

Farmers' adaptation choices to climate change: a case study of wheat growers in Western Iran

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ABSTRACT

Climate change is expected to disproportionately affect farmers by further exacerbating the risks that they face. These risks have a huge negative impact on their livelihood. However, mounting evidence has revealed that farmers can effectively manage this negative impact by adapting their farming practices to climate change. The objectives of this study were to evaluate the farmers' ongoing adaptation measures, and to identify factors that influence their choice of adaptation methods in wheat production in the Kermanshah district in Western Iran. A sample of 350 farmers living in this region was selected through a multi-stage stratified and random sampling method. Principal component analysis revealed that three components play a role in the farmers' decisions on adaptation methods, namely, farm production practices, farm financial management, and government programs and insurance. The relative influence of the factors listed under each of the three components was assessed using a multiple linear regression analysis. Our analysis showed that these factors accounted for 50%, 25%, and 40% of the adaptation responses analyzed, respectively. In sum, our findings yield recommendations for agriculture extension and risk communication strategies that could promote adaptation behavior among Iranian farmers.

Key words | adaptation behavior, agriculture extension, climate change, Iran, risk perception

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INTRODUCTION

The 2014 IPCC report (IPCC 2014) confirms that climate change negatively affects different sectors of society and ecosystems. Studies revealed that agriculture is the most vulnerable to climate change, particularly in developing countries that rely heavily on their environmental resources (IPCC 2007; Hayati *et al.* 2010; Yazdanpanah *et al.* 2013a, 2013c; Yegbemey *et al.* 2013; Limantol *et al.* 2016). The negative impact of climate change, resulting in changes in weather patterns, precipitation, as well as other related factors, can both lower yields and increase production risks. Consequently, farmers' livelihoods, food security, and health may all suffer (Mazur *et al.* 2013; Swe *et al.* 2015; Kibue *et al.* 2016). Findings by Nelson *et al.* (2009) have indicated that climate change may cause yield losses ranging

from 3% to 30%, and the extinction of 15–37% of land plants and animal species by 2050. According to the 2007 IPCC report, rain-fed crop yields will decline by 10–20% by 2050, and crop revenue may decrease by 90% by 2100. Furthermore, the 2008 IPCC report (Bates *et al.* 2008) confirms that climate change has led to a decrease in the production of cereals such as rice, maize, and wheat in many parts of Asia. In addition, the same 2007 IPCC report states that the rise in temperature may cause an increase in pest populations and disease occurrence, which in turn, may directly affect the food security and poverty level among farming communities (IPCC 2007). However, empirical evidence has revealed that farmers can effectively manage the negative impact of climate

change by adapting their farming practices (Füssel 2007; Arunrat *et al.* 2017). Such adaptation will soften the impact of climate change, help protect farmers' livelihoods, and lead to other potential advantages (Gandure *et al.* 2013). In other words, farmers can reduce the damage their farms may suffer by adapting their agricultural practices to the consequences of climate change (Hassan & Nhemachena 2008). Research on adaptation in agriculture is therefore crucial (World Bank 2006) to providing farmers with the knowledge and information on how they can adapt to climate change. Since adaptation is an important strategy for reducing the negative impact of climate change on agriculture (Jin *et al.* 2016), it is pivotal to promote adaptation measures among farmers to help them protect their crops from extreme climate events (Adger *et al.* 2003; Ashraf *et al.* 2014; Obayelu *et al.* 2014).

Before policymakers and researchers attempt to educate farmers about adaptation measures, they need to understand the farmers' perspectives and attitudes towards climate change. Such understanding will, in turn, help us see how such pre-existing perceptions can be changed in order to encourage adaptation behavior (Bryan *et al.* 2013). Therefore, to explore sustainable mechanisms to minimize the negative impact of unpredictable natural disasters due to climate change, we need to comprehend the factors that influence adaptation choices among farmers (Opiyo *et al.* 2016). Such understanding can positively affect policy measures towards climate impact management, as well as enhance farmers' ability to cope with the negative impact of climate change on their livelihoods (Ashraf *et al.* 2014). Furthermore, Hassan & Nhemachena (2008) have argued that although farmers have traditionally coped with setbacks and disasters in different ways, understanding the rationale behind their chosen strategies is essential for designing incentives to encourage adaptation at the farm level.

