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Rice farmers at risk of water scarcity: analysis of the decisive factors in adaptation strategy acceptance

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Abstract

The problem of excessive water consumption in the traditional puddled transplant rice (PTR) cultivation method has increased efforts to develop the dry direct seeded rice (DDSR) system as a favorable alternative to achieve sustainable rice production. However, current data show that the rates of DDSR use in the Iranian rice production systems fall below the goals set by the higher management of agriculture. This study's primary objective was to investigate the elements that led rice farmers to fully embrace, reject, or partially use DDSR as a suggested technique for growing rice in paddy fields in order to conserve water. A cross-sectional survey was carried out in 2021 to collect data from 694 paddy farmers in Golestan province, northeastern Iran. Farmers' socioeconomic characteristics, farm management factors, and Protection Motivation Theory (PMT) concepts were all included in the data. PMT constructs such as perceived severity and perceived self-efficacy had a positive relationship with both adoption behaviors, i.e., using only DDSR and using both DDSR/PTR. Percentage of products that are self-consumed, annual income of rice farming, land area under rice cultivation, percentage of family labor force in rice farming, amount of rice yield, and using private wells as sources of irrigation water use in rice fields were identified as the predictors for both of the adoption behaviors. On the other hand, PMT constructs such as perceived vulnerability, response efficacy, and obtaining information about DDSR from extension agents were only predictors of DDSR adoption. Overall, the potential of PMT in explaining rice farmers' behavior towards pro-water saving innovation was supported. Finally, agricultural extension programs that consider the aforementioned factors for improving the rate of DDSR adoption may fundamentally change farmers' behavior to save water in paddy fields.

Keywords Direct seeded rice · Protection motivation theory · Behavior change · Water shortage · Water saving

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1 Introduction

In Iran, like many parts of the world, the rice production system is dominantly based on transplanting seedlings from the nursery into muddy soil (i.e., land preparation with wet tillage). This system of cultivation is severely affected by water scarcity and recently by the high cost of the labor force in many parts of Asia (Li & He, 2021; Wheeler & Von Braun, 2013). Moreover, the sustainability of the farming system is under pressure due to maximum mechanical soil disturbance, high loss of water, more surface evaporation, and high cost of labor and energy (Bhushan et al., 2007; Ishfaq et al., 2020; Rahman, 2019). As a result, rice production has become increasingly unprofitable and many smallholder farmers have been deprived of the opportunity to improve their livelihoods (Bhatt et al., 2016). Moreover, the drudgery involved in the puddled transplant rice (PTR), a job mostly undertaken by the female and older labor force, is deeply worrying (Panneerselvam et al., 2020). All the aforementioned factors call for a major switch from PTR to DDSR as a suitable alternative method for rice cultivation, which can maintain or boost farm performance while using less labor and irrigation input in rice fields (Ishfaq et al., 2018; Rahman, 2019).

It has been proven that the DDRS is an appropriate way to achieve higher water use efficiency and ensure sustainable rice production (Gathala et al., 2014; Roy et al., 2016). Therefore, wide use of DDSR is expected to reduce irrigation and total water input (rainfall and irrigation) over the whole crop season (Liu et al., 2015; Tao et al., 2016). The DDRS is often seen as one of the very effective options that might save farmers from increasing labor force costs (Rahman, 2019). Other potential benefits of DDSR include faster and easier field preparation, reduced wage rates and production cost, earlier crop maturity, less need for investment in farm inputs, and higher tolerance for water shortage. All the aforementioned advantages have increased interest in switching from PTR to DDSR to cope with the major challenges of sustainable rice production.

In Golestan province, rice cultivation has a relatively significant share (about 12%) of the total area under cereals (MPOGP, 2019). In this region, 72,000 hectares were dedicated to rice cultivation, yielding approximately 350,000 tons of paddy in 2020 (Goli et al., 2023). Due to reduced rainfall in recent years in most parts of the province, water scarcity is a serious problem threatening the traditional rice production system (Kiani et al., 2019). According to statistics from Golestan Agricultural Jihad Organization (GAJO, 2020), approximately 30% of the total arable land in the province is affected by prolonged drought and has experienced severe water stress. It is also estimated that the province may experience a considerable decline in cereal production by the next decade due to water shortage (Kiani et al., 2019). Adaptation to water scarcity consequences in rice production systems has therefore become a major concern to various stakeholders in the province, with special emphasis on how to assist rice farmers in maintaining their productivity (Razzaghi et al., 2020).

The Golestan Agricultural Jihad Organization created an intervention campaign to encourage the use of DDSR among farmers in the area in 2009 in response to climate change consequences, including protracted drought and subsequent water shortages in rice fields (GAJO, 2020). By providing some incentives, such as targeted extension services, rice farmers in the area are being encouraged to switch from transplanting to dry direct seeding methods (Kiani et al., 2019). Despite the heavy emphasis on the use of DDSR for minimizing water and labor requirements and facilitating work conditions in rice fields, adoption by farmers remains low, and access to secure water resources continues to decline in the area. Since 2020, approximately 10% of rice farmers have adopted DDSR, and more than 90% were loyal to the transplanting method of rice establishment in the province (GAJO, 2020). Therefore, farmers, water planners, and political authorities need to consider why the DDSR recommended by consultants and water experts is not widely adopted by rice farmers. It is essential for decision-makers in the agricultural sector to investigate whether the recommended DDSR is in any way compatible with farmers' values and expectations or if there are other factors that influence their adoption behavior at paddy fields (Rabiei et al., 2016). The Protection Motivation Theory (PMT) (Rogers, 1983) has been used in the current study to examine the elements that influence farmers' decisions to fully embrace, reject, or partially adopt DDSR, which is a method of rice production currently advocated for saving water in paddy fields. To date, few studies have investigated this issue in the field or within any theoretical framework.

