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The willingness to pay for agricultural irrigation water and the influencing factors in the Dujiangyan irrigation area: An empirical double-hurdle model analysis

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Water prices are an efficient way to manage and allocate water resources. A scientific and reasonable water price standard can assist farmers to optimize their water allocations and ensure an efficient agricultural water system. However, under the current agricultural water pricing policy, it is difficult for water resource management departments to achieve sustainable operation because of unreasonable water price standards and the unwillingness of farmers to pay for agricultural irrigation water. Therefore, to ensure the sustainable management of agricultural water departments, it is important to design scientific and reasonable water price mechanisms that give full play to the regulatory role of agricultural water prices and encourage farmers to pay agricultural water fees. Based on survey data from 335 farming households in the Dujiangyan Irrigation Area, Sichuan, China, in 2019, a double-hurdle model was used to assess the willingness to pay for agricultural irrigation water. The willingness to pay was positively impacted by age, education level, willingness to participate, the arable land area, the water fee proportion, and water-saving awareness but negatively impacted by the water price standard and the farmers' perceptions of the water price standard. Based on these results, to encourage farmers to participate in and afford agricultural water payments and to give full play to the water price adjustment function and other countermeasures, it is proposed that 1) water-saving awareness training be strengthened; 2) agricultural modernization be promoted; and 3) water price standards be scientifically and rationally formulated.

KEYWORDS

water crisis, agricultural irrigation water price, willingness to pay, double-hurdle model, Dujiangyan irrigation area

1 Introduction

In the last 5 years, water availability has become one of the top five major global risks (WEF, 2017), with developing countries facing more severe challenges because of water inefficiencies and water supply reductions (Mo et al., 2020). Agriculture is a key economic sector in developing countries; however, because of the increase in urban and industrial water use, fewer water resources are being allocated to the agricultural sector (Wakamori et al., 2020). This growing water demand has been putting enormous pressure on agricultural water use (Fedoroff et al., 2010; Shao et al., 2019; Tuninetti et al., 2019). The increases in agricultural water demand (Rosegrant et al., 2009; Xiang et al., 2017) have been difficult to meet, which in turn has put pressure on global food security and sustainable development.

Water price regulations have been introduced in many countries to better control and promote efficient water use (Rogers et al., 2002; Seagraves and Easter, 2010; Hoekstra, 2013; Schmidt, 2019) and improve water valuations and irrigation water efficiency (Molle, 2009; Speelman et al., 2009; Giannoccaro et al., 2010). Many studies have found that using economic means to optimize water resource allocation efficiency and adjust water prices is an effective strategy for regulating water demand (Ohab-Yazdi and Ahmadi, 2015) and cost-effectively allocating water resources (D'Odorico et al., 2020). Therefore, water pricing can promote water conservation, regulate water demand, and efficiently allocate water resources (Kanakoudis, 2002; Kanakoudis, 2008). However, unreasonable water price standards can result in poor water utilization.

China is the largest developing country in the world. China started a new round of comprehensive agricultural water price reforms in 2016, with the goal being to design a water price mechanism that optimized agricultural water resource allocations. However, the desired reforms have not yet been achieved, primarily because the current agricultural water prices do not account for factors such as regional water resource endowment, affordability, crop types, or irrigation methods, that is, the current water price standard is a one-size-fits-all policy. Consequently, there has been increasing farmer resistance to the agricultural water fees, a decreasing willingness to pay (Zhang et al., 2016), and falling water fee collection rates, which has hampered sustainable water management department operations and reduced the maintenance funds needed for rural water conservancy facilities (Li, 2018). This lack of funds has meant a reduction in maintenance frequencies, incomplete maintenance of water conservancy facilities, and low water supply efficiency. Therefore, research on reasonable water prices can assist in guaranteeing the sustainable utilization of regional water resources (Lei et al., 2008; Feng, 2010; Wang et al., 2013).

Because agricultural irrigation water is a public resource (Albiac Murilo et al., 2020), its value is often underestimated, which means that users rarely pay the true value (Hoekstra, 2013) and some are even reluctant to pay. Therefore, it has become extremely challenging to encourage farmers to participate in agricultural irrigation water payments and develop reasonable agricultural water pricing mechanisms. However, affordability, efficiency, and equity are extremely important when formulating water prices; therefore, when there are water price changes, the basic principles of irrigation water pricing and the attitude of and acceptance by the agricultural sector must be considered (Abu-Zeid, 1998; Abu-zeid, 2001; Wang et al., 2013; Yin and Cai, 2016). Huang et al. (2022) found that the water price bearing capacity of grain crops was between 0.058 and 0.521 CNY/m3, and the water price bearing capacity of economic crops was between 0.178 and 4.329 CNY/m3, which indicated that these considerations needed to be included when water price standards are formulated.

The willingness to pay (WTP) refers to the amount that farmers are willing to pay to use irrigation water. There has been extensive research on the WTP for agricultural irrigation water prices in China. For example, Chen et al. (2009) introduced the conditional value method (CVM) into a study on the WTP for agricultural irrigation water prices, after which the CVM was widely used. Wang et al. (2018), Yin and Cai (2016), and Qiao et al. (2018) respectively used the CVM to examine the farmers' WTP and the influencing factors in Guanzhong, Zhangye, and the Weigan River Basin. Zhang et al. (2014) studied agricultural water prices and the influencing factors on the farmers' psychological affordability. Mu et al. (2019) evaluated the impact of agricultural comprehensive water price reform on farmers' willingness to use water for irrigation in Northwest China and found that farmers in water-scarce areas had a higher WTP, and Du et al. (2019) used a multivariate ranking and selection model to study the farmers' WTP for irrigation water prices in Minqin County.

Most of the world has made agricultural water resources a commodity and has adopted the pricing and charging system as one of the main economic measures to save irrigation water (Johansson, 2000). Many empirical studies have also confirmed that the psychological bearing capacity of irrigation water price will affect farmers' water fee payment behavior and pointed out that the formulation of irrigation water price should consider farmers' psychological bearing capacity and pay attention to their willingness to pay (Chen and Yu, 2006; Zhou and Yue, 2009). The WTP for agricultural irrigation water price and its influencing factors have been widely studied; however, as agricultural irrigation water is a quasi-public good and farmers currently do not pay the supply costs related to water extraction and delivery (Wahl, 1989; Anisfeld, 2010) and in some cases do not pay for their agricultural water in advance (Lika et al., 2016), existing research has failed to include the farmers' water fee payment behavior nor sought to understand the farmers' agricultural water payment behavior. To conduct an in-depth analysis of the impact of farmers' WTP for water and to propose countermeasures to promote participation in agricultural irrigation water payments, this study divided the research on the WTP for agricultural irrigation water into two stages: participation and payment. To ensure the sustainable operation of the agricultural system and improve agricultural irrigation water fee payments, the research results provide a reference for more scientific, reasonable water price mechanisms for agriculturally water-stressed regions.

2 Research framework and research hypotheses

2.1 Theoretical analysis

In 1982, American psychologists Prochaska and Diclemente proposed the behavioral stage-change theory, which was divided into five stages: no plan, plan, preparation, action, and maintenance (Prochaska et al., 1997). This theory claims that human behavioral change is a process that is driven by different needs and motivations. Therefore, only by providing interventions that meet these needs can the object be transformed to the next stage and final adoption achieved.

To determine whether farmers were willing to pay for agricultural irrigation water and the highest price they were willing to pay, this study decomposed the WTP for agricultural irrigation water price into two stages: a willingness to participate and a willingness to pay the price, which were aligned with the two stages of pre-contemplation and action in the behavioral stage-change five-stage model. While some people in the pre-contemplation stage may have a certain WTP for agricultural irrigation water, they may not necessarily participate; therefore, the focus was on the mechanisms needed to motivate the farmers to use agricultural water and transition from a pre-intention fee payment stage to an action stage and on the development of a more equitable water price. The influencing mechanisms for each factor on the WTP for agricultural irrigation water price were clarified by analyzing the influencing factors on the farmers' willingness to participate and willingness to accept a price.