Although a substantial body of literature about farm-level adaptation strategies and their determinants worldwide exists (Piya *et al.* 2013), Abdur Rashid Sarker *et al.* (2013) argued for the importance of country- and region-specific studies on adaptation measures in farming. This is because adaptation strategies undertaken by farmers tend to be localized and context-specific, and can vary due to different climatic conditions and farm types, as well as influenced by other political, economic, and institutional factors

(Brondizio & Moran 2008; Hisali *et al.* 2011; Nguyen *et al.* 2016).

Iran, on the one hand, is already subjected to periodic extreme weather events, including recurrent droughts and dust storms and it is expected that these events are very likely to intensify due to climate change (see Yazdanpanah *et al.* 2013b, 2013d, 2014a, 2014b; Allahyari *et al.* 2016; Athari *et al.* 2017; Salehi *et al.* 2018) and on the other hand, due to a general dearth of research on adaptation behavior and its determinants in Iran. Therefore, the objectives of this study are to evaluate the farmers' ongoing adaptation measures, and to identify factors that influence their choice of adaptation methods in wheat production in the Kermanshah district in Western Iran. This study will shed light on factors that either enhance or limit the capability of Iranian farmers to formulate adaptation strategies. Moreover, the findings will help researchers and policymakers determine the type of services these farmers need in order to protect livelihoods against climate change events. Such services, although essential, are currently very rare in Iran; therefore, studies such as the one described in this paper are vital for designing adaptation strategies that address the impact of climate change and its variability on similar production systems (Opiyo *et al.* 2016).

Our results from this study may also be applicable to farming in other countries in the MENA region, which have similarly arid and semi-arid environments (Yazdanpanah *et al.* 2011, 2015). Moreover, these countries have similar religious and cultural backgrounds, and face similar risks of water shortage. The findings from our study will not only improve our knowledge of how climate change affects farmers and the adaptation strategies that they currently use, but will also yield critical information that is useful for policymakers. Based on this information, policymakers can implement measures to mitigate the negative impacts of climate change, as well as to increase the farmers' capability to cope with and adapt to the challenges posed by climate change to their agro-based livelihood.

ADAPTATION BEHAVIOR

Adaptation to climate change is inevitable and critical in many developing countries that rely on agriculture as a

source of income. In particular, farmers in developing countries need to adapt their agricultural practices to maintain yields and minimize their vulnerability to climate change. Therefore, adapting to climate change is a response to a perceived vulnerability with the intent to reduce the risks associated with farming (Hassan & Nhemachena 2008; Arbuckle *et al.* 2013). Adaptation to climate change can occur at the individual, regional, sectorial, national, and global levels (Bryant *et al.* 2000). For instance, adaptation is common at both the individual (i.e., smallholder-led farms) and regional levels (Smit & Skinner 2002). Adaptation at each level has its own characteristics (Le Dang *et al.* 2014). In this study, we focused on adaptation at the individual level in order to understand what drives the farmers to implement adaptation measures. Adaptation in this context refers to initiatives and measures to reduce the vulnerability of man-made systems against actual or expected climate change effects (IPCC 2007, 2012). It is a dynamic process shaped by institutional, cultural, and socio-economic contexts (Arunrat *et al.* 2017).

Adaptation seeks to moderate or avoid the harmful effects of climate change, and if possible, exploit any benefits arising from adaptation measures (IPCC 2014). It is considered a purposeful proactive or inactive response to climate change (Bryant *et al.* 2000) and directly correlates with sustainable agriculture (Wall & Smit 2005). Adaptation can be divided into different categories. On the one hand, Arunrat *et al.* (2017) identified three types of adaptation behaviors: anticipatory adaptation, autonomous adaptation, and planned adaptation. On the other hand, Smit & Skinner (2002) named four main adaptation categories: farm production practices, farm financial management, technological development, and government programs and insurance. The current study used the four categories named by Smit & Skinner (2002) to analyze adaptation behavior and actions among farmers both inside and outside their farms. In this regard, we also consider the options that are available to these farmers and how they decide which methods to use. Our analysis is different from other adaptation studies because we take into account the farmers' actual adaptation measures, rather than those that they think of but do not execute. Adaptation to climate change at the farm level and beyond includes many possibilities. These possibilities include crop switching, changing

