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# Impacts of Climate Change and Water Scarcity on Farmers' Irrigation Decisions in North-Khorasan Province: Major Crops

**A. Azizi[1], H. Mehrabi Boshrabadi[2*], M. Zare Mehrjerdi[3]**

1- Ph.D. Student, Department of Agricultural Economics, College of Agriculture, Shahid Bahonar University of Kerman, Kerman, Iran

2- Professor, Department of Agricultural Economics, College of Agriculture, Shahid Bahonar University of Kerman, Kerman, Iran

3- Professor, Department of Agricultural Economics, College of Agriculture, Shahid Bahonar University of Kerman, Kerman, Iran

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## Abstract

This paper evaluates the effect of water scarcity and climatic conditions on farmers' irrigation decisions in the production of major crops including wheat, barley, cotton, sugar beet, and alfalfa in North-Khorasan province. Farmers' irrigation decisions are defined with a management model composed of equations of the share of irrigated land, technology adoption, and the irrigation frequencies, which investigated the effect of water scarcity indicators and climatic factors, farm water supply method, land characteristics, and farmers' demographic features. For this purpose, the required data were collected from the 380 questionnaires, completed by farmers in cultivation year of 2017-2018. Then, the equations of the management model were estimated using fractional logit, binomial logit, and OLS methods. The results indicated that economic and physical scarcity of water resources, climatic conditions of temperature and precipitation, severe events of frost and heat, and drought have noticeable impact on farmers' irrigation decisions. Farmers try to reduce the damage caused by climate change and water scarcity by deciding to irrigate their farms and adopting new irrigation technologies. Also, the type of water sources, i.e. surface and groundwater, irrigation method, soil quality of cultivated land, and land size have significant effects on their decisions. In regions without available surface water resource, the cultivation areas of irrigated land are declined. Also, due to water scarcity, farmers are more willing to invest on new technologies to improve irrigation efficiency. In the farms with higher soil quality, improved cropland direction and slope, and resource availability, farmers are more willing to invest on new irrigation methods and increase irrigation frequencies. Therefore, the implementation of policies on improving land quality and cropland integration can increase the acceptance of new technologies, and reduce the water usage. In addition, farmers' demographic characteristics such as experience, tenure, and education influence their decisions for irrigation. Creating suitable conditions for the education and training of farmers will increase farmers' awareness of new agricultural methods and the importance of water resources. Findings of this study provide vision on – how of farmers reaction against crop production systems as well as mitigation policies to confront climate change impacts.

**Keywords:** Climate change, Fractional logit, Irrigation decisions, Water scarcity

## Introduction[1]

Sensitivity of agricultural production against climate change impacts is confirmed by laboratory and experimental studies (Jawid, 2019; Mendelsohn and Dinar, 2003). Increasing temperature and changing precipitation patterns affect the yield and quality of both rainfed and irrigated crops (Siddig *et al.*, 2020). Due to important role of climate conditions in crop production, farmers tend to respond to climate changes by adjusting their methods. Technologies

(*- Corresponding Author Email: hmehrabi@uk.ac.ir)

and practices already exist for climate change adaptation (Etwire, 2020).

The growing water scarcity and misuse and lack of management of the available water resources are major threats to the sustainable development of various sectors. Today, in most countries suffering from water scarcity, it is important to ask whether the water crisis can be prevented (Hamdy *et al.*, 2003). Drought contributes to surface water shortages and groundwater over-abstraction, and damages the agricultural sector (Howitt *et al.*, 2014). Therefore, adapting irrigation management is one of the main mechanisms for agriculture to adjust and respond to climate change and water scarcity (Olen *et al.*, 2016). One of the most effective ways to reduce water shortage is to increase irrigation efficiency at the water transmission, distribution, and application stages. Water loss can be prevented by using modern irrigation systems.

The agricultural sector has a special place in North-Khorasan province so that it accounted for about 20.7% of GDP and 37.3% of the total employment in 2017 (Statistical Yearbook of North-Khorasan province, 2019). The most important crops produced in this region are cotton, wheat, barley, legumes, vegetables, industrial plants, and fodder. This province had 229984.6 hectares of cultivation area in cultivation year of 2017-2018 which 49.2% and 50.8% was irrigated and rainfed, respectively (Agricultural Jihad Organization of North-Khorasan province, 2017). The climate of the province is arid and semi-arid. Consecutive droughts, population growth, inefficient water resources management, and traditional and low-yield agricultural methods have caused much of the province's area to suffer severe groundwater depletion. Decreased precipitation and rising temperatures have changed the province's climate in recent years. Reforming consumption patterns is the only way to overcome the crisis of water scarcity and depletion of water resources (Agricultural Jihad Organization of North-Khorasan province, 2017). Fig. 1 depicts the average precipitation and temperatures for the period of 2006-2018.

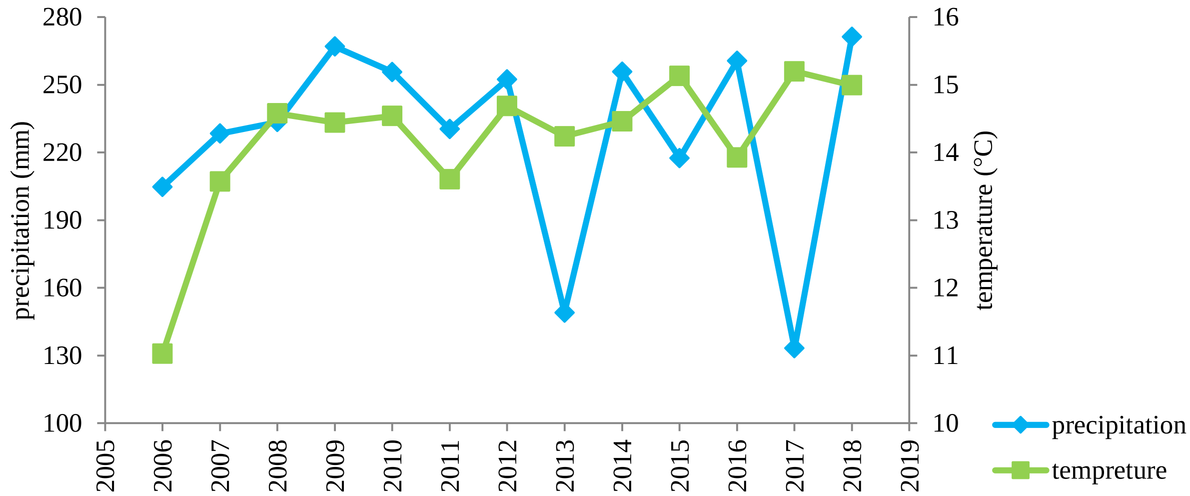


**Fig. 1- Annual average precipitation and temperature changes in North-Khorasan province**

As can be seen, the precipitation has experienced a decreasing trend in recent years while the temperature has had an increasing trend. These changes are indicative of climate change in the region. The history of precipitation shows that the average annual precipitation in the province has decreased over the past years, implying that the province will be struggling with a water crisis in the coming years. Also, the increasing trend of average annual temperature in the province has directly affected the water requirements of crops. This, along with a decrease in precipitation and a subsequent decrease in water reserves, has aggravated the water crisis.

