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Impact of Agricultural Cooperatives on Farmers' Collective Action: A Study Based on the Socio-Ecological System Framework

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Abstract: Agricultural cooperatives greatly influence agricultural and rural modernization in China. Based on 381 farmer samples in the arid Tarim River Basin, this empirical study aimed to construct an index system for the exploration of the relationship between cooperatives and farmers' collective action by using the Socio-Ecological System framework. The results showed that agricultural cooperatives helped to empower farmers to act collectively. Agricultural cooperatives, with the mechanisms of collective decision making, institutional constraints, and internal supervision, could realize the integration of resources required for farmers' collective action and promote the sharing of risks and benefits. By providing financing support and a platform for resource integration, cooperatives could reduce constrains induced by economic difference among farmers; enhance village leadership, organization, and coordination; and promote the accumulation of social capital and villagers' sense of identity with the village. Particularly, cooperatives could support farmers to adopt water-saving irrigation technologies and reduce their over-dependence on chemical pesticides and fertilizers, thus promoting farmers' collective action. Therefore, the development of agricultural cooperatives will help enhance farmers' collective action, promote the modernization of rural governance, and realize rural revitalization.

Keywords: value perception; agricultural cooperatives; water-saving irrigation technology; Tarim River Basin

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1. Introduction

At present, China's rural areas are facing a series of problems in rural public affairs. Although progress has been made in economic development, the growth of rural residents' incomes, and the construction of public facilities, some regions are faced with the problem of institutional decay. Specifically, in some rural areas, there has been a decline in natural environment, cultural environment, and grassroots governance. The essence of these problems lies in the decline of the capacity for collective action [1]. In terms of the natural environment, due to the lack of effective collective action and coordination mechanisms, farmers' awareness and actions on environmental protection and pollution control have become weak, resulting in great difficulty in environmental governance in many rural areas. In terms of the cultural environment, cultural values, social cohesion, and community services are also weakening due to the low collective action capacity, which has a certain impact on the healthy development of the cultural environment. In terms of grassroots governance, the declining collective action capacity has long existed within grassroots organizations, resulting in problems such as reduced effectiveness of grassroots organizations, an unfair distribution of resources, organizational instability, as well as difficulties in decision making and task implementation [2]. To sum up, the natural environment in rural areas has been seriously damaged, the cultural environment has gradually lost its characteristics and vitality, and the functions of grassroots organizations have gradually been lost due to poor operation. The declining collective action capacity in rural areas poses a great challenge to the sustainable development and revitalization of rural areas. Finding ways to improve collective action capacity in rural areas has become a key part of the governance modernization and sustainable development of rural areas.

Although the decline in collective action capacity has hindered agricultural modernization, there are still factors that have a positive impact on rural collective action [3]. For example, Cai et al. [4] pointed out that cooperatives had advantages over other forms of organization in terms of agricultural technology services, agricultural material procurement, product sales, and warehousing and logistics, and greatly increased the probability of reducing the use of chemical fertilizers and pesticides. Feng and Huo [5] found that the social networks established by cooperatives expanded farmers' access to information and prompted farmers to choose environmentally friendly technologies. In addition, Wan and Cai [6] pointed out that cooperatives promoted the adoption of soil property measurement-based fertilization and standardized production. However, cooperatives also face some challenges in the process of modernizing agriculture. Due to the lack of effective supervision, non-standard operation, insufficient funds, etc., members may have a "free ride" in production, management, and other links. Additionally, the overall impression and perception of members to cooperatives' management performance also affect cohesion, cooperation with other cooperatives, and the leading role of cooperatives, which may make it difficult to unify product quality. To a certain extent, these problems undermine the process of cooperatives promoting agricultural development.

Cooperatives take advantage of economies of scale and resource allocation to provide a platform for farmers to collaborate and cooperate [7]. By increasing the collective action capacity of cooperatives, farmers can jointly purchase agricultural materials, sell products, and participate in technological innovation activities so as to promote the optimal allocation of resources and increase production efficiency [8]. In the process of pursuing common interests and implementing collective action, farmers have strengthened their sense of collective identity, which enhances the collective action capacity and promotes the harmonious and stable development of rural communities. Therefore, this study argued that cooperatives were important positive factors to improve the collective action capacity of farmers in rural areas in China. Therefore, this study focused on the impact of cooperatives on rural residents' collective action capacity, aiming to provide some reference and policy enlightenment for China's rural revitalization.

Scholars have realized that cooperatives have a significant effect in promoting agricultural modernization, but there is still room for improvement. First of all, in terms of the research perspective, previous studies have mainly focused on the dynamic mechanism and economic benefits of cooperatives, but rarely considered the influence mechanism of cooperatives on rural collective action capacity from a micro perspective. Secondly, previous empirical studies lack a theoretical basis and have limited indicators. To solve the above problems, this study used the binary Logit model to empirically analyze the impact of cooperatives on rural residents' collective action capacity based on the socio-ecological system (SES) analysis framework and the sample data of 381 farmers in the Tarim River Basin.

The objectives of this study were (1) to construct an index system for the exploration of the impact of cooperatives on farmers' collective action and (2) to analyze the mechanism by which cooperatives impact farmers' collective action using a new analysis framework, SES, taking the adoption of water-saving irrigation technology as the specific analysis object.

2. Materials and Methods

2.1. Research Framework

Farmer professional cooperatives (hereinafter referred to as cooperatives) are service organizations based on the principle of mutual aid, and their main goal is to provide services to their members. The Law of the People's Republic of China on Farmer Professional

Cooperatives defines farmer professional cooperatives as follows [9]: farmer professional cooperatives established on the basis of rural household contract management are economic organizations that jointly carry out the large-scale operation of similar agricultural products and carry out democratic management on the principle of "voluntary entry and freedom to withdraw". In cooperatives, the rights and obligations of members are unified. Based on the interest linkage mechanism of "risk sharing and benefit sharing", members have the right to enjoy the services and convenient means of production provided by the cooperative and should also abide by the articles formulated by the cooperative, such as contributing capital to the cooperative and bearing losses. Since the promulgation of the Law of the People's Republic of China on Farmer Professional Cooperatives, China's farmer cooperatives have developed rapidly, and the number of registered cooperatives has exceeded 2.2 million, which includes nearly half of the country's rural households. Thus, cooperatives have grown into one of the important agricultural business entities in China [9]. Cooperatives influence farmers' collective action by triggering changes in specific factors in the socio-ecological system.