Agricultural water is a common pond resource, and the payment of agricultural irrigation water prices is also difficult to avoid "free-rider" behavior (Yang et al., 2015). As for the factors affecting the supply of public goods such as farmers' participation in agricultural irrigation water price payment, existing studies have analyzed them from different perspectives. In the theory of public goods, farmers are regarded as rational economic persons, whose decisions are influenced by their individual characteristics and their own needs (Jia, 2020), but in fact, farmers are not rational economic persons, but social persons. The difference in the supply of public goods by farmers is caused by the heterogeneity of social preferences, so family characteristics have a significant impact on it (Zhou et al., 2013). Scholars who study environmental psychology believe that situational factors act on individual preferences and then affect human behavior, and the environment has a guiding role in human behavioral decision-making (Xu et al., 2020). Therefore, production characteristics have an important impact on farmers' willingness to pay for agricultural water price. Professor E. Brucegoldstein clearly pointed out the important role of perception and knowledge in human decision-making in his book "Cognitive Psychology" (Brucegoldstein, 2020). So it is certain that cognitive characteristics also have an impact on farmers' willingness to pay for agricultural water price. Therefore, based on the existing research results, this study divided the influencing factors into four aspects: individual characteristics, family characteristics, production characteristics, and cognitive/knowledge characteristics. The theoretical analysis framework is shown in Figure 1.

The WTP for irrigation water price is affected by both internal and external factors. This study defined the WTP for agricultural irrigation water based on whether the farmers were willing to pay for agricultural irrigation water and the highest water price they were willing to pay or could afford. Therefore, the WTP for irrigation water was divided into two stages: the willingness to participate in the first stage and the willingness to accept the price in the second stage, with the overall WTP being a combination of these two stages (Figure 2 shows in detail the two-stage behavior of the farmers' participation in agricultural irrigation water price payments). When the WTP for agricultural irrigation water price is decomposed, the willingness to participate in the first stage corresponds to the preparation stage in the behavior change stage theory, that is, the farmers decide whether to participate in the payment of agricultural irrigation water. The willingness to accept the price in the second stage corresponds to the action stage in the behavior change stage theory and refers to the highest water price the farmers are willing to pay for agricultural irrigation water, given the various internal and external factors. Because agricultural irrigation water is a public resource (Sun et al., 2011), some farmers may continue to use water resources without paying any agricultural water fees (Lika et al., 2016) and other farmers may not be willing to pay for other reasons. Therefore, in these cases, the WTP has a zero value of authenticity and a zero value of protest (Feng et al., 2018; Ao et al., 2016).

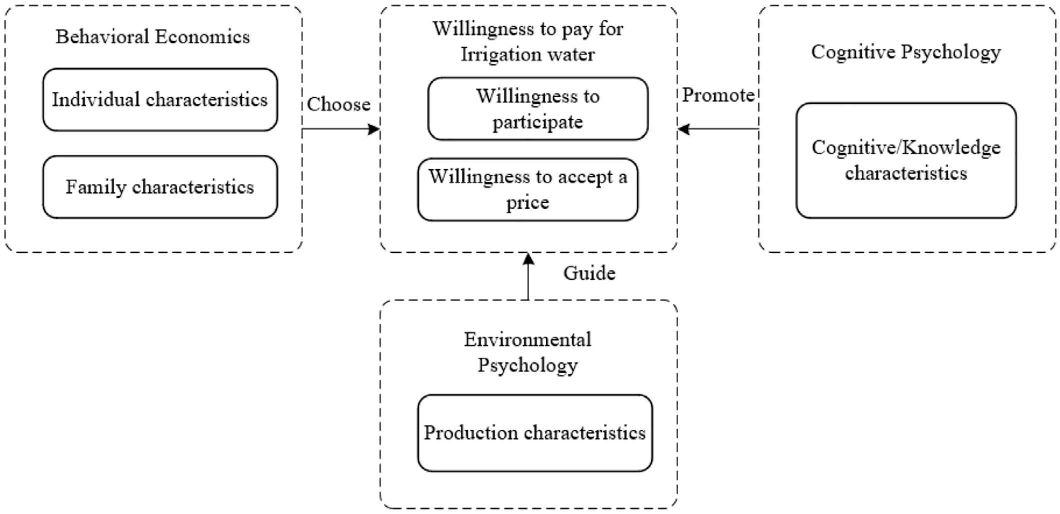

FIGURE 1
Theoretical analysis framework of the study.

2.2 Research hypothesis

Using two keyword phrases—"willingness to pay for agricultural irrigation water price" and "agricultural water price affordability"—nine studies were found that identified the influencing factors (Table 1).

Based on these studies, the following research hypotheses were developed.

1) Influence of individual characteristics on the WTP for agricultural irrigation

H1: Individual characteristics have a significant impact on the willingness to participate and the WTP for agricultural irrigation water.

The individual characteristics identified were gender, age, and educational level. ① Gender. As males generally have stronger decision-making power than females in Chinese farming families, according to the China Household Finance Survey (CHFS) data in 2013 and 2015, female household heads accounted for only 13.87%[1], and it was assumed that male household heads would be more willing to pay for the agricultural irrigation water and to have a higher price willingness. ② Age. Young people are generally more receptive to new things, while the elderly are more conservative; therefore, it was assumed that older farmers would be more reluctant to pay for agricultural irrigation water and have lower price willingness. ③ Education. The higher the education level, the better the understanding of the value of water resources and the stronger the awareness of the need to pay for the resources; therefore, it is assumed that farmers with higher education levels would be more willing to pay for agricultural irrigation water and would have a higher price willingness.

2) The influence of family characteristics on the WTP for agricultural irrigation water

H2: Family characteristics have a significant impact on the willingness to participate and the WTP for agricultural irrigation water

The family characteristics considered were per capita net income of the family, the agricultural income proportion, whether the family member had migrant work experience, and whether the family members were village cadres or other managers. ① Per capita net income. The higher the per capita family net income, the lower will be the consumption constraints; therefore, it was assumed that farmers with higher per capita net income would be more willing to pay for agricultural irrigation water and have a higher price willingness. ② Proportion of agricultural income. The higher the proportion of agricultural income, the stronger will be the household's dependence on agricultural production, the more urgent the demand for agricultural water, and the more unacceptable an increase in agricultural production costs. Therefore, it was assumed that farmers with a high proportion of agricultural income would have stronger