Several studies have examined the effects of climate change and drought on the agricultural sector. Most studies have focused on the impact of climate change on agricultural production, land, water resources, and farmers' incomes. For instance, Calzadilla *et al.* (2011), Coffel *et al.* (2019), and Dinar *et al.* (2019) have shown that water supply is affected by climate change and water scarcity combined with an increasing demand for food and water for irrigation of agricultural lands due to population growth. So, it requires a careful revision of water use in agriculture. McDonald and Girvetz (2013) predicted the impact of climate changes on both the fraction of agricultural land irrigated and the irrigation rate in the United States. According to the results, during the period of 1985-2005, both quantities have been highly positively correlated with moisture deficit (precipitation), and if the current trend continues, climate change will increase agricultural demand for irrigation in 2090 by 4.5 to 21.9 million hectares. In addition, without significant increases in irrigation efficiency, climate change would increase the average irrigation rate from 7,963 to 8,400–10,415 $m^3$/ha. The irrigation area has increased the most in humid states, however the irrigation rate has increased the most in arid states.

Sheidaeian *et al*. (2014) showed that decreasing precipitation and increasing temperature would increase evapotranspiration potential and the amount of water used. Khaledi *et al*. (2016) reported that climate change and reduced precipitation have a detrimental effect on agriculture. According to them, farmers' adaptation to climate change is one way to alleviate the effects of this phenomenon. They also showed that lack of financial resources, shortage of water resources, inattention by officials, lack of credit, and cuts in subsidies were the most important obstacles to farmers' adaptation. In a study in Kermanshah province, Iran, Tavakoli *et al*. (2016) showed that crisis management strategies had a positive and significant relationship with the severity and recurrence of farmers’ perceived drought, owned lands, irrigated lands, and farmers’ individual and family characteristics. Parhizkari *et al*. (2017) investigated the impact of climate change by applying precipitation reduction scenarios to available water resources, the economic value of water, and the irrigated area. This study showed that reducing precipitation would reduce the cultivation area and the volume of water used in irrigated farms. Li *et al*. (2020) found that the combined assessment of the impact of water scarcity on economic, social, and environmental aspects and system sustainability could give a more comprehensive picture of efficient water resources management and would contribute to water scarcity remission. They showed that the optimal allocation of water to crops varied in different regions and under different climatic conditions.

In a review of the strategies to face drought and water scarcity, Bressers *et al*. (2019) took the natural circumstances, socio-economic factors, and institutional circumstances in a specific area into account. They argued that factors such as different climatic conditions, access to water resources, water ownership, foresight, and socio-economic conditions of farmers affect the behavior towards water use. This study proposed regulating water supply, saving on water, and recycling water as the strategies towards water supply management. They also recommended the adoption of regulatory measures and financial incentives for water demand management. Zhang *et al*. (2019) also examined farmers’ practices when facing water scarcity based on a field survey in Beijing, China. Based on their results, 53.1% of the farmers adopted water-saving irrigation technologies when facing water scarcity. Factors such as education, farm size, cooperatives, training, groundwater, access to information, and drought-prone areas significantly improved farmers’ adaption to water scarcity, while age, production specialization, and cost had a negative impact on farmers’ adoption of water-saving irrigation technologies.

Some studies such as Rahmani *et al*. (2016), Balali *et al*. (2016), and Movahedi *et al*. (2017) have examined the factors influencing farmers' decision to adopt new irrigation technologies using the logit regression model and questionnaire information. In these research studies, the effect of such variables as age, education, experience, training, land ownership, type of water supply source, etc. has been investigated on the acceptance of farmers. However, few studies have addressed the effects of climate change combined with other factors on farmers' irrigation decisions. For example, Olen *et al*. (2016) estimated the irrigation management model to assess the impact of water scarcity and climate on farmers’ irrigation decisions on the western coast of the United States. Their results showed that economic and physical scarcity of water and climatic factors had significant impact on farmers’ irrigation decisions. Farmers used sprinkler technologies or extra water to reduce the risk of crop damage in extreme climate events. In another study, Frisvold and Bai (2016) examined the effect of climate and other factors on the choice of sprinkler technology in 17 western US states. They revealed that sprinkler irrigation had been adapted to a greater extent in relatively cooler areas with extreme precipitation events and among larger farms with higher water costs and relied more on groundwater.

Research has shown that drought and climate change can have detrimental effects on the agricultural sector and various factors are effective in facing and adapting to climate change. Most studies on the effects of climate change have been conducted for the entire agricultural sector at a national or regional level. Also, studies that have examined the factors influencing irrigation decisions of farmers such as irrigation technology selection, irrigation frequency, etc., have paid less attention to climatic factors and water scarcity. Simultaneous studies of climate change, water scarcity indicators, and other factors affecting farmers' decisions have received less attention. Due to the crisis of water scarcity, drought, reduction of water resources in most plains of North-Khorasan province in recent decades, as well as using more than 69% of the province's water resources by the agricultural sector, it is necessary to reform the water use pattern in this sector. Therefore, recognizing the factors influencing farmers' decisions to irrigate their fields seems necessary, and this study aimed to identify the factors that are effective in farmers' management and irrigation decisions in North-Khorasan province. For this purpose, farmers' irrigation decisions were defined in the context of a management model including the share of irrigated lands, irrigation technology adaptation, and irrigation frequencies. Then, the focus was put on the effect of water scarcity indicators, climatic factors, farmers' land and individual characteristics, water supply sources, etc.

## Materials and Methods

### Empirical Model

It is assumed that producers make irrigation decisions to maximize farm profit according to climatic conditions (C), water scarcity (S), water supply method (M), land characteristics (L), and demographic characteristics (D). To investigate how these variables influence irrigation decisions, an irrigation management model is estimated for major crops in North-Khorasan province. This management model includes equations of the share of irrigated land (SI), technology adoption (TA), and irrigation frequencies (IF). SI is defined as the share of croplands that are irrigated and takes a value from 0 to 1 (total irrigated croplands to total cultivated croplands). TA is defined as 0 and 1. IF also refers to the total number of irrigations of a crop over the growing season.

$$SI_i = \alpha + \beta_i C_i + \beta_i S_i + \beta_i M_i + \beta_i L_i + \beta_i D_i + \varepsilon_i \quad (1)$$

$$TA_i = \alpha + \beta_i C_i + \beta_i S_i + \beta_i M_i + \beta_i L_i + \beta_i D_i + \varepsilon_i \quad (2)$$

$$IF_{ij} = \alpha + \beta_{ij} C_{ij} + \beta_{ij} S_{ij} + \beta_{ij} M_{ij} + \beta_{ij} L_{ij} + \beta_{ij} D_{ij} + \varepsilon_i \quad (3)$$

Where i= 1, …, I represents the farms, and j= 1, …, 5 represents the crop (cotton, barley, sugar beet, wheat, and alfalfa). Climate and weather conditions influencing irrigation decisions are presented by vector C. Farmers have different responses to climate change and drought conditions (Olen *et al*., 2016). The vector C includes the variables of average annual precipitation (mm) and average annual temperature (°C) of the county .Variables indicating whether cold stress has affected farm irrigation in recent years (Yes /No), whether heat stress has affected farm irrigation in recent years (Yes /No), and whether the farm is located in a region with frequent droughts and the irrigation of the farm is affected by these events (Yes /No) are also included in vector C.