In recent years, a new research paradigm has emerged in the international academic community, namely the analysis of complex socio-ecological systems. This paradigm uses the SES framework as an analytical tool to assess socio-ecological systems and to better explain the interrelationships between human society and natural ecosystems. The SES framework was developed by the Nobel laureate economist Elinor Ostrom and her team in 2007 [10]. It is a logical framework used for analyzing the governance of public affairs. This framework applies interdisciplinary knowledge from ecology, economics, sociology, and political science to the analysis of the complex relationship between social systems and ecosystems, and it provides a framework and interdisciplinary common language to describe and explain the complex relationships between social systems and ecosystems, as well as between subsystems within social systems [11]. The framework has a two-level structure. The first level consists of four core systems, including ResoArce Systems (RS), ResoArce units (RA), actors (A), and governance systems (GS), as well as eight primary variables, such as interactions (I) and outcomes (O) that occur in the macro context of Social Systems (S) and Ecosystems (ECO). Each primary variable can be further decomposed into over 50 secondary variables (Figure 1).

The SES framework is a multi-dimensional coupled and interactive system that includes all of the resources involved in the interactions of human society and the ecosystem [12]. Therefore, it is increasingly used by scholars in various fields to study the influencing factors of various types of collective action. For example, Su et al. [13] constructed a rural socio-ecological system based on the SES framework and analyzed the impact of land transfer on rural residents' collective action. Researchers do not need to use all of the variables in the SES framework, but they should select relevant variables from the SES framework according to the specific research situation for model construction and analysis [14].

This study adopted the SES framework to explore the mechanism of the impact of cooperatives on farmers' collective action. As a carrier for individual farmers to participate in the modern agricultural system, a cooperative is essentially a type of agricultural and economic cooperation organization where agricultural producers can adapt to the needs of the market economy, overcome their own scale limitations, and realize a collective effect based on mutual aid. The emergence of cooperatives has changed the governance pattern from the traditional single leadership of the government to the democratic participation of members with a market orientation, and it has realized the pluralistic coordination of the government, market, and social subjects [15]. Through professional management, cooperatives have successfully increased the participation and decision-making power of rural households, better met the market demand, and improved the overall economic efficiency. Therefore, this study considered cooperatives (S4-1) as the third-level variables of other governance systems (S4) of the second-level variable in the social, economic, and political context (S), and introduced two third-level variables, market entities (GS2-1) and social agents (GS2-2), in the second-level variable of non-governmental organizations (or third-party organizations) in the governance system (GS) (Table 1).

The development of agricultural cooperatives has promoted the integration of resources in agricultural production. On the one hand, cooperatives use their scale advantages and social capitals to expand the production and trading options of rural households and enhance their competitiveness in the market. At the same time, in agricultural production, cooperatives help farmers master the key points of new technologies through knowledge sharing by organizing technology training, reducing farmers' costs. With the platform of cooperatives, rural households have stronger voices among the market players. According to Schultz's rational smallholder hypothesis [16], when farmers join cooperatives, self-interest motivation is stimulated due to the increase in personal income. To maximize profits, farmers tend to invest more labor, capital, and production factors into cooperatives. In this process, two-way resource integration has been realized between cooperatives and rural households, achieving large-scale operation and an efficient use of resources. While enjoying the benefits of diversified distribution channels, technical and financial support, and risk control provided by cooperatives, farmers also begin to consider and respect the collective and individual interests in cooperatives. The cooperative members participate in collective decision making on an equal footing, jointly formulate the code of conduct and rights and obligations, and regard the operation of the cooperative as their own responsibility and business. Under the internal supervision mechanism of cooperatives, farmers will take the initiative to reduce "free-riding" behavior [17]. Based on the above analysis, agricultural cooperatives are closely related to the governance system. Therefore, the third-level variables collective resource integration (GS5-1) and benefit sharing (GS5-2) were introduced into the operating rules of the governance system (GS5). In terms of the collective choice rule (GS6) of the governance system, the third-level variables collective decision making (GS6-1) and institutional constraints (GS6-2) were added. In addition, in terms of the oversight and sanctions rules (GS8) for the governance system, a third-level variable, internal oversight (GS8-1), was introduced. Factors such as differences in economic status among villagers (A2-1), village public leadership (A5-1), villagers' sense of belonging to the village (A6-1), and use of green production technologies (A9-1) were considered as third-level variables when studying the rural collective action capacity. These factors correspond to second-level variables, such as actors' socio-economic attributes (A2), actors' leadership/entrepreneurship (A5), social norms/social capital (A6), and alternative technologies (A9), under the actor (A) subsystem.

Cooperatives play an important role. On the one hand, cooperatives narrow the gap between farmers' economic statuses by providing economic opportunities and a platform for resource integration. On the other hand, cooperatives shape farmers' behaviors and expectations, strengthen their cooperation and sense of common responsibility, and enhance the accumulation of social capital, farmers' sense of identity with the village, and public leadership and coordination through norms within the cooperatives (A6). In addition, cooperatives contribute to the development of agriculture in a resource-saving and environmentally friendly direction. To solve the problems of the excessive use of chemical fertilizer and pesticides, agricultural non-point source pollution, and increasing ecological disasters, the development goals of cooperatives tend to be ecological, and the production and operation activities of cooperatives develop in the directions of low consumption, low pollution, and high added value. This can continuously improve the quality of agricultural products and increase farmers' income while achieving ecological benefits. Specifically, cooperatives cultivate farmers' ecological values (O2-1). The ecological knowledge provided by cooperatives' trainings help farmers understand some ecological concepts. Cooperatives promote the development of green agricultural products (O2-2) and pay attention to environmental protection while ensuring there is good yield of agricultural products and income. Cooperatives organize the construction of ecological systems (O2-3) and integrate ecological norms into production. For example, in agricultural production, cooperatives promote the use of organic fertilizer, microbial fertilizer, and other green production technologies (A9-1) to solve the problems of soil compaction and nutrient loss caused by the excessive use of chemical fertilizers, and they improve soil quality. It can be seen that cooperatives effectively guarantee the win-win situation of social performance (O1) and ecological performance (O2) in the process of their development.