PMT, with its focus on understanding how individuals are motivated to protect themselves from adverse consequences, provides a compelling theoretical foundation for investigating the adoption of the DDSR system in the context of water scarcity in Golestan province. Unlike the PTR system, which is water-intensive, DDSR offers a protective behavioral response that aligns with the goals of PMT. Using PMT as a conceptual framework, we can better comprehend why farmers, faced with persistent water shortages and the elimination of the PTR system by provincial agricultural authorities, are transitioning to DDSR. This shift can be seen as a strategic move to safeguard their livelihoods, minimize conflicts with neighboring farmers over water resources, and ensure a stable income from rice cultivation. Moreover, given the long-standing expertise of the farmers in rice cultivation, the switch to DDSR is not only a protective strategy but also a practical adaptation to regulatory changes. Our rationale for selecting PMT is further reinforced by its specific development to explicate behaviors that aim to mitigate environmental threats, such as water crises, a topic researched in the literature by Goli et al. (2020) and Wang et al. (2019). In the Golestan region, rice cultivation is a significant water consumer, requiring an average irrigation allocation of 14,000 m^3 ha^{-1} $year^{-1}$, as noted by Karimi Fard et al. (2020). This intensive use has historically led to disputes among water users in the area, highlighting the urgency for more water-efficient practices. Additionally, PMT accounts for the increase in vulnerability of the rice industry due to the gradual decline in financial assistance, which makes it imperative for farmers to adopt more resilient agricultural practices like DDSR. This not only helps in managing water resources efficiently but also reinforces the economic sustainability of rice farming in the face of environmental and socio-economic stressors. In summation, PMT is exceptionally suited to guide this research, providing a nuanced understanding of farmers' adoption of DDSR as a strategic and protective response to environmental and regulatory challenges, while also considering the practical implications for livelihood security in the context of Golestan province's water-scarce environment.

2 Conceptual framework

Several studies (e.g., Bagagnan et al., 2019; Delfiyan et al., 2021; Ghanian et al., 2020; Keshavarz & Karami, 2016) on determinants of farmers' adoption of adaptation strategies have frequently applied behavior prediction models such as the Theory of Planned Behavior (TPB) (Ajzen, 1988, 1991), the Diffusion of Innovations Theory (DIT) (Rogers et al., 2014), the Technology Acceptance Model (TAM) (Davis, 1989), and the Protection Motivation Theory (PMT) (Rogers, 1975, 1983). The TAM posits that the perceived usefulness and ease of use of technology inform an individual's intention to technology adopt, though this intention does not always translate into actual adoption behavior. In fact, the TAM suggests that if users perceive a technology as useful and easy to use, they are more likely to have a positive attitude towards it and intend to use it, which ultimately leads to the adoption and actual usage of the technology (Montes de Oca Munguia et al., 2021). The TPB has been widely applied to understand adopters' internal decision-making processes and how these are shaped by external influences like social norms and perceived behavioral control. Finally, the DIT lends insight into how innovations spread through communication channels over time within a social system. The application of these theories is a useful tool to explain the role of attitudes, beliefs, and values in predicting a broad range of human behaviors (Mullan et al., 2016).

In the current research, PMT was used as a conceptual framework to form a precise theoretical basis for gaining insights into determinants of DDSR adoption as an effective adaptation strategy to cope with water scarcity in paddy fields. The origin of PMT was in the 1980s, and it appeared promising as a framework for explaining the factors predicting individuals' desire or willingness to engage in a particular protective-related action (Rogers, 1983). Under the conditions of the present study, which are related to the adoption of DDSR in paddy fields, protective behavior refers to the adoption of DDSR as an effective strategy to mitigate the threats resulting from water scarcity due to the continuous use of the PTR system in rice fields. The basic structure of PMT consists of two main components that are assumed to affect protective behavior, threat appraisal, and coping appraisal (Fig. 1). An individual's knowledge and evaluation of the risk posed by a hazardous occurrence are referred to as their threat appraisal (Rogers, 1983; Woon et al., 2005). Perceived susceptibility and perceived severity are its two subcomponents. The term "perceived vulnerability" relates to one's assessment of the likelihood that hazardous conditions may materialize. Perceived vulnerability in this study alludes to the dangers of a water deficit in rice crops. Perceived severity is the assessment of the severity of the consequences of the occurrence of dangerous conditions. In this case, perceived severity refers to the crop damage and decline in farm performance due to water scarcity in the farm field.

A person's judgment of his or her possible ability to deal with or lessen the impairment brought on by the occurrence of the threatening event is described by the component of coping appraisal (Woon et al., 2005). The three components of self-efficacy, response efficacy, and response costs are included in the coping appraisal. Self-efficacy is the belief in one's own ability to conduct a certain preventive activity (Bandura, 1991). Self-efficacy is defined in this study as a collection of abilities and activities necessary for the effective application of DDSR

Fig. 1 Motivational Protection Behavior Model taken from Bockarjova and Steg (2014)

as an alternate method to deal with the danger of water scarcity in rice fields. Response efficacy is the expectation of a person that following certain measures can eliminate or mitigate the consequence of a dangerous situation (Rogers, 1983). In this study, response efficacy refers to the benefits that are gained by adherence to DDSR as an effective solution for mitigating the risk of water shortage in rice field. Response cost refers to all the challenges and problems that arise if the recommended protective action is implemented. Response cost in the current study describes all unfavorable impacts associated with DDSR use in paddy fields, i.e., performance reduction, increased occurrence of weeds, and weak technical knowledge of farmers.

A body of research has established PMT as a robust framework for analyzing individuals' responses to a range of environmental and climate-related risks. Key studies have identified a consistent set of factors such as perceived vulnerability, response efficacy, and response costs that significantly influence the adoption of adaptation strategies in the face of challenges like drought and water scarcity. For instance, Delfiyan et al. (2021) linked these factors to farmers' adaptive actions during droughts, while Keshavarz and Karami (2016) expanded on these by including psychological and social determinants of pro-environmental behavior. Ghanian et al. (2020) and Grothmann and Reusswig (2006) found that beliefs about climate change, self-efficacy, and adaptation efficacy play crucial roles in shaping protective responses. Moreover, Bagagnan et al. (2019) illustrated how perceived threats and barriers direct not only the motivation to protect oneself but also the implementation of conservation practices. Other psychological dimensions identified in the literature as influential in the adoption of adaptation measures include risk appraisal and the role of social norms (Wens et al., 2021), perceived barriers, perceived severity and susceptibility, cues to action (Zobeidi et al., 2021), as well as climate risk perception, trust, and the concept of psychological distance (Azadi et al., 2019).

Farmer demographics and farm management variables significantly influence the application of adaptation strategies. Research indicates that a farmer's age, education, income, farming experience, access to government services, and secure land tenure rights are pivotal factors (Abid et al., 2016; Alam, 2015; Anik et al., 2021; Ashraf et al., 2014; Esfandiari et al., 2020; Owusu & Yiridomoh, 2021; Thinda et al., 2020). Younger farmers, those with better access to modern irrigation tools (Esfandiari et al., 2020), and those with secure ownership that entitles them to local water resources (Alam, 2015) tend to adopt adaptive measures more readily. Studies also point to the role of financial resources, such as bank loans, and information-related factors, including weather forecasts and market insights, as determinants of adaptation strategies (Abid et al., 2016; Ghorbani-Kolahi et al., 2010). The influence of psychographics, asset holdings, and the quality of extension services have been recognized in promoting farm-level adaptation (Antwi-Agyei et al., 2021; Owusu & Yiridomoh, 2021). However, the existing literature has limitations. There is a gap in understanding the specific impact of these variables on the acceptance of DDSR as there is a tendency to focus on intention (e.g., Wens et al., 2021) rather than actual behavior, and the distinctiveness of DDSR compared to other adaptation strategies may mean that findings from broader studies are not fully applicable to DDSR adoption. Therefore, integrating socio-demographic factors with PMT components could offer a more nuanced prediction of DDSR adoption among rice farmers.

