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ORIGINAL ARTICLE

# Comparison of different modern irrigation system adopters through socio-economic, innovation characteristics and social capital values

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## Abstract

Diffusion of modern irrigation systems is one of the most important objectives of Iranian water policies targeting the sustainable use of water resources to resolve the water crisis. Despite considerable policy support, high subsidization, and a range of benefits, farmers have only minimally adopted modern irrigation systems in most parts of Iran. Therefore, the water crisis persists in almost all parts of the country. Thus, decision makers must recognize why diffusion of these systems has not been successful among farmers despite strong financial and political support. The aim of the current study was to investigate differences between adoption groups of modern irrigation systems and more critically whether the aspects affecting approval were altered by ongoing diffusion prejudiced by policy support. In other words, we explored the postponement of adoption among the early and the later adopters of modern irrigation systems and aimed to identify reasons behind different adoption behaviors. To achieve these aims, we developed a research framework of adoption that integrates multiple theories. In addition to the already established measures (human and physical capital), the current study integrated social capital and technology characteristics. A cross-sectional survey was carried out in Behbahan district in Khuzestan province southwest Iran. A total of 274 farmers were interviewed, of which 100 farmers had not and 174 farmers had adopted modern irrigation systems. A multinomial logit model was applied by using $STATA_{14}$ to identify the most effective factors for farmers' adoption decisions. We distinguished four groups; three consisted of adopters (early, middle, and late adopters) and a fourth group of non-adopters who did not accept modern irrigation technologies. The study found that farmers' delayed adoption of drip irrigation technologies was due to the complexity of the application process and the availability of family and work social capital. Additionally, the study suggested that improved trust in institutions could increase the likelihood of earlier adoption of these technologies. The results also revealed divergent perspectives among pioneer (early adopters), follower (middle adopter), and laggard (late adopter) farmers regarding the adoption of drip irrigation technologies.

**Keywords** Adoption · New irrigation system · Multinomial logit model · Iran · Water

## Introduction

Water security is a key component to achieving sustainable development (Shahangian et al. 2022). However, water resources are currently in an unstable and critical situation in most parts of the world (Cosgrove and Rijsberman 2014; Savari and Moradi 2022) directly threatening the income security, food security, and livelihood of rural populations alongside regional welfare and development worldwide, particularly in dry regions (Zhang et al. 2017). Due to water scarcity, over half of the world's population is at risk of water insecurity (Shahangian et al. 2022). In particular, approximately 40% of the world's population live under water shortage circumstances, mainly in dry and arid environment such as the Middle East (Zhang et al. 2017). Therefore, in these regions, allocating water between different users in diverse sectors makes the sustainable use of water one of the biggest political challenges of present times (Alcon et al. 2019). As much like several other nations in the Middle East, Iran has been contending with a severe water scarcity issue for decades, beginning with a decline in water potential per capita during the 1960s (Shahangian et al. 2021). The water

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scarcity problem in Iran has become so severe that it is projected to worsen by decreasing the country's per capita water availability by 50% by 2050 (Yazdanpanah et al. 2014; Shahangian et al. 2021, 2022). Due to Iran's heavy reliance on water consumption (around 90 to 93% of the country's total water resources are used in agriculture), irrigated agriculture is a vulnerable sector as water scarcity could threaten farmers' income, food security, and livelihoods (Yazdanpanah et al. 2014; Zobeidi et al. 2021). However, such problems are not only limited to the agricultural sector. Water scarcity issues impact all other sectors of the economy and go so far as to threaten national security (Boazar et al. 2019). Therefore, solving or mitigating the water crisis and associated threats is key to decision makers and other stakeholders (Mohammadinezhad and Ahmadvand 2020). For this purpose, different measures that can be divided into supply and demand approaches have been introduced by different stakeholders (Yazdanpanah et al. 2014). Water supply management helps to increase the available water to keep pace with rising water demand. This approach ensures adequate access to water with acceptable water quality and is the most traditional way to manage water resources. Supply approaches include operating rules and institutional arrangements, such as changing or expanding infrastructure for water collection and distribution (Wang et al. 2016) and rely mainly on dam building (Yazdanpanah et al. 2016).

On the other hand, water demand management helps to decrease water demand to better align with available supply. In the operational definition of water demand management, there are five components: (1) reducing the quantity or quality of water required to perform a particular task, (2) adjusting the nature of the work in such a way that it can be done with less water or less quality water, (3) reducing losses in movement from source through use to disposal, (4) shifting the time use to periods outside of peak consumption, and (5) increasing ability of the system to act during drought (Brooks 2006). In general, the most cost-effective way to optimize water resources is to move toward demand-driven approaches (Fan et al. 2014). In the south region of Iran, traditional irrigation methods such as strip irrigation method and marginal or ridge irrigation are still popular despite their inefficiency and high water consumption. The government has taken initiatives to address these issues with demand-driven approaches through promoting the adoption of water-saving technologies such as piped delivery systems, laser leveling of fields, conversion to pressurized systems for sprinklers, and conversion to drip- or sub-surface drip irrigation, that maximize the beneficial use of water by crops and improve the timing and reliability of water deliveries.

In particular, modern irrigation systems as a water-saving technique have been accompanied by high and intensive subsidies and other incentives provided to Iranian farmers. Among modern irrigation systems, drip irrigation stands out for its high water use efficiency, which is around 90%, while sprinklers have a water use efficiency of 70–80% (Alcon et al. 2019). Therefore, in the current study, we focused specifically on modern irrigation systems that use drip irrigation. In 2001, the Iranian government identified the encouragement of modern irrigation system use as a priority in its water conservancy reforms, investing approximately $300 million USD to support their adoption (IRNA 2019). However, despite the political support, high subsidization, and range of benefits, the adoption of modern irrigation systems has been slow in most parts of Iran, with only a small portion of the irrigated land using these systems. This slow diffusion of modern irrigation technologies has contributed to the persistence of the water crisis in almost all parts of the country. It is therefore crucial to gain a better understanding of the factors affecting farmer adoption, particularly given the heavy investment made by the government in promoting water conservation and modern irrigation technologies.