1 Data source: 2013 and 2015 China Household Finance Survey (CHFS), see details at https://chfser.swufe.edu.cn/datas/

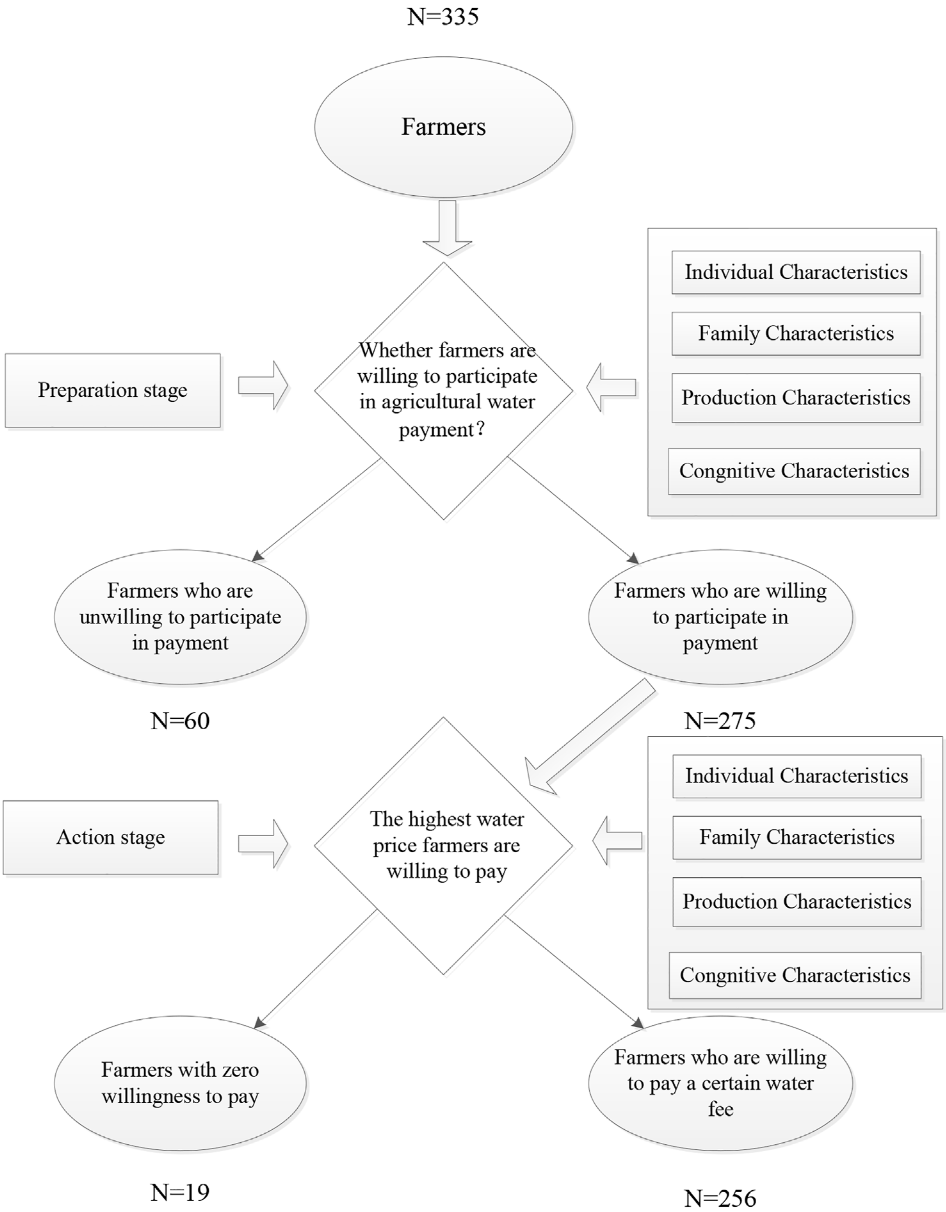

FIGURE 2
Two-stage behavior of farmers participating in agricultural water fee payments. "N" was added here to represent the number of samples in each stage of the study.

participation willingness but lower price willingness. ③ Migrant work experience. Farmers with migrant work experience tend to have a broader vision, more open ideas, and a stronger impact on family decision-making. Therefore, it was assumed that migrant work experience would positively affect the willingness to participate and price willingness. ④ Whether the family members were village cadres or other managers. Village cadres are managers in the rural collective and are responsible for implementing relevant water price policies and paying the agricultural water fees. Therefore, it was assumed that households that included village cadres or other managers would be more willing to pay for agricultural irrigation water and would have a higher price willingness.

3) Influence of production characteristics on the WTP for agricultural irrigation water

H3: Production characteristics have a significant impact on the willingness to participate and willingness to pay the agricultural irrigation water price

TABLE 1 Research progress on the WTP and agricultural water price affordability.

Title	Conclusion
Farmers' psychological capacity to bear the irrigation water price based on the contingent valuation method	There was a significant correlation between the main labor force and the cultivated land area of the farmers' families in the study area and the psychological affordability of the irrigation water prices (Chen et al., 2008)
Quantitative method for assessing the farmers' bearing capacity for the irrigation water price	Many influencing factors on the farmers' affordability were found related to economic and psychological factors (Chen et al., 2009)
Model for determining the influencing factors for the farmers' willingness to pay for irrigation water price based on social capital	Social capital was found to be one of the important factors affecting the farmers' WTP for irrigation water prices; factors such as the farmers' main labor force, arable land area, water supply timeliness, and the working ability of water managers also had significant impacts on the farmers' WTP the irrigation water prices (Zhang et al., 2010)
Psychological references point, willingness to pay, and irrigation water price: evidence from 567 farmers from 20 counties in Sichuan	Education, gender, last year's household expenditure, last year's rice income, and whether the water price was fair were found to affect the farmers' psychological references point water price to varying degrees (Zhang et al., 2014)
Farmers' willingness to pay for water and the influencing factors: a case study of Zhangye City in Heihe River Basin	WTP was significantly related to seven factors: total sown area, corn sown area, type of irrigation water, total household income, age of the main family labor force, individual risk perception, and location (Yin and Cai, 2016)
Analysis of the farmers' willingness to pay for the irrigation water and effecting factors in the Guanzhong area	Household income level, water supply quantity, water supply quality, and water fee collection fairness all had a significant positive impact on the farmers' WTP the water price, whereas irrigation times had a significant negative impact on the WTP (Wang et al., 2018)
Farmers' willingness to pay for agricultural irrigation water and its influence factors in the Weigan River basin	Factors such as age, gender, educational level, water-saving irrigation, accepting government water conservation for industrial development, and cities (projects) paying for water and giving compensation had a significant impact on the WTP of farmers in the basin (Qiao et al., 2018)
Study on the irrigation water price, farmers' willingness to pay in arid areas, and its influencing factors: a case study in Minqin county in Gansu Province	Age and education level of the respondents, average education level of the family labor force, the concentration of the family's cultivated land, the annual per capita net income of the family, the proportion of agricultural income to total income, the respondents' understanding of ecological and environmental protection knowledge, the awareness of the urgency of ecological protection, satisfaction with the water resources management policy, and the support of water-saving technology had a significant impact on the willingness to pay the irrigation water price (Du et al., 2019)

The production characteristics determined in this study were cultivated land area, regional type, water price standard, water fee charging method, and the proportion of the water fee to the total agricultural production cost. ① Cultivated land area. Agricultural production has increasing returns to scale, that is, the larger the cultivated land area, the higher will be the income the farmers get from a unit of cultivated land. Therefore, it was assumed that farmers with larger cultivated land areas would be more willing to participate in the payment of agricultural irrigation water and would have higher price willingness. ② Regional type. The regional types covered in this study were mountainous, hills, and plains. As plains have more abundant water resources and less difficulty in obtaining water resources, it was assumed that farmers would be more reluctant to participate in paying for agricultural irrigation water and would have a lower price willingness. As mountainous areas are relatively remote and have insufficient water conservancy facilities, it is difficult to divert water, which means that water availability is a major concern. Therefore, it was assumed that farmers in mountainous regions would be more willing to participate in paying for agricultural irrigation water and would have a higher price willingness. In hilly regions, it was assumed that farmers would be less willing than farmers in the mountains but more willing than farmers on the plains to participate in paying for agricultural water and would have a lower price willingness. ③ Current water price standard. The higher the current water price standard, the more obvious will be the resistance of farmers to the water price; therefore, it was assumed that the current water price standard would negatively impact the willingness to participate but positively impact price willingness. ④ Water fee charging method. The water fee charging methods involved in this study were government transfer payments, collections by water associations or local financial departments, or farmers paying by themselves. Under government transfer payments, farmers no longer need to pay water fees; therefore, there would be an obvious resistance to paying for agricultural irrigation water. When the fees are collected by the water use associations or financial departments, the water charges are uniformly deducted from the agricultural subsidies, that is, there is a mandatory collection of the water charges; therefore, there is some resistance. If the farmers pay by themselves, the farmers are more aware of the agricultural water price policy and generally are aware that they are paying for the use of resources. Therefore, it was assumed that the farmers who paid their own water fees

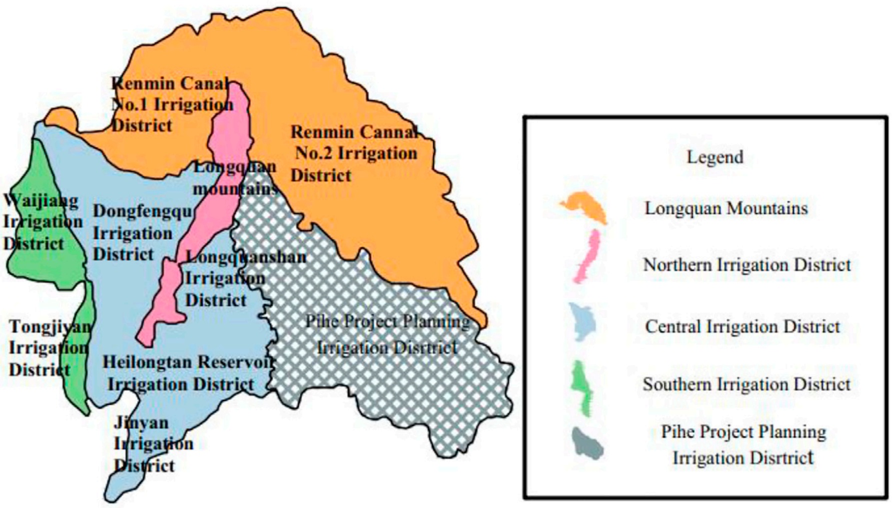

FIGURE 3
Composition map of the Dujiangyan Irrigation Area.

would be more willing to participate in paying for agricultural irrigation water and would have a higher price willingness; however, farmers with government transfer payments would have the lowest willingness to participate and the lowest price willingness. ⑤ The proportion of water fee to the total agricultural production cost. The higher the water fee proportion, the more inefficient agricultural production may be; therefore, there would be greater reluctance to pay the water fees and the ability to pay would be weaker. Therefore, it was assumed that the water fee proportion would negatively impact participation and price willingness.