3 Methodology

3.1 Study area

The current study was conducted in Golestan province, northeastern Iran (Fig. 2). The total geographical area of the province is 20,438 km^2, and about 70% of the area is forest and rangeland. Most parts of the province have a Mediterranean moderate climate, but the plain areas have a semi-arid and dry climate due to their proximity to the Turkmenistan desert and their increasing distance from the Caspian Sea (Shirzadi et al., 2015). The average temperature ranges from 8 to 20 °C, and the mean annual rainfall is about 470 mm. The rainfall for the reference season of the study (2021) was 267 mm (44% below the long-term average). The province consists of 14 counties, 27 districts, and 1049 rural settlements. Agriculture contributes to about 24% of the Province's Gross Domestic Product (SGDP), and 44% of the workers are engaged as cultivators and agricultural laborers (GAJO, 2020). The dominant crops cultivated in the area include rice (one of the important rice production zones in Iran), wheat, cotton, canola, soybean, sunflower, and barley (Abdollahzadeh et al., 2021).

The total cultivable area of agricultural lands in the region is approximately 600,000 hectares, about 12% of which is under rice cultivation (GAJO, 2020). The main reason for conducting this survey in Golestan province was the relatively long history of implementing intervention programs that provided the required technical and extension services for rice farmers to shift from the traditional PTR production systems to DDSR. However, most rice farmers rely on transplanting systems to establish rice due to a lack of confidence in using DDSR as a new rice cultivation system. Additionally, researchers have long experience in field studies in this area and were invited by the provincial agricultural authorities to conduct this study.

3.2 Sample selection

To achieve the objective of the study, the data was collected by concentrating mainly on the seven counties where PTR and DDSR are being carried out (N = 22,073 farmers). All villages located in the selected counties were included as clusters. Five villages were

Fig. 2 Geographical location of the study area

randomly chosen from each county (totally 35 villages were covered) based on the following criteria: group 1: DDSR farmers (framers who have applied the DDSR method to total lands cultivated for rice), group 2: DDSR/PTR farmers (farmers who have used both the DDSR and the PTR methods to part of their lands), and group 3: PTR farmers (farmers who have not applied the DDSR method, but have used the PTR method in total lands cultivated for rice). Villages that had these three cultivation methods were covered in the sample. The maximum sample sizes for each group were determined based on the Krejcie and Morgan Table (1970). This resulted in required sample sizes of 217, 370, and 107 respondents for DDSR farmers (N = 495), DDSR/PTR farmers (N = 148), and PTR farmers (N = 21,430), respectively. Then the samples were chosen randomly with proportional assignment within these three groups. The database of the Golestan Agricultural Organization was used to obtain the list and addresses of the rice farmers.

Therefore, a list of three groups of farmers was solicited from each village, which were then numbered and selected at random using a random number generator. In order to ensure a sufficient number of questionnaires, more individuals were included in the survey. Data from four respondents were excluded due to incomplete responses, and then 694 questionnaires (the final sample size of the study) were chosen for statistical analysis. The final sample consisted of three groups: 370 (53.3%) PTR farmers, 217 (31.3%) DDSR farmers, and 107 (15.4%) DDSR/PTR farmers. The data collection started in February 2021 and ended in August 2021. The questions used all refer to the knowledge, skills, and abilities required to implement the DDSR system. Therefore, they all measure one concept, and the average of the final score of these eight items is used as a proxy variable for constructing self-efficacy. In order to control potential biases in farmers' answers to questions, local informants or agricultural extension agents were recruited and trained on modality for data collection within each village. They were also given specific instructions regarding the nature of the items in the questionnaire and precise instructions for completing each section of the instrument in the local dialect. After establishing the willingness of the farmer to participate, a face-to-face interview was arranged in the farm field. Completing each questionnaire took about 30 to 45 min on average.

3.3 Questionnaire development

A research-made questionnaire was developed to gather the required data from rice farmers. The questionnaire consists of four sections. The first portion gathers farmers' sociodemographic statistics such as gender, age, education, years of experience in DDSR and PTR, share of rice product eaten by oneself, and farm revenue. The second component comprised farm characteristics such as the land area under rice cultivation, share of family labor force in farming, rice production, number of land parcels under rice cultivation, source of irrigation water, and source of DDSR information. Section three was developed to gather data about the mode of rice cultivation among farmers (solely DDSR, both DDSR and PTR, and solely PTR) and sources of information about DDSR. The last section of the questionnaire contains different statements about the farmer's perceptions relating to DDSR based on the five constructs of PMT: perceived vulnerability, perceived severity, response efficacy, response costs/barriers, and perceived self-efficacy. Table 1 lists the variables studied and their Cronbach's alpha reliability coefficients. The farmers were requested to show their level of agreement towards the statements using a five-point Likert Scale anchored by 1 (strongly disagree) to 5 (strongly agree). A higher score signifies a stronger perception of a specific construct. This section of the survey instrument was specifically designed for the

Table 1 Description and definition of the variables used in the MNL model

Variable	Explanation of measurement
Dependent variable (adoption status)	Dummy variable: DDSR farmers = 2, DDSR/PTR farmers = 1, PTR farmers = 0
DDSR farmers	Farmers who have applied the DDSR method to total rice-grown lands
DDSR/PTR farmers	Farmers who have applied both DDSR and PTR methods to part of their lands
PTR farmers	Farmers who did not apply DDSR, but used the PTR method on total rice-grown lands
Independent variable	
Farmers' characteristics	
Gender	Dummy variable: female = 0, male = 1
Age	Continuous variables: number of years
Years of experience in rice cultivation	Continuous variables: number of years working on the farm
Years of schooling	Continuous variables: number of years with formal education
Percentage of products that are self-consumed	Continuous variables: the percentage of rice consumed out of the total rice production
Farm management variables	
Annual income from rice farming	Continuous variables: US $[a]
Land area under rice cultivation	Continuous variables: hectares of land
Family labor force in rice farming	Continuous variables: the percentage of family members working on the farm out of total family members
Rice yield	Continuous variables: tons per hectare
Number of land parcels under cultivation	Continuous variables: number of land parcel
Sources of irrigation water	Dummy variable: private well = 1, other (water quota from rivers or dams) = 1
Sources of information about DDSR	Dummy variable: extension agents = 1, extension and training courses = 2, mobile social media = 3, none (lack of information source) = 0
PMT constructs	
Perceived vulnerability	Continuous variables: mean score of 3 items[b] (Cronbach alpha = 0.71)
Perceived severity	Continuous variables: mean score of 4 items[b] (Cronbach alpha = 0.71)
Response efficacy	Continuous variables: mean score of 5 items[b] (Cronbach alpha = 0.71)
Response costs/barriers	Continuous variables: mean score of 10 items[b] (Cronbach alpha = 0.71)
Perceived self-efficacy	Continuous variables: mean score of 8 items[b] (Cronbach alpha = 0.71)

