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Research paper

Modeling of agricultural water policies to guarantee water supply under climate change

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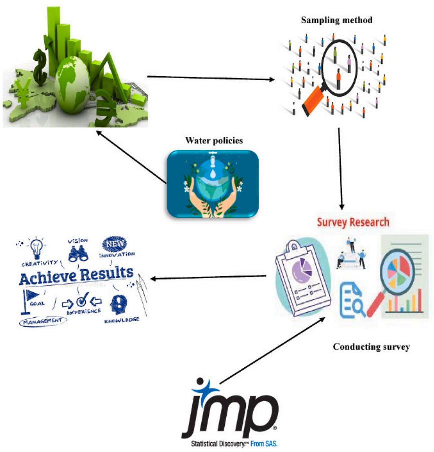
HIGHLIGHTS

- Evaluate attributes of policies to guarantee agricultural water supply by using CE method.
- Farmers didn't have an amount of guaranteed irrigation water supply due to frequent droughts.
- CL model with interaction effects has been used to import the socio-economic characteristics of farmers.
- The policies aimed at the adoption of water-saving technologies should be given a higher preference.
- A common understanding of water management is needed by stakeholders.

GRAPHICAL ABSTRACT



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ABSTRACT

The efficient and sustainable use of water has become a necessity in regions prone to drought and water scarcity. One such region is the Fars province of Iran, where farmers often face uncertainties in irrigation water supply due to frequent droughts and declining groundwater levels. This study employed a quantitative research methodology, utilizing surveys and questionnaires to collect data. Specifically, the study used the choice experiment (CE) methodology to evaluate policy attributes aimed at guaranteeing agricultural water supply. The research was conducted in Marvdasht County within the Fars province, with a sample size of 170 farmers and 4080 observations collected in 2015. The collected data were analyzed using the conditional logit (CL) model. The sample size was determined using the stratified random sampling method. The results of the study indicate that age has a negative effect on farmers' willingness to pay (WTP) for guaranteed water supply, while education has

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a positive effect. Additionally, the study found that farmers' WTP for different policies varied, with the highest WTP observed for the use of water-saving technologies (estimated at 254.89 IRR per m3) across all areas. Consequently, the study recommends that policies promoting the adoption of water-saving technologies should be prioritized globally. It is worth noting that water policies can significantly differ between countries and regions due to various factors, including local water challenges, legal frameworks, cultural norms, and socio-economic conditions. Therefore, when formulating water policies, it is crucial to consider the specific context and tailor them to the unique circumstances of each region or country.

1. Introduction

Climate change is one of the most important disasters that has numerous negative effects on the environment and humans, such as poverty, political and social conflicts, water scarcity, and water shortage (Karimi et al., 2018, 2023). Water, as a crucial input for agricultural production, holds a special place in the sustainable development of the agricultural sector, which in turn contributes to the economic development of other sectors. The imbalance in water availability can be attributed to two factors: natural limitations in terms of precipitation and temperature, and non-economic use of available water by certain economic activities, whether on a local, national, or even global scale (Chizeri et al., 2005; Barati et al., 2023).

Irrigation represents the largest consumer of water demand, accounting for 70% of total freshwater resources worldwide (Albiac et al., 2006; Islami and Rahimi, 2019). However, it is also the least efficient sector in terms of water use. Presently, the most significant challenge in irrigation water supply is associated with two issues: an increase in the uncertainty of the quantity and timing of supply (Kavosi Kelashomi and Peykani, 2014). The water crisis is a major challenge currently faced by regions worldwide, particularly arid and semi-arid areas. These challenges, combined with issues such as population growth, low efficiency of water consumption, and high evaporation and transpiration rates, significantly limit economic growth in many countries (Nasiri et al., 2009; Amiri et al., 2020).

In Iran, a substantial portion of the total annual water consumption, approximately 90%, is attributed to the agricultural sector, while the municipality and industry sectors account for about 2% and the services sector for about 8% (Irans' energy ministry, 2023). The lack of efficient and sustainable water use poses significant challenges for policymakers worldwide, particularly in water-scarce countries. Therefore, it is crucial to consider information on the economic value of water in decision-making processes, utilizing supportive decision tools such as cost-benefit analysis. In the absence of water markets, shadow prices are determined through economic valuation methods. Such decision-making processes adopt a social welfare perspective to prevent the misallocation or under-optimal allocation of scarce resources (Turner et al., 2004).

Water pricing serves as an economical and efficient option to promote sustainable water use (Turner et al., 2004; Dinar and Mody, 2004; Karimi et al., 2024), as it provides monetary incentives for consumers to conserve water. According to economic theory, water consumption in irrigated land should decrease as water prices rise (Gomez-Limon and Riesgo, 2004). However, Dinar and Mody (2004) argue that water valuation alone may not be sufficient to stimulate desirable changes in water consumption. In some cases, when opportunities to increase water productivity arise, farmers may become more market-oriented, assigning higher value to products that require more water. This results in a more inelastic demand for water (Fernandez-Zamudio et al., 2012; Karimi et al., 2024).

To effectively manage scarce water resources in agriculture, a range of strategies have been proposed, including supply augmentation and demand management, along with various policy instruments and economic incentives (Tiwari and Dinar, 2002; Karimi et al., 2017). While several options exist to create economic incentives for water savings (Tsur, 2005; Mirzavand and Bagheri, 2020), equity issues play a critical role in developing effective and politically acceptable instruments. It is generally expected that pricing approaches built upon local experiences and involving local stakeholders have a better chance of acceptance (Martin-Ortega, 2012). Economic policy instruments often complement each other since they operate within an institutional context (Sterner, 2003; Sabzevar et al., 2021). Therefore, developing socially appropriate instruments to govern water resources in a fair, equitable, and environmentally sustainable manner should consider local institutional settings and the range of alternative incentives and enabling environments available to modify human behavior. While water supply reliability is crucial for the survival of irrigated agriculture, achieving a balance between water demand and supply is no easy task (Alcon et al., 2014; Karimi et al., 2021).

Addressing the issue of water supply reliability requires an integrated approach and a set of actions, as no single source of supply can fully alleviate water scarcity (Jaber and Mohsen, 2001). In recent years, the use of non-conventional water sources, such as treated wastewater from urban areas or desalinated water, has been considered as complementary sources to mitigate the shortage of conventional water supply, especially in regions where the potential of fresh water resources has been fully exploited. Therefore, the reuse of treated wastewater is seen as a promising measure to alleviate water shortages (Carr et al., 2011; Karimi et al., 2023).

In addition to supply-side measures, demand-side management practices are essential for promoting sustainable water use in agriculture. These practices include improving irrigation efficiency through the use of modern irrigation techniques, such as drip irrigation and precision agriculture, as well as adopting water-saving practices like deficit irrigation and crop rotation (Karimi et al., 2021, 2023). Implementing water-saving technologies and practices can significantly reduce water consumption in agriculture without compromising productivity.

Furthermore, effective water governance and institutional frameworks are crucial for managing water resources sustainably. This involves establishing clear water rights and regulations, promoting stakeholder participation and collaboration, and ensuring the enforcement of water laws and regulations (Karimi et al., 2017, 2024). Integrated water resources management approaches that consider the interconnectedness of water systems and the various competing demands for water can help optimize water allocation and reduce conflicts.

In conclusion, addressing the water crisis in agriculture requires a combination of supply-side and demand-side measures, along with effective water governance. Pricing mechanisms can provide economic incentives for water conservation, but they should be complemented with other policy instruments and consider local contexts and equity issues. Improving water-use efficiency, promoting water-saving technologies, and adopting sustainable irrigation practices are essential for reducing water consumption in agriculture. Additionally, exploring alternative water sources, such as treated wastewater and desalinated water, can help alleviate water scarcity. Ultimately, integrated approaches that consider the economic, social, and environmental dimensions of water management are necessary for achieving sustainable water use in agriculture.

There are similar studies which has been done in the field of water pricing:

Baghestani and Zibai (2010a,b) used contingent valuation method in a study to estimate the WTP of farmers for underground water in

Ramjerd region in Iran. The results showed that the WTP of farmers who use underground water and surface water in combination is less than farmers who only use underground water. Cropping pattern, the area under rice cultivation, lands dispersion and farmer's income and age have shown a significant effect on WTP.

In another study, Baghestani and Zibai (2010a,b) used the parametric programming method to measure the WTP of farmers for underground water in Ramjerd region in Iran. The results showed that the WTP of farmers for using of deficit irrigation strategies and increasing irrigation efficiency increase with increasing in water price.

Asad Falsafizadeh and Saboohi Saboon (2011) calculated the value of water input and the amount of WTP of farmers in Beyza region, in Iran, using the CE method. The results showed that the WTP of farmers is between 10 and 15 percent of the water price they pay.

Alcon et al. (2010) calculated the non-market value of reclaimed wastewater for use in agriculture in the Segura River basin located in the southeast of Spain using the contingent valuation method. The results showed that the use of reclaimed wastewater for irrigation has significant non-market environmental benefits.

Mesa-Jurado et al. (2012) in a study using contingent valuation, obtained WTP of farmers for guaranteed irrigation water supply in the Guadalbullon River located in southern Spain. The results showed that farmers are willing to increase 10–20% more than their current annual payment also willing to reduce the average supply by 30% of their official water rating to increase the guarantee of water supply.