the type of seed planted, altering the timing of planting, implementing new irrigation measures, and purchasing insurance, as well as improving soil fertility or soil conservation practices, mixed crop, and livestock farming systems. Therefore, our study aims to identify different types of adaptation behavior and factors that determine this behavior. This information will help policymakers determine how to encourage farmers to implement various adaptation measures to protect their farms. While an extensive and comprehensive body of literature on adaptation practices exists, there is a dearth of research on the factors affecting household adaptation choices (Piya *et al.* 2013). Nonetheless, research conducted on farms in developing countries has highlighted various socio-economic, environmental, socio-psychological, financial, infrastructural, farm-specific factors that determine adaptation behavior among farmers (Leiserowitz 2006; Deressa *et al.* 2009; Fraser *et al.* 2011; Silvestri *et al.* 2012; Piya *et al.* 2013; Opiyo *et al.* 2016; Arunrat *et al.* 2017).

Our selection of the hypothesized explanatory variables used in the regression model is based on theoretical behavioral hypotheses and a comprehensive review of empirical literature on climate change adaptation (Hassan & Nhemachena 2008; Deressa *et al.* 2009). These variables are household characteristics such as gender, education, age of the head of household, household size, income from sources unrelated to farming, farming experience, and livestock ownership, access to extension services and production, information on climate, soil fertility, membership in rural organizations, access to credit, social networks, beliefs, and risk perception about climate change, and self-efficacy. The independent variables that may affect farmers' responses to climate change are presented in Table 1 and Figure 1. It is important to note that this paper does not aim to discuss in detail the explanatory variables shown in Table 1, since these are well-known standard measures of one's capacity to adopt conservation practices (Prokopy *et al.* 2008). Nonetheless, although detailed analyses have been done elsewhere (e.g., Hassan & Nhemachena 2008; Deressa *et al.* 2009; Piya *et al.* 2013; Opiyo *et al.* 2016), a brief analysis of them is necessary to form the basis for our own study (Table 2).

The selection of the explanatory variables used in our study is based on a comprehensive review of literature on

Table 1 | Factor loadings of actual adaptation measures used by farmers

Attitudinal statements	FPP	FFM	GPI	Mean	S.D.	None (0)	Very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
Change amount of chemical inputs (pesticides, herbicides)	0.721			3.38	1.17	12, 3.4%	12, 3.4%	44, 12.6%	91, 26.0%	145, 41.4%	46, 13.1%
Shifting planting dates	0.699			3.61	1.16	8, 2.3%	17, 4.9%	23, 6.6%	77, 22.0%	154, 44.0%	70, 20.0%
Decrease the size of cultivated land	0.678			4.05	1.04	6, 1.7%	6, 1.7%	14, 4.0%	43, 12.3%	151, 43.1%	130, 37.1%
Use of manure and compost	0.641			3.52	1.21	12, 3.4%	13, 3.7%	34, 9.7%	79, 22.6%	147, 42.0%	65, 18.6%
Practice crop rotation (wheat, barley, and peas)	0.622			3.97	1.01	3, 0.9%	7, 2.0%	18, 5.1%	58, 16.6%	147, 42.0%	117, 33.4%
Change timing of chemical inputs (pesticides, herbicides)	0.594			3.70	1.16	11, 3.1%	9, 2.6%	24, 6.9%	65, 18.6%	161, 46.0%	80, 22.9%
Diversifying into other crops	0.581			3.60	1.20	7, 2.0%	16, 4.6%	35, 10.0%	79, 22.6%	129, 36.9%	84, 24.0%
Use of meteorological information	0.423			3.75	0.98	5, 1.4%	5, 1.4%	21, 6.0%	78, 22.3%	172, 49.1%	68, 19.4%
Find off-farm jobs		0.692		2.87	1.34	13, 3.7%	55, 15.7%	60, 17.1%	91, 26.0%	93, 26.6%	35, 10.0%
Some members of the family emigrate to find jobs and earn money		0.664		2.62	1.42	26, 7.4%	66, 18.9%	66, 18.9%	79, 22.6%	84, 24.0	29, 8.3%
Ask for help from others (financial aid or assistance in farm work)		0.643		3.91	1.06	5, 1.4%	8, 2.3%	19, 5.4%	59, 16.9%	151, 43.1%	108, 30.9%
Sale of assets		0.629		2.89	1.39	27, 7.7%	29, 8.3%	74, 21.1%	81, 23.1%	103, 29.4%	36, 10.3%
Renting of agricultural land		0.572		1.55	1.25	73, 20.9%	126, 36.0%	75, 21.4%	38, 10.9%	37, 10.6%	1, 0.3%
Using the knowledge, information, and training provided by agricultural experts and relevant agencies			0.695	2.87	1.65	43, 12.3%	40, 11.4%	56, 16.0%	57, 16.3%	86, 24.6%	67, 19.1%
Insurance of agricultural production			0.660	1.90	1.55	84, 24.0%	35, 10.0%	70, 20.0%	48, 13.7%	45, 12.9%	12, 3.4%
Receive a loan			0.579	2.16	1.23	24, 6.9%	94, 26.9%	98, 28.0%	79, 22.6%	46, 13.1%	9, 2.6%
Selling livestock			0.529	3.45	1.22	4, 1.1%	19, 5.4%	44, 12.6%	58, 16.6%	112, 32.0%	57, 16.3%
Eigenvalues	4.418	1.937	1.339								
% Variance explained	24.546	10.761	7.437								
% Cumulative variance	24.546	35.307	42.744								
Cronbach's alpha	0.795	0.599	0.536								