Economic and physical indicators of water scarcity are shown in vector S. Water cost (million IRR) per unit area is introduced as an economic water scarcity indicator, and piezometric water level (meters) in the region is introduced as a physical indicator of water scarcity since water shortage increases the cost of pumping groundwater and water supply. So, farmers will be inclined to adopt new technologies to save water (Caswell and Zilberman, 1986). There is, also, greater competition for water in densely populated areas, so the variable of population density is defined as a physical indicator of water scarcity to reflect human demand for water (Calzadilla *et al*., 2011; Coffel *et al*., 2019; Liu *et al*., 2017). North-Khorasan province has eight counties, including Esfarāyen, Bojnourd, Jajarm, Raz and Jargalan, Shirvan, Farooj, Garmeh, and Maneh and Samalqan. In this study, the ratio of the population of the county (people) to its area ($km^2$) is defined as the variable of population density.

The variables of irrigation water supply source, irrigation method, irrigation frequencies, the number of labor for farm irrigation (day/people), and labor cost for irrigation (million IRR) are denoted by vector M. These variables may affect the volume of water used and irrigation costs of the farm. In the third equation, because the frequency of irrigation is defined as a dependent variable, this variable is removed from vector M. The source of water supply includes rivers, dams, wells, springs, and aqueducts, which are classified into two groups: surface and groundwater. Also, the method of farm irrigation is surface (furrow and basin) or mechanized (drip and sprinkler) depending on crop type.

Vector L represents land characteristics, which includes the variables of land size (hectare) and cropland quality. Potentials and limitations of agricultural land such as soil quality, agricultural land direction and slope, access to water resources and land distance to the water resource, the proximity of agricultural land to required services and easy access to them, and climatic conditions of the region are effective in the quality and valuation of agricultural land. Due to the interaction between crop yield and water availability, the water holding capacity of the land is an important dimension of soil quality (Caswell and Zilberman, 1986) and affects farmers' irrigation decisions. In this study, cropland quality is classified into the three groups of good, medium, and poor based on the farmer's opinion regarding land potentials and limitations.

Vector D examines the effect of farmers' demographic features such as farmer age, experience, tenure, education, and household size. The experiences farmers accumulate over time affect their behaviors (Alam, 2015; Seekao and Pharino, 2016). Experienced farmers are less likely to adopt new management practices as they are approaching retirement (Olen *et al*., 2016; Zhang *et al*., 2019). Tenure (land owned / tenant) influences the producers' decision to choose the type of irrigation methods and accept new irrigation methods. In addition, farmers' educational and training level influences their decisions (Abdulai and Huffman, 2005; Alam, 2015; Cremades *et al*., 2015). In this study, education is classified into illiterate, elementary-school level, intermediate-school level, diploma, associate degree, and bachelor's degree and higher.

## Estimation method

The dependent variable of Equation (1), SI, is the share of irrigated land and is defined as a fraction. The fractional logit econometric method is used to estimate this equation. Fractional models were first introduced by Papke and Wooldridge (1996), using the statistical topics of generalized linear models (GLM) and quasi-likelihood literature (QL) method. This model is a kind of generalized linear models whose parameters are estimated using a quasi-verification method. To obtain the fraction model, it is assumed that there are independent and dependent variables {(Xi, Yi): i= 1, 2,…, N} where $0 \leq Y_i \leq 1$ and N is the sample size that tends to infinity ($N \to \infty$). The following model is also considered for the conditional expectation of the fractional response variable:

$$E\left(y_i \,\middle|\, x_i\right) = G(x_i\beta) \qquad (4)$$

Where G(.) is a known function satisfying $0 < G(z) < 1$ for all Z∈Rs, which ensures that the predicted values of $y$ lie in the interval (0,1). For this purpose, G (.) is typically chosen to be a cumulative distribution function (CDF), with the two most popular examples being $G(z) = \Lambda(z) = \exp(z)/[1+\exp(z)]$ (the logistic function) and $G(z) = \phi(z)$. Also, β is the vector of model parameters. In Equation (4), there is no assumption about the structure from which the dependent variable is derived, which is one of the advantages of this model.

In this study, the TA equation examines the effect of independent variables on the adoption of irrigation technology. According to the type of dependent variable in the TA equation, the binomial logit model is used for its estimation. The dependent variable of Equation (3), IF, indicates the frequency of irrigation per hectare for each crop. This equation is estimated for each crop separately, using the ordinary least squares (OLS) method.

## Data

In this study, farmers who cultivated wheat, barley, cotton, sugar beet, and alfalfa were selected as the statistical population. The selection of this statistical population was based on the highest area of crop cultivation in North-Khorasan province. The required data were collected from the studied statistical population. A cross-sectional survey was conducted using a questionnaire and interviews with farmers in the cultivation year of 2017-18. In this study, to improve the sampling accuracy and incorporate statistical population features, the stratified sampling method was adopted in which the statistical population was divided into different subgroups (county), and then selections were made randomly from each subgroup. Using Cochran's formula, 380 sample sizes of the farmers were gathered out of 38,450 farmers in North-Khorasan province. Then, the sample size of each county was determined using following formula:

$$n_i = \frac{N_i}{N}.n \qquad (5)$$

Based on the number of farmers per county where $N$ is the total number of farmers of the selected crops in the province, $N_i$ is the number of farmers of the selected crops in county $i$, $n$ is the total sample size, and $n_i$ is the samples size of county $i$. Then, questionnaires were completed based on the cultivation area of each crop in the county.

**Table 1- Number of farmers and samples studied in North-Khorasan province**

| County | Bojnurd | Esfarāyen | Farooj | Garmeh | Jajarm | Maneh-Samalqan | Raz and Jargalan | Shirvan | Total |
|---|---|---|---|---|---|---|---|---|---|
| Statistical population | 2762 | 9437 | 4102 | 1427 | 3570 | 10245 | 1537 | 5334 | 38450 |
| Sample size | 27 | 93 | 41 | 14 | 35 | 101 | 16 | 53 | 380 |

Source: Research Findings

In this study, data on precipitation, temperature, and piezometric water level were collected from Meteorological Organization and the Regional Water Administration of North-Khorasan province. Also, data on the population of the counties were collected from the National Statistics Portal of Iran.

## Results and Discussion

This section first presents the descriptive statistics of the data extracted from the questionnaires and the data collected from the relevant departments (Table 2).