Alcon et al. (2014) in a study using CE method and the conditional logit model, investigated the acceptance of policy strategies by farmers to increase the guaranteed water supply in Segura, in the southeast of Spain. The results showed that farmers are willing to pay twice the current price of irrigation water.

This study makes several contributions. First, this is one of important studies in Iran to calculate the WTP for farmers, using CE method, with focus on socio-economic variables for attributes such as amount of guaranteed water supply and water supply measures including: water transfer from Doroodzan dam and river, control over groundwater abstraction, strengthening and development of agricultural water market and use of water-saving technologies. Second, although several decades have passed since the introduction of the CE method in the world, the number of researches conducted based on this method in the field of water in Iran is few and mostly the contingent valuation method has been used. Also, the advantages of the CE method are more than the contingent valuation method, so it is appropriate to use the CE method in this research. Finally, the prioritization of WTP for attributes helps policy makers to make policies and decisions to guarantee irrigation water supply in Iran and findings of this research enable policy makers to consider farmers' preferences for accepting water supply and demand management policies.

Overall, the objective of this study was examining the agricultural water policies that guarantee water supply in the South of Iran and the research questions are given below:

1. What effect does amount of guaranteed water supply attribute have on the guarantee of water supply for farmers?
2. What effect does water supply measures attribute have on the guarantee of water supply for farmers?
3. WTP for which of the attributes such as amount of guaranteed water supply and water supply measures is greater?

2. Research area

Marvdasht County, with an area of 4649 km2, has occupied 8.3% of the total area of the Fars province. This county is located almost in the center of Fars province. Center of Marvdasht County is located at 52° and 48 min of longitude and 29° and 52 min of latitude and altitude 1595 m above sea level. Its climate is temperate and the most important rivers in this county are the Kor and Sivand River, which are very important and vital (Nasiri et al., 2009). The average annual rainfall is about 500 mm (Khosh Akhlagh et al., 2010). This is located in a suitable area, which is important for the cultivation of agricultural products, including grain and vegetables. Marvdasht County, despite the expansion of physical activities in the last three decades to store seasonal surface water by converting runoff to the aquifer, has faced a decrease in the static level of aquifers and other water sources, including springs, wells and even aqueducts, This reduction in water sources is due to the irregular increase in population, the development of agricultural and industrial activities, irregular abstraction of water and also intermittent droughts (Roosta et al., 2009). Considering the existence of these conditions in this county, it is necessary to study what policies would be acceptable to farmers to increase the reliability of water supply in this region.

3. Methodology

3.1. Choice experiment method (CEM)

CEM is used for valuing non-market goods. Non-market valuation methods are important when determining the costs and benefits of public projects. Non-market goods valuation research has been developed using two types of methodologies: One, revealed preference (RP) method, and two, stated preference (SP) method. The revealed preference method values a non-market good by studying actual behavior in a relevant market. The general advantage of the revealed preference method is that it is based on real choices of individuals. However, it also has disadvantages. The stated preference method evaluates the value of environmental goods through the use of the expressed behavior of individuals in a hypothetical set. This method includes different viewpoints, including contingent valuation (CV) and CEM. In most studies, the contingent valuation method (CVM) has been used (Sharzei and Javidi Abdollahzadeh Aval, 2011).

CEM is a subset of a choice modeling method and it is from the family of stated preference approach. Choice modeling is one of the derivatives of conjoint analysis (Carson et al., 1994). Theoretical structure of CEM results from multinomial discrete choice (MDC) analysis in which respondents choose the most preferred option from several choices (Arcidiacono et al., 2012). Each option includes several attributes that are described at the corresponding levels. The main purpose of CEM is the estimation of the structure of consumer preferences by emphasizing the relative importance of attributes. To achieve this goal, the person is asked to choose one of several choices that are gathered in a choice set and the utility that the person obtains from a particular option in a choice set is computed by the individual's utility of the levels of each attribute in the selected option (Sharzei and Jalili Kamjoo, 2013).

3.2. Economic valuation model

CVM and CEM have a common theoretical framework, so that both of them are expressed in the form of a random utility model (RUM). In this template, the indirect utility function of each individual can be shown as below (Adamowicz et al., 1998):

$$u_i = v_i + \varepsilon_i \quad (1)$$

This utility function consists of a visible component (v_i) and a random component (ε_i). In CEM, the visible component includes the characteristics of that selective option, but in CVM, it includes the suggestion variable and intercept. Econometric justification of the random component may be the eliminated variables, the measurement error and the audience's disregard relative to the decision taken. The existence of this component in the model makes it possible for the analyst to have a probabilistic explanation of consumer behavior (Adamowicz et al., 1998). In this situation, the individual will choose option i versus option j if the following relationship is instated (Adamowicz et al., 1998).

$$U_I > U_J \equiv v_i + \varepsilon_i > v_j + \varepsilon_j \tag{2}$$

This relationship can be rewritten in the form of possibilities and with more than one option, as shown below:

$$Pr(i) = Pr\{v_i + \varepsilon_i > v_j + \varepsilon_j; \forall\, i \neq j\} \tag{3}$$

The systematic component of utility is a part of the product's attractiveness, which could be related to its characteristics, so that its amount depends on the individual's ability to identify and measure them. Also, key factors, including individual characteristics, economic and social conditions can affect individual choices. An analyst must first define the correct combination of variables that make the individual's systematic preferences, then select the utility function that correctly predicts the relationship between defined variables and the choice of individuals (Adamowicz et al., 1998). The systematic component of the utility function can be shown as a linear function in the parameters, as below:

$$V_i = \acute{\beta} X_i \tag{4}$$

where, β is the vector of utility coefficients related to explanatory variables of a model including individual characteristics, price, product characteristics, and their interactions (Adamowicz et al., 1998). Therefore, the Relationship (4) can be rewritten as below:

$$Pr(i) = Pr\{\acute{\beta} X_i + \varepsilon_i > \acute{\beta} X_j + \varepsilon_j; \forall\, i \neq j\} \tag{5}$$

The choice is systematically different from person to person. In order to take into account these individual differences, it is necessary to use a set of explanatory variables, including psychological and demographic variables. Individual differences may affect utility by affecting the intercept component, and may change the vector of coefficients β. The final goal of estimating the choice model is unbiased estimation of taste parameters (vector β), which includes marginal utility of attributes (Adamowicz et al., 1998). One of the advantages of CEM is to compute the marginal willingness to pay (MWTP) for each of the attributes, so that the implicit price of the attribute indicates the final rate of substitution between non-market attributes and monetary attribute. The implicit price can be obtained from Equation (6) as the ratio of the coefficient of non-monetary attribute to the coefficient of monetary attribute (Adamowicz et al., 1998).

$$Marginal\ WTP = -\left[\frac{\beta\ non\ Monetarey}{\beta\ Monetarey}\right] \tag{6}$$

Conditional Logit (CL) Model: In the CL model, the explanatory variables change during the options, but the parameters remain constant during the options. In this model, the probability that alternative j will be selected is equal to (Isazadeh et al., 2012):

$$Pr[Y_i = j\ /\ W_i] = \frac{exp(\beta_{0,j} + \gamma_l w_{i,j})}{\sum_{l=1}^{J} exp(\beta_{0,l} + \gamma_l w_{i,l})} \tag{7}$$

$$j = 1, \ldots, J$$

In this model, the probability of choice depends on the explanatory variable as shown below (Isazadeh et al., 2012):

$$w_i = (w_{i,1}, w_{i,2}, \ldots, w_{i,J}) \tag{8}$$

One needs to apply a constraint to identify the intercept $\beta_{0j} = 0$ .So the parameter γ_l is the same for all options and is always identifiable, unless there is a common effect of γ_l on the probability:

$$w_{i,1} = w_{i,2} = \ldots = w_{i,J} \tag{9}$$

In this case, it becomes the multinomial logit model. The probability of selection in the CL model is also a nonlinear function of the parameter γ_l. There is no direct interpretation of the model coefficients and the explanatory variables to the dependent variable and the odds ratio is used to investigate the effect of the independent variables. The odds ratio (OR) of choosing option j against option l is calculated by the following equation (Isazadeh et al., 2012):

$$\varphi_{j/l}(w_i) = \frac{Pr[Y_i = j/w_i]}{Pr[Y_i = l/w_i]} = \frac{\exp(\beta_{0,j} + \gamma_l w_{i,j})}{\exp(\beta_{0,l} + \gamma_l w_{i,l})} = \exp(\beta_{0,j} - \beta_{0,l}) + \gamma_l(w_{i,j} + w_{i,l}) \tag{10}$$

$$l = 1, \ldots, J$$

The interpretation of the intercept parameter will be similar to the multinomial logit model. Therefore, individuals prefer option j to option i for positive amounts of γ_l and larger positive amounts of $(w_{i,j} - w_{i,l})$, so that $j \neq 1$. However, if $\gamma_l < 0$, the reverse effect is observed. The likelihood ratio in the non-logarithmic Equation (10) for the j option shows the effect of the change in the explanatory variables on the probability that the j option is selected compared to the other options (Isazadeh et al., 2012). One of the important necessities for restating the CL model is that selections from within a choice set must follow the Independence of Irrelevant Alternative (IIA) feature, and based on this feature, the presence or absence of an option does not affect the likelihood ratio associated with other available options in the choice set (Louviere, 2006). If the IIA is not accepted, more complex statistical models are needed to satisfy this assumption than CL. These models include the Multinomial Probit Model (Hausman and Wise, 1978), the Mixed Logit (ML) Model (Random Parameter Logit) (Train, 2003) and the Nested Logit Model (McFadden, 1978). There are various statistical tests that can be used to test the IIA hypothesis including the extended test by Hausman and McFadden (1984) which is widely used (Ghorbani and Firooz Zare, 2009). The Hausman-McFadden test is applied to test this property and its statistic is calculated by this equation (Isazadeh et al., 2012):

$$T = (\widehat{\beta}_r - \widehat{\beta})^{\prime}(\widehat{V}_r - \widehat{V})^{-1}(\widehat{\beta}_r - \widehat{\beta}) \sim\ \chi^2(\mathrm{m}) \tag{11}$$