Factor loadings are derived from PCA. The content of a component is best interpreted by examining items with factor loadings of 0.4 or above. FPP, farm production practices; FFM, farm financial management; GPI, government programs and insurance.

climate change adaptation. Previous studies (e.g., Fraser et al. 2011; Arbuckle et al. 2013; Zobeidi et al. 2016) have indicated that perceptions of climate change determine one's

adaptation behavior. One's perception of climate change is thought to be important because how an individual perceives change, including causes and threats, influences

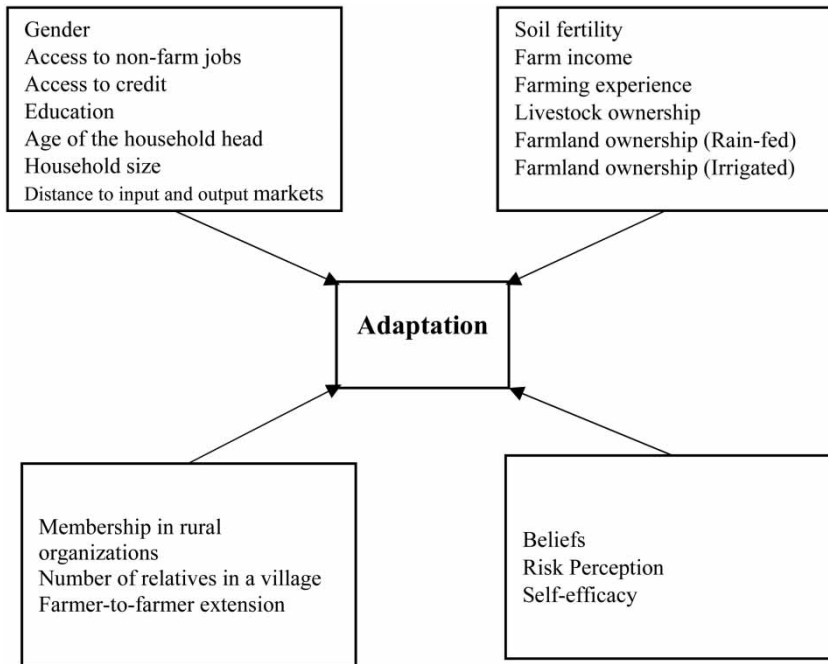


Figure 1 | Research framework.

his decision on whether to adapt to climate change and to take action (Grothmann & Patt 2005; Deressa et al. 2009; Frank et al. 2011; Mazur et al. 2013). In other words, the farmers' ability to understand climate change can facilitate their adaptation measures (Nhemachena & Hassan 2007). The awareness and perception of threats from climate change are critical arbiters of either action or inaction among farmers (Arbuckle et al. 2013). Therefore, research on beliefs and awareness concerning climate change as well as risk perception has amounted in an extensive body of literature. These two variables have been identified as the main motivators for adaptation behavior (Barnes & Toma 2012; Akter & Bennett 2011; Arbuckle et al. 2013; Mase et al. 2017).