4) Influence of cognitive characteristics on the willingness to pay for agricultural irrigation water

H4: Cognitive characteristics have a significant impact on the willingness to participate and pay for agricultural irrigation water

The cognitive characteristics identified in this study include water-saving awareness and an understanding of the current water price standard. ① Water-saving awareness. The strength of a farmer's water-saving awareness reflects their awareness of the importance of water resources. As farmers who have a strong water-saving awareness would be more aware of the importance and rational use of water resources, it was assumed that water-saving awareness would have a positive impact on participation and price willingness. ② Knowledge of the current water price standard. Farmers believe that the current water price standard is low, indicating that they may be more willing to pay for the current water price standard, and the water price had some room for an upward adjustment. Therefore, it was assumed that farmers with low water price standards would have a stronger willingness to participate and a higher price willingness.

3 Materials and methods

3.1 Research region

The Dujiangyan Irrigation Area, located at 106°36 ′E and 31°01′ N, has a humid mid-subtropical climate. The climate is suitable all year, the soil is fertile, the annual average precipitation is 900–1240 mm, and there can be two or three harvests a year. The irrigation area, which is part of the world-famous Dujiangyan Water Conservancy Project built by Li Bing and his son in 256 BCE, has developed into the largest irrigation area in China, has an irrigated area of 756,000 hectares and includes seven cities, Chengdu, Mianyang, Deyang, Suining, Leshan, Meishan, and Ziyang, and 37 counties (districts), and has a permanent population of more than 27 million. The center of the irrigation area is the world-famous Dujiangyan Water Conservatory Project in Sichuan Province. The Dujiangyan Irrigation Area is widely known for its "large historical span, large project scale, large scientific and technological content, large irrigation area, and great social and economic benefits" (Liang, 2007). In addition to being extremely important to politics, the economy, and culture, the irrigation project guarantees normal agricultural production, industrial development, and the daily water demand of the residents. Figure 3 shows the composition of the Dujiangyan Irrigation Area.

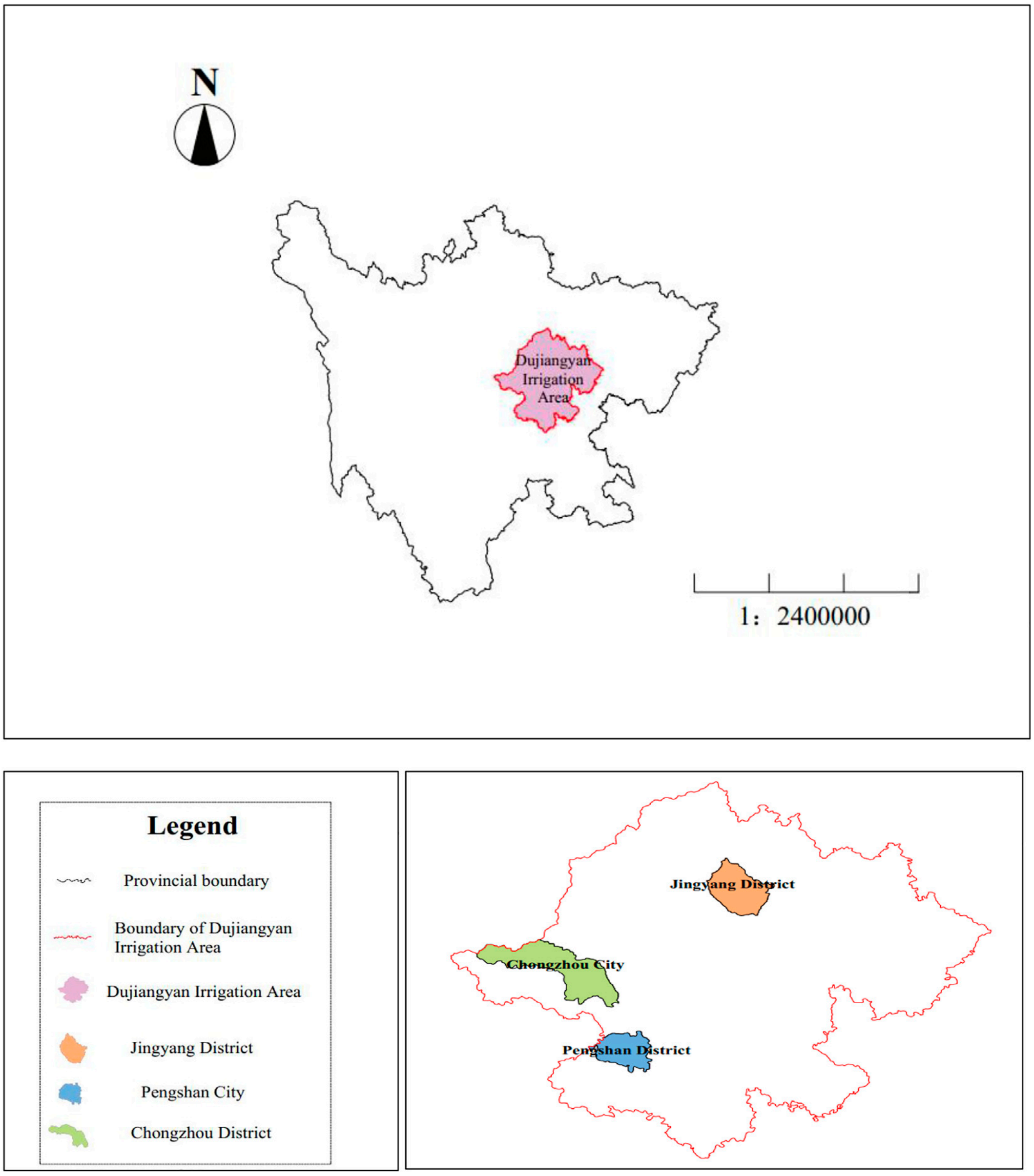

FIGURE 4
Dujiangyan Irrigation Area in Sichuan Province and the three selected study areas.

3.2 Basis for selection of research areas

The Dujiangyan Irrigation Area was selected as the research object because it is the largest irrigation area in China, has good quality management and strong representativeness, has been a key pilot area for the comprehensive reform of agricultural water prices in Sichuan Province since 2017, and because few previous studies have focused on agricultural water prices in areas with relatively rich water resources. Figure 4 shows the geographical location of the Dujiangyan Irrigation Area in Sichuan Province and the three selected study areas.