Wherein, $\widehat{\beta}_r$ is a column vector of the estimated parameters in the unconstrained pattern, $\widehat{\beta}$ is the column vector of the estimated parameters in the constrained pattern, $\widehat{V}_r$ is the variance-covariance matrix of the constrained pattern and $\widehat{\beta}$ is the variance-covariance matrix of the unconstrained pattern. This test has a statistic called χ^2. The Hausman test is an application of comparing constrained and unconstrained models. At the completion of this test, the CL model is superior to the ML model.

3-3- AIC and BIC criteria to assess the goodness-of-fit of the statistical models:

The Akaike information criterion (AIC) is a mathematical method for evaluating how well a model fits the data it was generated from. AIC is most often used to compare the relative goodness-of-fit among different models under consideration and to then choose the model that best fits the data. AIC determines the relative information value of the model using the maximum likelihood estimate and the number of parameters (independent variables) in the model. Lower AIC values indicate a better-fit model. If a model is more than 2 AIC units lower than another, then it is considered significantly better than that model (Bevans, 2023).

The Bayesian information criterion (BIC) is a well-known general approach to model selection that favor more parsimonious models over more complex models (i.e., it adds a penalty based on the number of parameters being estimated in the model) (Schwarz, 1978; Raftery, 1995). Lower values indicate better model fit, and the model with the lowest BIC is generally preferred. BIC is a measure that considers both the likelihood value of a model and the number of parameters estimated. A good model, according to BIC, has a high likelihood value without using many parameters. This combination results in a low BIC value (Muthen and Muthen, 2000).

The AIC and the BIC are two popular measures for comparing maximum likelihood models. AIC and BIC are defined as (StataCorp, 2023):

$$\mathrm{AIC} = -2\ln L + 2K \tag{12}$$

$$\mathrm{BIC} = -2\ln L + K \ln N \tag{13}$$

Where, lnL is the maximized log-likelihood, K is the number of parameters estimated and N is the number of observations (StataCorp, 2023). The default K is always 2, so if your model uses one independent variable your K will be 3, if it uses two independent variables your K will be 4, and so on (Bevans, 2023).

3.3. Identifying the attributes

Attributes and their levels in the study questionnaire are presented (Table 1).

According to the defined attributes and their levels, the number of possible options for CE will be 125, but it is not possible to test this number of options and a limited number of these options should be selected using statistical methods. Accordingly, using the JMP software package based on the Fractional Factorial Design, 32 options were selected and 16 choice sets each containing two options were formed. Then a none-option or the status quo (SQ) was added to each choice set and divided into two blocks with 8 choice sets and placed into two separate questionnaires. In other words, each choice set consists of two hypothetical policies to guarantee agricultural water supply and a none-option or SQ option. An example of the choice set that was provided to the farmers has been presented (Table 2).

This research is based on the positivist paradigm, and the methodology of this research is quantitative that the data collection tool is a questionnaire.

3.4. Sampling method

The statistical population of this study was farmers in Marvdasht County. The data used in this study was collected in 2015 through a questionnaire and field studies in this County. A stratified random sampling method was used to select farmers. According to this sampling method, first the study area was divided into three classes of low-water, medium-water and almost full-water based on the amount of water resources and each of the villages in this area was assigned to each of the three groups according to the status of their water resources. A pilot study was performed to determine the number of samples in each class. The variance of the studied trait (area under cultivation) for each of the low-water, medium-water and almost full-water classes was calculated at 27.7, 41 and 54.8, respectively. According to the variance of the area under cultivation and the number of farmers in each class given in Table 3, using equation (14) which determines the number of samples in the stratified random sampling method, the total sample size was determined.

Table 1
Attributes and their levels.

Attribute	**Level**
Amount of guaranteed water supply (m^3/ha)	18900
	19240
	19604
	19838
	20229
Water supply measures	Water transfer from Doroodzan dam and river
	Use of treated urban wastewater
	Control over groundwater abstraction
	Strengthening and development of agricultural water market
	Use of water-saving technologies
Water price (IRR/m^3)	130
	150
	170
	190
	210

Table 2
Example of a choice set.

Attributes	Plan A	Plan B	**None**
Amount of guaranteed water supply (m^3/ha)	18900	19240	18666 (Your status quo (SQ) that is without guarantee)
Water supply measures	Water transfer from Doroodzan dam and river	Use of treated urban wastewater	Without any measures (Well and dam water)
Water price (IRR/m^3)	130	190	110
Choice	☐	☐	☐

Table 3
The number of farmers and the variance of the area under cultivation in three classes.

Area	Number of farmers.	Variance of the area under cultivation
Low-water	5929	27.7
Medium-water	6209	41
Almost full-water	8363	54.8
All areas	20501	

$$n = \frac{\sum_{i=1}^{l} N_i \,\delta_i^{\,2}}{ND + \frac{1}{N}\sum_{i=1}^{l} N_i \,\delta_i^{\,2}} \tag{14}$$

Where, N is the number of sampling units in the population, N_i is the number of sampling units in the i-th class, L is the number of classes, $\delta_i^{\,2}$ is the variance of the studied trait in the i-th class, D is equal to $\frac{\beta^2}{4}$ where β is the amount of desired error by the analyst. According to equation (14) and the information related to the number of farmers and pilot study (variance of the area under cultivation in each class) given in Table 3 and considering $\beta = 1$, the total sample size was obtained at 170. The information related to the number of farmers and the variance of the area under cultivation in three classes that has been obtained by conducting the pilot study can be seen in Table 3:

In the next step, according to the total sample size obtained from equation (14), the sample size in each of the three classes was proportionally allocated using equation (15) given below.

$$n_i = n\left(\frac{N_i}{\sum_{i=1}^{l} N_i}\right) = n\left(\frac{N_i}{N}\right) \tag{15}$$

Sample sizes for low-water, medium-water and almost full-water areas were obtained at 49, 52 and 69, respectively.

3.5. Variables and models specification

The variables that were entered in the CL model and CL model with interaction effects have been presented (Table 4).

In this study, Stata14, SPSS22 and Excel 2013 software packages have been used in different stages for the purpose of estimations and different statistical operations.

We used the Statistics > Binary outcomes > Conditional logistic regression menu and the following syntaxes to estimate the conditional logit model and conditional logit model with interaction effects in Stata14, respectively:

clogit choice sq guarand price trans ground market techno, group (idvar).

Table 4
Selected variables in the model.

Variable name	Definition of variable	**Operational form of variables in the model (Coding of variables)**
Status quo (SQ)	The current situation of farmers	Dummy variable Without water supply measures (SQ) = 1 With water supply measures = 0
Water price (PRICE)	Corresponding levels of PRICE	Continuous variable
Amount of guaranteed water supply (GUARAN)	Corresponding levels of GUARAN	Continuous variable
Water transfer from Doroodzan dam and river (TRANS)	The first level of water supply measures	Dummy variable Water transfer from Doroodzan dam and river = 1 Other water supply measures and SQ = 0
Control over groundwater abstraction (GROUND)	The third level of water supply measures	Dummy variable Control over groundwater abstraction = 1 Other water supply measures and SQ = 0
Strengthening and development of agricultural water market (MARKET)	The fourth level of water supply measures	Dummy variable Strengthening and development of agricultural water market = 1 Other water supply measures and SQ = 0
Use of water-saving technologies (TECHNO)	The fifth level of water supply measures	Dummy variable Use of water-saving technologies = 1 Other water supply measures and SQ = 0
Age (AGE)	Age of the studied people	Continuous variable
Education (EDU)	Education level of the studied people	Dummy variable Diploma and under diploma people = 0 Top of diploma = 1″
Income (INC)	The monthly income of the studied people	Less than 1 million tomans = 1 1 to 2 million tomans = 2 2 to 3 million tomans = 3 More than 3 million tomans = 4
Area under cultivation (AREA)	Area under cultivation of the studied people	Continuous variable
Product type (PRODU)	The planted product type by the studied people	Dummy variable Products with high water requirement = 1 Products with low water requirement = 0
Flooded irrigation system (FLOOD)	Irrigation system type of the studied people	Dummy variable Flooded irrigation system = 1 Pressurized irrigation system, flooded and pressurized irrigation system together = 0
Well irrigation source (WELL)	Irrigation source type of the studied people	Dummy variable Well irrigation source = 1 River, river and well irrigation source together = 0

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clogit choice sq guarand price trans ground market techno pricearea sqage sqedu sqinc sqarea sqprodu sqflood sqwell, group (idvar).
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Choice is dependent variable, indicating choice of plan A or B or none of them and its amount is 1 for selected option and 0 for not selected option also idvar indicates each unique choice made by respondent on survey that its numbers for all 3 choices in every choice set for every respondent are the same.