[a] 1 USD was equal to 240,000 Iranian Rials in 2021

[b] On a 5-point Likert-type scale: strongly agree, agree, no comment, disagree, and strongly disagree

SD standard deviation

current study (Bagagnan et al., 2019; Delfiyan et al., 2021; Ghanian et al., 2020; Ghorbani-Kolahi et al., 2010; Keshavarz & Karami, 2016; Luu et al., 2019) with some modifications based on contextual factors influencing the rice cultivation system. The initial version of the questionnaire was peer-reviewed by six local extensions technician who had long practical experience with rice cultivation systems. This phase was used to assess the content validity of the questionnaire and the comprehensiveness of the questions as well as the compatibility of PMT items with the mode of rice cultivation in the area. Prior to the actual survey, the questionnaires were pre-tested with 15 rice farmers, mostly for simplification and better drafting of statements and items of the scales.

3.4 Data analysis

The SPSS software version 22.0 was used to evaluate the data collected from rice growers. The analysis included descriptive statistics, chi-square cross-tabulation, one-way analysis of variance (ANOVA), and multi-nominal logistic (MNL) regression analysis (McFadden & Train, 2000). First, one-way ANOVA with Tukey post-hoc test and chi-square tests were employed to examine differences in demographic characteristics, field characteristics related to variables, and composite scores of PMT structures in three groups of farmers (DDSR, both, PTR). Composite scores of each PMT construct were calculated by averaging the individual items of those constructs, as follows:

Finally, to examine the predictors of rice cultivation methods by the farmers, the MNL analysis was performed. Method of rice cultivation (both DDSR and PTR) was considered as the dependent variable, and demographic variables, farm management variables, and attitudinal variables such as sources of information about DDSR were considered as independent variables. The reference category for the dependent variable is the PTR farmers. The normal distribution of continuous variables was tested and confirmed by the Kolomogrov-Smirnov test, coefficients of skewness, and kurtosis (Munro, 2005).

The MNL model is recommended when a dependent variable underlies a specified order and when the lengths between the scale points cannot be referred to as numerically equivalent (Agresti, 2002). Because the dependent variable in this study was the adoption status of the DDSR system, the MNL models were used to account for the three types of DDSR farmers, DDSR/PTR farmers, and PTR farmers. The models generated two sets of coefficients: one comparing DDSR farmers to PTR farmers and the other DDSR/PTR to PTR farmers. As a result, PTR farmers were chosen as the reference category for the analysis.

The regression model is set according to the following Eq. (1):

$$\text{Composite score of each component} = \frac{\text{Total sum of value (the number of the Likert scale rating points } (1,2,3,4,5) \text{of all items of each component)}}{\text{Number of items in each component}}$$

$$\ln\left(\frac{p_i}{(1-p_i)}\right) = \beta_o + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki} \tag{1}$$

where subscript I represents the i-th observation in the sample, Pi represents the probability of the outcome, o represents the intercept, and 1, 2…, k represents the regression coefficients of variables X1, X2…, Xk, respectively. Positive coefficients for the variables signify a rise in log chances, or, depending on the case, the possibility of being DDSR or DDSR/PTR farmers. Furthermore, the Wald statistic, which is used to examine the significance of a single coefficient in the model (Hair et al., 1998), is the square of the t-statistic.

4 Results

4.1 Descriptive statistics of PMT constructs

The descriptive data for the PMT constructs investigated are presented in Table 2. The average scores and key insights for perceived vulnerability, perceived severity, response efficacy, response costs/barriers, and perceived self-efficacy across DDSR farmers, DDSR/PTR farmers, and PTR farmers are detailed. Moreover, the response efficacy items reflect lower scores, indicating a lack of clarity for farmers regarding the efficiency of the DDSR system compared to the PTR system. Common response costs/barriers, such as "increased weed damage in rice fields" and "advanced irrigation methods required for DDSR", are highlighted. The perceived self-efficacy construct garnered the lowest mean score, reflecting inadequate technical knowledge and skills among farmers in the study area, particularly for DDSR. Moreover, all items for the PTR and DDSR/PTR farmer groups scored below the scale's midpoint, signaling the need for enhanced knowledge and capabilities in utilizing the DDSR system. Additionally, composite scores for each PMT construct were calculated by averaging individual items, as shown in Table 1. The coefficients of skewness and kurtosis for the final composite scores of PMT constructs were also included in Table 2, with all calculated values falling within the range of -2 to $+2$, confirming a univariate normal distribution for all composite scores of PMT constructs (Georg, 2011).

4.2 Differences in categorical variables among the farmer groups

The chi-square cross tabulation test shows that the choice of rice cultivation methods is independent of the farmer's gender but significantly influenced by the irrigation water sources and information channels about DDSR (Table 3). Most farmers were male, with 78.3% adopting DDSR, 81.6% using PTR, and 80.4% employing both methods. River or dam water users mostly prefer PTR (89.5%), whereas only 10.3% of those with private wells use this system ($\chi 2 = 63.62$, $p < 0.01$). Regarding DDSR information sources, 25.8% of DDSR farmers rely on extension agents, compared to only 14% of DDSR/PTR farmers and 11.1% of PTR farmers. A significant percentage of PTR farmers (64.9%) reported no specific information source on DDSR, which is lower in DDSR (50.2%) and DDSR/PTR farmers (58.9%). Lastly, only a small fraction of all farmer groups received DDSR information through courses and social media.