Table 1. Socio-ecological system (SES) framework in this study.

Social, Economic, and Political Background (S) **S1—Economic Development; S2—Demographic Trends; S3—Policy Stability; S4—Other Governance Systems; S5—Marketization; S6—Media Organizations; S7—Technology;** **S4-1 Cooperative**	
Resource system (RS)	Governance system (GS)
RS1: Resource sector RS2: Clarity of system boundaries RS3: Size of the resource system RS4: Human-made facilities RS5: Productivity of the system RS6: Balance RS7: Predictability of system dynamics RS8: Resource storage feature RS9: Location	GS1: Government organizations GS2: Non-governmental organizations GS2-1: Market players GS2-2: Social agents GS3: Network structure GS4: Property rights system GS5: Operational rules GS5-1: Collective resource integration GS5-2: Benefit sharing GS6: Collective selection rules GS6-1: Collective decision making GS6-2: Institutional constraints GS7: Constitutional rules GS8: Rules of supervision and punishment GS8-1: Internal oversight
Resource units (RAs)	Users (A)
RA1: Mobility of resource units RA2: Growth or update rate RA3: Interaction between resource units RA4: Economic value RA5: Number of resource units RA6: Obvious marking RA7: Spatiotemporal distribution RA8: Importance of resources	A1: The number of actors A2: Socio-economic attributes of actors A2-1: Differences in economic status among villagers A3: History of usage A4: Location A5: Leadership or business management skills of actors A5-1: Public leadership in the village A6: Conventional social norms (special trusting and reciprocal agreements)/social capital A6-1: Villagers' sense of belonging to the village A7: Knowledge or mindset about SES A8: Importance of resources (dependency) A9: Options of technologies A9-1: Use of green production technologies
Interaction (I)—Outcome (O)	
I1: Level of resources obtained I2: Information sharing I3: Negotiation I4: Conflicts I5: Investment activities I6: Lobbying activities I7: Self-organizing activities I8: Network activity I9: Oversight activities I10: Assessment activities	O1: Social performance measurement O1-1: Collective action by farmers O2: Ecological performance measurement O2-1: Farmers' ecological values O2-2: Development of green agricultural products O2-3: Construction of ecological system O3: Impact/externality to other SES
Associated ecosystems (ECO) ECO1—Climatic Conditions; ECO2—Contamination Situation; ECO3—Inflow and Outflow of the Focused SES	

Source: The third-level variables of this study are listed based on the second-level variables of [15].

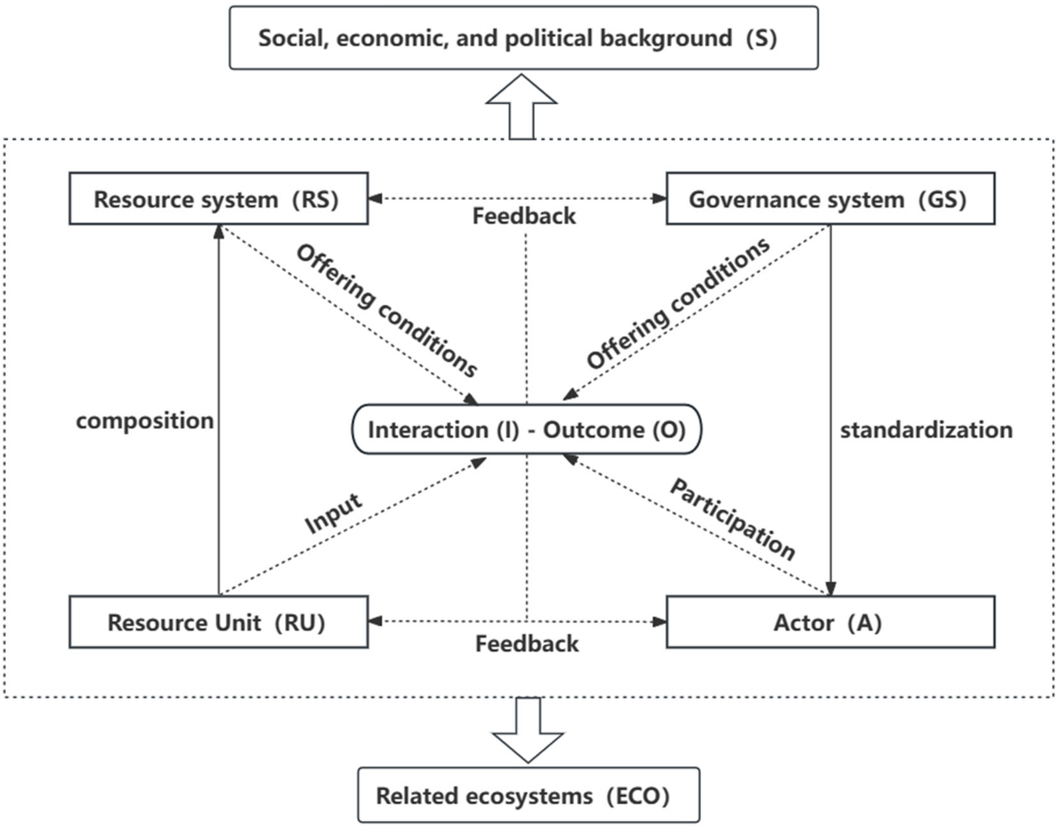

Figure 1. Diagram of the social-ecological system (SES) framework.

