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Factors affecting climate-smart agriculture development in Fars Province, Iran

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ABSTRACT

In recent years, climate change has reduced the production and revenue of agricultural products. Despite farmers' increasing vulnerability and poverty due to climate change, climate-smart agriculture strategies (CSAs) have not been implemented adequately in developing areas. So, the present study evaluated the effective factors of adopting CSAs at three spatial, farm, and individual levels. In this study, data were collected using a questionnaire from 443 farmers during 2018-2019 in four different climatic regions of Fars Province, Southwest Iran. Consequently, the CSAs utilized in the three groups of management of nutrient and water-smart strategies, conserving or enhancing soil fertility-smart strategies, and the combination of these two groups were analyzed by dividing the solutions through Poisson count regression and multinomial-logit estimations for these strategies expansion. The study of spatial characteristics revealed that the agricultural sector of Fars Province lacks a logical model for smart agriculture and has failed to adopt smart strategies to climatic conditions. According to farm and individual research, younger farmers with greater access to credit, increased participation in social groups, and better awareness and perception of climate change risk are more likely to adopt CSAs. In this regard, the variables of access to credit and trust in individuals have the most positive and negative effects on the adoption of climate-smart strategies, respectively. It is expected that with an increase of 1 unit in the amount of these variables, the changes of the dependent variable will be 1.25 and -1.32, respectively. All the same, larger farms and higher farm incomes ensure that farmers in the province will utilize CSAs. Hence, it is recommended to focus on awareness and education of farmers regarding these strategies along with facilitating access to extension services and financial credits as well as using the potential of formal and informal associations to encourage farmers to participate in social activities to develop CSAs.

Keywords: Climate change, Climate-smart agriculture, Multinomial logit model, Poisson regression.
Article type: Research Article.

INTRODUCTION

Climate change significantly threatens food quantity, quality, and economic value (Teklewold *et al.* 2019). Numerous studies have demonstrated that climate change can reduce agricultural output and heighten the economic difficulties of farmers. Consequently, climate change can increase the vulnerability and poverty of farmers, especially in developing countries (Altieri & Nicholls 2017; Ado *et al.* 2018; Mirzaei & Zibaei 2021). Adaptive strategies have been shown to mitigate the negative effects of climate change and reduce farmers' vulnerability (Mirzaei *et al*. 2022). So, various studies have evidenced that adaptation strategies are critical to improving the livelihoods of vulnerable households (Makate *et al.* 2016). Indeed, the challenges associated with climate change in the agricultural sector demonstrate the necessity of adopting innovative strategies to enhance the resilience of farmers and mitigate the effects of climate change. Arid climate in Iran makes it particularly susceptible to the impacts of climate change. One of the most significant effects is the alteration of rainfall patterns, exacerbated by factors like population growth and unsustainable water consumption practices. As a result, freshwater resources in Iran have been severely impacted, with per capita access to fresh water dropping

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from 2000 m^3 in 2000 to a projected 1500 m^3 by 2030 (Memarbashi *et al.* 2022). The agricultural sector in Iran faces significant challenges due to population growth, rising food demand, diminishing fertile land, and the escalating threat of drought (Karimi *et al.* 2018; Layani *et al*. 2021). Numerous studies (Khalili *et al.* 2021; Savari *et al.* 2022) in the country have substantiated the adverse effects of climate change, especially droughts, on the agricultural sector productivity. Therefore, the development and implementation of climate change adaptation technologies are of paramount importance in addressing these challenges. The Food and Agriculture Organization of the United Nations (FAO 2017) refers to this collection of solutions as Climate Smart Agriculture (CSA). CSA practices such as soil and water conservation and diversity of crop systems are the foundation of ecosystem performance and are required for productive advances in agriculture by increasing crop yield, input efficiency, and farmer net incomes (Khatri-Chhetri *et al.* 2017; Teklewold *et al.* 2019). In addition to retaining or increasing farm productivity, CSAs can improve farmers' resilience and reduce the effects of climate change (Pagliacci *et al.* 2020). Hence, these strategies are an effective tool to reduce poverty and food insecurity by increasing farmers' production and income, especially in developing countries (FAO 2017). Climate change phenomenon in Iran has unavoidably manifested and is spreading. The average rainfall in Iran is about 250 mm (Talebi 2023), less than one-third of the average rainfall in the world (860 mm). The distribution of rainfall in Iran is also disproportionate, and in many regions of the country, evapotranspiration exceeds the amount of annual precipitation. Furthermore, according to the 10-year index (satellite-derived estimates of precipitation, temperature, and evaporation), 98.1% of area in Iran has experienced varying degrees of drought. During this period, only 1.6% of the country's area is in normal condition, and 0.3% is primarily in wet periods (Meteorological Organization of Iran 2018). According to reports, Iran has experienced an increase in the frequency of droughts, a rise in temperature, an intensification of irregular rainfall patterns, and the depletion of underground water resources due to climate change (Mardani Najafabadi *et al.* 2022). Consequently, it is necessary to consider expanding CSAs in Iran. Numerous studies have been performed to understand better the adaptive behavior of farmers regarding climate change in Iran (Azadi *et al.* 2019; Yaghoubi Farani *et al.* 2019). Despite the great benefits of CSAs, the adoption of these strategies by farmers is low, especially in developing countries such as Iran (Khatri-Chhetri *et al.* 2017; Westermann *et al.* 2018; Mirzaei *et al.* 2022). In this regard, identifying the factors influencing farmers' adoption of smart agricultural strategies against climate change is regarded as an effective strategy for increasing the number of farmers employing these strategies. Numerous studies have been conducted on the effective factors in adopting agricultural adaptation strategies (Dong *et al.* 2019; Marie *et al.* 2020; Bahinipati *et al.* 2021; Guja & Bedeke 2024). Previous studies have mainly focused on the attitudes and motivations of farmers, human communication, and farmers' social capital (Li *et al.* 2019; Azadi *et al.* 2019; Pagliacci *et al.* 2020; Azarn *et al.* 2022). Farm characteristics are also one of the effective factors in the adoption of CSAs. Multiple studies have shown the positive and significant effect of farm characteristics such as farm size and income on farmers' participation in programs adapted to climate and environment (Trinh *et al.* 2018; Khan *et al.* 2020). Thus, the results of a review of prior research indicate that a wide variety of political, technical, environmental, and climatic characteristics of regions, structural characteristics of farms, socioeconomic variables, and farmers' tendencies influence farmers' participation (Luo *et al.* 2016; Pagliacci *et al.* 2020). The objective of expanding agri-environmental programs, such as climate-smart development programs, is not met when a program is unable to differentiate between farms and different areas based on their vulnerability (Raggi *et al.* 2015). Assuming that farmers are agents attempting to maximize their profits, the focus of most studies on the development of environmentally friendly and climate-friendly programs is limited to economic indicators, while a wider range of factors determining farmers' participation, such as location and neighborhood and regional effects, have been neglected (Daniele *et al.* 2017). Consequently, it seems necessary to investigate the impact of spatial dimension on farmers' participation in agri-environmental programs (Daniele *et al.* 2017; Pagliacci *et al.* 2020). Raggi *et al.* (2015) found that spatial differences in extension services affect rural development program participation. According to Pagliacci *et al.* (2020), regions with poor access to irrigation resources, high precipitation, low nitrate vulnerability, and low agricultural share are less likely to adopt CSAs to reduce water and fertilizer use. Thus, a more precise evaluation of the factors influencing the implementation of expanding agri-environmental programs is necessary regarding spatial and regional variables. Based on the background discussed above, the present study aimed to evaluate comprehensively the effective factors for adopting CSA in Iran. First, the spatial (access to irrigation, rainfall, soil type, and agricultural size) factors influencing the number of farmers who employ climate-smart strategies were identified. Thus, the first hypothesis is that the rainfall variable has a greater impact on the number of farmers adopting climate-smart strategies than other spatial variables. The effect of the farm (farm size and farm income) and individual (social-capital, psychological, and socioeconomic variables) factors on farmers' adoption of smart strategies was then evaluated. The second hypothesis of the present research is that the contribution of the social capital variable to the adoption of climate-smart strategies is more than psychological characteristics. In other words, in this study, the potential of spatial or regional factors to increase the number of farmers adopting climate-smart strategies was determined first, followed by the effective factors for increasing the adoption of these strategies. In addition to emphasizing social capital and psychological characteristics, this study has another unique characteristic. In general, considering all of the influencing factors in different dimensions on the adoption of smart strategies against climate change, along with the addition of the spatial dimension, has contributed to the comprehensiveness and novelty of this study. A thorough literature review reveals that such a comprehensive study on climate change adaptation strategies has not been conducted, particularly in Iran.