3.3 Data sources

The data used in this study came from farmers in three Dujiangyan Irrigation Area county-level administrative units: Chongzhou, an administrative unit in Chengdu; Jingyang District, an administrative unit in Deyang; and Pengshan

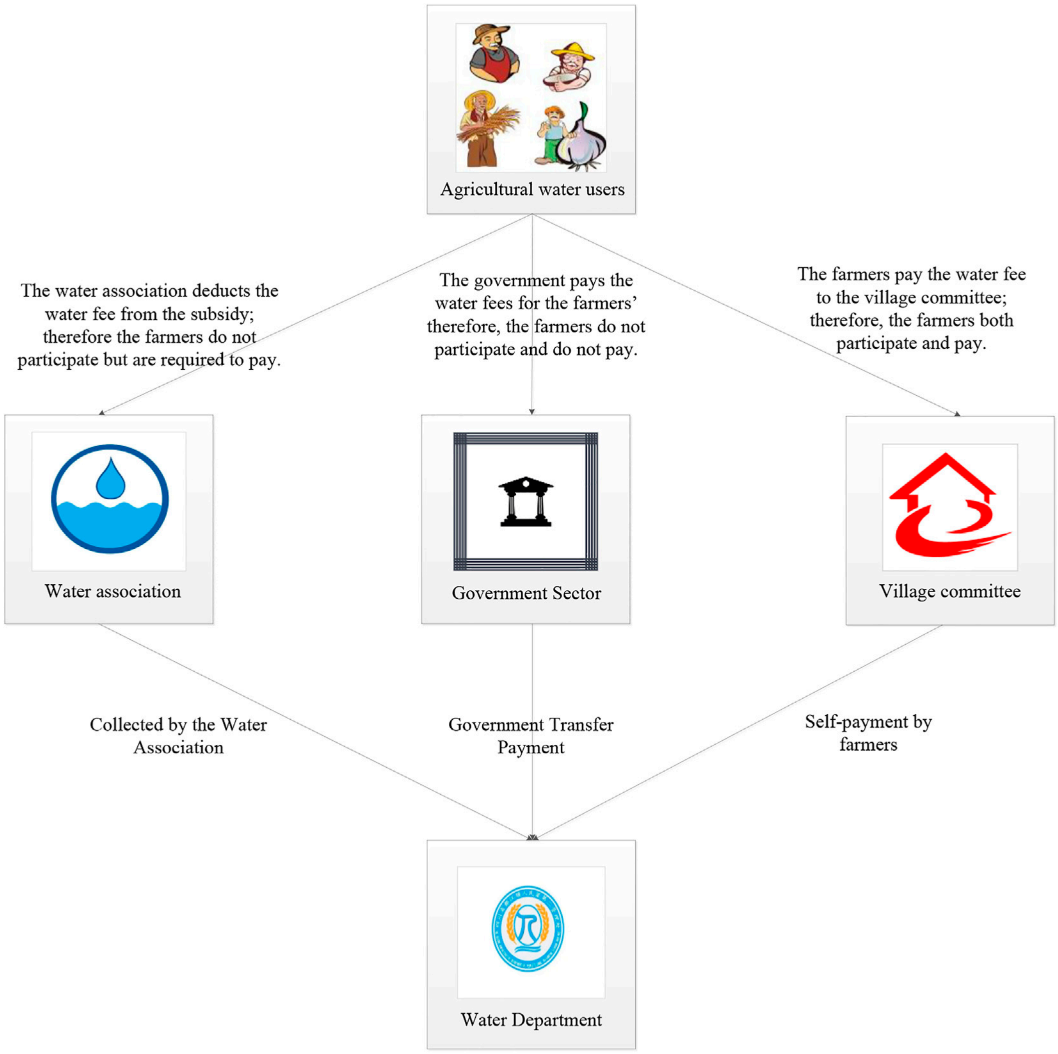

FIGURE 5
Schematic diagram of the water fee charging mechanism.

District, an administrative unit in Meishan. These areas were selected for the following reasons: the three current water fee collection methods in the Dujiangyan Irrigation Area are government transfer payments, farmer self-payment, and collection by the water association or other departments. The water fees in Chongzhou are paid by the government, the water fees in Jingyang District are paid by the farmers, and the water fees in Pengshan District are collected by the local financial department and water association. Figure 5 shows the detailed mechanisms for the three water fee charging mechanisms. It should be noted that in the three surveyed regions, training was conducted or explanations were given about agricultural water prices to ensure that the farmers had a certain understanding of the water price standards in their regions. These three regions comprise plains, hills, and mountains and have high and relatively similar agricultural development quality; therefore, these three units are representative of the Dujiangyan Irrigation Area. A combination of sample surveys and interviews was conducted. The interviews with the water management departments in the three sample counties (districts) identified one to two townships that were still charging water fees. One to two villages were selected that had a high proportion of farmers engaged in agricultural production. Then, based on the proportion of farmers still engaged in agricultural production, each village randomly selected 20% of the farmers still engaged in agricultural production and a questionnaire survey is conducted on them. From this adjustment, 360 questionnaires were distributed and 357 questionnaires were recovered, of which 23 questionnaires had incomplete information and inconsistencies and were

TABLE 2 Distribution of sample data sources.

Counties	Townships (town)	Village	No. of interviewed farmers
Chongzhou City	Jixian	LiangJing	35
	Xinglong	Gaota	32
Jingyang District	Shuangdong	Dongmei	79
		Qianxin	72
Pengshan District	Gongyi	Xinrong	53
	Yihe	Heqiao	64
Total			335

excluded; therefore, there were 335 valid questionnaires and an effective rate of 93.84%. Of these, 69 questionnaires were collected and 67 were valid from Chongzhou, 162 questionnaires were collected and 151 were valid in Jingyang District, and 126 questionnaires were collected and 117 were valid from Pengshan. The details are given in Table 2.

3.4 Econometric model

The conditional value evaluation method (CVM) has been widely used to calculate the WTP, with most studies employing either the Tobit model or the OLS regression model. As the OLS model requires the dependent variable to be a continuous variable, when there are zero observations, the estimations can result in biases for different estimated parameters. However, the Tobit model is unable to handle true zero observations, that is, when the farmers are willing to participate in the payment of agricultural irrigation water fees but the highest water price they are willing to pay is zero, or protest zero observations, that is, when the farmers are unwilling to participate in the payment of irrigation water fees, which results in an unobservable maximum water price that the farmers are willing to pay and biased estimation results. Therefore, correctly dealing with these two observation types can improve the accuracy of the CVM estimation results. The double-hurdle model, which was proposed by Cragg (1971), has two individual decision-making thresholds related to participation in an activity: the first determines whether the individual wishes to participate and the second determines the degree of the individual participation. Therefore, as it was significantly better than the Tobit or OLS models, the double-hurdle model was selected to study the influencing factors in the WTP for agricultural irrigation water. A payment behavior decision was introduced into the consumption behavior analysis, and the zero observation values were included in the model calculations, which resolved the zero value problem and allowed for an analysis of the influencing factors involved in participation and price willingness.

The application of the double-hurdle model for payment behavior meant that the decision-making mechanism for the surveyed farmers under the hypothetical CVM scenario was interpreted as a two-stage process. In the first stage, the farmers decided whether to participate in the water price payments, that is, a willingness to participate, and the second stage determined the maximum payment the farmers were willing to pay, given their specific circumstances. Only when these two decisions are established at the same time can comprehensive agricultural irrigation water price payment systems be developed. The two-column model was able to deal with the zero observations in the CVM survey and was able to analyze and identify the WTP and the differences in the influencing factors on the highest acceptable water prices. The model was expressed as follows.

First, the willingness of the farmers to participate in the payment of agricultural irrigation water fees was investigated, the formula for which was

$$Prob\left[y_i = 0|X_{1\mathrm{i}}\right] = 1 - \varphi\,(\alpha X_{1\mathrm{i}}), \tag{1}$$

$$Prob\left[y_i > 0|X_{1\mathrm{i}}\right] = \varphi\,(\alpha X_{1\mathrm{i}}). \tag{2}$$

Equation 1 indicates that the farmers are unwilling to participate in agricultural irrigation water payments, and Eq. 2 indicates that the farmers are willing to participate in the agricultural irrigation water payments, where $\varphi\,(\varphi X_{1i})$ was the cumulative function for a standard normal distribution, y_i was the dependent variable, which indicated whether the farmers were willing to participate in agricultural irrigation water payments, X_{1i} was an independent variable that represented the individual characteristics, family characteristics, production characteristics, and cognitive characteristics of the farmers, α was the corresponding parameter to be estimated, and i represented the *i*th observation variable.

Then, the willingness of the farmers to pay for agricultural irrigation water was investigated, the formula for which was

$$(E[y_i|y_i > 0, X_{2i}] = \beta X_{2i} + \delta\lambda)\ (\beta X_{2i}/\delta), \quad (3)$$

where $E(\cdot)$ was the conditional expectation representing the highest water price that the farmers were willing to pay for agricultural irrigation water, $\lambda(\cdot)$ was the inverse Mills ratio, X_{2i} was an independent variable representing the individual characteristics, family characteristics, production characteristics, and cognitive characteristics, β was the corresponding coefficient to be estimated, δ was the standard deviation for the intercepted normal distribution, and the other symbols were previously mentioned.