2.2. Theoretical Analysis and Research Hypotheses

Based on the SES framework, this study focused on the impact of agricultural cooperatives on farmers' collective action and explored how agricultural cooperatives (S4-1) affect governance performance (O) by changing the action context and governance system (GS) conditions faced by actor (A) in a rapidly changing economic and social context (S). According to the available literature, agricultural cooperatives can promote the collective action of farmers through relevant variables of socio-ecological systems.

2.2.1. Agricultural Cooperatives (S4-1) Promote the Collective Action of Farmers (O1-1) by Cultivating Village Public Leadership (A5-1)

As a form of organization at the village level, cooperatives actively cultivate public leadership in villages by participating in farmers' cooperation and consultation in agricultural production and community affairs management. On the one hand, cooperatives provide a platform for collective action and cooperative decision making for villagers [18]. Cooperatives, as a collective organization, encourage and facilitate the participation of farmers in the decision making of agricultural production and community affairs through meetings, consultations, and voting. This form of participation can enhance interaction and cooperation among villagers and develop their leadership skills and decision-making skills. On the other hand, cooperatives have a management mechanism, including the election of the person in charge of the cooperative, the establishment of rules and regulations, and the formulation of decision-making procedures. Through this mechanism, cooperatives can stimulate the enthusiasm and sense of responsibility of villagers, cultivate public leadership in the village [19], and promote the standardized and efficient management of various affairs in the village, thereby improving farmers' collective action capacity.

2.2.2. Agricultural Cooperatives (S4-1) Promote the Collective Action of Farmers (O1-1) by Enhancing Villagers' Sense of Belonging to the Village (A6-1)

Participation in cooperatives can promote cooperation and mutual assistance among farmers, alleviate constraints on agricultural production induced by various risks, and enhance their sense of belonging to the village. The nature of agricultural production determines that it has natural vulnerability, in which natural disaster risks, market fluctuations, and emergency situations run through the whole process of agricultural production and marketing. In this context, cooperatives provide villagers with a risk-sharing, risk-bearing mechanism through collective action, such as the centralized purchase of agricultural insurance and the joint raising of emergency funds [20]. This effectively helps individual farmers reduce risks and stabilize agricultural income. Under the mechanism established by cooperatives, farmers have established interest relationships and interpersonal communication through resource sharing, risk sharing, and cooperative management, which further enhances farmers' sense of belonging and identity to the village [21], thereby enhancing farmers' collective action capacity.

2.2.3. Agricultural Cooperatives (S4-1) Promote the Collective Action of Farmers (O1-1) by Increasing Financing Capacity of Villagers (A2-1)

In agricultural production, farmers often need to improve agricultural infrastructure and purchase related technologies and equipment. However, these often require a large amount of capital investment. Cooperatives have played important roles in alleviating farmers' financial constraints and expanding financing channels. Among them, the complex social networks within cooperatives provide possibilities and convenience for informal lending among farmers [22]. In addition, cooperatives, as a collective organization that operates on a large scale and enjoys a high credit rating, can not only enhance the willingness of banks to lend to farmers, but also obtain government subsidies easily. Therefore, the fundraising mechanism of cooperatives has the potential to increase the economic strength of villagers, which effectively alleviates farmers' financial constraints and has a positive impact on farmers' collective action [23].

2.2.4. Agricultural Cooperatives (S4-1) Promote Farmers' Collective Action (O1-1) by Promoting Farmers' Use of Green Production Technologies (A9-1)

The Chinese government is currently focusing on promoting green, high-quality, and efficient agricultural production, with a special emphasis on promoting green production technologies in agricultural production. In this context, cooperatives play important roles in coordinating and managing agricultural production in rural households. Firstly, cooperatives provide farmers with the necessary technical support and guidance through the promotion of green production technologies. Cooperatives organize training courses and on-site demonstrations to teach farmers the relevant knowledge and operational skills of green production technologies. This actively stimulates farmers' enthusiasm for adopting green production technologies [24]. Secondly, cooperatives can provide farmers with the material and economic support they need to adopt green production technologies. Cooperatives help farmers access the resources they need for green production technologies through collective procurement and centralized supply. In addition, cooperatives can enhance farmers' ability and motivation to adopt green production technologies by alleviating the financial constraints and providing necessary material and economic support [25,26]. All of the above ultimately promotes farmers' collective action.

To sum up, agricultural cooperatives have realized the integration of resources required for farmers' collective action and further promoted the sharing of benefits through collective decision making, institutional constraints, and internal supervision. The development of agricultural cooperatives helps to solve the problems of declining public leadership, weakening villagers' sense of belonging to the village, the low-level adoption of green production technologies, and increasing economic status difference among villagers. Agricultural cooperatives have an important improvement effect on the collective action capacity of farmers (Figure 2). Based on this, the research hypothesis of this study was proposed:

Hypothesis 1 (H1). *Participation in cooperatives may help farmers adopt water-saving irrigation technologies, which, in turn, improves farmers' collective action.*

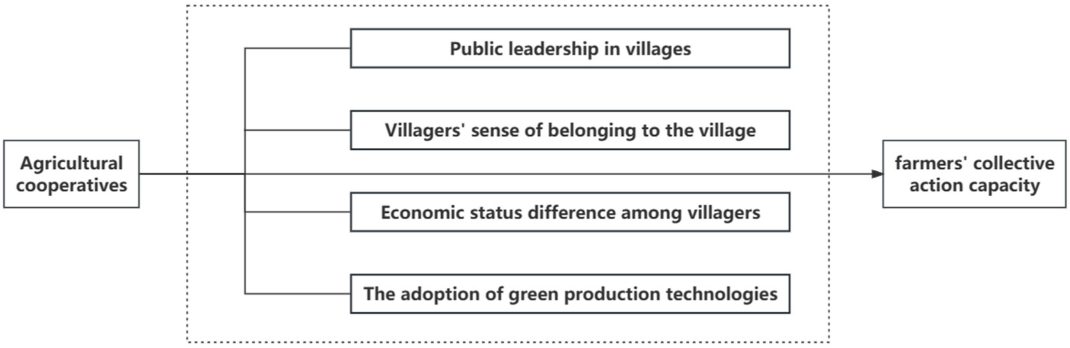

Figure 2. The mechanism by which agricultural cooperatives influence farmers' collective action capacity.