MATERIALS AND METHODS

Conceptual framework

The conceptual framework of the present study is shown in Fig. 1. The proposed framework examined the effects of three spatial, farm, and individual characteristics on farmers' adoption of CSAs. Access to water resources for irrigation (Ren *et al.* 2018), rainfall condition (Khatri-Chhetri *et al.* 2017), dominant soil type (Giller *et al.* 2011), and size and extent of agricultural fields (Pagliacci *et al.* 2020) were considered as explanatory variables of the adoption rate of climate-smart strategies. Numerous studies have investigated the influence of farm variables on adopting climate-smart strategies. The issue of farm size variables (Teklewold *et al.* 2019; Makate *et al.* 2019; Pagliacci *et al.* 2020) and farm income (Khatri-Chhetri *et al.* 2017; Pagliacci *et al.* 2020) were considered as farm characteristics in this study. The present study categorizes personal, socioeconomic, social capital, and psychological variables as effective individual variables. Individual variables include age, education level, household head's background, and the number of household members. Socioeconomic variables, such as access to promotion, access to credit, and off-farm income, have been utilized in the majority of studies effective factors on farmers' participatory behavior (Mariano *et al.* 2012; Teklewold *et al.* 2019). The variables of individuals trust in governance institutions, and social participation are considered social capital characteristics based on a review of the literature (Hunecke *et al.* 2017; Saptutyningsih *et al.* 2020). Farmers' perceptions of climate change and risk beliefs were also identified as psychological variables (Azadi *et al.* 2019). The year of adopting the CSAs is considered the final explanatory variable for identifying the strategies that have gained popularity among farmers in recent years. Finally, ten CSAs in three general groups of management of nutrient and water-smart strategies, conserving or enhancing soil fertility-smart strategies, and their combination were considered after reviewing the literature and the required information in the study area (Pagliacci *et al.* 2020). Among these strategies are enhancing crop varieties, modern irrigation systems, managing irrigation scheduling, harvesting and utilizing rainwater, land leveling, drainage management, crop coverage, conservative tillage, limiting chemical fertilizers and using green manure, hybrid cultivation, and crop rotation (Wassmann *et al.* 2019; Zerssa *et al.* 2021; Branca *et al.* 2021).

Study area

This study examines the adoption of climate-smart agricultural strategies in Fars Province, Southwest Iran (Fig. 2). The study area, Fars Province (27°03′–31°40′N, 50°36′–55°33′E), is located in the Southwest Iran, covering an area of 1.33×10^5 km^2 (Fig. 2A). This province accounts for approximately 7.4% of Iran's area and ranks as the fourth largest province. Fars Province is primarily agricultural and is distinguished as one of the country's leading agricultural regions, ranking first in some crops such as wheat, beans and some horticultural products. In general, over 12% of total agricultural production in Iran is produced in this province (Khalili *et al.* 2020). It has 28 cities and more than 200 villages, most of these areas are major centers of agricultural production (Figs. 2B & 2C). The average annual rainfall in Fars Province from 1992 to 2013 was approximately 322 mm (SCI 2017). In recent years, the province has been impacted by severe climate change. The province's severe drought between 2003 and 2011 has been considered a variable effect of climate change (Keshavarz *et al.* 2014). In recent years, it has been demonstrated that Fars Province has experienced both a rise in temperature and a decline in soil moisture (Gandomkar & Dehghani 2012). By decreased precipitation in this province, groundwater extraction has increased significantly. Nowdays, the groundwater balance in many province plains is negative, rendering agriculture and crop production impossible.