Based on Eqs 1, 3, the likelihood logarithm function was established as

$$\ln L = \sum_{y_i=0}\{\ln[1-\varphi(\alpha X_{1i})]\}$$
$$+\sum\nolimits_{y_i>0}\{\ln\varphi(\alpha X_{1i}) - \ln\varphi(\beta X_{2i}/\delta) - \ln(\delta) + \ln\{\varphi[y_i - \beta X_{2i}/\delta]\}\}. \quad (4)$$

3.5 Variable selection and descriptive statistical analysis

3.5.1 Selection of explanatory variables

This study analyzed the factors influencing farmers' agricultural irrigation water price payment behavior by combining the individual characteristic variables, the family characteristic variables, the production characteristic variables (Wang et al., 2018), and the cognitive characteristic variables, the details of which are given in subsection 2.2.

3.5.2 Definition of the explained variables

The influencing factors on the WTP for agricultural irrigation water involved the following: 1) a willingness to participate, that is, were the farmers willing to pay for agricultural irrigation water and 2) price willingness, that is, what was the maximum water price the farmers were willing to pay for agricultural irrigation water. The questionnaire included the following question to determine this information: are you willing to pay for agricultural irrigation water? If yes, the highest water price you are willing to pay is CNY/ha.?

1) Participation willingness variable

The participation willingness variable was whether farmers were willing to participate in paying for agricultural irrigation water. In this study, farmers who were willing to pay included real positive payers, that is, a willingness to pay greater than zero, and real zero payers (Strazzera et al., 2003; Meyerhoff andLiebe, 2006; Lo and Jim, 2015), that is, farmers with a non-positive WTP but a no protest attitude toward payment. Farmers who were unwilling to participate were classified as protesting zero-payers (Ready et al., 1996), that is, farmers who had no real WTP for agricultural water due to an unmet demand for water supply or excessively high water prices.

Values of 0 (unwillingness to pay) and 1 (willingness to pay) were assigned to the participation willingness variable.

2) Price willingness variable

The price willingness variable was the highest agricultural irrigation water price the farmers were willing to pay or could afford, the data for which were obtained from the questionnaire. The farmers who were willing to pay were screened out and the maximum they were willing to pay was determined.

3.5.3 Variable descriptive statistical analysis

The meanings and descriptive statistical analysis for the variables used in this study are shown in Table 3. The average value for the farmers' willingness to participate was 0.821, that is, a majority of farmers were willing to pay for agricultural irrigation water. The farmers' WTP was 841.305 CNY/ha., which was slightly lower than the average WTP of 937.5 CNY/ha. for farmers in Guanzhong (Wang et al., 2018) and significantly lower than the average WTP of 1130.55 CNY/ha. by Ganlin farmers in Zhangye (Yin and Cai, 2016). This indicated that the WTP by farmers in areas with relatively abundant water resources was lower than in arid regions. On the whole, the farmers' willingness to participate was relatively high, but their price willingness was relatively low. The analysis of the individual characteristics found that the average age of the respondents was 58 years, with the oldest being 85 years old, which indicated that aging was becoming a problem for agricultural producers. The survey results showed that the household head "decision-making power" male to female ratio was 11:9 and the farmers had an average of 6 years of education, indicating that the overall educational level was relatively low. The highest per capita net income was 205,000 CNY, which was relatively high, and the lowest was 16,231 CNY. Agricultural income accounted for 71.3% of the total income, the average cultivated land area was 0.87 hectares, 76.4% of the family members had migrant work experience, and 5.6% of households included village cadres or other management personnel.

The analysis of the production characteristics found that farmers were more inclined to produce in mountainous and hilly terrains and the average water price paid was 684.75 CNY/ha., which was between the water price standard set by the government of 300 CNY/ha. and 2295 CNY/ha. and slightly lower than the average price willingness of 841.305 CNY/ha., which indicated that the water price standard had some room for an upward adjustment. However, the water price standard in some areas was much higher than the average farmer payments,

TABLE 3 Definitions of the variables and descriptive statistical analysis.

Types of variables	Variable name	Variable description	Mean value	Standard deviation
Decision variable	Participation willingness	0 = no participation, 1 = participation	0.821	0.384
	Price willingness	Highest water price willing to pay, CNY per hectare	841.305	470.61
Individual characteristics	Sex	0 = male, 1 = female	0.448	0.498
	Age	Age	58.367	10.541
	Education level	Years of education, years	6.018	3.472
Family characteristics	Per capita net income	Take the logarithm of per capita income	9.35	0.94
	Proportion of agricultural income	Proportion of agricultural income in total income, %	0.713	0.277
	Migrant work experience	0 = no, 1 = yes	0.764	0.425
	Whether the family members have village cadres or other managers	0 = no, 1 = yes	0.056	0.231
Production characteristics	Cultivated land area	Acreage, hectare	0.867	4.354
	Regional type: Mountains	Mountains = 1, others = 0	0.015	0.121
	Hills	Hills = 1, others = 0	0.573	0.495
	Plains	Plains = 1, others = 0	0.412	0.496
	Current water price standard	Water price, CNY per hectare	45.648	23.952
	Water fee charging method. Farmers pay by themselves.	Farmers pay by themselves = 1, others = 0. Water association or financial department collects = 1, others = 0. Government transfer payment = 1, others = 0	0.429	0.496
	Water association or financial.		0.376	0.485
	Government transfer payment		0.194	0.396
	Proportion of water fee to the total agricultural production cost	Proportion of water fee in the total cost, %	0.0649	0.834
Cognitive characteristics	Water-saving awareness	1 = extremely weak, 2 = very weak, 3 = general, 4 = very strong, 5 = extremely strong	4.149	0.635
	Cognition of the current water price standard	1 = extremely low, 2 = very low, 3 = general, 4 = very high, 5 = extremely high	3.340	0.864

which indicated that there may be difficulties in managing the agricultural water. The analysis of the cognitive characteristics showed that the average water-saving awareness was 4.15, that is, most farmers had a strong water conservation awareness, and the average perception of the current water price standard was 3.34, which was relatively high.

4 Results and discussion

4.1 Correlation test

A multi-collinearity test on the explanatory variables was conducted before the application of the double-hurdle model regression analysis to ensure there were no correlations between the explanatory variables. The test results are shown in Table 4, in which it can be seen that the maximum VIF value in the participating equation was 1.98 and the maximum VIF value in the payment decision equation was 5.81, both of which were far less than 10; therefore, the multi-collinearity between the explanatory variables was small.

4.2 Analysis of the influencing factors on the willingness to participate

Stata16 software was used to estimate the data, the parameter estimation results for which are shown in Table 5. A total of seven factors influenced the farmers' willingness to participate in agricultural irrigation water payments: whether the family members had village cadres or other managers in the household; the cultivated land area; the water fee charging method; the proportion of water fee to the total agricultural production cost; water-saving awareness; current water price standard; and the farmers' awareness. However, gender, age, education level, the proportion of agricultural income, migrant work experience, regional type, and per capita net income were not significant at a 10% level.

Table 4 shows the estimation results for the parameters in the participation equation, which was

$$y_i = -1.149X7 + 0.025X8 - 0.014X11 + 1.501X12$$
$$-1.356X13 + 0.039X14 + 0.666X15 - 0.846X16. \quad (5)$$

TABLE 4 Multi-collinearity test results on the explanatory variables.

Variable type	Variable name	Willingness to participate	Price willingness
		Variance inflation factor (VIF)	Variance inflation factor (VIF)
Individual characteristics	Sex	1.20	1.26
	Age	1.41	1.45
	Education level	1.42	1.52
Family characteristics	Per capita net income	1.26	1.30
	Proportion of agricultural income	1.98	5.81
	Migrant work experience	1.09	1.20
	Whether the family members have village cadres or other managers	1.08	1.10
Production characteristics	Cultivated land area	1.86	5.39
	Regional type	1.56	1.36
	Current water price standard	1.39	1.33
	Water fee charging method	1.35	1.30
	Proportion of water fee to the total agricultural production cost	1.35	1.29
Cognitive	Water-saving awareness	1.11	1.10
characteristics	Cognition of the current water price standard	1.26	1.20

TABLE 5 Influencing factors for the willingness to participate.

