property rights patterns affecting the adoption categories of water-saving technologies by farmers, and the results remain robust by replacing the estimation method.

5. Further Discussion

5.1. Agricultural Water Management Policy

In contrast to other agricultural water management policy studies [5–10], this study examines agricultural water management, agricultural water conservation, and the effective governance of agricultural water facilities from the perspective of clear property rights for agricultural water facilities. Agricultural water management policies are enriched.

The conclusion that clear property rights for agricultural water facilities can improve the quality of maintenance of agricultural water facilities is further evidence that clear property rights for public pond resources can contribute to their maintenance effectiveness, which is consistent with the findings of existing studies [11,23,25].

However, the findings on promoting farmers' adoption of water-saving technologies differ from the existing literature. The current research has focused on the impact of water pricing [27,30], water conservation promotion [31], and technology diffusion on farmers' adoption of water conservation technologies [34]. However, this study is based on the reform of property rights of agricultural water facilities and argues at a deeper level that clear property rights can help promote the adoption of water-saving technologies by farmers.

Compared to the existing literature on the governance model of farmland water facilities [41], this study innovatively proposes and summarizes two models of property rights governance that have emerged after the property rights reform, namely, the "Multiple cooperative governance model" and the "Private contracting model". Specifically, both models have achieved clear property rights, solved the problem of the confusing governance of farmland water conservancy facilities, and reduced the serious waste of agricultural water. Our study found that farmers under the multiple governance model are passive in terms of agricultural irrigation. Under the private contract governance model, farmers have an active role in irrigating their farms. In addition, the types of water-saving technologies adopted by farmers in the two governance models differed significantly. The main reason for the difference in governance between the two models is the different ownership of property rights, with whoever holds the property rights to agricultural water facilities having the power to make the rules, which in turn determines the difference in the effectiveness of farmers' adoption of water saving technologies and agricultural water management [4]. This provides a typical experience and reference for the promotion of agricultural water management models in other countries and regions.

5.2. Shortcomings of the Research

The study data and study area are not comprehensive enough. Long-term panel data were not available due to the early introduction of this reform policy, as well as the small sample size. Additionally, due to the limitations of epidemic control in China, we only studied the most typical reform pilot in Yunnan. In the future, the group intends to expand the sample size and collect panel data over multiple periods to further substantiate the findings of this study. Additionally, the study needs to be further expanded to include different reform pilots in the empirical analysis, taking into account regional heterogeneity to make the results more generalizable.

The choice of research perspective could have been broader. This study only examined the quality of the maintenance of farmland water facilities and the adoption of water-saving techniques by farmers. Future attempts could be made to study other reform effects, such as the impact of property rights reform on farmers' income and the impact on farmers' cropping restructuring.

The case studies are limited in their scope of representativeness. Due to the vast differences in hydrological, economic, and topographical conditions around the world, the two property rights governance models presented in this case study are not representative of their replicability in all regions, and further research is needed to explore their replicability and scalability in other regions, as well as to explore additional governance models to enrich agricultural water management policies.

6. Conclusions

Based on field research data from a typical pilot agricultural water facility reform in Yunnan, China, this study uses a combination of Oprobit and instrumental variables to conduct empirical analysis. After effectively avoiding the endogeneity problem, the following conclusions are drawn:

The reform of property rights of agricultural water facilities has significantly improved the quality of maintenance of agricultural water facilities and enhanced farmers' adoption behavior of water-saving technologies. There was no significant difference in the quality of facility maintenance between the "Multiple cooperative governance model" and the "Private contract governance model". However, under the "Private contract governance model", the overall water supply capacity was relatively higher and the number of irrigation delays by farmers was relatively lower. Drip irrigation technology is mainly used by farmers in the "Multiple cooperative governance model", and sprinkler irrigation technology is mainly used by farmers in the "Private contract governance model". From the analysis of farmer heterogeneity, the degree of non-farming of farmers has a negative moderating effect on the quality of facility maintenance; it has a positive moderating effect on the adoption of water-saving technologies by farmers. This effect is weaker with the marginal effect of poorer farmer health on the quality of facility maintenance. The following policy insights are offered based on this study:

Further promote the reform of property rights for agricultural water facilities and incorporate policies on property rights management for agricultural water facilities into the scope of agricultural water management policies to promote the scientific and effective management of agricultural water and reduce the wasteful use of agricultural water.

It is important to strengthen the effective interface between the reform policy on property rights of agricultural water conservancy facilities and other agricultural water management policies. On the basis of clear property rights of facilities, the water pricing system, irrigation system, and management system for the operation of agricultural water conservancy facilities should be improved in accordance with other agricultural water management policies.

The "Multiple and cooperative governance model" and the "Private contractual governance model" can be promoted in accordance with local conditions.

The construction of institutional rules in the process of reforming the property rights of agricultural water conservancy facilities should pay attention to both the degree of non-farming of farmers and the disadvantaged groups of farmers to achieve the maximum effect of the reform policy.

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