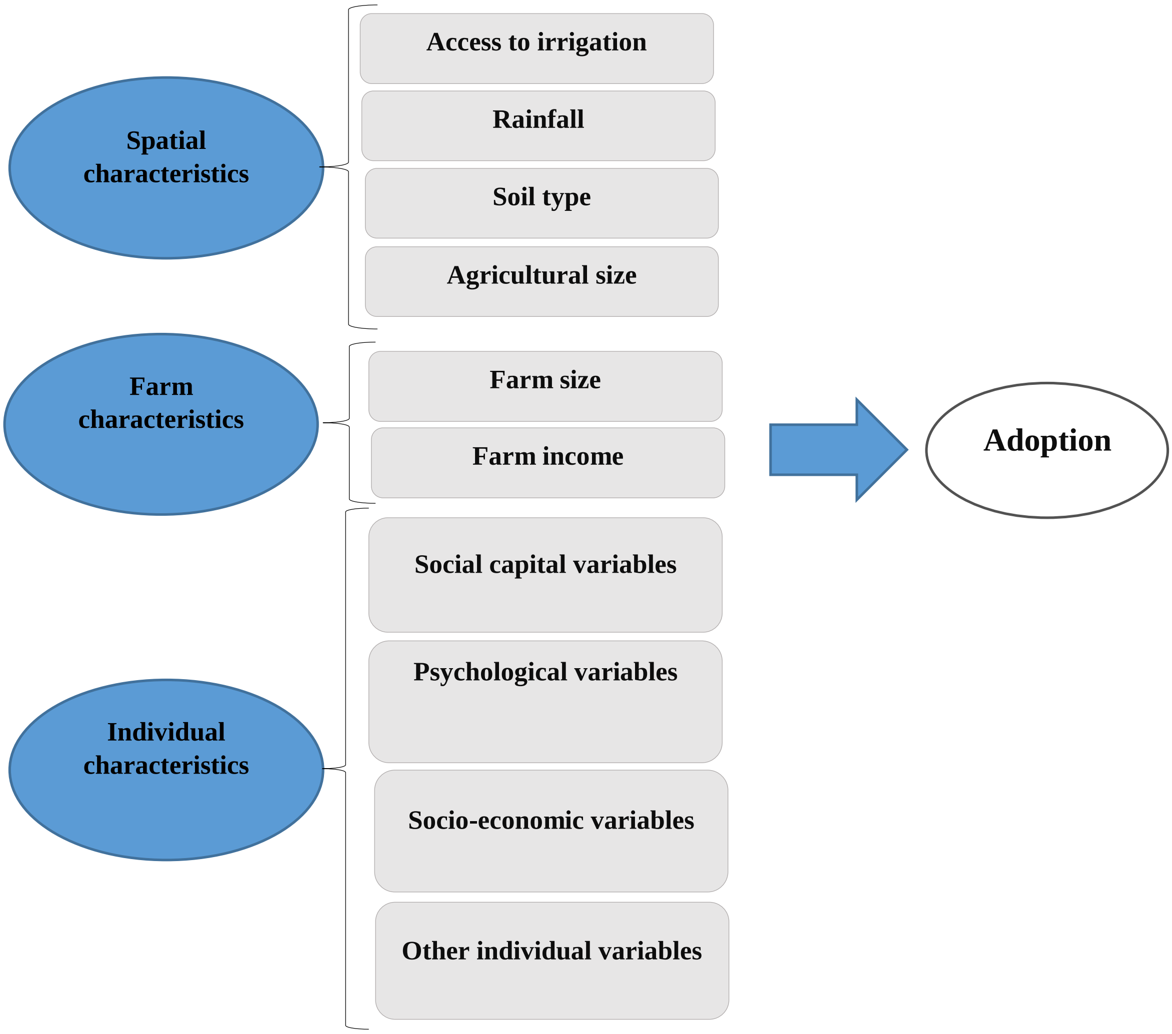

Fig. 1. The proposed conceptual framework (Bahinipati *et al.* 2021; Azadi *et al.* 2019).

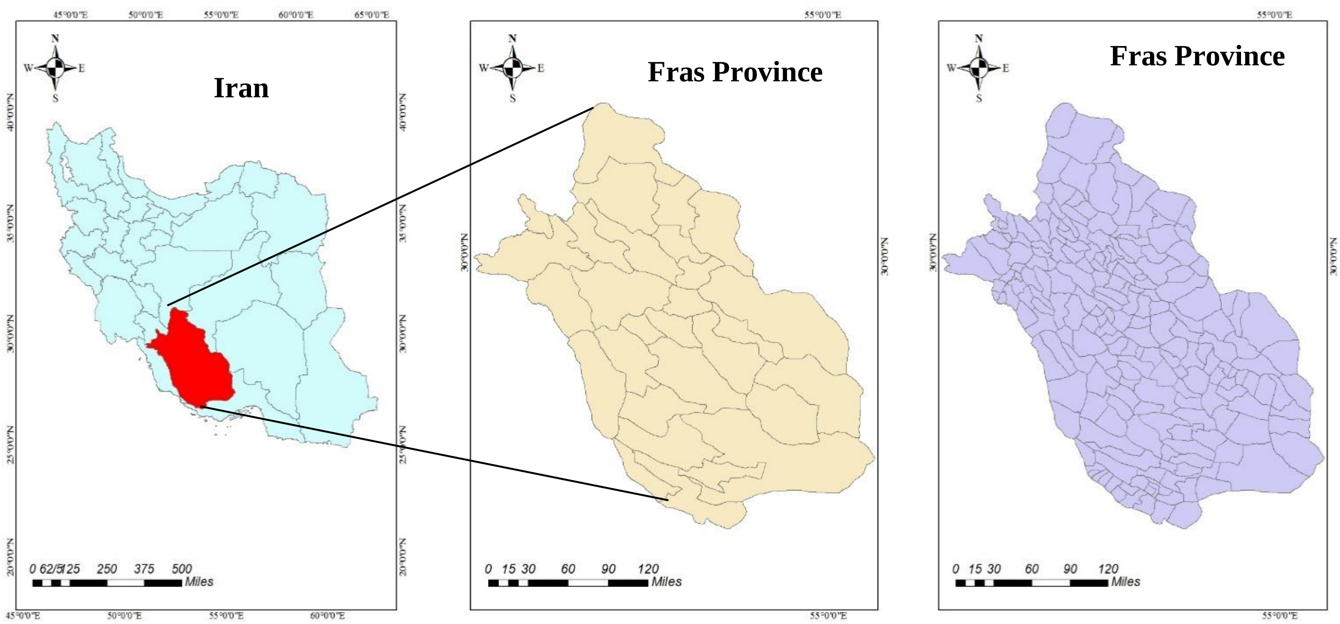

Fig. 2 A. Map of Iran by province. **Fig. 2 B.** Map of Fars Province by cities. **Fig. 2 C.** Map of Fars Province by villages.