2.3. Methodology

2.3.1. Study Site

Tarim River Basin, an important cotton and fruit production base in China, is a typical arid area with uneven spatial and temporal distribution of water resources and precipitation. Precipitation cannot meet the needs of crop growth; thus, artificial irrigation is usually required. With the increase in water use for irrigation and the decrease in surface water availability, the dependence of irrigation on groundwater continues to increase, resulting in serious groundwater overextraction [27,28]. Therefore, water-saving irrigation technologies are very important for agricultural development in the basin [29]. The unique environmental and agricultural conditions make the Tarim River Basin become a key area for the study of the adoption of water-saving irrigation technologies, which provides preferred conditions for investigating the collective action among farmers.

2.3.2. Sampling and Sample Size

The data used in this paper were from a field survey conducted in the Tarim River Basin from January to February 2022. The survey covered the information of rural households, villages, infrastructure, human settlement environment, farmland irrigation facilities, and village governance. Based on the combination of simple random sampling and stratified random sampling, six counties were randomly selected in Kashgar, Aksu, and Kizilsu Kirgiz (two for each) in the Tarim River Basin, 4–6 towns were randomly selected in each county, and 3–5 villages were randomly selected in each town to carry out field research. A total of 891 questionnaires were distributed.

2.3.3. Data Collection

To ensure the validity of the questionnaire, one-on-one interviews were conducted, and the questionnaires were filled in by professional researchers. After retrieving the questionnaires, filtering was conducted according to the purpose of the survey. Firstly, the samples of farmers whose farmland had been leased to others and landless farmers were excluded (because these two types of farmers do not need to make decisions on the adoption of water-saving irrigation technologies). Then, the samples of non-cooperative households were excluded. After filtering, 381 samples were included in this empirical analysis.

2.3.4. Analytical Model

Farmland irrigation is a typical rural public affair in arid areas in China, and the construction and maintenance of farmland irrigation facilities can reflect farmers' participation in rural collective action, which is the epitome of rural public affairs governance. According to the research in the field of public affairs governance, the meaning of collective action includes four main points [15]: (1) A group composed of individuals with interdependent relationships is the decision-making unit of collective action, and a group composed of individual members is the carrier of collective action. (2) Common interests, which are the motivation of collective action and the purpose of the formation of the group. (3) Collective decision-making, that is, the negotiation of individual members on the realization of common interests. (4) Institutional arrangement, which is the specific way to achieve collective action.

The adoption of water-saving irrigation techniques involves a large number of collective action issues. Firstly, the adoption of water-saving irrigation techniques requires consultation among farmers because there is a certain capital threshold to purchase, maintain, and use water-saving irrigation equipment. The high cost of water-saving irrigation equipment often discourages small farmers. To solve the problem of the weak bargaining power of small farmers, collective action is necessary. This is usually achieved by cooperatives, village organizations, etc. Collective purchasing can improve the bargaining power of small farmers, so that small farmers can purchase water-saving irrigation equipment at low prices. Such consultative collective action contributes to the realization of common economic interests. Secondly, the proper functioning of water-saving irrigation equipment requires collective decision making. The proper functioning of water-saving irrigation equipment not only involves the purchase, laying, maintenance, and recycling of the water-saving equipment, but also includes the maintenance of village irrigation canals, the opening of channel gates, and the distribution of irrigation canal water. The solution to these problems requires consultation and cooperation among villagers. Thirdly, the adoption of water-saving irrigation techniques requires the establishment of institutional arrangements. Before installing water-saving irrigation equipment, villagers may face a series of potential disputes such as the allocation of agricultural resources, the management and maintenance of irrigation equipment, the determination of boundaries of pipe laying in farmlands, and the bearing of cost. Appropriate institutional arrangements are needed to resolve these issues, which must be formulated and implemented through collective action. Fourthly, the adoption of water-saving irrigation techniques is conducive to saving the cost of agricultural production for farmers, cooperatives, villages, etc., and has economic spillovers. The cost-saving and efficiency-enhancing effects brought about by the adoption of water-saving irrigation techniques can increase collective interests. Fifthly, the adoption of water-saving irrigation techniques has ecological spillovers. The water-saving irrigation techniques can reduce the amount of irrigation per unit area, the water loss during water transmission, and the leakage loss in the field so as to improve the water use efficiency [30]. Therefore, they can effectively alleviate the problem of insufficient irrigation water in arid areas and avoid the tragedy of the commons due to excessive water consumption for irrigation.

Therefore, by drawing on the existing research [3,4,31], combined with the collected data and local situation, this paper selects the "adoption of water-saving irrigation techniques" as the dependent variable to measure collective action.

According to the efficiency, irrigation techniques can be divided into inefficient techniques (such as flood irrigation) and high-efficiency techniques (such as sprinkler irrigation and drip irrigation). In this study, when farmers chose to use sprinkler irrigation or drip irrigation, they were deemed to adopt water-saving irrigation techniques, and 1 was assigned; otherwise, 0 was assigned.

Cooperative operation was selected as the independent variable. The question "Are you a cooperative farmer" in the questionnaire was used to judge whether the farmer had participated in a cooperative. The value of 1 was assigned to "Yes", and 0 was assigned to "No".