Variables name	Coef.	Se	z	*p*
Sex (X1)	0.057	0.264	0.21	0.831
Age (X2)	0.017	0.139	1.24	0.216
Education level (X3)	0.028	0.038	0.72	0.470
Per capita net income (X4)	−0.147	0.134	−1.10	0.272
Proportion of agricultural income (X5)	−0.165	0.245	−0.68	0.499
Migrant work experience (X6)	−0.341	0.367	−0.93	0.353
Whether the family members had village cadres or other managers in the household (X7)	−1.149	0.546	−2.10	0.035**
Cultivated land area (X8)	0.025	0.015	1.65	0.098***
Plain (X9)	−2.848	166.216	−0.02	0.986
Hill (X10)	−2.345	166.216	−0.01	0.989
Current water price standard (X11)	−0.014	0.006	−2.48	0.013**
Farmers pay by themselves (X12)	1.501	0.528	2.84	0.005***
Transfer payment (X13)	−1.356	0.378	−3.59	0.000***
Proportion of water fee to total agricultural production costs (X14)	0.039	0.020	0.90	0.057*
Water-saving awareness (X15)	0.666	0.254	2.62	0.009***
Knowledge of the current water price standard (X16)	−0.846	0.197	−4.30	0.000***

Note: *, **, and *** respectively indicate significant at the 10, 5, and 1% levels.

1) Whether family members included village cadres or other managers was significant at a 5% level with the influence coefficient being negative, which indicated that the presence of village cadres or other management personnel in the family negatively impacted the willingness to participate in paying for agricultural irrigation water. Most of Sichuan Province has implemented a reduction in agricultural water, which village cadres and other management staff understand much more than most farmers. Village cadres and other managers also eagerly hope that the village will reduce or exempt water charges; therefore, families with village officials or other management personnel are less willing to participate in agricultural water payments.

2) The cultivated land area was significant at a 10% level, with the influence coefficient being positive, which indicated that the cultivated land area had a positive impact on participation willingness. As the area of arable land increases, the demand for water resources also increases. Most farmers with large areas of arable land have developed cooperatives or family farms, which are highly dependent on agricultural water resources. To better maintain their agricultural production, they prefer to pay the water fees to meet their production needs. Therefore, the cultivated land area was positively correlated with a willingness to participate.

3) The current water price standard was significant at a 5% level, with the influence coefficient being negative, that is, the water price negatively impacted the willingness to participate in paying for agricultural irrigation water. The higher the water price standard, the higher will be the water price per mu of cultivated land. High water price standards could result in dissatisfaction and even conflict with agricultural irrigation water prices. Therefore, the water price standard negatively affected the farmers' willingness to participate.

4) The water fee charging method was significant at a 1% level, with the influence coefficient for the water fee collection method being positive for farmers who paid by themselves and negative for the government transfer payment method. This indicated that farmers who paid the water fees themselves were more willing to participate in the payment of agricultural irrigation water fees, but farmers who had government-transferred water fees were more reluctant to pay for irrigation water. This was because when farmers pay on their own initiative, the process is more transparent and more acceptable. However, the collection method, whereby the water fee is directly deducted from the government subsidy, is mandatory and not transparent enough, which results in resistance. Because the transfer payment means that the government pays the water fee, the farmers never pay for water, which means that they are resistant to paying for water. Therefore, the willingness to participate in agricultural irrigation water payment gradually decreased from self-payment to collection to transfer payments.

5) The proportion of the water fee to total agricultural production costs was significant at a 10% level, with the influence coefficient being positive, that is, the proportion of the water fee in the production costs was positively correlated with participation intention. The possible reason was that the higher the water fee proportion, the higher will be the water consumption or the lower the production technology. Because agricultural water is more important for production, they are more willing to pay; therefore, the water fee proportion had a positive impact on the willingness to participate.

6) Water-saving awareness was significant at a 1% level, with the influence coefficient being positive, that is, water-saving awareness had a positive impact on the willingness to participate. Farmers with strong water-saving awareness believe that water resources are valuable; therefore, the more they recognize the rational use of water resources, the more they can accept paying for these resources.

7) The knowledge of the current water price standard was significant at a 1% level, with the influence coefficient being negative, that is, knowledge of the current water price standard negatively impacted the willingness to participate. When farmers think the water price standard is too high, they find it more difficult to accept the water price and are less willing to pay. On the contrary, if farmers think the water price standard is too low, they are more willing to accept the current water price and are more willing to pay.

4.3 Analysis of influencing factors for price willingness

Stata16 software was used to perform the Tobit regression and double-hurdle regression on the data, the results for which are shown in Table 6

Table 6 shows the estimated results for the payment equation. The comparison of the estimated results from the double-hurdle model and the Tobit model showed that more variables in the estimated results for the double-hurdle model had a more significant impact on the WTP. As the Tobit model treats all zero values as protest zero values, the coefficient of the constant term in the Tobit model estimation result was higher, which led to an overestimation of the farmers' real WTP. Therefore, based on the estimation results from the double-hurdle model, the payment equation was

$$\begin{aligned} E = 54.410 + 0.507X2 + 1.344X3 + 7.24X6 - 29.477X9 \\ - 22.542X10 + 0.636X11 - 13.059X13 - 0.361X14 \\ - 4.701X15 - 11.528X16. \end{aligned} \tag{6}$$

Equation 6 revealed the following.

1) Age was significant at a 1% level, with the influence coefficient being positive, that is, age was positively correlated with price willingness. The age of the respondents in this study was generally older. Many older respondents said that they were paying up to 3,000 CNY per hectare. Due to historical factors, their higher water price payment experiences led to higher price willingness.

2) The educational level was significant at a 5% level, with the influence coefficient being positive, that is, the educational level positively affected price willingness. Farmers with higher educational levels have richer knowledge and a more thorough understanding of the ecological and social value of water resources; therefore, they are more willing to pay more for the use of water resources. Conversely, farmers with low education levels have relatively weak knowledge reserves and a

TABLE 6 Influencing factors for price willingness.

Variables name	Coef.	Se	z	p	Coef.	Se	t	*p*
Model	**Double-hurdle model**				**Tobit model**			
Sex (X1)	2.559	3.419	0.748	0.454	−2.167	3.713	−0.58	0.560
Age (X2)	0.507	0.173	2.936	0.003***	0.390	0.189	2.07	0.040**
Education level (X3)	1.344	0.548	2.455	0.014**	0.767	0.596	1.28	0.200
Per capita net income (X4)	1.704	1.957	0.871	0.384	0.539	2.117	0.25	0.799
Proportion of agricultural income (X5)	1.276	6.380	0.200	0.841	2.621	6.564	0.40	0.690
Migrant work experience (X6)	7.240	3.753	1.929	0.054**	6.740	4.221	1.60	0.112
Whether the family members have village cadres or other managers (X7)	−3.399	6.647	−0.511	0.609	−4.261	7.310	−0.58	0.560
Cultivated land area (X8)	0.005	0.058	0.088	0.930	−0.011	0.058	−0.18	0.854
Plain (X9)	−29.477	11.392	−2.587	0.009***	−34.896	12.865	−2.71	0.007***
Hill (X10)	-22.542	10.937	−2.061	0.039**	−22.284	12.439	−1.79	0.074*
Current water price standard (X11)	0.636	0.073	8.647	0.000***	0.696	0.082	8.52	0.000***
Farmers pay by themselves (X12)	0.600	3.584	0.167	0.867	7.278	3.896	1.87	0.063
Transfer payment (X13)	−13.059	6.744	−1.936	0.053*	−0.106	7.309	−0.01	0.988
Proportion of water fee to total agricultural production cost (X14)	−0.361	0.191	−1.887	0.059*	−0.233	0.213	−1.09	0.277
Water-saving awareness (X15)	−4.701	2.854	−1.647	0.099*	−3.884	3.066	−1.27	0.206
Cognition of the current water price standard (X16)	−11.528	2.053	−5.615	0.000***	−13.922	2.211	−6.29	0.000***
cons	54.410	29.577	1.839	0.066*	71.701	32.70	2.19	0.029**
chi2	154.067				116.710			

Note: *, **, and *** respectively indicate significance at 10, 5, and 1% levels.

poorer understanding of the value of water resources, which means their price willingness is relatively low.