Study data collection

This study was based on a cross-sectional survey conducted in Fars Province, Iran. During the summer and fall of 2019, questionnaires were used to collect the required data, and an in-person survey was conducted. The study sample was selected using a multistage stratified random sampling method. Due to the climate diversity of the study area and the extreme changes in precipitation and evaporation, climate classification is emphasized (Arab Amiri & Gocić 2021).

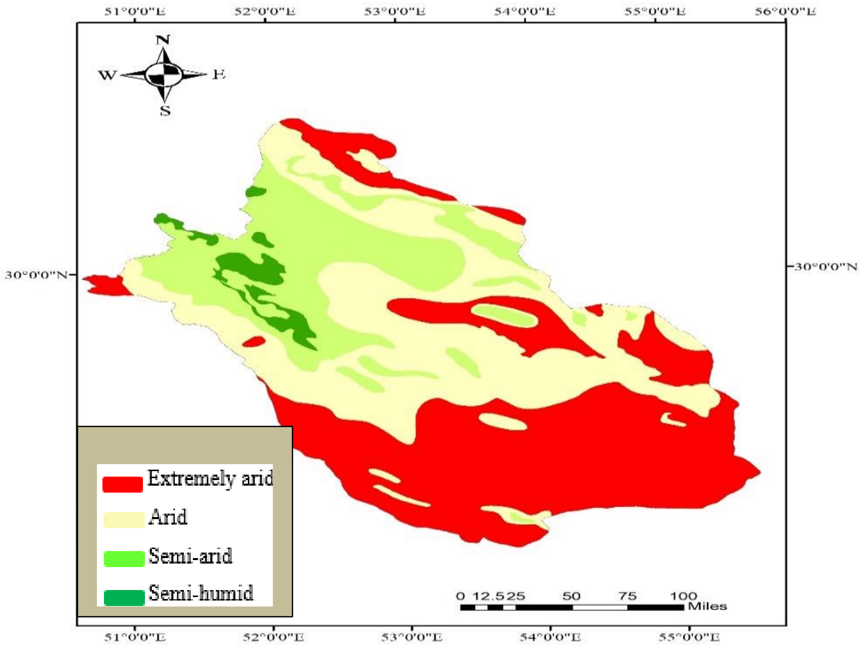

Fig. 3. Divisions of Fars province based on climatic conditions.

In this regard, Fars Province was initially divided into four categories based on climatic conditions: extremely arid, arid, semi-arid, and semi-humid (Mirzaei *et al.* 2022). In this research, the province was categorized into four distinct climatic zones through multi-stage stratified random sampling based on weather conditions. Subsequently, 75 rural districts (These rural districts include Bahman, Shahrmian, Khanjesht, Surmaq, Hassan Abad, Ahmed Abad, Mashaikh, Jozar, etc., as shown in Fig. 5) each serving as a representative sample of the diverse climatic zones, were randomly chosen from the map of province for further study. Finally, 443 farmers whose sample sizes were determined using Morgan's table were randomly selected among the villages selected.

Poisson method and multinomial-logit

In this study, the effects of spatial factors on the number of farmers adopting CSAs were evaluated using Poisson count regression. Since spatial characteristics in terms of rainfall, soil type, access to irrigation, etc. are the same for farmers in each region. Therefore, it is not possible to examine spatial factors such as individual and farm factors. Hence, to evaluate the effects of spatial variables on the adoption of climate-smart strategies, the number of farmers accepting these strategies was recorded. In cases where the dependent variable is a count variable (number of farmers), discrete variable distributions, such as the Poisson or negative binomial distributions, are preferable for its modeling. If the mean values and variance of the dependent variable data are identical to the Poisson distribution, and if the variance value is greater than the mean value (high scatter of the count variable), then the negative binomial model is a suitable distribution to explain the count dependent variable based on other independent variables (Saffari *et al.* 2012). Notably, the dependent variable in count models is a discrete variable as opposed to a continuous variable; it is not a decimal number but a count number. Therefore, the researcher cannot utilize the conventional econometrics method, namely the ordinary least squares method. Shaw's (1988) study used the first count distributions. The i^{th} observation of the dependent variable y_i, which is the number of farmers adopting smart agriculture strategies for the sample climate in each village, is modeled as a Poisson random variable with mean λ in the Poisson regression model.

$$prob(\ y_i) = \frac{(e^{-\lambda}).\lambda^{y_i}}{y_i!} \quad \textbf{(1)}$$

An important feature of the Poisson regression model is the equality of the distribution's mean and variance, equal to λ.

$$E(\ Y \mid X) = \ var(Y \mid X) = \ \lambda \quad \textbf{(2)}$$

Where y denotes the actual number of dependent variables, X represents the set of explanatory variables with the same properties at the spatial level, and λ is the expected number of dependent variables, y. Multinomial-logit regression was used to examine the effects of individual and farm characteristics on the adoption of smart agricultural strategies. This method has the advantage of allowing decision-making analysis in more than two categories (Wooldridge 2001). Furthermore, alternatively, this method is easily calculable. These multi-equation models, extended versions of logit models, display the probability of a state belonging to a particular class or group. Multiple studies have demonstrated that, even if the alternative independence assumption is violated, the multinomial logit model yields more accurate results than the multinomial Probit model (Sam *et al.* 2019). In this study, farmers were classified into four groups. The first group consisted of farmers who had adopted nutrient and water management strategies. The second group comprised farmers who have implemented soil conservation or enhancement strategies. The third group was farmers, who selected a combination of strategies from the first two groups. Also included were farmers who have not adopted CSAs. This study utilized Amemiya's (1981) model to estimate the data. Thus, the effects of explanatory variables (X) on the probability of the dependent variable (Y) with positive integers (S = 1, 2, and 3) were evaluated relative to the group that has not adopted climate-smart agricultural strategies (S = 4). As a result, the S-1 model estimates the logit equation and probability for each group as Equation (1).

$$P(y_i|x_i) = \frac{exp(B_S x_i)}{1+\sum_{s=2}^{S} exp(B_s x_i)} \quad \textbf{(3)}$$

The probability of a reference group is:

$$P(y_i\ = 4|x_i) = \frac{1}{1+\sum_{k=2}^{K} exp(B_k x_i)} \quad \textbf{(4)}$$

The probability of each group relative to the reference group is calculated as the relative risk ratio as follows:

$$\frac{P(y=k)}{P(y=4)} = \exp(\beta_k x_i)\,, \quad for\ k\ = 1,2,3 \quad \textbf{(5)}$$

As the negative effects of climate change become more apparent, Iran's Fifth Development Plan emphasizes more than ever the need to protect water and soil resources. To this end, funds were considered to develop new irrigation systems and improve soil fertility. In this study, the first year of the Fifth Development Plan (2011) was considered as the beginning of adopting climate-smart strategies. Farmers who adopted climate-smart strategies before 2011 were classified as pioneers, while those who adopted these strategies after 2011 were classified as laggards.