Based on the list of variables in Table 2 and the results of the academic community's identification of key variables affecting collective action, three control variables were selected to control the impacts of resource system (RS), resource unit (RU), governance system (GS), and actor (A) on farmers' collective action. These control variables included the location of the irrigation system (RS9), the adequacy of the resource unit (RU5), and the economic and social status of the farmer (A2). Firstly, in this study, five variables of rural households, including gender, age, health status, years of education, and off-farm employment, were introduced to control the characteristics of household heads. These are also the important factors influencing farmers' collective action, but what the impact will be is uncertain. Some studies have found that farmers' ages and education levels have a positive impact on farmers' collective action [3,32], while other studies reached the opposite conclusion [4,31]. Secondly, to express the household resource endowment in detail, this study selected two household-level control variables: the proportion of household labor force and the proportion of household farm income. Household farm income mainly reflects the degree of dependence of households on agricultural production. If a household's main income comes from agriculture, this means that they attach greater importance to arable land and irrigation systems. Studies have shown that the more arable land a household owns, the greater its contribution to the village's collective action. This may be due to the fact that households with larger farmland in arid areas are more dependent on irrigation facilities, and therefore, they are more willing to participate in collective action to maintain and improve these facilities [33]. Thirdly, based on the difficulty level of implementing water-saving irrigation for different farmlands, the adoption of water-saving irrigation technologies by farmers may be determined according to the characteristics of the farmland. Based on a previous study [34], this study introduced three variables, namely the average area of farmland, the degree of water scarcity, and the difficulty level of irrigation, to control the influence of the characteristics of farmland (Table 2). Studies have shown that farmers who often face irrigation water shortages are less likely to participate in collective irrigation action in their villages [3,4], while others have reached the opposite conclusion [4,35].

Table 2. Variable definitions and descriptive statistics.

Variable Category	Variable	Description	Mean	Standard Deviation
Dependent variable	Farmers' adoption of water-saving irrigation technologies	Whether a farmer adopts water-saving irrigation technology; yes = 1, no = 0	—	0.500
Independent variable	Farmer's participation in cooperatives	Whether a farmer participates in cooperatives; yes = 1; no = 0	—	0.487
Control variable	Gender	Male = 1; female = 0	—	0.371
	Age	Respondent's self-reported age (years)	46.027	10.451
	Health condition	Self-rated health status: very healthy = 1; somewhat healthy = 2; healthy = 3; unhealthy = 4; very unhealthy = 5	1.765	1.043
	Years of education	Respondent's self-reported years of education (years)	7.673	2.711
	Off-farm employment	Whether respondents worked outside the home in the past five years; yes = 1, no = 0	—	0.483
	Proportion of household labor force	The proportion of labor force individuals aged 16-65 to the total number of family members	0.506	0.216
	Proportion of household farm income	The proportion of farm income to total household income	0.474	0.346
	Average farmland area	The total area of agricultural land divided by the total number of agricultural lands (ha)	16.255	19.531
	Degree of water scarcity	Self-rated degree of water scarcity: severe shortage = 1; shortage = 2; merely enough = 3; abundant = 4; very abundant = 5	2.987	1.153
	Difficulty level of irrigation	Difficulty level of applying WSIT for the managed lands: unable = 1; difficult = 2; easy = 3; very easy = 4	3.783	0.612

Since the dependent variable is a dichotomous variable, and the independent variable is verified by the Shapiro–Wilk test to conform to the normal distribution, a binary Logit model was established for empirical analysis [36].

$$\text{Irrigationi} = \beta 0 + \beta \text{i Cooperativei} + \sum \text{j } \gamma \text{ij controlij} + \varepsilon \text{i} \quad (1)$$

where Irrigationi represents the adoption of water-saving irrigation technologies by farmer i; Cooperativei represents farmer i's participation in cooperatives; Controlij represents the jth control variable of farmer i, including three dimensions, which are farmer level, household level, and farmland level; β0 is the constant term; βi and γij are the coefficients to be estimated, which are used to judge the significance and positivity/negativity of the influence of independent variable and control variables on farmers' collective action to adopt water-saving irrigation technologies; and εi is the random error term.

3. Results

3.1. Benchmark Model Analysis Results

The multicollinearity diagnosis results showed that the variance inflation factor (VIF) values of all variables were less than 2.5, indicating a low level of multicollinearity. In this study, Stata 15.0 was used for fitting. In Equation (1), the farmers' collective action to adopt water-saving irrigation technologies was the dependent variable, the participation in cooperatives was the independent variable, and X3~X12 were used as the control variables to perform the benchmark analysis. Table 3 shows the empirical test results. Since the estimation coefficient of the binary Logit model could only reflect the significance and positivity/negativity of the effect, the average marginal effect (AME) was further calculated. Firstly, the correlation analysis results showed that participation in cooperatives promoted farmers' collective action to adopt water-saving irrigation technologies (R^2: 0.393, $p < 0.05$). That is, participation in cooperatives has a significant positive impact on farmers' collective action to adopt water-saving irrigation technologies. Secondly, compared with non-cooperative farmers, the probability of cooperative farmers adopting water-saving irrigation technologies increased by 5.6%. This confirms that participation in cooperatives is conducive to promoting farmers' collective action to adopt water-saving irrigation technologies. Thus, the results support Hypothesis 1.

Table 3. Robustness test using lumped plasticity model.