3) Migrant work experience was significant at a 5% level, with the influence coefficient being positive, that is, migrant work experience had a positive impact on price willingness. People with migrant work experience are more receptive to new things, more open-minded, and have a broader vision; therefore, they are more willing to pay a higher price for water.

4) The regional type was significant, with the influence coefficient being negative, that is, the willingness to pay by farmers in plain and hilly areas was lower than farmers in mountainous areas. The value of water resources is closely related to scarcity. Compared with hilly and plain areas, water resources are relatively scarce in mountainous areas; therefore, farmers are more willing to obtain agricultural water at higher costs, that is, farmers in mountainous areas have higher price willingness.

5) The current water price standard was significant at a 1% level, with the influence coefficient being positive, indicating that the water price standard was positively correlated with price willingness. Farmers pay for agricultural water based on the current water price standard; however, farmers who pay a higher water price have a higher price willingness because they are more likely to accept the water price due to the smaller difference compared to the previous water price.

6) Of the water fee collection methods, the transfer payment method was significant at a 10% level, with the influence coefficient being negative, that is, the willingness to pay by farmers paying under the government transfer method was higher than the willingness to pay by farmers who pay water fees to water use associations or financial departments. Farmers operating under the government transfer scheme do not need to pay water fees; therefore, even if they were willing to participate, they would be less willing to pay higher water fees.

7) The water fee proportion to the total agricultural production costs was significant at a 10% level, with the influence coefficient being negative, that is, the water fee proportion was negatively correlated with price willingness. If all other costs remain unchanged, as the water fee increases, the farmers' enthusiasm for production gradually decreases. When the water fee increases to a certain amount, farmers choose to give up agricultural production. As the water price indirectly reflects the water fees that farmers need to pay for the use of agricultural irrigation water, farmers with low water cost proportions would be more likely to accept a proportional increase within a certain range and a higher water price.

8) Water-saving awareness was significant at a 10% level, with the influence coefficient being negative, that is, water conservation awareness and price willingness were negatively correlated. Farmers with strong water conservation awareness may have better water conservation behaviors to reduce the cost of agricultural water or they may take water conservation measures because of high water prices. Therefore, water-saving awareness negatively impacted price willingness.

9) Knowledge of the current water price standard was significant at a 1% level, with the influence coefficient being negative, that is, farmers who believe that the current water price was high had lower price willingness. Farmers' knowledge of the water price standard can reflect their acceptance of the current water price. Farmers who think that the water price is low are more likely to accept the current water price and accept a relatively higher water price. However, farmers who think the water price is high are less likely to accept the current water price and hope that the water price can be reduced. Therefore, knowledge of the current water price standard negatively impacted price willingness.

4.4 Discussion

While there has been significant research into the influencing factors on the WTP for agricultural irrigation water, few scholars have analyzed the WTP for agricultural irrigation water in two stages using the double-hurdle model. Therefore, this study examined the factors affecting the WTP for agricultural irrigation water based mainly on the second stage, that is, the factors affecting the price willingness to pay for agricultural irrigation water.

Research has found that the age of the respondents (Yin and Cai, 2016; Du et al., 2019) and the cultivated land area (Qiao et al., 2018) negatively affected the willingness to pay, while education level, per capita net household income, satisfaction with water management policy (Du et al., 2019), planting area, risk perception ability, regional type (Yin and Cai, 2016), water supply quantity, water supply quality, water fee collection fairness (Wang et al., 2018), water-saving irrigation awareness (Qiao et al., 2018), and other factors positively affected the willingness to pay.

While few studies have been conducted in water-rich areas, it has been found that the previous year's household expenditure negatively affected the WTP for agricultural water, and the education level and the fairness of water price setting positively affected the WTP, with females being more willing than males (Zhang et al., 2014).

This study found that education level, the water fee ratio, and farmers' perception of the water price standard on the WTP were the opposite of previous research. First, the proportion of respondents aged 70 and above was relatively large; therefore, there may have been a difference in the age structure of the respondents. It may also have been because the respondents employed more water conservation production behaviors to reduce their agricultural water use, or it may be that the water prices were too high, which forced them to employ more water conservation production behaviors.

To further explore the impact mechanism of the related variables on the WTP, the WTP was divided into two stages: a willingness to participate and a willingness to pay a certain price. The water price standard and farmers' perception of the water price standard negatively affected the willingness to participate. The WTP by farmers with village cadres and other managers at home was lower than in households without village cadres and other managers. The stronger the willingness to participate, the lower the willingness of farmers to participate in the government transfer payment of water fees. Age, education level, and the water price standard positively affected the farmers' price willingness, but the water fee ratio, water-saving awareness, and farmers' perception of the water price standard negatively affected price willingness.

Compared with the mountainous areas, the farmers in the plain and hilly areas had lower price willingness. Compared with the farmers whose agricultural water fees were collected by water use associations or financial departments, the price willingness of farmers whose water fees were transferred by the government was lower. The results of this study showed that the effects of some variables on the WTP were roughly the same as in previous studies; however, some variables had different effects on the WTP. Because of the two-stage analysis in this study, the WTP for agricultural water was clearly shown, which can assist in the development of constructing a more scientific, reasonable water pricing mechanism.

5 Conclusion and suggestion

5.1 Conclusion

Based on survey data from 335 households in the Dujiangyan Irrigation Area in 2019, this study constructed a double-hurdle model to analyze the influencing factors for the WTP for agricultural irrigation water under a zero observation value premise. It was found that the willingness to participate and the willingness to pay a certain price were affected by a combination of factors.

The willingness to participate was positively impacted by the area of arable land, the water fee proportion, and water-saving awareness, but negatively impacted by farmers' perception of the water price standard. Price willingness was positively impacted by age, education, water level, and the water price standard but negatively impacted by the water fee, water conservation awareness, and the perception of the water price standard.

Because agricultural water price affordability has not been considered in many parts of the world and water resource allocation and utilization are inefficient, it has been difficult to manage by water management agencies. To identify measures to encourage farmer participation in agricultural water payments and to develop a more reasonable water price system that can optimize agricultural water allocation and improve agricultural efficiency, this study examined the WTP for agricultural irrigation water in the Dujiangyan Irrigation Area by examining both the willingness to participate in agricultural water payments and the price farmers were willing to pay. The results and suggestions provide an important reference for agricultural water price adjustments and reforms in similar regions in other developing countries.

Because of the dual pressures of climate change and population growth, water scarcity problems have been intensifying, which has resulted in conflicts around agricultural water use. Therefore, research into the factors influencing the willingness to participate in and the WTP for agricultural irrigation water has become more important when formulating reasonable water price mechanisms to improve agricultural productivity and resolve water crises.

5.2 Policy recommendations

1) Strengthen the water conservation awareness training of farmers and promote participation in agricultural water payments.

The farmers' poor water conservation awareness has resulted in low water utilization efficiency and a low willingness to participate in paying for agricultural irrigation water. Therefore, strengthening water conservation publicity and promoting water conservation technologies could improve the efficiency of agricultural water use, help resolve the global water crisis, encourage farmers to voluntarily participate in paying for agricultural irrigation water, and resolve water management departments' difficulties in charging agricultural water fees.

2) Promote agricultural modernization and improve the farmers' abilities to afford agricultural water prices.

Improvements in agricultural production could significantly reduce agricultural production costs and improve the ability to afford agricultural water prices. Further increasing the scale of agricultural production and encouraging farmers to adopt water conserving irrigation technology could improve agricultural development quality and agricultural water use efficiency.

3) Scientific and rational formulation of water price standards are needed to give full play to water price adjustment functions.

Because of factors such as the regional environment, the water resource endowment, local water price standards, agricultural production structure, sown area, age, and other factors, there are differences in farmers' abilities to afford agricultural irrigation water prices. Therefore, these key factors should be considered when formulating water price mechanisms. To ensure effective and efficient water resource allocations, water price mechanisms must consider the farmers' willingness and ability to pay.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for this study in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

HT conceptualized the research framework, collected the data, calculated the results, and wrote the manuscript. ZY conceptualized the research framework, constructed the model, collected data, calculated the results, and wrote the manuscript. RR designed the study and wrote and revised the manuscript. ZG and CY constructed the model and collected data. FH contributed to the discussion and conclusion.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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