RESULTS AND DISCUSSION

Following confirmation of the questionnaire's validity and reliability (the validity of the questionnaire was confirmed using expert opinion. In addition, the reliability was satisfied by a Cronbach's alpha value greater than 0.7. The data on explanatory variables were collected from 443 farmers in Fars Province between 2018-2019. Fig. 1 depicts the frequency with which the sample farmers used smart agriculture strategies (4). According to the findings, 28.4% of farmers implemented nutrient and water-smart strategies (6 strategies) and conserving or enhancing soil fertility-smart strategies (4 strategies), respectively. Furthermore, 26% of farmers used a combination of these strategies, while over 16% did not use any smart agriculture strategies. According to Mirzaei *et al.* (2022), approximately 20.5, 23.5, and 21% of Iranian farmers, respectively, chose to adopt strategies related to changing crop varieties, crop patterns, and irrigation technologies. To examine the effects of spatial characteristics on the adoption rate of CSAs, the number of farmers adopting smart agriculture strategies in 75 sample rural districts was considered a dependent variable. Fig. 5 illustrates the distribution of farmers who accept climate-smart practices in the study areas. It can be said that the selected samples cover almost the entire studied area. The results of the Poisson regression analysis of the spatially effective factors on the number of farmers adopting CSAs are provided in Table 1. Farmers who have implemented at least four of the ten CSAs in the study are recognized as adopters. The results indicated that rainfall conditions and the size of agricultural fields in the region have a positive and statistically significant effect on the number of adopters of CSA practices. The positive and significant effect of the rainfall variable suggests that the number of farmers accepting CSAs (water and soil conservation) is greater in regions with better rainfall. However, when precipitation levels are lower, farmers are expected to be more likely to adopt CSAs to reduce water use and improve soil quality (Pagliacci *et al.* 2020).

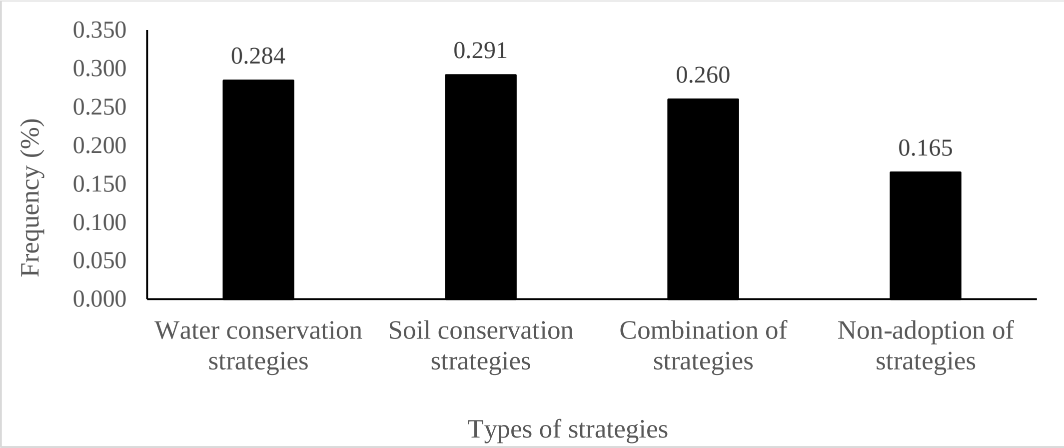

Fig. 4. Frequency of strategies adopted by farmers.

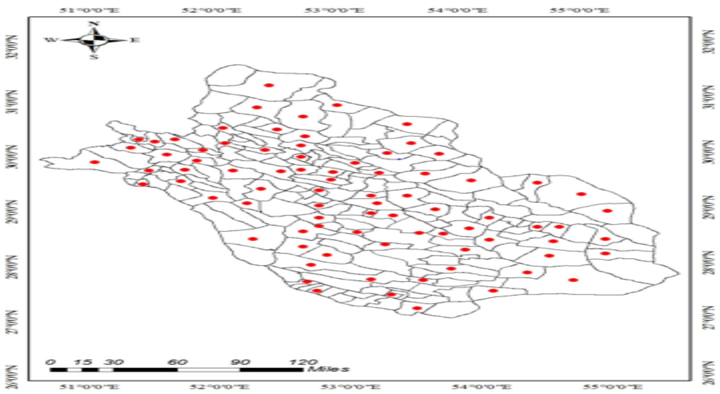

Fig. 5. Distribution of farmers adopting CSAs in the selected areas. This figure illustrates the rural districts chosen at random to represent various climatic conditions. Subsequently, 443 farmers from these regions were selected as the study sample.

Table 1. The effects of spatial characteristics on the number of farmers who accepted climate-smart agricultural strategies (Poisson regression, n = 75).

Variables	**β**	**SE (β)**
Intercept	-3.77**	1.83
Availability of water resources for irrigation (five-point Likert scale, 1 = very good to 5 = very poor)	0.61	0.47
Precipitation condition (five-point Likert scale, 1 = very good to 5 = very poor)	0.87***	0.28
Dominant soil type (sandy = 1, clay = 2)	-1.02	0.88
Size and extent of agricultural fields (hectares)	0.08**	0.02
Log-likelihood (fitted model)	-38.84	
Nagelkerke pseudo-R^2	0.63	

Notes:1. A quasi-Poisson model was calculated when over dispersion occurred;2. β is the estimated coefficient and SE(β) is the standard error of the estimate; ** and *** represent significance at 5% and 1%, respectively.