According to the function 4, the utility function of individual i for alternative j (V_{ij}) in conditional logit model and conditional logit model with interaction effects can be written as bellow, respectively:

$$V_{ij} = \beta_s\,SQ + \beta_p\,PRICE + \beta_g\,GUARAN + \beta_t\,TRANS + \beta_{gr}\,GROUND + \beta_m\,MARKET + \beta_t\,TECHNO$$

$$V_{ij} = \beta_s\,SQ + \beta_p\,PRICE + \beta_g\,GUARAN + \beta_t\,TRANS + \beta_{gr}\,GROUND + \beta_m\,MARKET + \beta_t\,TECHNO + \beta_{pa}\,PRICE{*}AREA + \beta_{sa}\,SQ{*}AGE + \beta_{se}\,SQ{*}EDU + \beta_{si}\,SQ{*}INC + \beta_{sar}\,SQ{*}AREA + \beta_{sp}\,SQ{*}PRODU + \beta_{sf}\,SQ{*}FLOOD + \beta_{sw}\,SQ{*}WELL$$

Where β_s, β_p, β_g are the coefficients for the status quo, water price and amount of guaranteed water supply, respectively, and β_t, β_{gr}, β_m, β_t are the coefficients for the various water supply measures. β_{pa} is the coefficient for interaction effect between water price and area under cultivation (PRICE*AREA) also β_{sa}, β_{se}, β_{si}, β_{sar}, β_{sp}, β_{sf}, β_{sw} are the coefficients for interaction effects of status quo with age (SQ*AGE), education (SQ*EDU), income (SQ*INC), area under cultivation (SQ*AREA), product type (SQ*PRODU), flooded irrigation system (SQ*FLOOD) and well irrigation source (SQ*WELL), respectively.

4. Results and discussion

4.1. CL model for low-water area

The results of the CL model for low-water area are presented (Table 5). As it is clear from the table, the coefficients (Coef.) and possibility (P) for status quo, water price, amount of guaranteed water supply, water transfer from Doroodzan dam and river, control over groundwater abstraction, strengthening and development of agricultural water market, use of water-saving technologies variables are −0.832, −0.006, 0.000, 0.457, 0.546, 0.524, 1.373 and 0.005, 0.032, 0.996, 0.039, 0.015, 0.018, 0.000 respectively. It is observed that all coefficients except one for amount of guaranteed water supply attribute are significant at the level of 1%. In such models, the interpretation of coefficients is not done directly, except for the interpretation of the significance and relative size of the coefficients. Due to the insignificance of amount of guaranteed water supply, it can be concluded that this attribute at available levels is not important to the farmers in this area and does not play a significant role in their preferences. In other words, most farmers in this area have had a similar reaction to this component, while other variables play a role in their preferences due to their significance. The positive signs of the coefficients of variables, such as water transfer from Doroodzan dam and river, control over groundwater abstraction, strengthening and development of agricultural water market, use of water-saving technologies indicate that farmers in this area accept policies which have applied water supply measures, such as water transfer from Doroodzan dam and river, control over groundwater abstraction, strengthening and development of agricultural water market or use of water-saving technologies. The negative sign of the price coefficient indicates that farmers in this area do not prefer policies that lead to an increase in water price. This matter corresponds with the utility economic theory that a price increase leads to a decrease in utility by being constant for the rest of the conditions (Hashemi Bonab, 2012). In addition, one can see that the largest coefficient is estimated for the use of water-saving technologies. Control over groundwater abstraction, strengthening and development of agricultural water market, water transfer from Doroodzan dam and river and amount of guaranteed water supply are in the second, third, fourth and fifth ranks, respectively. The negative sign of the status quo coefficient indicates that farmers in this area prefer policies that guarantee irrigation water supply to their current situation, that there is no guarantee for amount of water supply, no complementary measures are taken to ensure water supply in the future and water price remains unchanged.

There are examples and case studies to illustrate how these policies

Table 5
Results of CL for low, medium and almost full-water areas.

Variable	Low-water area			Medium-water area			**Almost full-water area**		
	Coef.	Std. Err.	P	Coef.	Std. Err.	P	Coef.	Std. Err.	**P**
SQ	−0.832	0.300	0.005	−0.313	0.300	0.297	−0.842	0.261	0.001
PRICE	−0.006	0.003	0.032	−0.005	0.003	0.053	−0.004	0.002	0.082
GUARAN	0.000	0.000	0.996	0.000	0.000	0.265	0.000	0.000	0.013
TRANS	0.457	0.221	0.039	0.872	0.225	0.000	−0.183	0.189	0.331
GROUND	0.546	0.224	0.015	0.901	0.228	0.000	0.690	0.187	0.000
MARKET	0.524	0.221	0.018	0.308	0.230	0.182	0.340	0.185	0.066
TECHNO	1.373	0.270	0.000	1.320	0.269	0.000	1.079	0.225	0.000
Obs	1176			1248			1656		
LL	−381.19			−406.01			−513.56		
LR chi2(7)	98.94		0.000	102.03		0.000	185.76		0.000
Pseudo-R^2	0.11			0.11			0.15		

might impact agricultural practices in the studied areas:

Water-saving technologies have a significant impact on the production efficiency of high-quality farmers. By mastering water-saving technologies, high-quality farmers can better utilize water resources, improve irrigation efficiency and soil fertility, thereby increasing agricultural production efficiency and farmers' income (Xiankai and Dongmei, 2024).

Findings of Foster et al. (2017) have important implications for research and policy related to groundwater management. They suggest that, in a depleting aquifer, efforts to reduce groundwater use should be targeted spatially and temporally to minimize future reductions in well yields and resultant negative impacts on agricultural productivity and resilience to drought.

In order to increase the efficiency of water consumption, increase the income of farmers, reduce the risk of farmers' income, increase the investment of the private sector in the Iran's water industry, increase the participation of people in the management of water resources, and reduce the government's expenses in the management and distribution of water resources, it is necessary to form and strengthen water markets should be taken into consideration by the policy makers of the water industry and the agricultural sector (Jofreh and Alizadeh, 2010).

Hailiang et al. (2008) investigated the water transfer effects on agricultural development in the lower Tarim River, Xinjiang of China. Water transfer improved greatly both agricultural production and animal husbandry, the areas utilized or available for farming increased greatly; furthermore, the total value of agricultural production increased by 128%.

Mesa-Jurado et al. (2012) concluded that, when water is scarce, farmers have non-market values associated with increased guarantee in addition to direct use for supplied water. This means that farmers perceive benefits in this change as their welfare increases, providing evidence of the predisposition to measures or strategies that permit such improvement.

Zamani et al. (2021) found that a water-pricing policy can change the cropping pattern and also irrigation system within the limitations of the case study. It can also be a driver to motivate farmers to use a modern and more efficient irrigation system.

4.2. *CL model for medium-water area*

The results of the CL model for medium-water area are presented in Table 5. Based on the presented information in this table, it is observed that the coefficients of measures, such as water transfer from Doroodzan dam and river, control over groundwater abstraction and use of water-saving technologies are significant at the level of 1%, which has been important to the farmers in this area and plays a role in their preferences. The coefficients of attributes, such as amount of guaranteed water supply, and strengthening and development of agricultural water market, are not significant and therefore, not important to farmers. In fact, the farmers in this area have had a similar reaction to these components. The positive signs of the coefficients of water transfer from Doroodzan dam and river, control over groundwater abstraction and use of water-saving technologies indicate that farmers in this area accept policies which have applied water supply measures such as water transfer from Doroodzan dam and river, control over groundwater abstraction and use of water-saving technologies. The price is significant and its coefficient is negative, which indicates farmers in this area do not prefer policies that lead to an increase in water price because it reduces their utility. This subject corresponds with the utility economic theory that a price increase leads to a decrease in utility by being constant for the rest of the conditions (Hashemi Bonab, 2012). In addition, we can see that the largest coefficient is estimated to the use of water-saving technologies. Control over groundwater abstraction, water transfer from Doroodzan dam and river, strengthening and development of agricultural water market and amount of guaranteed water supply are in the second, third, fourth and fifth ranks, respectively. The coefficient of the status quo variable is not significant and its sign is negative, which indicates farmers in this area do not care about the current situation and it has no role in their preferences.