4.3 Differences in continuous variables among the farmer groups

Continuous variables such as demographic characteristics, farm management variables, and PMT constructs significantly differed among the farmer groups (Table 4). Within these groups, DDSR farmers were generally younger with an average age of 44.03, compared to 46.16 for PTR and 48.95 for DDSR/PTR farmers. Despite similar standard deviations in age across the groups (between 9.52% and 13.44%), the ANOVA test identified a statistically significant variance in the average ages ($F(2, 297) = 5.63$, $p < 0.01$). This indicates that age differences are indeed relevant and statistically meaningful among the groups. Experience in rice farming varied, with PTR farmers averaging at around 26.78 years, higher than DDSR's 21.05 and DDSR/PTR's 22.93 years. In terms of education, DDSR farmers averaged 9.45 years, indicating a higher level of formal schooling compared to their counterparts in the PTR (6.78 years) and DDSR/PTR (6.88 years) groups. The percentage

Table 2 Descriptive statistics of items of PMT constructs

	DDSR farmers		DDSR/PTR farmers		PTR farmers	
	Mean	SD	Mean	SD	Mean	SD
Perceived vulnerability						
My farm field is at risk of water shortage	3.08	0.90	3.05	1.04	2.62	0.90
My water share from the local river is declining	3.18	0.73	3.16	1.07	2.58	1.02
I believe the potential of rice cultivation in this area is damaged due to water shortage	3.08	0.86	2.94	1.17	2.34	0.98
Overall score (Skewness: 0.37, Kurtosis: – 0.63)	3.11	0.83	3.05	1.10	2.51	0.97
Perceived severity						
Water shortage in rice fields can result in severe performance decline	3.47	0.95	3.00	1.22	2.38	0.76
Water shortage in rice fields causes complete destruction of the crop	3.36	1.01	2.80	1.15	2.30	0.80
Farmers are worried about losing the capability of land for rice cultivation due to long-term water shortages	3.50	0.93	2.90	1.18	2.44	0.87
Continuation of traditional rice cultivation has caused tension and conflict over water among paddy farmers	3.32	0.85	3.06	1.27	2.35	0.92
Overall score (Skewness: 0.46, Kurtosis: – 0.72)	3.41	0.94	2.94	1.21	2.37	0.84
Response efficacy						
I would find DDSR as an effective way to cope with water scarcity in rice fields	3.04	0.71	2.75	1.05	2.44	0.78
The use of DDSR is economical because it requires less workforce	2.41	0.80	2.45	1.02	2.39	0.73
DDSR is useful because it takes less time to prepare the land	2.63	0.77	2.38	0.95	2.39	0.73
The use of DDSR is economical because it requires less seeds for planting	2.64	0.81	2.23	0.97	2.46	0.84
DDSR allows timely planting of subsequent crops due to early harvest of direct seeded rice crops	2.65	0.83	2.49	0.98	2.41	0.82
DDSR is useful because it reduces drudgery by eliminating transplanting operations	2.92	0.73	2.73	0.95	2.37	0.88
Overall score (Skewness: 0.61, Kurtosis: 0.04)	2.71	0.77	2.50	0.99	2.41	0.80
Response costs/barriers						
Using DDSR increases weed damage in rice field	3.65	0.75	3.10	1.21	2.88	1.06
Using DDSR reduces rice grain yield	2.39	0.73	2.94	1.24	4.02	0.92
Using DDSR needs advanced methods for irrigation	3.32	0.64	3.28	1.26	3.70	0.93
Using DDSR reduces the availability of soil nutrients	2.98	0.71	2.91	1.37	3.40	0.89
Using DDSR increases dependence on herbicides	3.52	0.70	3.12	1.34	3.43	1.03

Table 2 (continued)

	DDSR farmers		DDSR/PTR farmers		PTR farmers	
	Mean	SD	Mean	SD	Mean	SD
DDSR is not compatible with most aspects of my farming practices	2.23	0.72	3.13	1.36	3.75	1.13
Using DDSR does not fit well with the way neighbor farmers like to work	2.42	0.77	3.27	1.32	3.76	0.89
I have been accustomed to the PTR for many years and it is difficult for me to shift to DDSR	2.43	0.75	2.72	1.31	3.70	0.97
There is insufficient technical knowledge to use DDSR among farmers in this area	3.01	0.76	3.16	1.35	3.32	1.16
Training and technical programs about DDSR are not well provided by agricultural authorities	3.05	0.81	2.81	1.17	3.29	0.96
Overall score (Skewness: –0.20, Kurtosis: –0.85)	2.90	0.74	3.04	1.29	3.53	1.00
Perceived self-efficacy						
I am confident that I have the required skills to prepare the seedbed	2.69	0.72	2.10	0.90	1.95	0.61
I know how to soak seeds and prepare them for planting	2.59	0.80	2.37	0.98	2.01	0.59
I am confident that I have knowledge of the application of the appropriate fertilizers and pesticides at the right time	2.60	0.78	2.44	0.80	1.98	0.64
I have the necessary knowledge about the amount and time of irrigation in the DDSR method	2.72	0.64	2.33	0.81	2.12	0.54
It would be easy for me to provide technical advice regarding using DDSR for other farmers	2.64	0.75	2.31	0.97	1.88	0.67
Without the help of others, I have the skills, experience, and expertise required for the use of DDSR	3.03	0.65	2.02	0.86	2.02	0.66
I am confident about my ability to use DDSR in this area	3.05	0.62	2.31	0.78	2.05	0.68
I would be able to use DDSR, even if I have never used it before	3.07	0.60	2.29	0.86	1.95	0.59
Overall score (Skewness: 0.46, Kurtosis: –0.37)	2.80	0.70	2.27	0.87	1.99	0.62

Table 3 Comparison of some categorical variables among the three groups of farmers (chi-square results). *Source*: research findings

Variable	DDSR farmers n (%)	DDSR/PTR farmers n (%)	PTR farmers n (%)	Chi-square
Gender				
Female	45 (20.7)	21 (19.6)	67 (18.1)	0.684 [ns]
Male	170 (78.3)	86 (80.4)	302 (81.6)	
Missing data	2 (0.9)	–	1 (0.3)	
Sources of irrigation water				
Private well	81 (37.3)	18 (16.8)	38 (10.3)	63.62**
Other (water quota from rivers or dams)	136 (62.7)	89 (83.2)	331 (89.5)	
Missing data	–	–	1 (0.3)	
Sources of information about DDSR				
Extension agents	56 (25.8)	15 (14.0)	41 (11.1)	12.15**
Extension and training courses	37 (17.1)	20 (18.7)	65 (17.6)	
Mobile social media	15 (6.9)	9 (8.4)	24 (6.5)	
None (lack of source of information)	109 (50.2)	63 (58.9)	240 (64.9)	

*Significant at $P<0.05$; ** Significant at $P<0.01$; *ns* Not significant

of rice self-consumed by PTR farmers was the highest at 23.35%, surpassing DDSR at 12.69% and DDSR/PTR at 14.98%. Farm management variables, including annual income, land area, labor force, yield, and number of land parcels, all varied notably among the groups, with PTR farmers generally showing higher figures across these variables (income: $2400.65, land area: 3.93 hectares, labor force participation: 36.39%, yield: 4.60 tons per hectare, and number of land parcels: 3.71). Lastly, PMT constructs correlated significantly with the adoption status of each farming group. DDSR farmers scored higher in perceived vulnerability, severity, response efficacy, and self-efficacy, while PTR farmers placed more emphasis on cost structure and response barriers.