Khatri-Chhetri *et al.* (2017) also reported that when rainfall is low, the likelihood of adopting CSAs rises as water use optimization becomes increasingly important. Contrary to expectations and the findings of other studies, the lack of significance in the variable of access to irrigation conditions was also found (Ren *et al.* 2018). According to Ren *et al.* (2018), farmers without access to irrigation are more likely to employ no-till farming techniques. However, farmers in areas with limited water resources should be encouraged to implement water and soil conservation strategies. Harmanny & Malek (2019) observed that water scarcity is the most significant factor influencing farmers' adoption of adaptation strategies. Reduced rainfall increases farmers' willingness to adopt adaptation strategies. In addition, Roco *et al.* (2015) emphasized the significance of farmers' access to irrigation technology for mitigating climate change-related risks. In areas with more agricultural fields, the adoption rate of CSAs was also found to be higher. This result is consistent with findings of Pagliacci *et al.* (2020). Zhang *et al.* (2019) considered the possibility that farmers with large farms accept more time-consuming labor and water costs and, as a result, are more likely to adopt new irrigation technologies to reduce these costs. The fragmented and small land size in South Asia, according to Aryal *et al.* (2020), reduces farmers' ability to adapt to climate change. In addition, the results demonstrated that the soil type variable does not affect the proportion of farmers who employ CSA strategies. Table 2 presents farm and individual explanatory variable descriptive statistics. The results indicated that the interviewees' ages ranged from 27 to 71 years, with a mean of 46.3 years and a standard deviation of 8.7 years. The average level of education is 2.4, between the primary and secondary education levels. Furthermore, the average agricultural history of household heads exceeds 30 years. In addition, over 70% of households consist of five or more individuals. The average size of farms in the study sample is close to 9 hectares. The typical farm income exceeds 110 million rials. According to an examination of descriptive statistics of socioeconomic characteristics, 55% of farmers have no off-farm income. In addition, 47% and 63% of farmers lack access to extension services and credit respectively. Furthermore, almost 60% of farmers lack confidence in government institutions. In contrast, farmers' confidence in society exceeds 70%. However, over 60% of households participate in community activities. Finally, the mean scores for belief in climate change and perception of risk are 3.3% and 2.8%, respectively. These statistics show that farmers are relatively aware of the severity and impact of climate change. In this study, the effective factors of farmers' selection of CSAs were estimated using a multinomial-logit model and STATA15 software (Table 3). The likelihood ratio (LR; 312.26) and pseudo-R^2 (0.46) statistics indicated that the model is statistically significant at the 1% level, and its fitting can be confirmed. The results of the household characteristics indicated that the age of the farmer has a negative and significant effect on the probability of adopting all three groups of CSAs. In other words, younger farmers are more likely than older farmers to adopt CSAs to combat climate change. This result is consistent with previous study (Khan *et al.* 2020). However, it contradicts the findings of Saptutyningsih *et al.* (2020).

Table 2. Descriptive statistics of explanatory variables.

Group	Variable	Unit	Descriptive statistics
Household characteristics	**Head of household**	**Years**	**Mean = 46.3 SD = 8.7**
	Level of education of the head of the household	Uneducated = 1 Primary school and high school = 2 Diploma = 3 Associate and BA = 4 MA and PHD = 5	Mean = 2.4 SD = 1.2
	The agricultural history of the head of the household	Years	Mean = 32.2 SD = 10.6
	Number of household members	People	Mean = 5 SD = 1.4
Farm features	Farm size	Hectares	Mean = 8.9 SD = 4.8
	Farm income	Million Rls	Mean = 112.2 SD = 28.4
Socioeconomic characteristics	Off-farm income	No = 1 Yes = 2	Frequency No: 245 Yes: 218
	Access to extension services	No = 1 Yes = 2	Frequency No: 210 Yes: 233
	Access to credit	No = 1 Yes = 2	Frequency No: 281 Yes: 162
Characteristics of social capital	Trust people	Five-point Likert scale (1 = strongly disagree, 5 = strongly agree)	Mean =4.3 SD=1.6
	Trust in governing institutions	Five-point Likert scale (1 = strongly disagree, 5 = strongly agree)	Mean = 2.6 SD=1.3
	Family participation in social activities	Five-point Likert scale (1 = strongly disagree, 5= strongly agree)	Mean = 3.1 SD = 0.95
Psychological characteristics	Belief in climate change	Five-point Likert scale (1 = strongly disagree, 5 = strongly agree)	Mean = 3.3 SD=1.4
	Perception of the risk of climate change	Five-point Likert scale (1 = strongly disagree, 5 = strongly agree)	Mean = 2.8 SD = 1.5
	Strategy adoption time	Year	Frequency Pioneer = 141 Laggard = 302