4.3. *CL model for almost full-water area*

The results of the CL model for almost full-water area are presented in Table 5. Based on the presented information in this table, it is observed that the coefficients of attributes such as amount of guaranteed water supply, control over groundwater abstraction and use of water-saving technologies are significant at the level of 1%. Also, the coefficients of attributes such as water transfer from Doroodzan dam and river and strengthening and development of agricultural water market are not significant. This means that they are unimportant to the farmers. In other words, the farmers in this area have had a similar reaction to these components. The positive signs of the coefficients of amount of guaranteed water supply, control over groundwater abstraction and use of water-saving technologies indicate that farmers in this area accept policies which increase amount of guaranteed water supply and have applied water supply measures such as control over groundwater abstraction and use of water-saving technologies. In addition, the variable of water price is not significant and its coefficient sign is negative, which indicates the water price changes are unimportant to farmers in this area and are ineffective in their preferences. In addition, we can see that the largest coefficient is estimated for the use of water-saving technologies. Control over groundwater abstraction, strengthening and development of agricultural water market, water transfer from Doroodzan dam and river and amount of guaranteed water supply are in the second, third, fourth and fifth ranks, respectively. The coefficient of the status quo variable is significant and its sign is negative, which indicates farmers in this area prefer policies that guarantee irrigation water supply to their current situation.

4.4. CL model for all areas

The results of the CL model for all areas are presented in Table 6. Based on the presented information in this table, it was observed that all of the coefficients are significant at the level of 1%. The positive signs of coefficients of variables such as amount of guaranteed water supply, water transfer from Doroodzan dam and river, control over groundwater abstraction, strengthening and development of agricultural water market and use of water-saving technologies indicate that farmers in all areas accept policies which increase the amount of guaranteed water supply and have applied water supply measures such as water transfer from Doroodzan dam and river, control over groundwater abstraction, strengthening and development of agricultural water market and use of water-saving technologies. In other words, the farmers in the whole area prefer all attributes of policies that guarantee the supply of irrigation water. The negative sign of price variable means that the options with higher suggested prices reduce the utility of farmers and have a lower probability of choice than other options. In other words, the farmers in all areas did not prefer policies that lead to an increase in water price. This subject corresponds with the utility economic theory that a price increase leads to a decrease in utility by being constant for the rest of the conditions (Hashemi Bonab, 2012). In addition, one can see that the largest coefficient was for the use of water-saving technologies. Control over groundwater abstraction, strengthening and development of agricultural water market, water transfer from Doroodzan dam and river and amount of guaranteed water supply are in the second, third, fourth and fifth ranks, respectively. The negative sign of the status quo variable indicates that farmers in the whole area under study prefer policies that guarantee irrigation water supply to their current situation.

Since in CL models only the sign of the coefficients is interpreted, and since in this study the CEM was used, one can interpret the numerical amount of the coefficient so that larger coefficients can reflect the greater importance of attribute because it ultimately leads to more WTP. According to the results in Table 5 (in all three areas, including low, medium and almost full-water) as well as in Table 6 for all areas together, use of water-saving technologies is more important to farmers and leads to higher WTP for it compared to the other options.

4.5. Results of the CL model with interaction effects

Since socio-economic variables are the same throughout the choice sets but are different from person to person, to enter them, the interaction effects of these variables with the status quo and the interaction effect of price with the area under cultivation were added into the CL model. In this section, the results of the CL model with interaction effects for all three areas, including low, medium and almost full-water, as well as all areas are presented.

4.5.1. Low-water area

The results in Table 7 show that only the variables of the interaction effect that were found to be significant were age and the status quo, and well irrigation source and the status quo; other interaction effects were insignificant in the low-water area. On the other hand, the coefficients of the mentioned variables have become positive, which shows that an increase in the age of farmers raises the tendency to choose the current situation. Also, the positive sign of the coefficient of interaction effect between the well irrigation source and the status quo indicates that farmers using the well irrigation source tend to choose the status quo in this area compared to those using the river or river and well irrigation source together.

Table 6
Results of CL model for all areas.

Variable	Coef.	Std. Err.	P
SQ	−0.674	0.163	0.000
PRICE	−0.005	0.001	0.001
GUARAN	0.000	0.000	0.025
TRANS	0.321	0.119	0.007
GROUND	0.702	0.120	0.000
MARKET	0.384	0.119	0.001
TECHNO	1.218	0.144	0.000
Obs	4080		
LL	−1319.22		
LR chi2(7)	349.78		0.000
Pseudo-R^2	0.12		

4.5.2. Medium-water area

The results of Table 7 show that only the variable of the interaction effect of flooded irrigation system and status quo was significant in this area, and other interaction effects have become insignificant. The positive sign of the variable coefficient of interaction effect of flooded irrigation system and status quo indicates that farmers using the flooded irrigation system tend to choose the status quo compared to those using the pressurized irrigation system or both of them together in this area.

4.5.3. Almost full-water-area

The results of Table 7 show that only three variables of the interaction effect were significantly different from zero. These were: age and the status quo, education and status quo, and well irrigation source and status quo. In this area, the coefficients for the interaction effect of age, and the status quo and the interaction effect of the well irrigation source and the status quo, have become positive, similar to that observed for the low-water area. This indicates that older farmers and farmers using well water prefer the status quo in this area compared to those using the river or river and well water together. The negative sign of the variable coefficient of interaction effect of education and status quo indicates that farmers with higher levels of education have more tendency to accept the irrigation water policies to guarantee water supply in this area.

4.5.4. All areas

The results of the CL model with interaction effects for all areas are presented in Table 8. The results show that only the variables of interaction effect of age and status quo and that between education and status quo were significant in the combined all areas. Their coefficients were positive and negative, respectively, suggesting that the younger farmers and the farmers with higher levels of education have more tendency to accept the irrigation water policies to guarantee water supply in all areas rather than the status quo. Although it was expected that farmers who have more area under cultivation, are less sensitive to high water price, the results of this study showed that the interaction effect of price and area under cultivation variable was not statistically significant.

4.6. Assessing the goodness-of-fit of the statistical models

4.6.1. LR chi2 and pseudo-R2 statistics

LR chi2 and pseudo-R2 statistics for CL and CL model with interaction effects are presented in Table 9. LR represents the likelihood ratio criterion that is used to test the significance of the whole regression. Based on the obtained results, the null hypothesis based on the insignificance of all coefficients is rejected for all models. Pseudo-R2 represents the explanatory power of the model. According to Louviere et al. (2000), in order that the results of the model to be acceptable, the McFadden statistic or Pseudo-R2 of the model must be above 0.1 and in other words, its amount in the range of 0.2–0.3 is equal to its amount in the ordinary least squares in the range of 0.7–0.9. The amount of this statistic for CL model for low, medium, almost full-water areas, all areas and CL model with interaction effects for low, medium and almost full-water areas, all areas are equal to 0.11, 0.11, 0.15, 0.12, 0.17, 0.13, 0.19, 0.13, respectively, which indicates the good explanatory power of all models.

Table 7
Results of CL model with interaction effects for low, medium and almost full-water areas.

Variable	Low-water area			Medium-water area			**Almost full-water area**		
	Coef.	Std. Err.	P	Coef.	Std. Err.	P	Coef.	Std. Err.	**P**
SQ	−2.789	0.838	0.001	−0.063	0.889	0.944	−3.645	0.926	0.000
PRICE	−0.001	0.003	0.608	−0.005	0.006	0.338	−0.005	0.003	0.055
GUARAN	−0.000	0.000	0.778	0.000	0.000	0.291	0.000	0.000	0.009
TRANS	0.409	0.225	0.070	0.860	0.226	0.000	−0.166	0.189	0.379
GROUND	0.514	0.226	0.023	0.893	0.229	0.000	0.716	0.188	0.000
MARKET	0.465	0.224	0.038	0.294	0.231	0.204	0.371	0.187	0.047
TECHNO	1.306	0.273	0.000	1.303	0.270	0.000	1.123	0.227	0.000
PRICE*AREA	−0.000	0.000	0.095	0.000	0.000	0.959	0.000	0.000	0.352
SQ*AGE	0.058	0.013	0.000	−0.003	0.125	0.805	0.042	0.012	0.000
SQ*EDU	−0.672	0.374	0.073	−0.095	0.316	0.765	−0.885	0.312	0.005
SQ*INC	−0.253	0.180	0.158	−0.075	0.167	0.656	0.181	0.156	0.247
SQ*AREA	−0.003	0.154	0.825	−0.010	0.040	0.809	−0.119	0.015	0.442
SQ*PRODU	0.101	0.423	0.811	0.500	0.277	0.071	0.467	0.312	0.134
SQ*FLOOD	−0.255	0.326	0.434	0.743	0.301	0.013	−0.002	0.308	0.996
SQ*WELL	1.023	0.375	0.006	−0.412	0.323	0.202	1.369	0.511	0.007
Obs	1176			1248			1656		
LL	−357.20			−399.33			−489.87		
LR chi2(7)	146.91		0.000	115.38		0.000	233.14		0.000
Pseudo-R^2	0.17			0.13			0.19		

Table 8
Results of CL model with interaction effects for all areas.

Variable	Coef.	Std. Err.	**P**
SQ	−0.792	0.441	0.000
PRICE	−0.004	0.002	0.026
GUARAN	0.000	0.000	0.032
TRANS	0.310	0.119	0.009
GROUND	0.696	0.121	0.000
MARKET	0.371	0.120	0.002
TECHNO	1.206	0.145	0.000
PRICE*AREA	−0.000	0.000	0.612
SQ*AGE	0.031	0.007	0.000
SQ*EDU	−0.668	0.176	0.000
SQ*INC	0.019	0.086	0.828
SQ*AREA	−0.008	0.009	0.369
SQ*PRODU	0.215	0.166	0.195
SQ*FLOOD	0.073	0.162	0.650
SQ*WELL	0.323	0.193	0.094
Obs	4080		
LL	−1291.82		
LR chi2(7)	404.58		0.000
Pseudo-R^2	0.13		

4.6.2. *AIC and BIC criteria*

According to equations (12) and (13) and the amount of lnL, N, K in Tables 5–8, AIC and BIC for CL and CL models with interaction effects are calculated and presented in Table 10.