4.4 Determinants of DDSR adoption by the farmers

The MNL analysis revealed a significant connection between farmers' characteristics, farm management practices, PMT constructs, and chosen rice cultivation systems (DDSR, DDSR/PTR, and PTR) as shown in Tables 5 and 6. The fitting model predicted 85.3% of farmers' choices accurately, with a strong fit to the data (-2 log likelihood = 371.825, $\chi 2=906.310$, $p<0.001$), and R-squared values (Cox & Snell: 0.732, Nagelkerke: 0.849, McFadden: 0.666) indicating a 73.2% to 84.9% variance explanation in the dependent variable, highlighting the model's robust predictive capability.

Results of the estimated parameters for factors influencing the use of DDSR are indicated in Table 6. The reference category for the dependent variable was "farmers with the PTR system of cultivation". Column "B" shows the estimated coefficient for each independent variable. The likelihood of choosing DDSR over PTR was positively correlated with increased perceptions of vulnerability, severity, response efficacy, self-efficacy, usage of private well irrigation, and receiving information from extension agents. Conversely, the probability of adopting DDSR decreased with higher levels of product self-consumption,

Table 4 Comparison of farmers' characteristics, farm management variables, and PMT constructs among the three groups of farmers (ANOVA results). *Source*: research findings

Variable	DDSR farmers (a) Mean (SD)	DDSR/PTR farmers (b) Mean (SD)	PTR farmers (c) Mean (SD)	F	Tukey
Farmers' characteristics					
Age (years)	44.03 (9.52)	46.16 (13.31)	48.95 (13.44)	11.17**	a > c, b = c
Years of experience in rice cultivation	21.05 (7.83)	22.93 (13.43)	26.78 (13.51)	16.55**	c > a = b
Years of schooling	9.45 (5.90)	6.88 (5.02)	6.78 (5.63)	16.51**	a > b = c
Percentage of self-consumed products	12.69 (4.19)	14.98 (6.47)	23.35 (7.44)	208.87**	c > b > a
Farm management variables					
Annual income from rice farming (US $)	1534.84 (700.38)	926.45 (606.03)	2400.65 (1864.56)	53.98**	c > a > b
Land area under rice cultivation (hectares)	2.06 (1.20)	1.65 (1.12)	3.93 (4.58)	29.81**	c > a = b
Family labor force in rice farming (percent)	14.20 (6.98)	20.77 (10.61)	36.39 (15.10)	234.43**	c > b > a
Rice yield (ton per hectare)	3.18 (1.13)	2.79 (1.29)	4.60 (1.52)	113.17**	c > a > b
Number of land parcels under cultivation	2.99 (1.41)	2.36 (1.25)	3.71 (2.09)	28.01**	c > a > b
PMT constructs					
Perceived vulnerability	3.11 (0.83)	3.05 (1.10)	2.51 (0.97)	32.37**	a = b > c
Perceived severity	3.41 (0.94)	2.94 (1.21)	2.37 (0.84)	86.53**	a > b > c
Response efficacy	2.71 (0.77)	2.50 (0.99)	2.33 (0.80)	14.72**	a > b = c
Response costs/barriers	2.90 (0.74)	3.04 (1.29)	3.53 (1.00)	31.30**	b > c > a
Perceived self-efficacy	2.83 (0.70)	2.27 (0.87)	1.99 (0.62)	101.01**	a > b > c

*Significant at $P < 0.05$, ** Significant at $P < 0.01$

Table 5 Results of model's fitting indices. *Source*: research findings

Model	−2log likelihood	Chi-square	Sig	R^2		
				Cox and Snell	Nagelkerke	McFadden
Intercept only	1361.67	–	–	–	–	–
Final	371.825	906.310	0.000	0.732	0.849	0.666

Overall percentage of correct prediction = 85.3%

Reference category includes farmers with the PTR system of cultivation

Included observations = 694

annual rice farming income, land area, family labor force, and rice yield. Additionally, factors influencing the combined use of DDSR and PTR systems indicated an increased adoption likelihood with heightened perceived severity and self-efficacy and using private wells for irrigation. In contrast, increases in self-consumed product percentage, rice farming income, land size, family labor force, and rice yield significantly increase the likelihood of using both DDSR and the PTR systems in the farm field.

5 Discussion

This study explored how sociodemographic and farm management variables, alongside PMT components, relate to farmers' behavioral responses to water scarcity in paddy fields. The research explored three distinct behaviors: the exclusive adoption of the DDSR system, a combination of DDSR with the PTR method, and the exclusive use of the PTR system. The results revealed that rising income from rice farming and the percentage of products that are self-consumed by farmers' households lessened the likelihood of choosing only the DDSR system and both DDSR/PTR systems. Some previous studies confirmed that income from farming activities is an important variable in adopting adaptation strategies (Keshavar & Karami, 2016; Anik et al., 2021). In general, the tendency to embrace innovative sustainable agricultural practices decreases with an increase in farmers' age (Dessart et al., 2019). Since the PTR has been common in the region for many years, farmers have more experience with this system and tend to maintain the PTR system which has a stable and reliable function. In particular, the increase in rice farming experience because of aging is itself a psychological factor for conservatism in the face of change to a new system (Ainembabazi & Mugisha, 2014). Therefore, extension and training programs need to focus more on convincing experienced farmers to change rice cultivation systems by using climate-smart agriculture principles along with traditional farming methods. This is because one of the climate-smart agriculture principles is "to sustainably maintain and increase productivity". The main reason to adopt this kind of technology is to offer equal yields or higher net benefits.

Therefore, highly educated farmers are expected to adopt adaptation strategies (Alam, 2015; Anik et al., 2021). Educated farmers understand the importance of using the DDSR system to adapt to water scarcity due to more interaction with agricultural experts and authorities. Self-consumer farmers were more inclined to the PTR system because of the high yield and possibility of rice storing for personal consumption. Bisht et al. (2014) noted that in traditional production systems, farmers keep some part of the crop for