Variable	Logit		LPM
	Coefficient	Marginal Effect	Coefficient
Farmers' participation in cooperatives	0.393 (0.373) **	0.056 (0.053) **	0.038 (0.054) **
Gender	0.813 (0.521)	0.116 (0.071)	0.139 (0.082)
Age	−0.086 (0.022)	−0.012 (0.003)	−0.013 (0.003)
Health condition	0.069 (0.192)	−0.010 (0.027)	0.007 (0.028)
Education level	−0.023 (0.075) *	−0.003 (0.011) *	−0.004 (0.010) *
Off-farm employment	0.171 (0.384)	0.024 (0.055)	0.008 (0.059)
Proportion of household labor forces	0.086 (0.891)	0.012 (0.127)	−0.019 (0.120)
Proportion of household farm income	2.921 (0.645) ***	0.417 (0.078) ***	0.550 (0.100) ***
Average farmland area	0.054 (0.021) **	0.008 (0.003) **	0.005 (0.001) ***
Degree of water scarcity	−0.123 (0.176)	−0.178 (0.025)	−0.022 (0.026)
Difficulty level of irrigation	0.826 (0.360) ***	0.118 (0.050) ***	0.118 (0.049) ***
Constant	−1.529 (1.935)		0.319 (0.293)
Pseudo-R^2	0.3626		
LR chi^2	58.01		
Sample size	381	381	381

Notes: ***, $p < 0.01$; **, $p < 0.05$; *, $p < 0.1$.

3.2. Lumped Plasticity Model (LPM) Robustness Test

To verify the robustness of the fitting results, the LPM model was used to test the influence of participation in cooperatives on farmers' collective action to adopt water-saving irrigation technologies [37]. The test results (Table 3) were consistent with the benchmark model analysis results. This indicates that participation in cooperatives has a significant positive impact on farmers' collective action to adopt water-saving irrigation technologies. Thus, the results support Hypothesis 1.

3.3. Robustness Test by Propensity Score Matching (PSM)

In this study, the propensity score matching (PSM) method was used to re-estimate the impact of farmers' participation in cooperatives on farmers' collective irrigation action [36] for the following reasons: (1) participation in cooperatives is the voluntary choice of farmers. The samples of farmers who participate in cooperatives and those who do not participate in cooperatives are not randomly generated, and there is a problem of "self-selection". (2) Although the adoption of water-saving irrigation technologies by cooperative farmers was observed, no observation was made on whether non-cooperative farmers adopted water-saving irrigation technologies. This may lead to the problem of "data loss". If directly comparing the differences between cooperative farmers and non-cooperative farmers, the endogeneity problem will arise. Propensity score matching can effectively solve the endogeneity problem by constructing counterfactual hypotheses [36] to match cooperative farmers and non-cooperative farmers. Therefore, this study used the PSM method for estimation. To ensure the reliability of the PSM results, considering differences in different matching methods, the nearest neighbor matching (K value was set to 1), caliper matching (caliper was set to 0.02), and kernel matching (bandwidth set to 0.06) were used to test the robustness of the results.

Firstly, the matching quality of the whole sample was tested. Then, the nearest neighbor matching, caliper matching, and kernel matching were used for comparison in the processing. The results showed that the influence of participation in cooperatives on farmers' collective action to adopt water-saving irrigation technologies before and after matching did not change significantly. This is consistent with the results in Table 4. In addition, the three matching results differed slightly, and all of them passed the significance test. Their effects and significance levels were consistent. This indicates that the results of the influence of participation in cooperatives on farmers' collective action to adopt water-saving irrigation technologies obtained in this study are robust.

Table 4. Robustness test through propensity score matching.

Matching Method	Treatment Group	Control Group	Average Effect of Treatment on the Treated (ATT)	Standard Error	*t*-Test Value
Nearest neighbor matching	0.278	0.137	0.087	0.033	2.32 **
Caliper matching	0.278	0.143	0.093	0.036	2.345 ***
Kernel matching	0.278	0.151	0.076	0.031	2.63 ***

Notes: ***, $p < 0.01$; **, $p < 0.05$.

3.4. Heterogeneity Analysis

Due to obvious differences in value perception and technical understanding between farmers of different generations and between farmers with different economic conditions, it is easy to observe a differentiation in farmers' adoption of water-saving irrigation technologies. Therefore, it is necessary to group farmers according to different ages and different household economic conditions in the exploration of the effects of different farmer groups on the relationship between participation in cooperatives and farmers' collective action to adopt water-saving irrigation technologies. Based on the survey data and reference [3], respondents born in 1970 and before were classified as old farmers, and those born after

1970 were classified as new-generation farmers. Additionally, according to whether the total annual income of farmers (including farm income and non-farm income) exceeded the mean of samples, farmers were divided into two groups: farmers with better economic conditions and farmers with poor economic conditions. This aimed to clearly depict the heterogeneity in the effect of participation in cooperatives on farmers' collective action to adopt water-saving irrigation technologies.

3.4.1. Farmers of Different Generations

Participation in cooperatives had a significant positive impact on farmers' collective action to adopt water-saving irrigation technologies, but it did not have a significant impact on that of new-generation farmers (Table 5). This indicates that participation in cooperatives can effectively motivate old farmers to make collective actions to adopt water-saving irrigation technology. This may be due to the fact that old farmers have been engaged in agricultural production for several decades. Compared with new-generation farmers, they have richer agricultural knowledge and experience and better know the value and benefits of adopting new technologies, so they are more likely to understand and accept water-saving irrigation technologies. On the other hand, the part-time off-farm employment for new-generation farmers is higher; therefore, many new-generation farmers do not take agricultural production as the main source of income. Due to the long payback period and the low economic benefits of agricultural investment, their willingness to invest in agriculture is relatively low.

Table 5. Comparative analysis of farmers of different generations and farmers with different economic conditions.

Variable	New-Generation Farmers		Old Farmers		Farmers with Poor Economic Conditions		Farmers with Good Economic Conditions	
	Coefficient	Marginal Effect	Coefficient	Marginal Effect	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Participation in cooperatives	0.368	0.055	0.567 *	0.067 *	0.266	0.035	0.583 **	0.082 ***
	(0.337)	(0.047)	(0.367)	(0.045)	(0.345)	(0.057)	(0.252)	(0.037)
Control variable	Controlled		Controlled		Controlled		Controlled	
Pseudo-R^2	0.164		0.078		0.106		0.137	
LRchi^2	35.52 ***		42.67 ***		31.6 ***		47.34 ***	
Sample size	152		74		93		133	

Notes: ***, $p < 0.01$; **, $p < 0.05$; *, $p < 0.1$. The values in parentheses are standard errors. The control variables are consistent with those in Table 3.