**Table 2- Descriptive statistics of the variables**

| Variable | Variable definition | Mean | Median | Min | Max | Std. Dev. |
|---|---|---|---|---|---|---|
| **Climatic condition characteristics (C)** | | | | | | |
| Frost mitigation | Irrigation is used to prevent freeze damage (0/1) | - | 0 | 0 | 1 | 0.5 |
| Heat mitigation | Irrigation is used to reduce heat stress (0/1) | - | 1 | 0 | 1 | 0.39 |
| Drought | Historic drought region effect on field irrigation (0/1) | - | 1 | 0 | 1 | 0.47 |
| Temperature | County average temperature (℃) | 14.7 | - | 12.5 | 16.1 | 1.4 |
| Precipitation | County average annual precipitation (mm) | 211.7 | - | 123.4 | 309 | 62.9 |
| **Water Scarcity (S)** | | | | | | |
| Water cost | Farm irrigation cost ( million IRR) | 0.75 | - | 0.04 | 4.3 | 0.51 |
| Water level | Piezometric levels of water in the area (meters) | 41.5 | - | 7.57 | 101.6 | 20.5 |
| Population density | City population concentration (population /km$^2$) | 30.7 | - | 10.5 | 91.06 | 25.5 |
| **Method of water supply (I)** | | | | | | |
| Irrigation Source | Farm irrigation source (surface=1 & groundwater=2) | - | 2 | 1 | 2 | 0.5 |
| Irrigation method | Farm irrigation method (traditional=1 & mechanized=2) | - | 1 | 1 | 2 | 0.36 |
| Labor number | Labor number for farm irrigation during the growing season (Day/people) | 5.3 | - | 0.2 | 33.3 | 5.3 |
| Labor cost | Total labor cost for farm irrigation during the growing season (million IRR) | 0.25 | - | 0.005 | 2 | 0.26 |
| **Land Characteristics (L)** | | | | | | |
| Land size | Farm size (hectares) | 6.2 | - | 0.25 | 90 | 11.7 |
| Cropland quality | Quality of agricultural land (poor=0, medium=1, & good=2) | - | 1 | 0 | 2 | 0.63 |
| **Characteristics Demographic (D)** | | | | | | |
| Age | Farmer age (years) | 46.2 | - | 19 | 74 | 12.4 |
| Experience | experience operating the current farm (years) | 25.9 | - | 1 | 58 | 13.6 |
| Tenure | Type of land ownership (tenant=0 & land owned=1) | - | 1 | 0 | 1 | 0.43 |
| Education | Education (1/2/3/4/5) | - | 2 | 0 | 5 | 1.3 |
| Household size | Household size | - | 5 | 1 | 10 | 1.5 |
| Share of irrigated land | Share of Farmer Irrigated Land [1,0] | 0.73 | - | 0.05 | 1 | 0.29 |
| Technology Adoption | Adoption of field irrigation technology (0,1) | - | 0 | 0 | 1 | 0.37 |
| Irrigation Frequencies | Frequent irrigation of the field during the growing season | - | 6 | 1 | 18 | 3.32 |

Source: Research Findings

Then, farmers' decision-making equations (the share of irrigated lands, the irrigation technology adoption, and irrigation frequencies) are estimated and their results are reported and analyzed.

**Share of irrigated lands**

The equation for the share of irrigated lands is estimated using the fractional logit method whose results are presented in Table 3. According to Wald Chi2 (17), this method is highly efficient in estimating the model. Wald Chi2 showed that there is a significant relationship (P < 0.01) between the share of irrigated land and explanatory variables. The results of the marginal effects indicate that climatic variables have the greatest impact on the share of irrigated lands.

**Table 3- Results of estimating the factors affecting on the share of irrigated land**

| Variable | Coefficient | Z-Statistic | Marginal effect | Z-Statistic | Elasticities at mean |
|---|---|---|---|---|---|
| Temperature | 0.146*** | 2.06 | 0.024** | 2.08 | 0.445** |
| Precipitation | 0.003* | 1.89 | 0.001** | 1.91 | 0.145** |
| Frost mitigation | 0.297* | 1.88 | 0.045** | 1.9 | 0.03** |
| Heat mitigation | -0.363* | -1.65 | -0.06* | -1.65 | -0.062* |
| Drought | 0.293* | 1.81 | 0.049* | 1.81 | 0.04* |
| Water cost | 0.073 | 0.42 | 0.012 | 0.43 | 0.011 |
| Water level | -0.008** | -2.01 | -0.001** | -2 | -0.072** |
| Population density | -0.001 | -0.2 | -0.0001 | -0.2 | -0.004 |
| Irrigation Source | -0.3* | -1.73 | -0.05* | -1.74 | -0.095* |
| Irrigation method | 0.5** | 2.13 | 0.083** | 2.12 | 0.119** |
| Irrigation frequencies | -0.014 | -0.44 | -0.002 | -0.43 | -0.018 |
| Labor cost | -0.64** | -1.73 | -0.106* | -1.73 | -0.032* |
| Cropland quality | 0.264* | 1.91 | 0.044** | 1.91 | 0.06** |
| Land size | 0.041 | 1.23 | 0.007 | 1.24 | 0.048 |
| Experience | 0.017** | 2.08 | 0.003** | 2.09 | 0.088** |
| Tenure | -0.31* | -1.63 | -0.05 | -1.62 | -0.049 |
| Education | 0.215*** | 2.49 | 0.036*** | 2.51 | 0.096*** |
| Constant | -2.27* | -1.47 | - | - | - |
| Wald chi2(17) = 66.59 (0.00) | | | Log pseudo likelihood = -177.98 | | |

Note: (*), (**), (***) denotes significance at the level of 10, 5 and 1% (p <0.10, p <0.5, p <0.01), respectively. Source: Research Findings

The temperature has a positive and significant relationship with SI and the marginal effect of temperature is equal to 0.024, which indicates that if the temperature increases by 1ºC, the share of irrigated land will increase by 0.024 units. Moreover, as the estimation of elasticity at mean shows, 1% increases in temperature increases the share of irrigated lands by 0.445%. Increasing the temperature causes the amount of precipitation not to be enough for crop growth, therefore farmers have to increase the area of irrigated lands to cultivate the crop and irrigate the farm to compensate for the crop's water needs. According to the Findings, the precipitation variable is directly associated with SI, so that 1 mm increase in precipitation increases the share of irrigated lands by 0.001 units. Due to the fact that climate change is generally associated with reduced precipitation, changing the climatic conditions of the region and reducing the volume of precipitation increases the need for irrigation and reduces the volume of water available for irrigation. Eventually, the farmers will be forced to reduce their share of irrigated lands. Dashti *et al*. (2017) and Parhizkari *et al*. (2017) have confirmed the effect of reduced precipitation on the reduction of irrigated cultivation.