It is critical that the contemporary diffusion of irrigation systems is accounted for when struggling to illuminate uptake choices and it is also important for policy makers to understand why it has not been successful among farmers despite strong financial and political support. Furthermore, for success of such initiatives, decision makers need an understanding of what encourages farmers to accept new technologies or farming practices. Answering such questions can afford decision provision indication to expand the scaling path for the livelihoods of smallholder farmers. Moreover, understanding the impediments to innovation adoption is a precondition to a strategic diffusion of agricultural innovations (Mariano et al. 2012).

A vast body of literature exists on the diffusion of innovations in agriculture and particularly modern irrigation systems (Tan et al. 2020; Castillo et al. 2021; Yazdanpanah et al. 2022). The mainstream literature on innovation adoption has primarily focused on the typical assessment of differences between adopters and non-adopters (Cremades et al. 2015), with very few studies exploring the variances between innovation adoption groups in general and modern irrigation systems in particular which is in line with the general distinction made by Rogers (1962) on the diffusion of innovations. In his seminal work, Rogers divided adopters into five different groups, namely innovators, early adapters, early majority, late majority, and laggards. He assumed that each group had distinct characteristics that distinguished its members from other groups and these attributes determined the group's position in what he calls an adoption curve. Building on this classification, the current study aims to examine the distinctions between various adoption groups in Iran regarding modern irrigation systems. In particular, this study aimed to explore the postponement between the pioneers, followers, and laggards accepting modern irrigation systems and to elucidate why some farmers adopted more rapidly than others. In the context of modern irrigation technology adoption in our current research, pioneers are defined as innovators and early adopters who are quick to adopt new technologies. Followers, on the other hand, are those who adopt the technology after the pioneers have done so. Laggards are defined as those who are slow to adopt new technologies and may be isolated from opinion leaders in the community. Exploring these factors will contribute to an enhanced knowledge of adoption processes and help to facilitate the adoption of modern irrigation systems by farmers in Iran. To achieve these aims, the current study sought to develop a research framework of adoption integrating multiple frameworks and measures. A few studies have attempted to analyze modern irrigation systems adoption in Iran in the past by focusing on farmer's socio-economic features such as human capital (Yazdanpanah et al. 2022; Afrakhteh et al. 2015) which is defined as a person's innate and acquired assets, such as their skills, abilities, and capabilities (Savari et al. 2023a) and farm characteristics (e.g., physical capital) (Yazdanpanah et al. 2022; Bagheri and Ghorbani 2011) which are known as conventional measures. However, Smithers and Furman (2003) found conventional measures present relatively little explanatory value of the adoption pattern of agri-environmental programs. Furthermore, a pattern found in the literature has indicated studies have been narrowed to investigate just a few numbers of factors due to limited data (Mariano et al. 2012).

This research offers innovation from two aspects; first, the current study considers the variance between adopters according to time of technology acceptance and second, it develops a conceptual framework that integrates multiple measures to explain the adoption pattern of modern irrigation systems in Iran. While previous studies have focused on conventional measures such as the socio-economic features of farmers and farm characteristics, this study goes beyond these measures to include additional factors such as social capital and technology characteristics. The addition of these measures is based on the argument that the degree of acceptance of an innovation is usually correlated with the learning process, the features of the business that would house the innovation, and the innovation characteristics. By encompassing a variety of measures in the conceptual framework, this study aims to address the constraint of previous studies that have been limited to investigating only a few factors due to limited data.

The research objective in this study was to explore the differences between pioneers, followers, and laggards in their acceptance of modern irrigation systems and to elucidate why some farmers adopted more rapidly than others. Specifically, the study aimed to develop a research framework of adoption that integrates multiple frameworks and measures to identify these differences. The findings from this study will contribute to an enhanced knowledge of the adoption process and help to facilitate the adoption of modern irrigation systems by farmers in Iran, thereby informing initiatives targeted at the diffusion of modern irrigation systems.

## Conceptual framework

There is a long-standing body of literature that aims to evaluate the determinants of technology adoption in an agricultural context (Niles et al. 2016; Wubeneh and Sanders 2006). As such, with respect to the explanatory variables, the literature suggests several general frameworks of variables that may influence the adoption and diffusion of an innovation. Agricultural adoption studies traditionally have largely focused on economic incentives and human and physical capital. Although a great deal of studies has been devoted to exploring farmers and farm characteristics related to adoption, results have been rather consistent in showing that these features affect adoption only weakly (Huotilainen et al. 2006). Therefore, several authors have highlighted that social capital and innovation characteristics can successfully predict adoption of an innovation, thereby, emphasizing the importance of innovations' characteristics and social capital, as a characteristic of communities (Van Rijn et al. 2012), beyond human and physical capital. In this notion, this study integrates these four frameworks (Fig. 1). To provide and examine an integrated framework for predicting the factors that discriminate between adopters of irrigation technologies, that included traditionally factors of human and

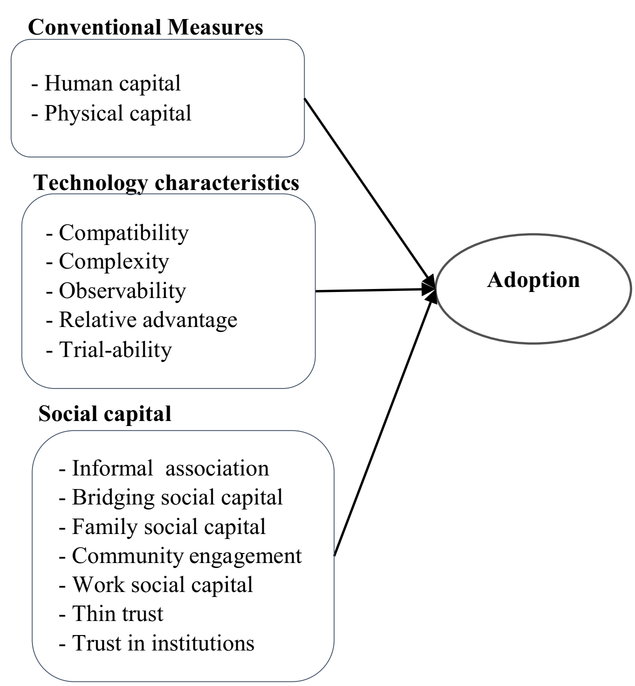


**Fig. 1** Conceptual framework

physical capital, farm characteristics, and conceptual factors, we consider all these variable in our study.