3.4.2. Farmers with Different Household Economic Conditions

Income level is one of the important factors restricting farmers' investment in agriculture. The results (Table 5) showed that participation in cooperatives had a significant promotion effect on the collective action to adopt water-saving irrigation technologies by farmers with better household economic conditions, but the effect on that of farmers with poor household economic conditions was not significant. This is in line with our expectations. This indicates that when household economic conditions are good, farmers are more likely to invest in water-saving irrigation technologies due to their higher investment ability and risk resistance [38]. The adoption of water-saving irrigation technologies means there is a big expense and a high risk for economically disadvantaged farmers; therefore, they prefer traditional irrigation.

4. Discussion

This study explored the impact of agricultural cooperatives on farmers' collective action in the Tarim River Basin by taking the adoption of water-saving irrigation technology in the survey area as an example to evaluate farmers' collective action capacity. According to the results of the Logit model, participating in cooperatives significantly promoted the adoption of water-saving irrigation technologies by farmers. The reasons are follows: on the one hand, after participating in cooperatives, the promotion of water-saving irrigation technologies and a full set of technical services from cooperatives improved farmers' awareness of the advantages and benefits of water-saving irrigation technologies, and then encouraged farmers to adopt water-saving irrigation technologies. Additionally, due to the water shortage in the Tarim River Basin, farmers in the area mostly rely on groundwater to irrigate crops. To extract groundwater and adopt water-saving irrigation technologies, it is necessary to invest in the construction of irrigation infrastructure, which is a large expenditure for farmers. Cooperatives formulate subsidy policies to mobilize farmers to adopt water-saving irrigation technologies, which can effectively reduce the cost of farmers' adoption of water-saving irrigation technologies. Therefore, the participation of rural households in cooperatives will undoubtedly help to reduce the risk of farmland investment, which further encourages farmers to adopt water-saving irrigation technologies to obtain potential efficiency and benefits. Ito et al. [31] found that melon farmers who joined cooperatives were able to obtain technical advice provided by cooperatives and the supply of factors conducive to production, and that under these conditions, farmers would actively choose new agricultural production technologies to increase the yields. Similarly, in Northern Nigeria [22] and Southwestern Nigeria [24], researchers found a positive correlation between farmers' cooperative membership and the adoption of innovative technologies in farmland/the use of green fertilizers.

In terms of control variables, among the farmers' characteristics, the education levels of farmers had a significant positive impact on the adoption of water-saving irrigation technologies. This indicates that the more education years farmers have, the less they are affected by the limitation of traditional agricultural production experience, and farmers are more likely to understand the value of new technology application in economic improvement and environmental protection. Therefore, the possibility of adopting new irrigation technologies is significantly increased. Similarly, in Bangladesh, where the level of education of householders was an important determinant of the adoption of alternate irrigation, AlaAddin et al. [25] proposed that water-saving irrigation technologies could be promoted through farmer education and training. Additionally, it was found that the proportion of household agricultural income, the average farmland area, and the difficulty level of irrigation had positive correlations with farmers' collective action to adopt water-saving irrigation technology. The larger proportion of household farm income partly indicates that farmers attach greater importance to arable land and irrigation in arid areas, which may force farmers to adopt water-saving irrigation technologies to improve irrigation water use efficiency. The positive correlation between the average farmland size and farmers' collective action to adopt water-saving irrigation technologies is consistent with the results of previous studies. For example, Zhang et al. [37] found that the larger the scale of cultivation, the more likely a farmer is to adopt new agricultural techniques for production. Ward et al. [39] also showed that the larger the scale of cultivation, the more capable farmers are to bear the risks brought by high costs and the adoption of new technologies; thus, the greater the possibility of adopting new technologies.

The results also showed that participation in cooperatives had a more obvious effect on the collective action to adopt water-saving irrigation technology of the older farmers and farmers with better economic conditions. Irrigation has increasingly become the primary factor restricting agricultural production in areas with water shortage, and the development of cooperatives and the popularization of water-saving irrigation technologies are important ways to solve the contradiction between water shortage and agricultural production.

There are some shortcomings in this study. There is a lack of discussion on the scale and quality of different types of cooperatives. The adoption rate of water-saving irrigation technologies is closely related to the type of cooperatives and the farmland soil and water conditions. Therefore, the influence of different types of cooperatives on farmers' collective action to adopt water-saving irrigation technologies will be further explored in future research.

5. Conclusions and Suggestions

Participation in cooperatives is an effective way to enhance collective action among farmers. Through collective decision making, institutional constraints, and internal supervision mechanisms, cooperatives not only achieve the integration of resources, but also provide necessary financial and information support for rural households. In particular, cooperatives have played a key role in the adoption of water-saving irrigation technologies. The consultation among farmers, institutional arrangements, and collective decision making all ensure the successful adoption and implementation of water-saving irrigation technologies. Such collective efforts have not only increased the probability of adopting water-saving irrigation technologies, but have also significantly strengthened collective action among farmers. Additionally, high education levels, large proportions of farm income, large areas of farmland, and low difficulty levels of irrigation all contribute to a great possibility for farmers to adopt water-saving irrigation technologies, thereby promoting their collective action. It should be noted that due to old farmers and rich farmers having more physical capital than the new generations and poor farmers, they are more likely to adopt water-saving irrigation technologies.

Cooperatives are of great significance to enhance farmers' collective action and promote sustainable rural development. The government and relevant institutions should introduce a series of policies and measures to promote the development of cooperatives, which can promote collective action-based resource sharing, risk sharing, and the application of green production technologies.

This study only evaluated the improvement of cooperatives on farmers' collective action. The impacts of different types of cooperatives on farmers' collective action in the adoption of water-saving irrigation technologies still needs further exploration to further validate these study results.

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