In addition to these variables, different socio-economic and environmental factors may also influence farmers' adaptation to climate change (Opiyo et al. 2016). Studies have shown age to be an attribute that has a mixed impact on farmers' adaptation to climate change. While some researchers have found that age does not impact farmers' ability to adapt to climate change, others have observed both positive (Arbuckle et al. 2013) and negative impacts on adaptation behavior. The same phenomenon has been observed for gender. For instance, Hassan & Nhemachena (2008) noted that gender is an important variable that affects the decision

to adopt adaptation measures at the farm level. Due to different access levels to various resources, education, and financial loans between males and females, we hypothesized that gender can have a significant impact on adaptation responses.

Farming experience is also an important factor that influences adaptation behavior. Some studies (e.g., Deressa et al. 2009; Silvestri et al. 2012; Li et al. 2017) have argued that more experienced farmers are more likely to adapt to climate change. Education level is generally considered a positive predictor of adaptation behavior (Li et al. 2017). Evidence from various sources indicates that there is a positive relationship between the farmers' education level and their ability to adapt to climate change (Maddison 2006; Arbuckle et al. 2013). Bryan et al. (2013) have argued that high education level is associated with access to information on markets and early warning about the negative impact of climate change. Therefore, it was hypothesized that heads of household with higher levels of education were more likely to adapt to climate change.

Household size is another important factor in adaptation behavior. Larger families have access to more man power required for intensive adaptation measures. Family members can also generate income from activities that are

Table 2 | Explanatory variables selected for our model

Qualitative variables	Unit	Frequency		Expected sign
		1	0	
Gender	Dummy; 1 = male, 0 = female	337	13	+/-
Access to non-farm jobs	Dummy; 1 = yes, 0 = no	136	201	-
Soil fertility	Dummy; 1 = strong, 0 = weak	257	90	-
Membership in rural organizations	Dummy; 1 = yes, 0 = no	118	230	+/-
Access to credit	Dummy; 1 = yes, 0 = no	155	185	+/-
Number of relatives in a village	Dummy; 1 = a lot, 0 = low	13	335	+/-
Farmer-to-farmer extension	Dummy; 1 = yes, 0 = no	186	162	+/-
Quantitative variables	Unit	Mean	S.D.	Expected sign
Education	Years of schooling	6.74	5.02	+/-
Age of the household head	Years	48.67	12.47	+
Household size	Continuous	6.24	1.55	+/-
Farm income	Continuous	32.57	20.84	+
Farming experience	Years	24.90	14.54	+/-
Livestock ownership	Continuous	14.53	22.99	+
Farmland ownership (rain-fed)	Continuous	7.49	5.106	+/-
Farmland ownership (irrigated)	Continuous	2.59	3.80	+/-
Distance to input and output markets	Continuous	14.16	10.33	-
	Unit	Mean	S.D.	Expected sign
Beliefs	Five-point Likert scale	32.71	5.02	+/-
Risk perception	Five-point Likert scale	55.39	8.96	+/-
Self-efficacy	Five-point Likert scale	10.24	3.58	+/-

not related to farming, or migrate to other areas to find work. Therefore, we hypothesized that bigger farm households are more willing to adopt adaptation measures. The farmers' income also plays an important role in facilitating decision-making regarding adaptation to climate change. Kelly & Adger (2000) have demonstrated that households with higher income are better equipped to manage the impacts of and losses resulting from climate change. Land ownership is another standard variable in climate change adaptation. Land ownership is generally observed to correlate positively with the willingness to implement adaptation measures (Maddison 2007; Arbuckle *et al.* 2013). In our study, we hypothesized that larger farms are more likely to adopt adaptation practices.

Livestock ownership plays a very important role in adaptation behavior by serving as a social, economic,

financial, and cultural asset for most pastoral communities (Megersa *et al.* 2014). Thus, for this study, we hypothesized that farmers who own livestock are more likely to implement adaptation to climate variability and change.