One way to reduce the effects of cold temperatures on farms is irrigation because water has a high heat capacity and releases a lot of energy before freezing. For this reason, frost damage is reduced at high humidity (Khaledi, 2004). So, if producers can irrigate their farms to reduce frost damage, the share of the irrigated lands will be 0.03% higher. This result is consistent with the findings of Olen *et al*. (2016). In addition, increasing the air temperature increases the crop's irrigation requirement and due to the available water volume, increasing heat and creating stress will reduce the cultivated area of the irrigated crops. Increased drought in recent years has also had a positive and significant effect on SI so that the share of the irrigated lands has been increased by 0.04%. Rising temperatures and droughts in recent years have led to an increase in water abstraction from the province's groundwater resources so that farmers have drilled authorized and unauthorized wells and have pumped more groundwater to supply irrigation water. This has led to a sharp decline in groundwater resources in some plains of the province (Velayati, 2006).

The irrigation method and water resource have a significant effect on SI. Improving the irrigation method and the use of new technologies will increase the share of farmers' irrigated lands by 0.12%. Also, due to the negative impact of the irrigation resource on SI, surface water shortage and withdrawal of groundwater resources reduce SI by 0.05 units. The results revealed that with the increase in labor costs and, consequently, the increase in farm irrigation costs, the share of irrigated land decreases. On the other hand, water depth has a negative and significant relationship with SI, which indicates that a one-unit increase in water depth (meters) will reduce SI by 0.072%. Caswell and Zilberman (1986) pointed out that increasing the depth of well water (piezometric level of water) would reduce the volume of available water and increase the final cost of pumping groundwater. As a result, increasing irrigation costs, rendering it uneconomic, makes farmers reluctant to irrigate the farm. The effect of improving the quality of agricultural lands on SI shows that farmers increase the share of irrigated lands if there are no restrictions on irrigation. Lichtenberg (1989) mentioned that improving the quality of cropland increases the fertility of the land and reduces the need for irrigation, so the farm profit will increase and farmers will be more interested in irrigated cultivation.

Farmer's experience and education have a positive and substantial effect on SI. In general, farmers who have been engaged in agriculture for many years have lands with more access to water recourse and higher quality. As Paltasingh and Goyari (2018) have shown, education increases farm productivity and leads farmers to use new technologies. Therefore, if more literate farmers use more modern irrigation methods, they can irrigate more croplands with a certain volume of water, thereby expanding their share of irrigated lands.

**Irrigation Technology Adoption (TA)**

The equation of irrigation technology adoption has been estimated using the binomial logit model and the results are reported in Table 4. Based on the LR chi2 statistics, the model estimated is significant at the $P < 0.01$ level, and according to the value of $R^2$, the independent variables account for 58% of the changes in the dependent variable. Based on the significance of the variables in the logit model, only the variables of water cost, water level, population density, and farmer tenure are not considerable, and other variables are significant.

**Table 4- Results of estimating the factors affecting on the irrigation technology adoption**

| Variable | Coefficient | Z-Statistic | Marginal effect | Z-Statistic | Elasticities at mean |
|---|---|---|---|---|---|
| Temperature | -0.406* | -1.76 | -0.02* | -1.81 | -5.92* |
| Precipitation | 0.009* | 1.67 | 0.004* | 1.7 | 1.88* |
| Frost mitigation | 1.3** | 2.25 | 0.064** | 2.35 | 0.616** |
| Heat mitigation | -1.16* | -1.73 | -0.058** | -.176 | -0.947** |
| Drought | -2.16*** | -2.75 | -0.108*** | -2.92 | -1.96*** |
| Water cost | -0.278 | -0.44 | -0.014 | -.045 | -0.207 |
| Water level | 0.009 | 0.67 | 0.0004 | 0.67 | 0.369 |
| Population density | -0.013 | -0.73 | -0.0006 | -0.74 | -0.393 |
| Irrigation Source | 1.31** | 2.3 | 0.065** | 2.41 | 2.001** |
| Irrigation frequencies | 0.569*** | 4.7 | 0.028*** | 5.79 | 3.56*** |
| Labor number | -1.45*** | -4.75 | -0.072*** | -5.91 | -7.77*** |
| Labor cost | 16.2*** | 3.45 | 0.807*** | 3.86 | 4.03*** |
| Cropland quality | 2.17*** | 4.1 | 0.108*** | 4.62 | 2.37*** |
| Land size | 0.074*** | 2.86 | 0.004*** | 3.07 | 0.439*** |
| Experience | 0.11*** | 3.94 | 0.005*** | 4.53 | 2.84*** |
| Tenure | 0.148 | 0.23 | 0.007 | 0.23 | 0.112 |
| Education | 0.81*** | 2.9 | 0.04*** | 3.11 | 1.74*** |
| Household size | 0.73*** | 3.38 | 0.036*** | 3.67 | 3.42*** |
| Constant | -11.29** | -2.13 | - | - | - |
| LR chi2(18)= 164(0.00) | | Log likelihood= -6.035 | | pseudo $R^2 = 0.58$ | |

Note: (*), (**), (***) denotes significance at the level of 10, 5 and 1% ($p < 0.10$, $p < 0.5$, $p < 0.01$), respectively. Source: Research Findings

According to the results, rising temperatures and frequent droughts in the region reduce the likelihood of technology adoption, and new irrigation technologies are less likely to be adopted in warmer regions. Rising temperatures and frequent droughts directly affect crop yields, so the decline in farm yields and incomes will reduce the farmer's financial ability to adopt new technologies so that farmers will not be able to invest in the farm. In interviews with farmers, one of the reasons for not accepting new technologies was their lack of financial ability, which is exacerbated by the drought. Furthermore, rising temperatures and drought can increase evaporative losses from sprinkler spray, so this irrigation method can be an inappropriate technology (Finkel and Nir, 1983; Olen *et al*., 2016). The results showed that increasing temperatures and drought reduce the likelihood of technology adoption by 5.92% and 1.96%, respectively. This result is consistent with the findings of Frisvold and Bai (2016), which concluded that the adoption of modern irrigation methods is less likely in warmer climates and under drier climate change scenarios, so other adaptation strategies may be more appropriate to pursue in hot and arid regions.

Based on results, 1% increase in precipitation increases the likelihood of technology adoption by 1.88%. One explanation is that careful irrigation can reduce water stress. Crops are sensitive to water stress caused by heavy and frequent rains due to their shallow roots. Increased precipitation leads to enhancing soil moisture, thereby reducing the depth of root activity and spreading the roots superficially. In this case, the plant will be justifiably vulnerable to sudden stress. The results indicated that producers who have used irrigation to reduce heat stress on the farm are 0.947% less likely to adopt the technology. In fact, farmers whose irrigation has been affected by heat stress do not have careful planning in farm management and are generally less willing to adopt new irrigation and farming methods. Also, farmers who irrigate their farms in the face of cold stress are 0.616% more likely to adopt the technology than farmers who do not.