When fitting models, it is possible to increase the maximum likelihood by adding parameters, but doing so may result in overfitting. Both BIC and AIC attempt to resolve this problem by introducing a penalty term for the number of parameters in the model; the penalty term is larger in BIC than in AIC for sample sizes greater than 7 (Stoica and Selen 2004). BIC favourises more parsimonious models than AIC due to its penalization (Gilbert, 2007) BIC is consistent. A consistent selector is one which will select the true model with probability approaching 100% as the number of observations (N) tends to infinity. AIC is not consistent because it has a non-vanishing chance of choosing an unnecessarily complex model as N becomes large (John et al., 2020).

In this study the number of observations for statistical models are large so for choosing the best models we use BIC criteria. BIC criteria for CL model for low, medium, almost full-water area and all areas together are 826.01, 876.18, 1093.83 and 2713.26 also these figures for CL model with interaction effects for low, medium, almost full-water area and all areas together are 834.59, 919.86, 1105.75 and 2724.91, respectively, which these amount for CL models are lower than them for CL models with interaction effects in every area. Therefor CL models are preferable compared to CL models with interaction effects.

4.7. *Calculation of willingness to pay (WTP)*

Due to the impossibility of direct interpretation of coefficients in such models, the final rate of substitution between non-market attributes and monetary attribute was calculated. The results of this calculation can be interpreted as the average ratio of marginal willingness to pay (MWTP) to change each attribute or the implicit prices of each attribute (Hausman and McFadden, 1984). In this study, the implicit price has been calculated as MWTP for farmers through an increase in water price per m^3 for a change in each of the attributes of policies to guarantee irrigation water supply for two models (Table 11).

Table 10
AIC and BIC for CL and CL model with interaction effects.

Statistical models	AIC	**BIC**
CL model for low-water area	780.38	826.01
CL model for medium-water area	830.02	876.18
CL model for almost full-water area	1045.12	1093.83
CL model for all areas	2656.44	2713.26
CL model with interaction effects for low-water area	748.40	834.59
CL model with interaction effects for medium-water area	832.66	919.86
CL model with interaction effects for almost full-water area	1013.74	1105.75
CL model with interaction effects for all areas	2617.64	2724.91

Table 9
LR chi2 and pseudo-R2 statistics for CL and CL model with interaction effects.

Statistic	**CL model**				CL model with interaction effects			
	Low-water	**Medium-water**	**Almost full-water**	**All areas**	**Low-water**	**Medium-water**	**Almost full-water**	All areas
LR chi2 (7)	98.94 (0.000)	102.03 (0.000)	185.76 (0.000)	349.78 (0.000)	146.91 (0.000)	115.38 (0.000)	233.14 (0.000)	**404.58 (0.000)**
Pseudo-R2	0.11	0.11	0.15	0.12	0.17	0.13	0.19	**0.13**

Results for the CL model with interaction effects are not compatible with reality or, in other words, are very far from reality, but in the first model, which is the CL, the results are consistent with reality and its results can be used as a basis of calculating WTP also according to the BIC criteria CL models are preferable compared to CL models with interaction effects. Since WTPs in the CL model are compatible with reality and did not lead to illusory results, it is not necessary to do the IIA test (In this study, other models including the ML Model were estimated, but because MWTPs had not much difference to the CL model, CL is sufficient). The highest WTP of farmers for amount of guaranteed water supply was estimated for low-water area. This shows that farmers are willing to pay more for amount of guaranteed water supply attribute in low-water area than those in the other two areas due to water shortage and no guarantee of irrigation water. The WTP of farmers for this attribute in the almost full-water and medium-water areas ranked second and third, respectively. The highest WTP of farmers for water transfer from Doroodzan dam and river attribute and control over groundwater abstraction attribute were estimated for the medium-water area. The WTP of farmers for water transfer from Doroodzan dam and river attribute in the low-water and almost full-water areas have the second and third ranks, respectively. The WTP of farmers for this attribute have been negative in the almost full-water area. In other words, WTP is less than the willingness to receive. This shows that the farmers in this area do not tend to pay for the transfer of water from the Doroodzan Dam, but they have willingness to receive because the wells of the farmers in this area have enough water and they do not have any limitations on water use. In fact, it can be inferred that if water is supplied from Doroodzan Dam, they have to limit the water abstraction of the well so that somehow the government has to pay reserve subsidy for non-abstraction of well water, which is one of the policies of the water sector. The farmers in low-water area had the highest WTP for the strengthening and development of agricultural water market attribute. In other words, they are willing to pay more money than the other two areas in order to develop and strengthen the agricultural water market. Also, WTP of farmers for this attribute in the almost full-water and medium-water areas are in the second and third ranks, respectively. Also, the farmers in the almost full-water area have the highest WTP for the use of water-saving technologies, because the area under cultivation for the pressurized irrigation in this area is less than the other two areas and the farmers in this area have more tendency to implement it. The WTP of farmers for this attribute in the medium-water and low-water areas are in the second and third rank, respectively. The highest WTP of farmers is related to the use of water-saving technologies in all three areas. According to the results of Tables 11, it can be observed that the highest WTP for the use of water-saving technologies is 254.89 IRR per m^3 and the lowest WTP for amount of guaranteed water supply is 0.05 IRR per m^3 for each farmer in the whole of area under study. WTP of farmers for control over groundwater abstraction, strengthening and development of agricultural water market and water transfer from Doroodzan dam and river are 146.92, 80.33 and 67.21 IRR per m^3, respectively. These are in the second, third and fourth ranks, respectively. WTP of farmers for water supply measures is more than WTP for amount of guaranteed water supply. Alcon et al. (2014) implemented a similar study in Segura, the basin of a low-water river in the south-east of Spain and found that the highest WTP for amount of guaranteed water supply and the lowest WTP is related to the strengthening and development of agricultural water market. Considering that WTP for amount of guaranteed water supply was higher than WTP for water supply measures in the recent study, it can be found that the results of this study are not in the same direction with the study of Alcon et al. (2014).

Calculating WTP estimates for water policy decision-making is a complex task that involves various limitations and uncertainties. It's important to recognize these limitations to ensure that WTP estimates are interpreted and used appropriately including:

Hypothetical bias (respondents may not behave the same way in real situations) and strategic behavior (respondents may manipulate their answers to influence policy outcomes) can affect the accuracy of WTP estimates (Whittington et al., 1990; Gschwandtner et al., 2020).

WTP estimates heavily depend on the information provided to respondents during valuation surveys. The way the survey questions are framed, the complexity of the information, and the context in which the valuation is conducted can influence respondents' WTP responses. Small changes in framing or information presentation may lead to significantly different WTP estimates (Wang et al., 2010; Tussupova et al., 2015).

The accuracy of WTP estimates depends on the representativeness of the sample used in the valuation survey. If the sample does not adequately represent the target population in terms of demographics, socioeconomic status, or geographic distribution, the estimates may not reflect the true preferences of the broader population (Kwak et al., 2013; Balana et al., 2013).

In summary, while WTP estimates provide valuable information for water policy decision-making, their limitations and uncertainties should be carefully considered. Acknowledging these limitations and adopting a multidimensional approach can enhance decision-making processes and promote more sustainable and equitable water policies.

5. Conclusion and policy implication

In this study, which was carried out using the CE framework and estimated using the CL model, WTP of farmers in Marvdasht County, who do not have an amount of guaranteed irrigation water supply due to frequent droughts and a reduction in the level of groundwater, was investigated for attributes of agricultural water policies to guarantee water supply in 2015. Also, the CL model with interaction effects has been used to import the socio-economic characteristics of farmers. Estimation of the CL model with interaction effects showed that age and education have negative and positive significant effects on WTP of farmers in all areas, respectively. WTP of farmers in low-water area for attributes, such as amount of guaranteed water supply, water transfer from Doroodzan dam and river, control over groundwater abstraction, strengthening and development of agricultural water market and use of water-saving technologies were 1.60, 78.69, 94.01, 90.32, 236.38; in the medium-water area were 0.039, 168.32, 173.90, 59.42, 254.84; in the almost full-water area were 0.097, −45.81, 172.20, 84.81, 269.35 and in all areas are 0.05, 67.21, 146.92, 80.33, 254.89 IRR per m^3, respectively. In other words, the highest and the lowest WTP of farmers are related to the use of water-saving technologies and amount of guaranteed water supply in the low-water and medium-water areas,

Table 11
MWTP of farmers for attributes in CL model and CL model with interaction effects (IRR/m^3).