Soil quality is the main driver of food production and has a strong inter-dependency with the climate (Lal 2004). Poor-quality soil experiences a greater risk of erosion and is associated with greater vulnerability to climate change (Paavola 2008). Therefore, poor soil quality may heighten farmers' awareness towards the negative impact of climate change.

Social networks can enhance farmers' adaptation behavior (Pelling & High 2005; Tumbo *et al.* 2013). A farmer's social network includes relatives, friends, and community organizations. Based on a study by Li *et al.* (2017), we categorized social networks into four different groups: direct social networks (membership in agricultural social groups),

indirect social networks (family member village), government-led educational networks (ability to access extension services and physical distance from locations that provide these services), and geographical networks (farmer-to-farmer extension). We hypothesized that these four types of social network can all potentially increase climate change perception and adaptation. Access to loans eases cash constraints and allows households to invest in production input. Thus, ability to access loans has been thought to correlate positively with adaptation to climate change (Opiyo *et al.* 2016). It is reported that access to credit facilitates adaptation by enabling investments in machinery and infrastructure (Hassan & Nhemachena 2008; Deressa *et al.* 2009, 2011; Gbetibouo 2009; Below *et al.* 2012). It is expected that access to credit will increase the number of adaptation options and reduce dependence on traditional coping strategies (Piya *et al.* 2013).

Physical distance to input and output markets also influence adaptation behavior. Households that are further away from the markets are less likely to adopt adaptation practices (Maddison 2007). Finally, self-efficacy is also an important factor that influences adaptation behavior. It is defined by Bandura (1977, 1991) as how easy or difficult an adaptation measure is to a farmer. In other words, self-efficacy pertains to how well one can strategize in order to overcome future hurdles (Bandura 1982; Yazdanpanah *et al.* 2016; Bijani *et al.* 2017). In this regard, Mazur *et al.* (2013) have stated that confidence in one's own ability to adapt is a pivotal factor in how people perceive their own ability to conduct adaptive measures (Le Dang *et al.* 2014).

METHOD

In this study, we conducted a quantitative analysis of how farmers decide on their adaptation measures based on a range of socio-economic variables and their perception of climate change, in addition to the social and institutional factors emphasized by the earlier studies. This study is based on a cross-sectional survey of data collected from wheat growers in Kermanshah County in Kermanshah province in Western Iran (Figure 2). Kermanshah province with cultivated areas of 425,699 ha was one of the most important wheat producers of Iran (in 2017 Kermanshah

province was ranked fifth in the production of wheat in Iran). The production of this province is around one million tons with average yield of 4,077 and 1,595 kg per hectare for irrigated and rained wheat agro ecosystems. Total irrigated and rained wheat agro ecosystems in this region are about 78,461 and 347,238 ha, respectively (Yousefi *et al.* 2016). FAO (2007) has reported that the potential impact of climate change on rain-fed agriculture strategies versus irrigated systems is not well understood. The population of interest consisted of 20,000 farmers who practice rain-fed agriculture, while 10,000 farmers use irrigated systems in the Kermanshah County (Statistical Center of Iran 2013). A multi-stage stratified random sampling was used to draw a sample of farmers from the study area. For this purpose, first the population of farmers in each stratum (rain-fed and irrigated farmers) was determined and summed. According to Krejcie & Morgan (1970), a total of 350 farmers was estimated as a sample size. Then, from each Deh (village), proportionate to its population in sum and also each stratum, numbers of farmers were selected randomly. Hence, the final sample consisted of 232 farmers who practice rain-fed agriculture and 118 who use irrigated systems.

We reviewed available literature in depth to develop the questionnaire to collect our data. Using this questionnaire, we conducted in-person interviews during November and December 2016 by engaging the help of an interviewer who is native to the research area.

We presented some of the questions in the questionnaire as statements with a five-point Likert scale. The selected farmers responded to these questions either in agreement or disagreement, with 1 being the strongest disagreement and 5 being the strongest agreement. Variables assessed in this type of question were beliefs, risk perception, and self-efficacy. We presented the remaining questions as either open- or close-ended questions. Table 1 lists various adaptation measures. The farmers were asked to indicate if and to what extent they had attempted the listed adaptation measures to reduce the impact of climate change based on a five-point Likert scale (1 = very low to 5 = very high). We reviewed this questionnaire extensively and made necessary adjustments before data collection.