The results demonstrated that the type of water supply has a positive and significant effect on technology adoption. It shows that the probability of technology adoption for groundwater resources is 2.001% higher than that of surface water resources. This result is consistent with the findings of Zarifian *et al*. (2020). In fact, farmers in areas with less available surface water have to use groundwater to supply the plant with water, and owing to fewer water resources, they are more inclined to use irrigation technologies to manage and save available water. Besides, at farms with more irrigation frequencies, the probability of adopting technology is 3.56% higher and farmers are more interested in modern technologies to reduce irrigation costs and manage water used. At farms where irrigation technologies are less likely to be adopted, more labor is used for irrigation. In fact, modern technologies require fewer laborers to irrigate the farm, and this is due to the negative relationship between the labor number and the technology adoption. Also, increasing the cost of the labor directly increases the cost of irrigating the farm and reduces the farmer's profit. Therefore, the probability of technology adoption increases by 4.03% with one unit of increase in labor cost.

Land quality and size have a positive and remarkable relationship with the acceptance of technology. If the land quality improves, farmers will be more willing to invest in the farm and improve irrigation and cultivation methods. Adopting new technologies for croplands with higher quality will be 2.37% higher than for those with lower quality. Increasing the farm size will also enhance the economic efficiency of investing in the farm. Based on the findings, the probability of technology adoption will be 0.439% higher with a 1% increase in land size. Finally, experienced and revenue-generating farmers are likely to be more inclined to adopt the technology and the probability of technology adoption increases by 2.84%.

With the increase in farmers' education, the probability of irrigation technology adoption increases by 1.74%. In fact, higher education increases farmers' awareness of new farming methods and new technologies. The household size has a positive and significant relationship with the adoption of irrigation technology, so it can be concluded that increasing the number of households creates a sense of collective support and synergy to improve agricultural conditions through using new technologies. Indeed, family members are a kind of support for the farmer and the farmer will feel less risky in adopting new technologies and cultivation methods. This result is consistent with the findings of Karppien (2005) and Behbahani Motlagh *et al*. (2017).

**Irrigation frequencies (IF)**

The results of estimating the irrigation frequencies equations using the OLS method are reported in Table 5. According to the F-stat statistic, all equations are significant, and the independent variables capture 63-94% of the variance in the dependent variable. It can be concluded from the results that the variables of the temperature and irrigation resource are quite significant in all equations.

**Table 5- Estimation results for the irrigation frequencies in the farm**

| Variable | Estimated coefficient | | | | |
|---|---|---|---|---|---|
| | Alfalfa | Barley | Cotton | Sugar beet | Wheat |
| Temperature | 1.14*** | 0.32*** | 0.7** | 0.49* | 0.4*** |
| Precipitation | -0.01** | -0.02*** | -0.002 | 0.01** | -0.02*** |
| Frost mitigation | -0.43** | -0.21 | -0.28 | 1.24** | -0.33** |
| Heat mitigation | -2.84** | -0.4** | 1.93*** | 0.32 | 0.36** |
| Drought | -1.4 | 0.7*** | 1.4* | -2.43*** | 0.1 |
| Water cost | 1.6*** | 0.75** | -3.19** | -0.22 | -0.58*** |
| Water level | -0.02 | -0.004 | 0.02* | 0.1*** | -1.3E-05 |
| Population density | 0.03*** | -0.02*** | 0.015 | 0.04*** | -0.01 |
| Irrigation Source | 0.85* | 0.41** | -0.71* | -1.5*** | -0.34* |
| Irrigation method | -0.72 | -0.71 | -2.42* | -2.08*** | 0.46* |
| Cropland quality | 0.61 | 0.33* | 1.61*** | 1.18*** | 0.03*** |
| Land size | 0.03* | 0.07* | 0.017 | 0.14** | -0.02*** |
| Experience | -0.04* | -0.008 | -0.05** | -0.03 | 0.01 |
| Tenure | -1.1** | -0.06 | -1.11** | -1.42** | -1.09*** |
| Education | 0.35 | -0..006 | -0.35 | 1.06*** | 0.35*** |
| Constant | -3.93 | 1.87 | 2.16 | -2.8 | 3.29** |
| $R^2$ | 0.94 | 0.77 | 0.63 | 0.82 | 0.83 |
| D-W stat | 1.92 | 1.59 | 1.62 | 2.55 | 1.67 |
| F-statistic | 25.4(0.00) | 13.9(0.00) | 3.4(0.00) | 7.26(0.00) | 27.5(0.00) |

Note: (*), (**), (***) denotes significance at the level of 10, 5 and 1% (p <0.10, p <0.5, p <0.01), respectively. Source: Research Findings

The results showed that weather and climate are important factors determining irrigation frequencies at the farm and almost all weather variables are significant. According to the results, increasing the temperature has a positive and meaningful effect on the irrigation frequency of all selected crops. One unit of increase in the temperature increases the average irrigation frequency per hectare of cotton, barley, sugar beet, wheat, and alfalfa crops by 0.7%, 0.32%, 0.49%, 0.4%, and 1.14%, respectively. Increasing the temperature cause more evapotranspiration of the crop and consequently, increase the water required by the plant. Therefore, the frequency of farm irrigation is increased to meet the water needs of the plant, which is a reason for the positive relationship between temperature rise and IF.

Based on the results, increasing the precipitation leads to higher IF in sugar beet farms, while decreases it at barley, wheat, and alfalfa farms. Increased precipitation enhances the volume of water available for farm irrigation, so farmers have less restriction on farm irrigation and can increase the frequency of on-farm irrigation. Due to the high water requirement and long growing period of sugar beet, irrigation helps its proper growth and development, so with increasing the volume of available water, the frequency of irrigation increases (Zarski *et al.*, 2020). On the other hand, as Olen *et al.* (2016) pointed out, the impact of precipitation on irrigation decisions has crop-specific thresholds, above which farmers respond very differently to climate changes. Only when precipitation is above thresholds, an increase in precipitation will lead to less irrigation frequency. With increasing precipitation, most of the water needed by the plant is supplied, hence the need for field irrigation is reduced, which caused decreasing the frequency of irrigation.

The exposure of wheat and sugar beet crops to cold stress has a negative and positive effect on IF, respectively, but this effect is insignificant on IF for other crops. In order to decline the damages caused by early cold in autumn and late cold in spring, farmers need to make appropriate decisions depending on crop type, time of stress, and plant growth stage. In North-Khorasan province, sugar beet is generally cultivated when it germinates and emerges during low temperatures. After germination, there is a possibility of late spring frosts and damage. At some farms, irrigation can reduce the effect of cold by increasing the temperature. As a result, the frequency of irrigation increases with the increase in the probability of cold. Wheat frosting may occur in two periods: before and after winter. Generally, most damage occurs due to late spring frosts, and the earlier the plant is in the growing stage, the lower the probability of damage is. Therefore, the probability of cold occurrence reduces the irrigation frequency. Agricultural experts also suggest refraining from irrigating wheat farms to prevent autumn frosts.