### *Conventional measures*

Conventional measures are mainstream in adoption research, concentrated on the effects of human and physical factors on adoption decisions. Therefore, previous literature has examined factors influencing farmers' adoption at the micro level, focusing on farmer and farm characteristics (Liu et al. 2018). Conventional measures assume adoption is closely related to the features of farmers and their farms that they control (Wang et al. 2015). These measures were based on the utility maximization assumption which indicates that if a farmer expects the utility of the new technology to be greater than that of the current technology, he/she will accept it (Wubeneh and Sanders 2006). Individual characteristics reflect the farmer's ability to understand existing technologies and the impact of those technologies on his/her agricultural activity (Sheikh et al. 2003). In this context, it is said that the quality of human capital plays a principally encouraging role on both the choice of new technology in agriculture, particularly for early adopters and the effective use of the technology (Feder et al. 1985). Past studies on innovation acceptance consider human and physical capital including age, education and farmers' experience, income and size of household, farm size, land ownership, and number of livestock as the main aspects affecting the utility of the technology (Hunecke et al. 2017; Liu et al. 2018; Sheikh et al. 2003; Wubeneh and Sanders 2006).

### Technology characteristics

Previous research on the adoption of innovations has compared those who adopted or rejected a particular innovation with concentration on farmer characteristics while not looking at the characteristics of the innovation itself. Yet, recognizing the impact of innovation characteristics on adoption can be very effective in improving planning for research and planning for the adoption of innovations as well as their production (Batz et al. 1999). Recent studies also confirm the significant role the characteristics of pro-environmental technology and activities play in agricultural farmers' decision-making which has been neglected in the literature (McCann et al. 2015; Varble et al. 2016). Rogers (2003) argued the characteristics of an innovation links with its diffusion indicating that how potential adopters perceive characteristics of a technology plays a crucial role in the adoption and diffusion of that technology (Negatu and Parikh 1999). A few empirical models confirmed the innovations' features govern their adoption and diffusion (Batz et al. 1999; Waarts et al. 2002).

Rogers (2003) described five innovation characteristics including (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability. Relative advantage refers to the farmer's understanding of the superiority of an innovation over the current practice. Farmers assess the innovation and parallel it with their traditional alternatives and adopt the new technology if its characteristics promise a higher utility (Batz et al. 1999). In Nigeria, for example, the advantage of increases in soybean yield influenced adoption among farmers more than other technology characteristics (Idrisa et al. 2010). Compatibility refers to the degree to which the innovation is consistent with socio-cultural values, previous ideas, and/or perceived need. In other words, if an innovation is to be accepted by a farmer, the technology must be compatible with the conditions facing the farmer (Conley and Udry 2010). A body of literature highlighted the importance of compatibility on adoption of innovation (Hall et al. 2008; Drape et al. 2013; McCann et al. 2015). Yazdanpanah et al. (2022) argued the compatibility was weighty in illumination modifications between the groups in adoption of the innovation. Haji et al. (2020) revealed that compatibility of new irrigation systems with farming and land coverage system as well as with the context-specific situations of growers had the most role in enlightening farmers' intent toward the adoption of the equipment. Warner et al. (2020) also found that compatibility expected acceptance of water conservation innovations overall.

Complexity refers to the degree to which an innovation is perceived as difficult to use or understand (Rogers 2003). Therefore, it is an important barrier to the adoption of innovation. Numerous studies (Reimer et al. 2012; McCann et al. 2015) have reported the effect of this variable in reducing adoption and decision-making. Dai et al. (2015) found that technical complexity impacted the adoption of three agricultural water-saving technologies including the rice-controlling irrigation technique, drip irrigation under plastic film, and sprinkling irrigation.

Observability refers to the ability to observe the innovation and its results which directly related to visual perception and other sensory experiences (McCann et al. 2015). Rogers (2003) argued the ability to observe an innovation and its effects by potential adopters directly affect its adoption rate. The more observable an innovation is, the higher its acceptance rate, and vice versa. The significance of this variable has been confirmed numerous times (e.g., McCann et al. 2015; Griskevicius et al. 2010; Reimer et al. 2012).

Trialability refers to the degree to which the innovation can be experienced on a limited basis or the ability to carry out trials of an innovation (McCann et al. 2015). Trialability means a farmer can devote part of her/his farm to new technology, such as a new seed, without abandoning her/his current method (Rogers 2003). Therefore, the more an innovation can be tested on a limited basis, the higher the probability of acceptance. However, many innovations cannot be tested on a small scale due to their high cost. For example, a new variety of soybeans, wheat, and corn can be easily tested on a small scale by the farmer. However, due to the need for substantial infrastructure to support installation (e.g., facilities and equipment), it is not possible for modern irrigation methods.

### Social capital

Social capital is a characteristic of a group or network of social system actors. It specifies how social actors are connected to other people and social groups (Savari et al. 2023b). In a study by Van Rijn et al. (2012), two distinct forms of social capital were identified: cognitive and structural. Cognitive social capital was found to be linked with norms, values, and trust, while structural social capital was associated with networks or inter-community ties. Structural social capital could be in the form of bonding social capital, which includes informal ties that bridge different communities or organizations such as family, friends, peers, and colleagues, or formal and open networks, as well as vertical relationships.

The relationship between social capital and innovation adoption is evolving and has captured the attention of researchers. Researchers have argued that social capital enhances acceptance of agriculture innovation (Yazdanpanah et al. 2022). Therefore, some researchers have studied the relationship between farmers' social capital and their adoption of agricultural innovations (Wu and Pretty 2004). The result has indicated traditional variables such as farm size or farmer income from the farm do not have an association with adoption of innovation but the number of adopted technologies in farm has a positive association with the farmer's social capital (Micheels and Nolan 2016). Furthermore, some researchers have found significant associations between social capital variables and adoption (Deressa et al. 2009; Wang et al. 2015). Social capital was found to significantly increase the adoption of adaptation strategies in Ethiopia (Deressa et al. 2009). It was found to facilitate the flow of information through members of a group or society which contributes to increased adoption (Hunecke et al. 2017). Some studies have proven social capital encourages the acceptance of an innovation since the externality of innovation can be internalized if farmers within the social network work together to overcome difficulties (Hunecke et al. 2017). Therefore, social capital acts as a catalyst for technology adoption because it generates a loop that makes information and technology accessible to the community and individuals in particular (Hunecke et al. 2017).