Table 6 MNL regression results for the use of DDSR. *Source*: research findings

	B	Wald	Sig	95%CI
Interception	6.026	6.037	0.014	
Farmers' characteristics				
Gender (male)	– 0.729	1.757	0.185	0.164–1.417
Age (years)	– 0.002	0.011	0.918	0.957–1.040
Years of schooling	0.050	1.465	0.226	0.970–1.140
Years of experience in rice cultivation	– 0.007	0.101	0.751	0.948–1.039
Percentage of self-consumed product	– 0.331	65.953	0.000	0.663–0.778
Farm management variables				
Annual income from rice farming (USD	– 0.054	4.170	0.041	0.899–0.998
Land area under rice cultivation (hectares)	– 0.333	5.648	0.017	0.544–0.943
Family labor force in rice farming (percentage)	– 0.190	66.463	0.000	0.790–0.865
Rice yield (ton per hectare)	– 0.734	18.066	0.000	0.342–0.673
Number of land parcels under cultivation	0.182	1.266	0.261	0.874–1.648
Sources of irrigation water (private wells)	2.118	10.244	0.001	2.272–30.394
Sources of information (extension agents)	1.870	8.015	0.005	1.778–23–659
Sources of information (extension and training courses)	0.479	0.689	0.407	0.521–5.002
Sources of information (mobile social media)	– 0.350	0.176	0.675	0.137–3.619
PMT constructs				
Perceived vulnerability	0.536	5.908	0.015	1.109–2.635
Perceived severity	1.065	25.536	0.000	1.919–4.384
Response efficacy	0.810	9.990	0.002	1.360–3.712
Response costs/barriers	– 0.137	0.376	0.540	0.563–1351
Perceived self-efficacy	1.715	28.420	0.000	2.957–10.433
Intercept	– 12.10	30.45	0.00	
Farmers' characteristics				
Gender (Male)	– 0.660	1.802	0.179	0.197–1.355
Age (years)	– 0.013	0.446	0.504	0.950–1.025
Years of schooling	0.033	0.744	0.388	0.959–1.113
Years of experience in rice cultivation	0.011	0.258	0.611	0.969–1.055
Percentage of products that are self-consumed	– 0.214	39.515	0.000	0.755–0.863
Farm management variables				
Annual income from rice farming (USD	– 0.131	21.942	0.000	0.831–0.927
Land area under rice cultivation (hectares)	– 0.597	18.198	0.000	0.418–0.724
Family labor force in rice farming (percentage)	– 0.102	34.264	0.000	0.873–0.934
Rice yield (ton per hectare)	– 0.948	33.914	0.000	0.282–0.533
Number of land parcels under rice cultivation	– 0.091	0.359	0.549	0.677–1.230
Sources of irrigation water (private well)	1.369	4.583	0.032	1.123–13.762
Sources of information (extension agents)	0.738	1.442	0.230	0.627–6.979
Sources of information (extension and training courses)	0.637	1.475	0.225	0.676–5.291
Sources of information (mobile social media)	0.123	0.027	0.870	0.258–4.968
PMT constructs				
Perceived vulnerability	0.342	3.176	0.075	0.966–2.050
Perceived severity	0.481	6.813	0.009	1.127–2.320
Response efficacy	0.389	3.120	0.077	0.958–2.273
Response costs/barriers	– 0.175	0.793	0.373	0.572–1.233
Perceived self-efficacy	0.919	9.893	0.002	1.414–4.443

Table 6 (continued)

**Significant at 1%; **Significant at 5%

Reference category includes farmers with the PTR system of cultivation

Included observations = 694

personal consumption, and any innovation that exposes production to minor changes is not welcomed. For this reason, farmers with less personal consumption of produced rice preferred the DDSR system in rice cultivation. The research findings showed that the income from rice farming was negatively associated with the use of only the DDSR system and both DDSR/PTR systems. In contrast to this finding, Esfandiari et al. (2020) reported that income is an important determinant of Iranian rice farmers' decision to use adaptation strategies. Owusu and Yiridomoh (2021) also reported that asset holdings were positively correlated with adopting adaptation strategies among female farmers who were exposed to climate extremes in the Upper West Region of Ghana. It should be noted that higher yields and, consequently, higher incomes from rice production in the PTR system prevent the studied farmers from being disappointed with this system of cultivation. There is a possibility of reducing farm yield due to the problem of weed inundation in the DDSR system. For this reason, the PTR farmers, who attach great importance to rice yield and thus farm income, have little desire to transfer to the DDSR system. This result suggests that more efforts are needed to introduce high-yielding seeds and field management methods that maintain the level of production in the DDSR system and are on par with the PTR system.

The PTR farmers had greater land area under rice cultivation, more family labor in rice cultivation, more rice yield, and more cultivated plots of land than the other two groups of farmers, according to an analysis of farm management characteristics in three groups of farmers. The findings of the MNL model also support the idea that as the area under rice cultivation increases, family labor involved in rice cultivation and rice production becomes less likely to adopt either simple DDSR or both DDSR/PTR systems. In other words, large-scale farmers, who use more family labor and have higher production performance, are more loyal to the PTR system in rice cultivation. This is similar to the results achieved by Ghorbani-Kolahi et al. (2010), who showed that the higher amount of rice production was an important predictor of DDSR adoption and adaptation to water shortage in Iran. Alam (2015) revealed the positive impact of secure tenure rights on rice farmers' crop diversity as a strategy to adapt to water scarcity in the semi-arid climate of Bangladesh. In the study area, large-scale farmers with high yields from the current PTR system are often unwilling to risk changing their yield and income, and therefore are not interested in choosing another system to cultivate their rice fields. In particular, the inputs required for the effective implementation of DDSR in the province, including herbicides, are often not timely available, and the risk of reduced yields due to weed infestation always threatens the farm performance in the DDSR system (Kiani et al., 2019). In addition, rice farmers were not well aware of the technical aspects of DDSR. In particular, the majority of them were not sufficiently familiar with the new weeds that reduce farm yields in the DDSR system. In this regard, the focus of agricultural authorities should be on the timely supply of production inputs required for the DDSR system, including the standard seed cultivars and herbicides as well as consulting services about farm management. Since the traditional PTR system requires a large labor force which is provided for free by family labor force, it was not surprising that an increase in the family labor force decreased the tendency to use the DDSR system. Due to the large family size, as well as the paucity of job opportunities in the non-agricultural sectors, family members often engaged in farm work. Therefore, farmers with access to family labor were less inclined to switch to new farming systems with less dependency on labor force, such as DDSR. These results highlight the need to develop diverse entrepreneurial opportunities in rural areas and replace farm mechanization with human labor force in rice farming.