According to the findings, the occurrence of heat stress and the use of irrigation to reduce the stress increase irrigation frequency at cotton and wheat farms and reduce it at barley and alfalfa farms. Various factors affect a plant's heat tolerance. In general, the temperature that causes damage to the plant is different depending on type of the plant and the region of plant growth. The highest area of cotton and wheat is in Maneh and Samalqan. The water resources of this county are in a better situation than other counties, as the average annual precipitation of this county is higher than the province-wide average, so in facing heat stress, farmers have less restriction on irrigating their farms. Therefore, with the occurrence of heat stress, the average irrigation frequency of the province at wheat and cotton farms will increase by 1.93% and 0.36%, respectively. Also, due to the higher average annual temperature of this county than the average of the province, the probability of heat stress is higher in this county. So, farmers respond to heat stress by increasing irrigation frequencies. Frequent droughts increase the average irrigation frequency at cotton and barley farms by 1.4% and 0.7% and decrease it at sugar beet and alfalfa farms by 2.43% and 1.4%, respectively.

Farmers increase water volume and frequency of farm irrigation in arid areas with frequent droughts to meet crop water requirements. In the studied province, 66% of the cotton acreage is in Maneh and Samalqan county and 40% of the barley acreage is in Esfarāyen county. Also, based on the reports of the Jihad Agricultural Organization of North-Khorasan Province, the counties of Maneh and Samalqan and Esfarāyen have had the highest areas affected by drought in recent years. Therefore, drought has increased the irrigation frequencies of these crops. On the other hand, restrictions on access to water resources as a result of drought and changes in drought-resistant crops have reduced the irrigation frequencies of sugar beet and alfalfa. Water scarcity occurs more in areas where precipitation decreases and air temperature increases, and the water required for the irrigation is supplied more from groundwater resources. Also, with increasing water scarcity, the cost of pumping and water supply to the farm increases. Since most of the areas cultivated by barley and alfalfa in North-Khorasan province are located in regions with lower average precipitation and higher temperatures, the need for farm irrigation to meet the crop water requirements increases due to higher evaporation and transpiration of the plant. Therefore, this is a reason for the positive relationship between higher water costs and higher irrigation frequencies.

Also, according to the findings, increasing the piezometric level of water in the region leads to increasing irrigation frequency at cotton and sugar beet farms. Increasing water depth means more water scarcity and drought in the region. Crops like cotton and sugar beet that have high water needs should be irrigated more frequently to meet their water demands, so farmers increase the irrigation frequencies on their farms. In addition, in North-Khorasan province, cotton is mostly cultivated in areas where surface water is available. Therefore, with increasing water scarcity, farmers extract groundwater to supply farm water. Also, the variable of population density has a positive and meaningful effect on irrigation frequency at sugar beet and alfalfa farms and has a negative effect at barley farms. There is greater competition for water in densely populated areas, which is more likely to lead to limited agricultural water deliveries or the voluntary transfer of agricultural water to higher-value uses (Burke *et al*., 2004). As the demand for water increases, the amount of water available to irrigate the farm decreases, which results in reducing the frequency of irrigation. However, based on the results, the positive effect of population density can be explained by the fact that the increase in population in a region leads to higher volume of livestock, and due to the need to provide livestock fodder, the area under cultivation and the irrigation frequencies of alfalfa farms increase for further harvesting. Although barley is also a livestock feed, farmers will be less willing to cultivate it and use water for its irrigation under water-scarce conditions due to the low benefit of barley farms.

The results revealed that the type of irrigation source has a negative and significant effect on irrigation frequency at cotton, wheat, and sugar beet farms. In other words, if water for farm irrigation is supplied more from groundwater sources, irrigation frequencies will be reduced. In fact, groundwater is mostly used for agriculture in areas where surface water is not available and the volume of water available is less, thus the irrigation frequency is reduced. On the other hand, irrigation source has a positive and significant effect on barley and alfalfa crops. The highest cultivation area of these crops is in Esfarāyen county, whose temperature is higher than the average temperature of the province. Also, it had the second-lowest annual precipitation after Jajarm in the province in 2018-2019. Besides, most of the water needed for agriculture in this county is supplied from groundwater sources, so more irrigation frequencies are taken to meet the water needs of the crop. The irrigation method at cotton and sugar beet farms has a negative and meaningful effect on irrigation frequencies, while its effect is positive and significant at wheat farms. Also, the irrigation method has no significant effect on irrigation frequency at barley and alfalfa farms where irrigation frequency is determined independently of the type of irrigation method.

Based on the results, the mechanized irrigation method reduces the average irrigation frequency at cotton and sugar beet farms by 2.42% and 2.08%, respectively and increases it at wheat farms by 0.46%. According to the comprehensive report of agricultural water productivity (Comprehensive report on agricultural water productivity, 2017) in the province, the adoption of new irrigation technologies reduces the volume of water used to irrigate farms. The volume of water used during the cultivation period is reduced through the reduction of the volume of water used in each irrigation or the reduction of irrigation frequency. At cotton and sugar beet farms, in addition to reducing the volume of water used, the frequency of irrigation has also been decreased. However, the irrigation frequency at wheat farms has increased as a result of the adoption of new technologies, and with the application of management practices to the water used in each irrigation, the total volume of the water used during the growing period has decreased. The results showed that improving the cropland quality increases the irrigation frequency at cotton, barley, sugar beet, and wheat farms. In fact, the type of soil texture, direction, slope, and farm position affect the need for irrigation, so changing the cropland quality changes the amount of irrigation requirement of the farm. In addition, improving the cropland quality affects the profitability of the crop grown in the farm, and farmers may have to spend more on the land to improve it and harvest more.

Based on findings, increasing the land size has a positive and significant effect on irrigation frequency at barley, sugar beet, and alfalfa farms and has a negative and meaningful effect on irrigation frequency at wheat farms. Considering that barley, sugar beet, and alfalfa have the highest area of cultivation in Esfarāyen and Jajarm counties and a higher percentage of agricultural water supply in these counties is from groundwater sources, so increasing the land size reduces irrigation frequency due to the limited water resources. Also, due to limited water resources, better management for farm irrigation is done in larger lands. The highest irrigated area of wheat is in Maneh and Samalqan County, where a higher percentage of irrigation water is supplied from surface resources. Furthermore, large farmers generally have less restriction on water supply with more access to water resources, so they apply more irrigations (along with efficient management in water used) for more production and profit.

Finding of the study demonstrated that farmers' demographic characteristics affect irrigation frequencies, too. Farmers' experience and tenure have a negative effect on irrigation frequencies. Since experience is related to the farmer age, older farmers are not motivated to use irrigation even if they have access to water resources due to the smaller household size (reduction of average household size and separation of children from families with increasing the farmer's age) and prefer to avoid laborious irrigation work. Wakeyo and Gardebroek (2017) have also mentioned this point in their study.