## Research method

A cross-sectional survey was used within Behbahan district in Khuzestan province southwest Iran which is considered an arid region. The total sample size for this study was 274 farmers, consisting of 174 farmers who had adopted drip irrigation in the region. We conducted interviews with all 174 farmers in their homes, by phone, or in the agriculture office, depending on their preference. To compare with the adopters, we randomly selected 100 non-adopters from the same region and asked them the same questions. The 174 adopters were further categorized into three groups (pioneers, followers, and laggards) based on their year of adoption during the period of 1995–2016. The adopters are classified into early ("pioneers," $n=30$ who adopted between 1995 and 2007), medium ("followers," $n=124$ who adopted between 2008 and 2013), and late ("laggards," $n=20$ who adopted between 2014 and 2016) groups as well as farmers who did not accept modern irrigation technologies ("non-adopters," $n=100$). Multinomial logit modelling was applied to evaluate effective factors on adoption of farmers. This model is appropriate when the dependent variable (i.e., adoption decisions) has more than two unordered categories (Badri et al. 2015). Thus, the dependent variable ($y$) can have positive integer values $k=1, 2,\ldots, K$. In addition, the model described the effects of explanatory variables ($x$) changes on the probability of each category when compared with the base category (Wooldridge 2001). The model estimated $k-1$ based on the suggestions of Amemiya (1981). The multinomial logit model was defined by the following equation:

$$Y = XB + U \tag{1}$$

To explain the multinomial logit model, $Y$ is the determinant of a vector of dependent variable that has values from 1 to 4 ($M=\{1, 2, 3, 4\} \mid \{1=\text{non-adopters}, 2=\text{pioneers}, 3=\text{followers, and } 4=\text{laggards}\}$). $X$ represents matrix of explanatory variables including traditional, innovation, and social capital variables; there are 21 explanatory variables here ($K=21$) and $B$ is matrix of estimation parameters of the explanatory variables. Then, the probability of the categories ($M$) was calculated by the following equation:

$$P\left(y_i = \mathrm{M}|x_i\right) = \frac{\exp(B_K x_i)}{1 + \sum_{k=2}^{K} \exp(B_k x_i)} \tag{2}$$

where $B_K$ represents matrix of estimation parameters of the explanatory variables ($x$). exp is indicates the exponential function. The probability of the base category ($M=1\{\text{non-adopters}\}$) was determined by the following equation:

$$P\left(y_i = 1|x_i\right) = \frac{1}{1 + \sum_{k=2}^{K} \exp(B_k x_i)} \tag{3}$$

The probability of each category relative to the base category as relative risk ratios was calculated as follows:

$$\frac{P(y = M)}{P(y = 1)} = \exp\left(\beta_k x_i\right), \text{for } M > 1 \tag{4}$$

The data was gathered through a questionnaire designed based on past studies (Aubert et al. 2012; Dai et al. 2015; Hunecke et al. 2017; Warner et al. 2020; Yazdanpanah et al. 2022) with a focus on adoption innovation, innovation characteristic, and social capital. To measure social capital and technology characteristics, the researchers developed scales consisting of multiple items. Informal association was measured using items such as "I engage in friendly and informal meetings with neighbors and friends." Bridging social capital was measured using items such as "I have many friends outside of my area." Family social capital was measured using items such as "I have a good relationship with family members." Community engagement was measured using items such as "I participate in local community events." Work social capital was measured using items such as "I feel like part of a team at work." Finally, trust was measured using two forms: thin trust, which was measured using items such as trusting many people in a given city (in this case, Behbahan), and trust in institutions, which was measured by asking participants about their trust in government, local officials and so on.

For measuring technology characteristics, compatibility was measured using items such as "Drip irrigation is compatible with my farm conditions." Complexity was measured using items such as "Drip irrigation requires a lot of skill." Observability was measured using items such as "Before installing drip irrigation, I have seen its benefits in neighbors' farms." Relative advantage was measured using items such as "Drip irrigation is easier than traditional methods." Finally, trialability was measured using items such as "It is not possible to drip irrigate only one part of my field."

Farmers were asked the extent to which they agreed or disagreed with these items using a 5-point Likert scale (*very low* = 1 to *very high* = 5) (Table 1).

We evaluated questionnaire validity and reliability through two distinct processes. First, the questionnaire was checked and corrected based on assistance from a panel of experts (with backgrounds and credentials in agriculture extension, sociology, and economics). They evaluated the content validity in terms of relevance and clarity of items.

Second, a pilot study was assumed with 30 farmers to examine the questionnaire's reliability. Cronbach's alpha coefficient was used to evaluate internal consistency reliability. A generally accepted rule of thumb is that 0.6–0.7 indicates a satisfactory level of reliability, and 0.8 or higher is a very good level (Hulin et al. 2001). The results revealed that the reliability of the questionnaire variables (0.60–0.91) was acceptable to very good.

## Result and discussion

The factors affecting the probability of adopting modern irrigation technologies between pioneer, follower, and laggard farmers were estimated through a multinomial logit model by employing the $STATA_{14}$ software package (Table 2). Both the LR (215.67) and Pseudo $R^2$ (0.30) statistics confirmed the model was significant at the 1% level.

### Conventional measures (individual, farm, socio-economic characteristics)

The results indicated the effect of age on the probability of adopting modern irrigation technologies in the pioneer and follower groups was positive and significant, whereas it was not significant for the laggard group. As such, the pioneer and follower farmers were older than the farmers of the laggard and non-adopter groups. This result was in contrast to previous research findings which have reported increases in age are accompanied by decreases in the probability of adopting modern irrigation technologies (Alcon et al. 2011; Wang et al. 2015; Zhang et al. 2019). Nevertheless, in some studies, the older farmers adopt modern irrigation technologies earlier (Rogers 2003). Furthermore, it is important to take into account that many young farmers who have begun their business may have less than 10 years of experience and thus would not be included in the pioneer or follower groups. For example, the mean year of adopting by the pioneer farmers was about 15 years ago.