The results of the MNL model also showed that farmers who have a private well as a source of water in rice cultivation are more inclined to adopt only DDSR and both DDSR/PTR systems. For private well owners, water is not a free commodity or a common resource, so they can be expected to be more concerned with more sustainable use of water resources in rice cultivation. The rationale of this group of farmers for using the DDSR system is understandable. Based on these findings, if the PTR system is used in rice cultivation, the amount of water consumption will increase and, as a result, the operating costs of the private well, including fuel, electricity, and repair costs, will increase. Therefore, moving towards a rational pricing system for public water resources, such as rivers and dams, can be an effective way to speed up the adoption rate of DDSR. Thompson (2000) implied that the governance system of public water resources is not effective enough to secure its optimal and sustainable use. In this study, the MNL analysis revealed that receiving information about DDSR from extension agents is positively connected to the adoption of the DDSR system. This means that instead of rejecting DDSR and continuing to use the PTR system, more DDSR will be used, which increases confidence in direct contact with the extended agent. Several prior studies highlighted the important role of extension services in facilitating the adoption of adaptation strategies (Abid et al., 2016; Anik et al., 2021; Owusu & Yiridomoh, 2021). However, this study's findings showed that close contact with extension workers was crucial to the success of DDSR development initiatives for rice farming. Due to the high effectiveness of personal interaction in farmers' behavior change (Sharifzadeh & Abdollahzadeh, 2021), funding extension programs with field-based education approaches, face-to-face recommendations, and field visits should be prioritized by the Ministry of Agricultural Jihad.

According to the current study's findings, rice farmers assess DDSR in ways that are compatible with the PMT framework, which is in accordance with other research that used PMT to forecast the adoption of adaptation techniques (Keshavarz & Karami, 2015; Bagagnan et al., 2019; Ghanian et al., 2020; Delfiyan et al., 2021). The findings of this study suggested, in particular, that adoption of DDSR rose when farmers believed they were more vulnerable to water scarcity and overestimated the severity of the impact of the shortage on the system for growing rice. These results are consistent with those by Keshavarz and Karami (2016) who found a relationship among PMT elements, farmers' responses to drought's effects, and understanding their sensitivity and severity. Moreover, employing both DDSR/PTR systems was predicted by perceived severity. This finding means that awareness of water shortage impacts is an important contributor to predicting the behavior that decreases these consequences. Thus, extension programs that offer accurate evidence to increase farmers' vulnerability to water scarcity and provide them with objective and documented evidence of the long-term consequences of the PTR system might reduce dependence on the PTR system and increase the shift towards the DDSR system.

Similarly, the likelihood of accepting a DDSR system with high evaluation rates, response effectiveness, and self-efficacy increased. Using both DDSR/PTR systems was also connected to perceived self-efficacy. These findings are in line with prior studies suggesting that any coping reaction will be widely used when beneficiaries find it effective and accessible (Keshavar & Karami, 2016; Delfiyan et al., 2021). These findings imply the need for intervention programs aimed at raising awareness of the effectiveness of DDSR in solving the problem of water shortage in the rice fields. In addition, technical aspects such as land bed preparation, introducing appropriate seed cultivars, planting time, pest and weed management, and proper irrigation methods should be included in these intervention programs. In such a situation, farmers have sufficient incentive to ignore the PTR system and pay more attention to the DDSR system (Kiani et al., 2019). Response efficacy and self-efficacy are imperative to ensure the long-term continued use of adaptation strategies (Grothmann & Pat, 2005). Hence, focusing on improving response efficacy and self-efficacy in training and supportive campaigns will have an important effect on increasing the acceptance rate of DDSR.

In contrast, PTR farmers and DDSR/PTR farmers overestimated the cost of and barriers to using the DDSR system. This means that either these two groups of farmers did not trust the benefits of using the DDSR system or they really lacked the farm infrastructure and inputs such as herbicide or advanced irrigation systems and technical knowledge to apply this system. In fact, the aim of the farmers is to maximize income through more yields, not to save water. To accept the benefits of DDSR/PTR, knowledge, attitudes, and awareness must be changed in addition to greater technical expertise or better infrastructure. In addition to saving water, one also benefits from its economic benefits. Prior applications of PMT in promoting adaptation strategies reported the importance of perceived response costs/barriers in predicting farmers' protection behavior (Keshavar & Karami, 2016; Delfiyan et al., 2021). Additionally, prior research has demonstrated that farmers' perception of the difficulty in utilizing innovative agricultural water-saving technology (Dai et al., 2015; Berthold, 2021) is a key factor in facilitating the initial adoption as well as the continuation of the adoption process. In the study area, there is a range of barriers to accomplishing the DDSR system in the farm field. In this regard, agricultural authorities should design support campaigns or extension programs with the aim of providing timely farm inputs and technical advice to increase the rate of the DDSR system development in paddy fields. Future research should focus on developing training and extension methods that can effectively promote PMT constructs among rice farmers.

This study has some limitations. First, it focused on predictors of one type of adaptation strategy in rice fields, while a variety of strategies are available for adapting to water scarcity in rice fields, and the study of farmers' reaction to using such strategies can be explored in future research. Moreover, the proposed items for measuring PMT constructs are specifically designed in the context of the DDSR system. Therefore, the proposed items to measure farmers' feelings and attitudes toward other climate change phenomena in different contexts should be applied with caution. However, empirical analysis of PMT constructs and another framework such as the Unified theory of acceptance and use of technology (UTAUT) in different samples of farmers is needed in upcoming research to verify the generalizability of the results to other fields and regions with different climatic conditions. In addition, it will be useful if further research examines different experiences in dealing with water scarcity by using qualitative research methodologies.

6 Conclusion and policy implications

DDSR is necessary to cope with the consequences of water shortage in paddy fields. However, the study's findings indicate that the adoption rate of DDSR in the research area's paddy fields is low. The findings of this study reveal the importance of PMT constructs in predicting the adoption of an adaptation strategy. These findings verified that PMT is an effective theory for predicting the adoption of pro-water saving technology in the rice cultivation system. In addition, this study underscored the importance of considering farmers' characteristics such as self-consumption rate and income of rice farming in explaining the adoption of the DDSR system. Moreover, farm management variables including land size, family labor, rice yield, sources of irrigation water, and sources of extension information should be considered in extension programs aimed at promoting the adoption of the DDSR system. Some of the costs/barriers highlighted by farmers involved in limiting the use of the DDSR system were mainly related to access to appropriate farm inputs, irrigation equipment, and technical knowledge. These findings are valuable for agricultural authorities to address the weaknesses and shortcomings of the development of the DDSR system in future interventions. Moreover, extension efforts should focus on increasing the adoption rate of DDSR by promoting farmers' trust in the effectiveness of DDSR in mitigating the consequences of water scarcity. As a result, water management policymakers and planners must take action to support farmers' concerns about declining incomes by developing a DDSR system that takes into account the economic benefits of farmers. DDSR development policies also require educational interventions that provide sufficient information to increase farmers' vulnerability to water scarcity and its severity. In this regard, officials need to examine why farmers have no idea about drought and why current water frameworks and laws in Iran do not encourage farmers to reduce water use on paddy lands. Furthermore, officials should provide sufficient information on the effectiveness of DDSR in reducing water scarcity, its potential low effects on farm performance, and the timely availability of field inputs, especially herbicides.

Data availability Upon request, the data will be made available.

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