Attributes	CL Model				**CL model with interaction effects**			
	Areas			All areas	Areas			**All areas**
	Low-water	Medium- water	Almost full- water		Low-water	Medium- water	Almost full-water	
GUARAN	1.60	0.039	0.097	0.05	−0.03	0.04	0.08	0.05
TRANS	78.69	168.32	−45.81	67.21	224.17	158.43	−31.34	74.43
GROUND	94.01	173.90	172.20	146.92	281.70	164.61	134.85	166.93
MARKET	90.32	59.42	84.81	80.33	255.07	54.16	69.88	89.06
TECHNO	236.38	254.84	269.35	254.89	716.25	240.04	211.51	289.32

respectively. The highest and the lowest WTP of farmers are related to the use of water-saving technologies and water transfer from Doroodzan dam and river in the almost full-water area, respectively. In other words, the farmers in this area have a willingness to receive for water transfer from Doroodzan dam and river measure. Also, the farmers in all areas have the highest to the lowest WTP for attributes such as use of water-saving technologies, control over groundwater abstraction, strengthening and development of agricultural water market, the water transfer from Doroodzan dam and river and amount of guaranteed water supply, respectively. According to the results, it is suggested that policy makers in Iran (and those for the Fars province) need to pay attention to this prioritization of the adopted policies and decisions to guarantee irrigation water supply. Furthermore, the policies aimed at the adoption of water-savings technologies should be given a higher preference. The result of the study recommended that water policy has significant impacts on the world, affecting various aspects of human life, the environment, and socioeconomic development. In this study, some key impacts of water policy are mentioned: Water Resource Management: Effective water policies help in managing water resources sustainably. They involve strategies for water allocation, conservation, and pollution control. By ensuring the availability of clean and adequate water supplies, water policies promote public health, agriculture, industry, and ecosystem preservation. Access to Clean Water: Water policies play a crucial role in ensuring access to clean drinking water for communities. They address issues of water quality, sanitation, and hygiene, particularly in developing regions where waterborne diseases are prevalent. Accessible and affordable clean water improves public health, reduces child mortality, and enhances overall well-being. Agricultural Production: Water policies influence agricultural practices and productivity. They often include irrigation management, water pricing mechanisms, and incentives for efficient water use. By promoting sustainable agricultural water management, policies can enhance food security, increase crop yields, and reduce water-related conflicts between different sectors. Industrial and Energy Sectors: Water is essential for various industrial processes and energy generation. Water policies guide the allocation and use of water resources among industrial sectors, ensuring equitable distribution and efficient utilization. Policies may encourage water recycling, efficiency measures, and the use of alternative water sources, minimizing the environmental impact of industrial activities. Ecosystem Conservation: Water policies consider the needs of ecosystems and biodiversity. They aim to protect and restore aquatic habitats, wetlands, and river systems. By maintaining ecological balance, water policies support the health of ecosystems, preserve biodiversity, and safeguard the services provided by natural water systems. Climate Change Adaptation: Water policies increasingly focus on climate change adaptation. They address the potential impacts of climate change on water availability, such as altered precipitation patterns and rising sea levels. Policies may include measures like water storage infrastructure, flood management, and drought preparedness, ensuring resilience in the face of climate-related challenges (Karamidehkordi et al., 2024). Transboundary Water Management: Many water bodies cross national boundaries, leading to shared water resources. Water policies facilitate cooperation and negotiation among countries for the equitable and sustainable management of transboundary waters. International agreements and frameworks are crucial in preventing conflicts and promoting collaboration in water management. Economic Development: Water policies have economic implications at various scales. They influence sectors such as agriculture, industry, tourism, and transportation, which rely on water resources. Effective policies can stimulate economic growth, create employment opportunities, and attract investments in water-related infrastructure. Social Equity: Water policies aim to ensure equitable distribution and access to water resources, particularly among marginalized communities. They address issues of water affordability, water rights, and social inclusion. By promoting social equity, water policies contribute to reducing poverty, improving livelihoods, and fostering social cohesion. Conflict Prevention: Water scarcity and competition for water resources can lead to conflicts and tensions between different stakeholders. Well-designed water policies help prevent conflicts by establishing clear rules, promoting dialogue, and fostering cooperation among users. By providing a framework for equitable and peaceful water management, policies contribute to stability and peace-building efforts. It is important to note that the impacts of water policy can vary depending on local contexts, governance structures, and the effectiveness of policy implementation.

Every research has a series of research limitations. This research includes several research limitations in the data collection phase, which including:

- The lack of sufficient funds to collect data from all the villages of the county.
- The lack of sufficient knowledge of farmers in completing the questionnaires, which leads to spending a lot of time in helping farmers to complete the questionnaires.
- The lack of trust of local communities in the field of data collection.
- The large dispersion of villages from each other, which led to spending a lot of time to reach the target community.
- Non-cooperation of government organizations in the field of access to demographic information.

CRediT authorship contribution statement

Zahra Saeedi: Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mohammad Ghorbani:** Validation, Supervision, Resources, Methodology, Conceptualization. **Suren Kulshreshtha:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration. **Vahid Karimi:** Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

Adamowicz, W., Louviere, J., Swait, J., 1998. Introduction to Attribute-Based Stated Choice Methods. Damage Assessment Centre. Report to NOAA Resource Valuation Branch.

Albiac, J., Martinez, Y., Tapia, X., 2006. Water quantity and quality issues in Mediterranean agriculture. In: Water and Agriculture: Sustainability, Markets and Policies. OECD (Organization for Economic Cooperation and Development), Paris.

Alcon, F., Pedrero, F., Martin-Ortega, J., Arcas, N., Alarcon, J.J., De-Miguel, M.D., 2010. The non-market value of reclaimed waste water for use in agriculture: a contingent valuation approach. Spanish J. Agric. Res. 8, 187–196.

Alcon, F., Tapsuwan, S., Brouwer, P., De-Miguel, M.D., 2014. Adoption of irrigation water policies to guarantee water supply: a choice experiment. Environ. Sci. Pol. 44, 226–236.

Amiri, A., Shaneche, M., Golshani, A., 2020. The effect of public policy process on water crisis in the Islamic Republic of Iran. Res. Lett. Polit. Sci. 15 (4), 45–72.

Arcidiacono, P., Bayer, P., Blevins, J.R., Ellickson, P.E., 2012. Estimation of Dynamic Discrete Choice Models in Continuous Time. National Bureau of Economic Research, Massachusetts, Cambridge. Working Paper. http://www.nber.org/papers/w18449.

Asad Falsafizadeh, N., Saboohi Saboon, M., 2011. Estimating the value of water from the farmers' point of view in order to reduce restrictions during drought. In: The 5th Watershed and Management of Water and Soil Resources Conference in Iran.

Baghestani, M., Zibai, M., 2010a. Measuring willingness to pay of farmers for underground water in Ramjerd region: use of CV method. J. Agric. Econ. 4 (3), 41–64.

Baghestani, M., Zibai, M., 2010b. Measuring willingness to pay of farmers for underground water in Ramjerd region using parametric mathematical programming. Agric. Econ. Dev. (Agricultural Sciences and Industries) 24 (3), 310–322.

Balana, B.B., Catacutan, D., Mäkelä, M., 2013. Assessing the willingness to pay for reliable domestic water supply via catchment management: results from a contingent valuation survey in Nairobi City, Kenya. J. Environ. Plann. Manag. 56 (10), 1511–1531.

Barati, A.A., Pour, M.D., Sardooei, M.A., 2023. Water crisis in Iran: a system dynamics approach on water, energy, food, land and climate (WEFLC) nexus. Sci. Total Environ. 882, 163549.

Bevans, R., 2023. Akaike Information Criterion | when & How to Use it (Example). Scribbr. Retrieved May 14, 2024, from. https://www.scribbr.com/statistics/akaike-information-criterion/.

Carr, G., Potter, R.B., Nortcliff, S., 2011. Water reuse for irrigation in Jordan. Perceptions of water quality among farmers. Agric. Water Manag. 98, 847–854.

Carson, R., Louviere, J.J., Anderson, D., Arabie, P., Bunch, D., Hensher, D.A., Johnson, R., Kuhfeld, W., Steinberg, D., Swait, J.D., Timmermans, H., Wiley, J., 1994. Experimental analysis of choice. Market. Lett. 351–368.

Chizeri, A.H., Sharzei, G.H.A., Karamat Zadeh, A., 2005. Determining the economic value of water with a goal programming method (A case study of Barzoo Shirvan Dam). J. Econ. Res. 71, 39–66.

Dinar, A., Mody, J., 2004. Irrigation water management policies: allocation and pricing principles and implementation experience. Nat. Resour. Forum 28, 112–122.

Fernandez-Zamudio, M.A., Alcon, F., De-Miguel, M.D., 2012. Effects of irrigation-water pricing on the profitability of Mediterranean woody crops. In: Manish Kumar, Dr (Ed.), Problems, Perspectives and Challenges of Agricultural Water Management. *ISBN: 978-953-51-0117-8*, InTech, Available from: http://www.intechopen.com/books/problems-perspectives-and-challenges-of-agricultural-watermanagement/effects-of-irrigation-water-pricing-on-the-profitability-of-mediterranean-tree-and-woody-crops.

Foster, T., Brozovic, N., Butler, A.P., 2017. Effects of initial aquifer conditions on economic benefits from groundwater conservation. Water Resour. Res. 53, 744–762.