The variable coefficients of formal education were positive and significant for all adopter groups of modern irrigation technology. Therefore, by improving education levels, the probability of adopting modern irrigation technologies increases, which has been supported in other studies (Alcon et al. 2011; Mariano et al. 2012). Zhang et al. (2019) described how more educated farmers had a greater ability to evaluate modern irrigation technologies as well as to understand the benefits of adopting.

The results presented in Table 2 indicated farmers with larger farms were more inclined to adopt modern irrigation technologies. The farm size coefficients were positive and significant for all adopter groups. Previous research has shown that farm size has different influences on adoption. Some studies have found that the effect of farm size on adoption is statistically insignificant (Bradshaw et al. 2004; Deressa et al. 2009), while other studies have found that farm size has a significant effect on adoption (Gebrehiwot and van der Veen 2013; Alam 2015). Mariano et al. (2012)

**Table 1** Explanatory variables selected for conceptual framework

| Variables | Unit | Descriptive | | Expected sign |
|---|---|---|---|---|
| Qualitative variable | | Frequency | | |
| | | 1 | 0 | |
| Access to extension | Dummy:1 = yes | 229 | 45 | + |
| Off-farm income | Dummy:1 = yes | 79 | 195 | + |
| Know farmers[a] | Dummy:1 = yes | 265 | 9 | + |
| Access to media | Dummy:1 = yes | Low = 40 Moderate = 158 High = 76 | | + |
| Quantitative variables | | Descriptive | | |
| | | Mean | SD | |
| Age | Years/continuous | 50.13 | 10.29 | ± |
| Education | Years/continuous | 10.08 | 3.88 | + |
| Farm size | Hectares/continuous | 15.16 | 16.14 | + |
| Likert type variables | | Descriptive | | |
| | | Mean | SD | |
| Environmental attitude | Five-point Likert scale | 4.04 | 0.42 | + |
| Risk | Five-point Likert scale | 3.85 | 0.37 | + |
| Compatibility | Five-point Likert scale | 3.82 | 0.53 | + |
| Complexity | Five-point Likert scale | 3.44 | 0.72 | - |
| Observability | Five-point Likert scale | 3.70 | 0.56 | + |
| Relative advantage | Five-point Likert scale | 3.87 | 0.43 | + |
| Trialability | Five-point Likert scale | 3.74 | 0.58 | + |
| Informal association | Five-point Likert scale | 3.90 | 0.37 | + |
| Bridging social capital | Five-point Likert scale | 3.63 | 0.56 | + |
| Family social capital | Five-point Likert scale | 3.91 | 0.48 | + |
| Community engagement | Five-point Likert scale | 3.90 | 0.48 | + |
| Work social capital | Five-point Likert scale | 3.95 | 0.43 | + |
| Thin trust | Five-point Likert scale | 3.66 | 1.39 | + |
| Trust in institutions | Five-point Likert scale | 3.52 | 0.62 | + |
| LR chi2(63) | 215.67*** | | | |
| Pseudo $R^2$ | 0.30 | | | |

[a]Do you know farmers who have accepted drip irrigation?

***$p < 0.001$

concluded that farmers with large farms could allocate part of their land to new technologies, which may result in reducing the risk of failure of these technologies which also aligns with Rogers (2003) emphasis on the value of trialability. In the research region, farmers who own larger farms may be more likely to adopt drip irrigation technology because larger farms have a higher potential for economies of scale, which means that the cost per unit of output may be lower for larger farms. By adopting drip irrigation technology, larger farms may be able to increase their yield and reduce their water usage, which could result in cost savings and increased profitability. In addition, larger farms may have more resources available to invest in new technology. This includes both financial resources and human resources, such as skilled labor and management expertise. More recently, Zhang et al. (2019) investigated the possibility that large-scale farms incurred more time, labor, and water resources costs which hints at the qualities of relative advantage and compatibility being greater for farmers operating larger farms. Therefore, they intend to adopt some modern irrigation technologies to decrease related costs.

The variable effect of off-farm income on the probability of adoption of modern irrigation technologies was not significant for all adopter groups. Therefore, off-farm income cannot be considered a critical factor to adopt some modern irrigation technologies in this case. The finding differs from Fernandez-Cornejo et al. (2005) and Deressa et al. (2009) who explored off-farm income and found it to be an important factor to adopting adaptive strategies by reducing available water. Moreover, in Wang et al.'s (2015) and Cremades et al.'s (2015) studies, off-farm income and farmer's assets had a significant positive impact on the probability of adopting modern irrigation technologies. Intuitively, one might think having outside incomes increases farmers' ability to

**Table 2** Results of the multinomial logit model (based group: non-adopter farmers)

| Variables | Pioneers | | Followers | | Laggards | |
|---|---|---|---|---|---|---|
| Traditional | | | | | | |
| Age | 0.15*** | (0.03) | 0.13*** | (0.03) | 0.05 | (0.03) |
| Education | 0.60** | (0.26) | 0.54** | (0.25) | 0.54** | (0.27) |
| Farm size | 0.11*** | (0.03) | 0.85*** | (0.03) | 0.05* | (0.03) |
| Off-farm income | 0.60 | (0.54) | 0.70 | (0.53) | − 0.18 | (0.53) |
| Access to extension | − 0.60 | (0.59) | − 0.68 | (0.58) | − 0.03 | (0.58) |
| Risk | − 0.05 | (0.12) | − 0.06 | (0.12) | − 0.02 | (0.12) |
| Environmental attitude | 0.08 | (0.11) | 0.10 | (0.11) | 0.06 | (0.11) |
| Know farmers[a] | − 1.36 | (1.47) | − 0.10 | (1.45) | − 0.91 | (1.30) |
| Access to media | − 0.07 | (0.39) | 0.07 | (0.39) | 0.22 | (0.41) |
| Innovation | | | | | | |
| Compatibility | 1.70** | (0.74) | 1.56** | (0.77) | 2.67*** | (0.75) |
| Complexity | − 0.45 | (0.42) | − 0.66 | (0.41) | − 1.09** | (0.42) |
| Observability | − 0.07 | (0.55) | 1.63** | (0.66) | 0.18 | (0.56) |
| Relative advantage | 0.18 | (0.60) | − 0.45 | (0.62) | 0.22 | (0.63) |
| Trialability | 0.07 | (0.54) | − 0.06 | (0.57) | 0.13 | (0.58) |
| Social capital | | | | | | |
| Informal association | 0.94 | (0.81) | 0.78 | (0.84) | 1.22 | (0.84) |
| Bridging social capital | − 0.05 | (0.46) | 0.08 | (0.48) | 0.89* | (0.51) |
| Family social capital | − 1.89*** | (0.58) | − 2.13*** | (0.61) | − 2.12*** | (0.63) |
| Community engagement | 0.95 | (0.66) | 1.70** | (0.68) | 0.80 | (0.65) |
| Work social capital | − 1.58** | (0.65) | − 1.40** | (0.64) | − 2.31*** | (0.71) |
| Thin trust | − 1.01** | (0.45) | − 0.91* | (0.47) | − 0.33 | (0.46) |
| Trust in institutions | 1.05** | (0.45) | 1.38*** | (0.49) | 0.22 | (0.46) |
| LR chi2(63) | 215.67*** | | | | | |
| Pseudo $R^2$ | 0.30 | | | | | |

[a]Do you know farmers who have accepted drip irrigation?