According to Mirzaei *et al.* (2022), young farmers in Iran were more receptive to cultivating drought-resistant cultivars and early maturing varieties. Thinda *et al.* (2020) also observed that younger farmers are more receptive to adopting new agricultural enhancement strategies to mitigate the effects of climate change. The coefficients of the variable education level are positive and statistically significant across all groups of CSAs. This implies that farmers with a higher level of education are more likely to participate in climate change adaptation strategies. Other studies have demonstrated that improving literacy increases the likelihood of adopting new irrigation technologies. For instance, Zhang *et al*. (2019) reported that farmers with higher literacy levels can better search new irrigation technologies and understand the advantages of adopting them. However, some studies have reported that the effect of farmers' education level on their decision to adapt to climate change is insignificant (Thoai *et al.* 2018). Despite the negative effect of the agricultural history variable on farmers' adoption of CSAs, this effect is not statistically significant. However, most studies have found a negative correlation between agricultural history and adopting innovation and new agricultural practices to adapt to climate change (Zakari *et al.* 2022). The number of household members or the household size exhibit a marginal effect on adopting nutrient and water management techniques. The negative effect of household size on adopting water and nutrient management strategies may be attributable to the high labor force and greater resistance of these households to new irrigation technologies requiring fewer human resources (Khan *et al.* 2020). Kpadonou *et al.* (2017) also argued that family size inhibited the adoption of agricultural practices in the West African Sahel. Nonetheless, this result contradicts the findings of Mwaura *et al.* (2021). The results showed that farm characteristics, such as farm size and income variables, positively and significantly affect adopting CSAs. According to studies conducted by Thoai *et al.* (2018) and Koirala *et al.* (2022), farm characteristics significantly impact the selection of CSA strategies. So that, farmers with larger farms are more likely to implement these strategies. This variable's coefficients are positive and statistically significant for all groups accepting the strategies utilized in the region. Mariano *et al.* (2012) found that farmers with large farms can allocate part of their land to new technologies and reduce the risk of failure of these technologies. In addition, Koirala *et al.* (2022) demonstrated that smaller farmers are more likely to engage in climate-compatible actions than large farmers. In some studies, however, the effects of farm characteristics on adopting CSAs were not statistically significant (Mirzaei *et al.* 2022). The coefficient of the agricultural income variable is also positive and significant. In other words, by the increase in farm income, the tendency of farmers to adopt climate adaptation strategies is elevated. Keshavarz's (2018) revealed that groups of farmers in Fars Province who adapted the least to climate change had the lowest income from agricultural activities. Ojo & Baiyegunhi (2020) found that rice farmers in Southwestern Nigeria who adopted CSAs had a significantly higher average net income than those who did not implement these strategies. The effect of off-farm income on the probability of adopting all three smart climate strategy groups is insignificant. Therefore, off-farm income cannot be considered an influential factor in adopting adaptation strategies for farmers in the current sample. However, Abbas *et al*. (2022) regarded off-farm income as a crucial factor in adopting adaptation strategies to adapt to the effects of climate change. In the study of Wang *et al.* (2018), off-farm work and income and farmers' assets positively and significantly impact the likelihood of adopting new irrigation programs and technologies. Access to extension services has little effect on the adoption of CSAs. This result contradicts the findings of Musafiri *et al.* (2022), who reported that contact with extension agents positively and significantly impacts adopting CSA practices. Wang *et al.* (2018) concluded that extension institutions have no significant impact on adopting adaptation strategies. The positive and statistically significant effect of the access to credit variable on the probability of adopting CSAs such as water and soil conservation and a combination of CSAs suggests that farmers with high access to credit can adopt costly strategies. In fact, the impacts of coefficient of this variable on the adoption of various CSAs are greater than one, indicating that adaptation strategies are implemented. Khan *et al.* (2020) confirmed the positive and significant impact of credit access on farmers' participation in the strategy of switching product types. However, this result is inconsistent with the findings of Thoai *et al.* (2018). The trust in people characteristic of social capital negatively and significantly affected farmers' participation in adaptive strategies (Hunecke *et al.* 2017). Thus, farmers who place their trust in others are less likely to participate in adaptation strategies. It appears that farmers' lack of awareness of climate change adaptation strategies has a negative and significant impact on their trust in individuals adopting adaptation strategies. This result contradicts Saputinessie *et al.* (2019) and Yazdanpanah *et al.* (2022). In addition, the variable trust in governance institutions significantly impacted the adoption of water and nutrient management strategies at the 5% level only. The expected result for the trust variable in institutions and organizations is that the increased farmers' trust in related institutions and organizations reduces farmers' risk of adopting water and nutrient management strategies. The variable of family members' participation in social activities had a positive and significant impact on the possibility of adopting all three types of CSA strategies (Hunecke *et al.* 2017). Farmers' social relationships with individuals from outside their region influence their decision-making regarding the adoption of CSAs. According to Heidati & Sorrento (2015), farmers' social participation substantially impacts reducing drought risks. Saptutyningsih *et al.* (2020) concluded that farmers' social participation could increase their knowledge of new climate change mitigation strategies. According to Table 3, psychological characteristics positively and substantially affect farmers' participation in CSAs. Thus, the role of climate change beliefs and risk perceptions is definite (Yazdanpanah *et al.* 2022). Xi'an *et al.* (2018) found that farmers' participation in adopting adaptive strategies could be increased by a greater awareness of climate change and its negative effects. Azadi *et al.* (2019) argued that farmers' beliefs regarding climate change have no bearing on their decisions regarding implementation of adaptive strategies. Furthermore, the effect of adoption time of technology on the probability of selecting water resources and soil conservation strategies is statistically significant and negative. It is less likely that farmers adopted costly water and nutrient management strategies, later adopt the existing strategies. In other words, farmers who adopted the strategies in recent years are less likely to adopt cost-effective water and nutrient management strategies. Pagliacci *et al.* (2020) also reported that the timing of adopting CSA practices or strategies significantly impacts their success.

Table 3. Results of estimating the multinomial-logit model (reference group: farmers who have not adopted water and nutrient management or conserving or enhancing soil strategies).

Variables	**Management of water and nutrient**		**Soil conservation and enhancement**		**Combined**	
	β	**SE (β)**	**β**	**SE (β)**	**β**	**SE (β)**
Household characteristics						
Head of household	-0.12***	0.03	-0.09***	0.04	-0.16***	0.03
Level of education of the head of the household	0.22***	0.08	0.14***	0.05	0.28***	0.11
The agricultural history of the head of the household	-0.04	0.03	-0.07	0.05	-0.01	0.05
Number of household members	-0.15***	0.06	-0.18	0.11	-0.15	0.09
Farm characteristics						
Farm size	0.06***	0.02	0.09***	0.04	0.11***	0.04
Farm income	0.58***	0.09	0.52***	0.10	0.52***	0.09
Socioeconomic characteristics						
Off-farm income	0.45	0.26	0.28	0.22	0.36	0.22
Access to extension services	0.01	0.09	0.04	0.15	0.03	0.11
Access to credit	1.25***	0.18	1.67***	0.22	1.56***	0.25
Social capital characteristics						
Trust individuals	-1.32***	0.37	-1.28***	0.30	-1.12***	0.22
Trust in governing institutions	0.18**	0.10	0.14	0.11	0.12	0.09
Family participation in social activities	0.35***	0.14	0.63***	0.24	0.85***	0.15
Psychological characteristics						
Belief in climate change	0.94***	0.38	0.58***	0.14	0.85***	0.17
Perception of the risk of climate change	0.17***	0.07	0.12**	0.06	0.14***	0.05
Strategy adoption time	-0.22***	0.10	-0.26	0.18	-0.20	0.14
LR chi2 (45)	312.26***					
Pseudo-R^2	0.46					

Source: Research findings (*, **, and *** indicate significance at 10%, 5%, and 1%, respectively).