## Conclusion

In this paper, farmers' irrigation decisions to produce major crops of wheat, barley, cotton, sugar beet, and alfalfa in North-Khorasan province were analyzed using econometric models. For this purpose, the effects of climatic and weather factors, water scarcity, irrigation method and source, land characteristics, and demographics were studied on the share of irrigated land, technology adoption, and irrigation frequencies. The climate of the province is semi-arid with cold winters and hot summers. The results provide useful information about how farmers react and adapt to climate change in crop production systems.

It can be concluded from the results that climatic factors of temperature, precipitation, severe frost, heat, and drought, and economic-physical indicators of water scarcity have a significant impact on farmers' irrigation decisions. Farmers try to reduce the damage caused by climate change and weather factors by deciding on irrigating their farms. The results indicated that farmers are more responsive to temperature changes than to other climatic factors. In areas with drought and warmer climates, the share of irrigated land increases and the likelihood of adopting technology decreases. Also, with increasing air temperature, the irrigation frequency of farms increases. Precipitation is positively related to the share of irrigated lands and the likelihood of adopting irrigation technology. According to the research results, the occurrences of drought and reduced precipitation in recent years have reduced the tendency to adopt new irrigation methods. This might be due to the reduced farm profitability and farmers' unwillingness to invest in farms. Therefore, to increase the efficiency of water used, it is suggested that the government formulate and implement support and incentive policies in this regard.

As the results showed, changes in the piezometer level of water significantly influence farmers' irrigation decisions. Therefore, sustainable groundwater management can provide an important signal for producers to use irrigation methods to save groundwater. Moreover, the type of irrigation source (surface and groundwater), irrigation method, cropland quality, and land size have notable effects on farmers' decisions. In regions where surface water is not available, the share of irrigated land declines, and due to water scarcity, farmers are more willing to invest in new technologies. In higher-quality farms, farmers are more willing to invest in new irrigation methods and the frequencies of farms irrigation are increased. So, policymakers can increase the penetration of new technologies by improving land quality and integration. By creating production cooperatives, production resources and factors can be provided to farmers at a lower cost, agricultural lands can be rehabilitated, farmers can be connected to government centers, and mechanization can be developed.

Given that weather, climatic, and water scarcity indicators, type of crop grown, and water supply method on the farm have significant impacts on farmers' irrigation decisions, the government should pay special attention to these factors in adopting water management and optimal water use policies (including water pricing and quotas). The government should also make policies according to the climatic situation of the region. The climatic conditions themselves sometimes lead farmers towards new technologies and the implementation of policies such as pricing only imposes additional costs on farmers and discourages them.

Based on the results, farmers' demographic characteristics such as education and experience influence their irrigation decisions. Increasing farmers' experience and educational level increase the likelihood of accepting new irrigation methods, so creating suitable conditions for the education and training of farmers will pave the way for technology acceptance. It is also necessary to motivate the young and educated generation to enter the agricultural sector to develop and adopt appropriate technologies.

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**مقاله پژوهشی**

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# تأثیر تغییرات اقلیم و کمبود آب بر تصمیم‌های آبیاری کشاورزان استان خراسان شمالی: محصولات عمده زراعی

**آسیه عزیزی[1]، حسین مهرابی بشرآبادی[2]*، محمدرضا زارع مهرجردی[3]**

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## چکیده

در این مقاله، اثر کمبود آب و شرایط اقلیمی بر تصمیمات آبیاری کشاورزان در تولید محصولات عمده زراعی گندم، جو، پنبه، چغندرقند و یونجه در استان خراسان شمالی ارزیابی شده است. تصمیم‌های آبیاری کشاورزان در قالب یک مدل مدیریت شامل معادلات سهم اراضی آبی، پذیرش تکنولوژی آبیاری و دفعات آبیاری مزرعه تعریف شده است و اثر شاخص‌های کمبود آب و عوامل اقلیمی، روش تأمین آب مزرعه، ویژگی‌های اراضی و جمعیتی کشاورز مورد بررسی قرار گرفتند. برای این منظور از طریق تکمیل پرسشنامه توسط ۳۸۰ کشاورز اطلاعات مورد نیاز جمع‌آوری و سپس با استفاده از روش‌های لاجیت کسری، لاجیت دوگانه و OLS معادلات مدل مدیریت برآورد شده‌اند. نتایج نشان داد که کمبود اقتصادی و فیزیکی منابع آب، شرایط اقلیمی دما و بارندگی و رخدادهای شدید سرمازدگی و گرمازدگی محصول و خشکسالی، تأثیر قابل توجهی بر تصمیم‌های آبیاری کشاورزان دارند. کشاورزان از طریق تصمیم به آبیاری مزرعه و اتخاذ تکنولوژی‌های جدید سعی می‌کنند خسارت ناشی از تغییر اقلیم و کمبود آب را کاهش دهند. همچنین نوع منبع آبیاری سطحی و زیرزمینی، روش آبیاری، کیفیت و مقیاس مزرعه بر تصمیمات کشاورز تأثیر معنادار دارد. در مناطقی که آب سطحی در دسترس نیست، سطح اراضی آبی کاهش می‌یابد و به دلیل کمبود آب، کشاورزان رغبت بیشتری برای سرمایه‌گذاری در فناوری‌های جدید دارند. مزارعی که از نظر جنس خاک مزرعه، جهت و شیب زمین زراعی و دسترسی به منابع از کیفیت بالاتری برخوردار هستند، کشاورزان تمایل بیشتری برای سرمایه‌گذاری در روش‌های نوین آبیاری دارند و دفعات آبیاری را در مزارع افزایش می‌دهند. لذا، اعمال سیاست‌هایی جهت بهبود کیفیت و یکپارچه‌سازی اراضی، میزان گسترش تکنولوژی را افزایش و حجم آب مصرفی در مزرعه را کاهش می‌دهد. همچنین، ویژگی‌های جمعیتی کشاورز از قبیل تجربه، مالکیت، تحصیلات بر تصمیماتی که کشاورز برای آبیاری مزرعه می‌گیرد تأثیرگذار هستند. ایجاد بستر تحصیل و آموزش کشاورزان، میزان آگاهی کشاورزان را نسبت به روش‌های نوین کشاورزی و اهمیت منابع آب افزایش می‌دهد. نتایج این تحقیق اطلاعات ارزشمندی در مورد چگونگی واکنش کشاورزان در سیستم‌های تولید و انطباق با تغییرات اقلیمی و اتخاذ سیاست‌های اثربخش فراهم می‌کند.

**واژه‌های کلیدی:** تصمیم‌های آبیاری، تغییر اقلیم، کمبود آب، لاجیت کسری

۱- دانشجوی دکتری، بخش اقتصاد کشاورزی، دانشکده کشاورزی، دانشگاه شهید باهنر کرمان، کرمان، ایران

۲- استاد بخش اقتصاد کشاورزی، دانشکده کشاورزی، دانشگاه شهید باهنر کرمان، کرمان، ایران

۳- استاد بخش اقتصاد کشاورزی، دانشکده کشاورزی، دانشگاه شهید باهنر کرمان، کرمان، ایران

(*- نویسنده مسئول: Email: hmehrabi@uk.ac.ir)

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