Standard errors (se) of coefficient are reported in parentheses

*$p < 0.1$

**$p < 0.05$

***$p < 0.001$

take risks and would relate positively to adoption. However, our study found that the effect of off-farm income on the probability of adopting modern irrigation technologies was not significant. One possible explanation for this result is that some farmers with non-agricultural incomes may not prioritize the management of natural resources, including water resources. It is possible that farmers with off-farm income are more occupied with their work and have less time to devote to agricultural activities, including water conservation. It is also possible this finding demonstrates how adoption decisions are not purely financial in nature. This could result in a lower likelihood of adopting drip irrigation technology, even if they have greater financial resources. Therefore, the relationship between off-farm income and the adoption of drip irrigation technology may be more complex than a simple positive correlation. Gebregziabher et al. (2009) find also that off-farm income is negatively related with access to irrigation.

Access to extension did not have a meaningful impact to adoption of modern irrigation technologies for all groups. This finding implies extension classes have failed to persuade sample farmers to adopt modern irrigation technologies, or perhaps those who have not engaged in extension classes are obtaining information elsewhere. The finding contradicts Mariano et al. (2012) which found farmers' engagement with extension had a positive and significant effect on the adoption of modern irrigation technologies. However, this finding was congruent with Wang et al. (2015) who concluded that extension agencies do not have a noticeable impact on the adoption of modern irrigation technologies.

The variable coefficient of risk on the probability of adopting modern irrigation technologies was also not significant for all adopter groups. Given farmers' risk tendency is not a critical factor in the adoption of modern irrigation technologies, this finding is similar to those of other researchers (Mariano et al. 2012).

Farmers' environmental attitude did not have a significant impact on the probability of adoption of modern irrigation technologies in all adopter groups. As such, the environmental understanding of farmers may not play a critical role in the adoption of modern irrigation technologies. Nevertheless, many past studies have concluded that some farmers in low-water regions are more likely to adopt modern irrigation technologies due to their understanding of environmental conditions (Cai and Rosegrant 2004; Schuck et al. 2005; Shrestha and Gopalakrishnan 1993).

Whether or not a farmer knows farms using modern irrigation technologies did not have significant impact on the probability of adopting modern irrigation technologies by all adopter groups. This result implies that either the results of using modern irrigation technologies were not apparent or the farmers' trust in each other is low. Despite knowing their neighboring farms that have adopted modern irrigation technologies, farmers are not willing to adopt these technologies. However, the studies conducted by Islam et al. (2013) and Zhang et al. (2019) described that neighbors may affect adoption of innovations.

The results confirmed that farmers' access to the media does not have a significant effect on the probability of adopting modern irrigation technologies by all adopter groups. The finding implied the media in the study region has not been successful in encouraging farmers to use modern irrigation systems. This result is in contrast to those of a study by Läpple and Van Rensburg (2011) that identified the media as an influential factor in the adoption of organic farming.

## Innovation variables

The results indicated the effect of the compatibility variable on the probability of adopting of modern irrigation technologies is positive and significant by farmers in all adopter groups (see Table 2). This finding implies if modern irrigation technologies are adapted to some issues including climate, agriculture, and social conditions of the region, farmers will be more likely to adopt. Hence, engineers and extension professionals must ensure these technologies are adapted to the conditions of the region before encouraging farmers to develop modern irrigation technologies at the farm level. This finding supports the positive and significant effect of compatibility characteristic on the adoption of innovative technologies or applications which has been validated in other studies (Lamm et al. 2017; Reimer et al. 2012; Warner et al. 2019).

The effect of the complexity variable on the probability to adopt the modern irrigation technologies for the laggard group is negative and significant, whereas this effect is not significant for the pioneer and follower groups. Accordingly, the farmers in the laggard group evaluate the complexity of implementing and installing modern irrigation technologies as a critical factor to adopt the modern irrigation technologies. In other words, the innovation's complexity is not an essential factor in the early adoption of new technologies, it has been recognized as an influencing factor over time, which can create it possible to adopt these technologies. Thus, pioneer farmers who adopt modern technologies earlier do not think about the complexity of setting up these technologies, and therefore, it is not an important factor in their decision-making (Warner et al. 2019). In contrast, farmers who are more resistant to the adoption of modern technologies consider the ease of adoption of these technologies and complexity is an important factor in their decision-making (Lamm et al. 2017).

The variable effect of observability on the probability of adopting modern technologies was positive and significant for the follower group. In contrast, this effect was not significant for pioneer and laggard groups. This factor was not important for pioneer farmers due to their earlier adoption and inability to observe the benefits of modern technologies. Also, for farmers in the laggard group, this factor was not effective, because for this type of farmers, there are other more important factors that may cause a delay in their adoption. In some studies, the feature of visibility has been recognized as an influencing factor on adoption (Moore and Benbasat 1991; Reimer et al. 2012; Warner et al. 2019) and other studies have reported no significant impact of this feature on innovation adoption (White and Selfa 2013; Lamm et al. 2017; Warner et al. 2019).