Conclusion and Recommendations

Considering all factors at three levels (spatial, farm, and individual), the present study sought to analyze, for the first time, the issues surrounding the non-expansion of climate-smart agriculture strategies (CSAs) by focusing on farmers' participatory behavior. In this study, we tried to evaluate all the dimensions and factors raised in previous studies that affect the willingness of farmers to implement each of the adaptive strategies. For this purpose, Fars Province in Iran was chosen as the study area. Thus, the present study is a comprehensive and inclusive framework considering all the spatial, farm and individual, socio-economic, social, and psychological capital of farmers. Spatial characteristics influencing the number of farmers adopting smart climate strategies were examined. The spatial characteristics analysis revealed that areas with limited water resources and unfavorable climatic conditions have a lower adoption rate of CSAs. Therefore, the agricultural sector of the province lacks a logical and efficient regional model for CSAs. In other words, the result of the present study is unexpected, revealing that stockholders have not taken any effective measures to develop CSA strategies in areas with unfavorable climates. Despite the unfavorable climate situation in these areas, the adoption rate of strategies is low. According to the results, farmers' participatory behaviors in CSAs have not changed significantly in areas with limited water resources or unsuitable rainfall and climate conditions. Evidently, the Fars Province agricultural sector has not adapted well to climate conditions. Consequently, it is necessary to provide an effective regional model for developing these strategies in the province by identifying the farm and individual factors that influence the farmers' adoption of CSAs. The effect of farm and individual factors on farmers' participation in CSAs revealed that education level, farm income, access to credit, family participation in social activities, and psychological characteristics of farmers (beliefs and perceptions of climate change risks) have a positive impact on farmers' participation in CSAs. However, variables such as the head of the household's age, the size of the farm, and trust in others negatively affect farmers' propensity to adopt CSAs. Furthermore, trust in governance institutions can increase farmers' willingness to adopt water and nutrient management techniques. Moreover, as household size increases, water and nutrient management strategies diminish. The absence of an effect of off-farm income on the adoption of CSAs in the current sample may be since farmers with incomes other than agricultural incomes place less emphasis on managing their resources, including water and soil resources, and having benefits other than agricultural income cannot guarantee that farmers will use CSAs. However, the negative coefficient of the trust in the people variable indicates that trust in the people may discourage farmers from seeking information outside their area and lead not to adopt a new strategy. The positive correlation between household participation in social activities and formal social networks supports the notion that formal social networks play a crucial role in encouraging farmers to participate in CSAs by improving access to information and technical knowledge through communication with consultants and experts. The availability of extension services and classes has not significantly impacted farmers' willingness to adopt CSAs. This finding demonstrates that extension efforts to persuade the present sample of farmers to adopt adaptation strategies have been unsuccessful and insufficiently effective. In conclusion, one of the most significant findings of this study is that public trust in society has no positive effect on adopting CSAs but decreases the willingness to adopt them. Consequently, establishing formal associations and organizations by organizations and institutions focusing on farmers and replacing family, neighborhood, and friend associations can enhance the adoption of CSAs. Furthermore, the results showed that beliefs and risk perception about climate change significantly predict farmers' adaptation behavior. Therefore, we suggest that policymakers and research centers provide information on climate risks, the effects of risks, and various estimates for farmers at the regional and national levels to ultimately affect farmers' opinions and understanding of risk. Generally, it can be observed that to develop CSAs in the Fars Province, farmers must be educated and informed on these strategies, and policies must be enacted to instill in farmers a positive outlook and disposition toward adopting these solutions. Based on the results, it can be concluded that increasing farmers' awareness and knowledge of climate change through the provision of appropriate extension services, credit granting, and the development of social groups through experts can effectively mitigate the negative effects of climate change. In addition, adaptation strategies can be adopted based on providing a suitable environment and creating and supporting formal associations.

Study limitations

This research has some limitations. Initially, the unavailability of reliable sources of information forced researchers to collect all information through questionnaires. It is true that the direct and in-depth interview is more in line with the real world. However, creating a database of spatial, farm and individual characteristics can help. We may not have considered all psychological and social capital variables. Therefore, it is suggested to increase the predictive power of the models by adding variables related to them. Moreover, in addition to social and psychological variables, the environmental, cultural and political dimensions affecting the adoption of CSAs can also be added to the variables. Finally, due to the negative impact of the time of adoption of CSAs, it is recommended that in future studies, farmers be categorized into different groups based on the time of adoption of CSAs and the effect of each of the factors used in this study be evaluated on these groups.

Data availability. The data that support the findings of this study are available on request from the corresponding author.
Conflict of interest statement. The authors have no competing interests to declare that are relevant to the content of this article.

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Questionnaire on the status of farmers in relation to climate smart strategies

Name of the region:……………….. Village:.................

Group	Variable	Unit	Description
Household characteristics	Age of head of household	Years	
	Level of education of the head of the household	Uneducated = 1 Primary school and high school = 2 Diploma = 3 Associate and BA = 4 MA and PHD = 5	
	The agricultural history of the head of the household	Years	
	Number of household members	People	
Farm features	Farm size	Hectares	
	Farm income	Million Rls	
Socioeconomic characteristics	Off-farm income	No = 1 Yes = 2	
	Access to extension services	No = 1 Yes = 2	
	Access to credit	No = 1 Yes = 2	
Characteristics of social capital	**Trust people** I think most of the people in the village are trustworthy.	Five-point Likert scale (1 = strongly disagree, 5 = strongly agree)	
	Trust in governing institutions: I think most government institutions are trustworthy.	Five-point Likert scale (1= strongly disagree, 5 = strongly agree)	
	Family participation in social activities: I mostly participate in social events and programs such as festivals, craft fairs and local decisions	Five-point Likert scale (1 = strongly disagree, 5 = strongly agree)	
Psychological characteristics	**Belief in climate change:** 1. I believe that precipitation and temperature have changed compared to the past. 2. I believe that droughts and other unusual weather events have occurred more frequently in recent years. 3. I believe that in recent years, dry and hot seasons will come earlier than in the past. 4. I believe that water resources have decreased more in recent years. 5. I believe that global warming is happening.	Five-point Likert scale (1 = strongly disagree, 5 = strongly agree)	
	Perception of the risk of climate change: 1. I believe that climate change leads to a decrease in the production of agricultural products in Zahedan province. 2. I believe that climate change will lead to the loss of biodiversity. 3. I believe that climate change will lead to an increase in pests and diseases. 4. I believe that soil fertility is being lost due to climate change. 5. I believe that climate change is a serious concern of society. 6. I believe that climate change is a serious threat to human health.	Five-point Likert scale (1 = strongly disagree, 5 = strongly agree)	
	Strategy adoption time	Year	

Variable	Unit	Description
The status of access to water resources for irrigation	1. Very good 2. Good 3. Medium 4. Weak 5. Very weak	
Rainfall status	1. Very good 2. Good 3. Medium 4. Weak 5. Very weak	
Dominant soil type	1. Sand 2. Clay	
The size and extent of farmer's land	Hectares	

Adaptation strategies (name the strategies you have used to reduce the effects of climate change

Type of strategy	The year of strategy adoption
1.	
2.	