Ghorbani, M., Firooz Zare, A., 2009. Evaluation of different attributes of air pollution in Mashhad. J. Econ. Res. 89, 215–241.

Gilbert, S., 2007. Model selection and predictive inference. HAL Open Science 92–97.

Gomez-Limon, J.A., Riesgo, L., 2004. Irrigation water pricing: differential impacts on irrigated farms. Agric. Econ. 31, 47–66.

Gschwandtner, A., Jang, C., McManus, R., 2020. Improving drinking water quality in South Korea: a choice experiment with hypothetical bias treatments. Water 12 (9), 2569.

Hailiang, X., Mao, Y., Jimei, L., 2008. The water transfer effects on agricultural development in the lower Tarim River, Xinjiang of China. *Agricultural Water Management*. Elsevier 95 (1), 59–68.

Hashemi Bonab, S., 2012. Evaluating the Economic-Environmental Consequences of Change of User in Lands in Mazandaran Province. University of Tehran. PhD thesis.

Hausman, J., McFadden, D., 1984. Specification tests for the multinomial logit model. Econometrica 52, 1219–1240.

Hausman, J., Wise, D., 1978. A conditional probit model for qualitative choice: discrete decisions recognizing interdependence and heterogeneous preferences. Econometrica 46 (2), 403–426.

Irans' energy ministry, 2023. Climatic Statistics in Fars Province. https://moe.gov.ir.

Isazadeh, S., Jalili Kamjoo, S.P., Madadi, S., Mahmoodinia, D., 2012. Valuation of non-market goods based on the express preferences. J. Nat. Resour. Econ. 1, 21–36.

Islami, R., Rahimi, A., 2019. Policymaking and water crisis in Iran. Quarterly J. Macro Strat. Pol. 7 (27), 410–435.

Jaber, O.J., Mohsen, M.S., 2001. Evaluation of non-conventional water resources supply in Jordan. Desalination 136, 83–92.

Jofreh, M., Alizadeh, S., 2010. The study of market's role in water resource optimal allocation. J. Financ. Econ. 3 (8), 74–89.

John, J.D., Donna, L.C., Stephanie, T.L., Runze, L., Lars, S.J., 2020. Sensitivity and specificity of information criteria. Briefings Bioinf. 21 (2), 553–565.

Karamidehkordi, E., Karimi, V., Hallaj, Z., Karimi, M., Naderi, L., 2024. Adaptable leadership for arid/semi-arid wetlands conservation under climate change: using Analytical Hierarchy Process (AHP) approach. J. Environ. Manag. 351, 119860.

Karimi, M., Tabiee, M., Karami, S., Karimi, V., Karamidehkordi, E., 2024. Climate change and water scarcity impacts on sustainability in semi-arid areas: lessons from the South of Iran. Groundw. Sustain. Dev. 24, 101075.

Karimi, V., Bijani, M., Hallaj, Z., Valizadeh, N., Fallah Haghighi, N., Karimi, M., 2023. Adaptation and maladaptation to climate change: farmers' perceptions. In: Strategizing Agricultural Management for Climate Change Mitigation and Adaptation. Springer International Publishing, Cham, pp. 113–132.

Karimi, V., Karami, E., Keshavarz, M., 2017. Vulnerability and adaptation of livestock producers to climate variability and change. Rangel. Ecol. Manag. 71 (2), 175–184.

Karimi, V., Karami, E., Keshavarz, M., 2018. Climate change and agriculture: impacts and adaptive responses in Iran. J. Integr. Agric. 17 (1), 1–15.

Karimi, V., Karami, E., Karami, S., Keshavarz, M., 2021. Adaptation to climate change through agricultural paradigm shift. Environ. Dev. Sustain. 23, 5465–5485.

Kavosi Kelashomi, M., Peykani, G.H.R., 2014. Economic evaluation of sufficient and sure irrigation water supply in paddy fields of Gilan province. Quarterly J. Rural Dev. Strat. 1 (2), 1–17.

Khosh Akhlagh, F., Ranjbar, F., Toolabi, S., Moghbel, M., Masoom Poor Sama Koosh, J., 2010. Study of drought in the water year 2007-2008 and its effects on water resources and agriculture: a case study of Marvdasht County. Scientific-Res. Quarterly J. Iran Geograph. Assoc. 24, 119–136.

Kwak, S.Y., Yoo, S.H., Kim, C.S., 2013. Measuring the willingness to pay for tap water quality improvements: results of a contingent valuation survey in Pusan. Water 5 (4), 1638–1652.

Louviere, J.J., 2006. What you don't know might hurt you: some unresolved issues in the design and analysis of discrete choice experiments. Environ. Resour. Econ. 34, 173–188.

Louviere, J.J., Hensher, D.A., Swait, J.D., 2000. Stated Choice Methods: Analysis and Applications. Cambridge University Press.

Martin-Ortega, J., 2012. Economic prescriptions and policy applications in the implementation of the European Water Framework Directive. Environ. Sci. Pol. 24, 83–91.

McFadden, D., 1978. In: Karlqvist and others, A. (Ed.), Modelling the Choice of Residential Location. Spatial Interaction Theory and Planning Models. North Holland Publishing, Amsterdam, pp. 75–96.

Mesa-Jurado, M.A., Martin-Ortega, J., Ruto, E., Berbel, J., 2012. The economic value of guaranteed water supply for irrigation under scarcity conditions. Agric. Water Manag., Els. 113, 10–18.

Mirzavand, M., Bagheri, R., 2020. The water crisis in Iran: development or destruction? World Water Policy 6 (1), 89–97.

Muthen, B., Muthen, L.K., 2000. Integrating person-centered and variable-centered analyses: growth mixture modeling with latent trajectory classes. Alcohol Clin. Exp. Res. 24 (6), 882–891.

Nasiri, M.A., Jabbari, S., Boostani, F., Shamsnia, S.A., 2009. Analysis and monitoring of Drought using standardized precipitation index (SPI): a case study of Marvdasht County. National Conference on Water Crisis Management. Islamic Azad University of Marvdasht.

Raftery, A.E., 1995. Bayesian model selection in social research. Socio. Methodol. 25, 111–163.

Roosta, A., Keshavarzi, S., Mobaseri, M., 2009. The Importance of Agricultural Water Productivity in the Drought Crisis of Fars Province: A Case Study of Marvdasht and Eghlid Counties. National Conference on Water Crisis Management.

Sabzevar, M.S., Rezaei, A., Khaleghi, B., 2021. Incremental adaptation strategies for agricultural water management under water scarcity condition in Northeast Iran. Regional Sustainability 2 (3), 224–238.

Schwarz, G., 1978. Estimating the dimension of a model. Ann. Stat. 6, 461–464.

Sharzei, G.H.A., Jalili Kamjoo, S.P., 2013. Modeling the choice of a new approach to the valuation of environmental goods: a case study of Ganjnameh Hamedan. Quarterly Journal of Economic Research (Sustainable Growth and Development), Thirteenth year 3, 1–18.

Sharzei, G.H.A., Javidi Abdollahzadeh Aval, N., 2011. Internalization of ancillary costs in electricity generation by Choice Experiment Method. Quarterly J. Energy Econ. Stud. 29, 1–29.

StataCorp, 2023. Stata 18 Base Reference Manual. Stata Press, College Station, TX.

Sterner, T., 2003. Policy instruments for environmental and natural resource management. Resources for the Future, Washington.

Stoica, P., Selen, Y., 2004. Model-order selection: a review of information criterion rules. IEEE Signal Process. Mag. 36–47.

Tiwari, S., Dinar, A., 2002. Balancing future food demand and water supply: the role of economic incentives in irrigated agriculture. Q. J. Int. Agric. 41, 77–97.

Train, K., 2003. Discrete Choice Methods with Simulation. Cambridge University Press, U.K.

Tsur, Y., 2005. Economic aspects of irrigation water pricing. Can. Water Resour. J. 30, 31–46.

Turner, R.K., Georgiou, S., Clarke, R., Brouwer, R., 2004. Economic valuation of water resources in agriculture. From the sectoral to a functional perspective of natural resource management. In: FAO Water Report, 27. FAO, Rome.

Tussupova, K., Berndtsson, R., Bramryd, T., Beisenova, R., 2015. Investigating willingness to pay to improve water supply services: application of contingent valuation method. Water 7 (6), 3024–3039.

Wang, H., Xie, J., Li, H., 2010. Water pricing with household surveys: a study of acceptability and willingness to pay in Chongqing, China. China Econ. Rev. 21 (1), 136–149.

Whittington, D., Briscoe, J., Mu, X., Barron, W., 1990. Estimating the willingness to pay for water services in developing countries: a case study of the use of contingent valuation surveys in southern Haiti. Econ. Dev. Cult. Change 38 (2), 293–311.

Xiankai, L., Dongmei, Y., 2024. Research on the impact of water-saving technologies on the agricultural production efficiency of high-quality farmers - taking Jiangxi province and Guangdong province in China as examples. Front. Environ. Sci. 12.

Zamani, O., Azadi, H., Mortazavi, S.A., Balali, H., Moghaddam, S.M., Jurik, L., 2021. The impact of water-pricing policies on water productivity: evidence of agriculture sector in Iran. Agric. Water Manag. 245, 106548.