Based on the obtained results, the variables of relative advantage and trialability did not have a significant effect on the probability of adoption of modern irrigation technologies for all adopter groups. This result implies that understanding the advantages and trialability of modern irrigation technologies cannot play an effective role to adopt innovation by farmers, which both supports and diverges from others' reported findings in this area. In Lamm et al.'s (2017) study, compatibility and complexity features were specified as highly affecting factors, while advantage and testability features were minor factors in adoption of water quality conservation innovations (Lamm et al. 2017). However, in a study by Warner et al. (2019), some attributes, such as relative advantage and testability, were influencing factors, and characteristics of compatibility and complexity were non-significant factors affecting the adoption of water conservation technologies. Like the present study, Zhang et al. (2019) reported a positive and significant effect of the testability factor on the adoption of modern irrigation technologies.

## Social capital variables

The effect of informal association on the probability of adopting modern irrigation technologies by all adopter groups was not significant. In other words, farmers' dependence and association with friends and neighbors as informal institutions were not factors affecting the adoption of modern irrigation technologies which was consistent with previous studies (Solano et al. 2003; Pannell et al. 2006; Hunecke et al. 2017). As such, establishing informal associations of the farmers may not be a way to expand the use of modern irrigation technologies.

The impact of both bonding and bridging social networks on the adoption of an innovation has been widely explored in the literature (Chou 2006; van Rijn et al. 2012). Farmers' social relationships with people outside their region (bridging social capital) did have a positive and significant effect on the probability of adopting modern irrigation technologies for the laggard group but this effect was not significant for pioneer and follower groups. It can be concluded that when farmers who are considered laggards in adopting modern irrigation technologies communicate with people outside of their native region, there is a greater chance of adopting these technologies. Accordingly, for laggard group farmers who have adopted modern irrigation technology later than other farmers, the factor of bridging social networks was an influential factor in their decision to adopt technologies. Nevertheless, for the pioneer and follower farmers, this factor did not play a critical role in their decision-making as there was no significant difference between the farmers in these two mentioned groups with the non-adopter group from the perspective of social relations with the outside.

Family social capital had a significant negative effect on the probability of adopting modern irrigation technologies for all adopter groups. Thus, those farmers with deep family connections were less likely to adopt modern irrigation technologies. Perhaps farmers with deep family ties relied on their family for labor and this reliance makes them less inclined to adopt modern technologies that reduce family members' roles (Hayami and Ruttan 1985; Läpple and Van Rensburg 2011).

The community engagement variable in the follower group has a positive and significant effect on their probability to adopt modern irrigation technologies. The finding confirmed that formal social networks play a catalytic role to enhance adoption by increasing access to information through both consultants and technical educators (Hunecke et al. 2017). Nevertheless, the effect was not statistically significant on the probability of adoption among the pioneer and laggard groups. In other words, for those farmers who adopt modern technologies sooner or later than others, community engagement does not have a significant impact on their decision-making while it was a critical factor for follower farmers' decision-making.

Work social capital, which refers to the quality of relationships and interactions among peer farmers, has a negative and significant effect on the adoption of modern irrigation technologies for all adopter groups. This means that regardless of their stage of adoption, farmers who feel more connected, respected, and supported by their peers are less likely to adopt modern irrigation technologies. This finding contradicts previous literature that suggested a positive relationship between work social capital and technology adoption (Hunecke et al. 2017).

This result implies that enhancing farmers' sense of work would reduce the probability of adopting innovations. Perhaps farmers with a high sense of work do not intend to adopt such modern irrigation technologies, which require less labor than traditional irrigation technologies or farmers with low work capital may be more likely to adopt because they want or need to rely less on others. This result implies that modern irrigation technologies are less likely to be adopted if the farmers tend to utilize a larger labor force, which has also been validated to analyze both the effects of farm size and family social capital variables (Hayami and Ruttan 1985; Läpple and Van Rensburg 2011).

The results of the present study for the two variables of trust in people and institutions indicated that more trust in institutions and organizations can increase the probability of adopting modern irrigation technologies of pioneer and follower groups. Impact of thin trust (public trust) and trust in institutions has previously been investigated in the literature (Narayan and Cassidy 2001; Krishna 2004; Chou 2006; van Rijn et al. 2012; Hunecke et al. 2017). Nevertheless, thin thrust can have a negative effect on the adoption probability (Fukuyama 2001; Hunecke et al. 2017; Newman and Dale 2007). It is expected that trust in related institutions and organizations can reduce farmers' perceived risk in adopting modern technologies. The related results from the thin trust variable implied that trust in the community may discourage farmers from gathering necessary information outside their region leading them to reject the new innovation. Also, the result indicated the effect of the two variables of trust in institutions and people on the probability of adopting modern irrigation technologies of the laggard group were not statistically significant. As such, the trust in institutions and people for the laggard farmers is not a critical factor affecting their adoption of modern irrigation technologies.

In this way, to compare those factors that affect the adoption of modern irrigation technologies between the pioneer and laggard adopter groups, the results indicated that some variables such as age, farm size, and trust in institutions were statistically significant (see Table 3). Compared to the laggard farmers, the pioneer farmers were older, have larger farms, and trust in institutions

**Table 3** Results of the multinomial logit model and comparison between adopter groups

| Comparison between | Pioneers | | Followers | | Pioneers | |
|---|---|---|---|---|---|---|
| | Laggards (based group) | | Laggards (based group) | | Followers (based group) | |
| Traditional | | | | | | |
| Age | 0.10*** | (0.03) | 0.08*** | (0.03) | 0.02 | (0.03) |
| Education | 0.06 | (0.28) | 0.01 | (0.28) | 0.06 | (0.23) |
| Farm size | 0.05** | (0.02) | 0.03 | (0.02) | 0.02 | (0.01) |
| Off-farm income | 0.79 | (0.56) | 0.88 | (0.56) | −0.10 | (0.49) |
| Access to extension | −0.57 | (0.64) | −0.65 | (0.63) | 0.07 | (0.60) |
| Risk | −0.03 | (0.12) | −0.04 | (0.12) | 0.01 | (0.11) |
| Environmental attitude | 0.08 | (0.12) | 0.04 | (0.12) | −0.01 | (0.11) |
| Know farmers | −0.46 | (1.70) | 0.81 | (1.68) | −1.26 | (1.73) |
| Access to media | −0.28 | (0.43) | −0.14 | (0.42) | −0.14 | (0.35) |
| Innovation | | | | | | |
| Compatibility | −0.97 | (0.74) | −1.10 | (0.78) | 0.13 | (0.72) |
| Complexity | 0.64 | (0.42) | 0.43 | (0.41) | 0.21 | (0.36) |
| Observability | −0.25 | (0.52) | 1.46** | (0.67) | −1.70*** | (0.63) |
| Relative advantage | −0.04 | (0.63) | −0.66 | (0.65) | 0.62 | (0.59) |
| Trialability | −0.06 | (0.60) | −0.20 | (0.63) | 0.13 | (0.54) |
| Social capital | | | | | | |
| Informal association | −0.28 | (0.81) | −0.44 | (0.86) | 0.16 | (0.72) |
| Bridging social capital | −0.94 | (0.53) | −0.80 | (0.55) | −0.13 | (0.43) |
| Family social capital | 0.23 | (0.56) | −0.01 | (0.60) | 0.24 | (0.52) |
| Community engagement | 0.15 | (0.67) | 0.90 | (0.71) | −0.75 | (0.65) |
| Work social capital | 0.72 | (0.66) | 0.91 | (0.70) | −0.19 | (0.59) |
| Thin trust | −0.67 | (0.46) | −0.58 | (0.49) | −0.10 | (0.42) |
| Trust in institutions | 0.83* | (0.46) | 1.15** | (0.50) | −0.33 | (0.44) |
| LR chi2(63) | 215.67*** | | | | | |
| Pseudo $R^2$ | 0.30 | | | | | |

*$p < 0.1$

**$p < 0.05$

***$p < 0.001$

is a factor influencing their adoption. Additionally, the variables of age, observability, and trust in institutions were three critical factors with a significant difference between follower and laggard farmers regarding adoption of modern irrigation technologies. The coefficients sign of these three variables indicated those farmers in the follower group are older than those in the laggard group with higher perceived levels of observability and trust in institutions were critical in their adoption. Finally, the comparison between the pioneer and follower groups indicated the observability characteristic is the only factor distinguishing the farmers in these two groups related to their adoption of modern irrigation technologies. The negative coefficient of this variable indicated that seeing and hearing the benefits of modern irrigation technologies was a critical factor in the follower farmers' adoption decision-making process.

## Conclusions and policy implications

This study investigated some critical factors affecting the adoption of modern irrigation technologies by farmers to cope with water shortage and answers the question of how each factor affects adoption by examining different groups of farmers. A multinomial logit model was estimated to investigate the factors affecting the adoption of modern drip irrigation systems in the three adopter groups. The results from the non-adopter group served as the foundational model. The traditional variables, two factors (formal education and farm size) had a positive and significant effect on the probability of adoption among the three adopter groups (pioneer, follower, and laggard). Also, the factor age had a positive and significant effect on the probability of adoption by the pioneer and follower groups. Moreover, the effects of factors such as risk tendency, environmental attitude, and knowing farms that use modern irrigation technologies and access to media were statistically insignificant on the adoption of all groups. Among the innovation variables, the effect of compatibility on the probability of adoption of all adopter groups was positive and significant. The effect of observability on the probability of adoption of the follower group was positive and significant and the effect of complexity on the probability of adoption of the laggard group was negative and significant. Furthermore, two innovation characteristics, relative advantage and test capability, were confirmed to have no influence on the probability of adoption of all groups. Among the variables of social capital, the two factors of family and work social capital had a significant and negative effect on the probability of adopting among all groups. The effects of trust in people and institutions were related negatively and positively to the probability of adoption of the pioneer and follower groups, respectively. The community engagement factor included a positive and significant effect on the probability of adoption of the pioneer group, whereas bridging social capital factor had a positive and significant effect on the probability of adoption of the laggard group.

Studying how various factors interact and influence the adoption of modern irrigation technology among pioneers, followers, and laggards can significantly contribute to the understanding of the diffusion of innovations in agriculture. Developing an integrated framework that considers traditional factors such as human and physical capital, as well as characteristics of innovation and social capital, can provide valuable insights into the intricate processes that shape modern irrigation adoption. In addition, the research contributes to the existing literature by highlighting the significance of distinguishing between different adopter groups when studying adoption behaviors among farmers.

Based on the results, some policy implications can be deduced:

According to the results of traditional variables, some important strategies are suggested to enhance both farmers' education and knowledge and to expand and strengthen the media to encourage farmers for adopting modern irrigation technologies. Policies should include provisions and funding for educational support targeting farmers as well as the media. Media initiatives should include information packaged for dissemination.

Emphasis should be placed on the compatibility factor on innovation adoption. The results confirmed that one of the important reasons for farmers' delayed adoption is the perceived complexity of applying modern irrigation technologies. Lastly, the follower farmers also considered observability as an essential factor to adopt the innovation. Therefore, it can be generally concluded that increasing adoption of modern irrigation technologies is possible by helping farmers understand how these technologies are compatible with their region, values, and existing needs; delivering training and providing information to simplify the process of adoption; developing opportunities for farmers to see these technologies; and providing some practical solutions to generate a positive outlook for farmers to adopt these technologies. Therefore, a map of extension policies at the regional level can be designed and implemented.

Based on the impact of the social capital factors on the adoption of modern irrigation technologies, the role of public and private institutions to generate trust for pioneer and follower farmers can be important. However, formal associations are also measures that can lead follower farmers to embracing innovations. Nevertheless, one of the main results is to validate the fact that public trust can have a positive effect on the adoption of an innovation but can also reduce the tendency to adopt depending on how early or late a farmer falls on the adoption curve. As a result, the establishment of formal associations by farmer-centered organizations and alternatives to family, neighborhood, and friends' associations can be effective in fostering adopting innovations. In other words, the informal associations and cooperatives, family connections, and social networks of the farmers in the study region have not expanded the use of modern irrigation technologies. Policies should therefore include the development of formal organizations and potentially provide incentives for farmers' engagement.

Finally, the results of this study distinguish differences in the perspectives of pioneer, follower, and laggard farmers when making adoption decisions associated with modern irrigation technologies as well as to apply the tools and policies needed to develop these technologies to combat water shortages. For instance, trust in institutions was a crucial factor that generates a difference between pioneer and laggard farmers. Note also that increasing trust in institutions may increase the probability of earlier adopting modern irrigation technologies or may reduce the probability of later adoption. To integrate this finding, institutions should provide farmers with opportunities to learn about what they do and voice their concerns and needs.

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**Data availability** Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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