After receiving approval from a panel of experts from related disciplines, we used this questionnaire for a pilot study in the Eslamabad-e Gharb district in Kermanshah

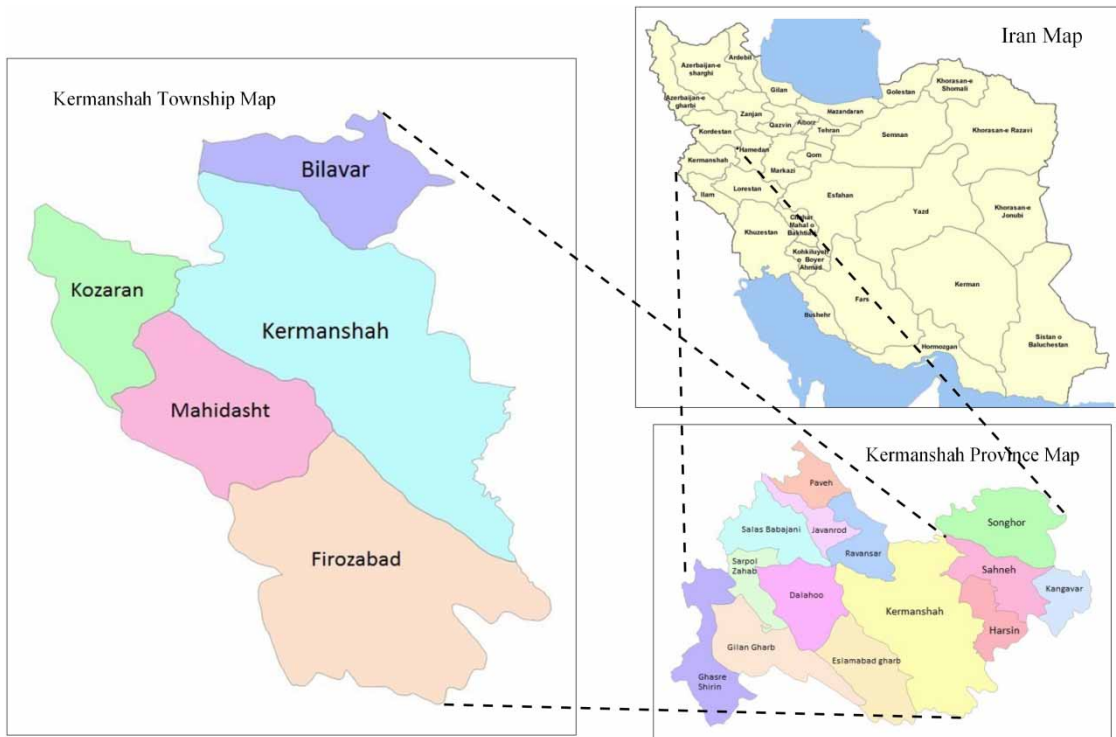


Figure 2 | Location of the study site in Iran.

Province. Most of the data were collected from the farmers at their farm, home, or elsewhere in their villages. The questionnaire took about 30–40 minutes to complete. All respondents were given the right to refuse to participate, and to refuse to answer any question. No payment was made to the farmers. Those who declined to participate were replaced by other farmers.

Table 2 contains definitions of the explanatory variables we analyzed in our study as well as their major statistical values. The Cronbach alpha reliability coefficients were high, indicating strong correlations between these variables and the farmers' adaptation behavior. Beliefs (eight items, $\alpha = 0.83$), risk perception (15 items, $\alpha = 0.89$), and self-efficacy (five items, $\alpha = 0.81$) were excellent.

Inspired by the idea presented by Smit & Skinner (2002) on different adaptation categories, we analyzed the adaptation items using principal component analysis (PCA) to obtain a more detailed representation of adaptation behavior. Furthermore, we used PCA to extract factors from the selected variables, and the Kaiser's criterion to determine the number of factors obtained. In other words, PCA

distinguishes common factors to account for most of the variation in our data and is performed by examining patterns of correlation among independent variables, namely, the adaptation items. When these items are highly correlated, they are considered to be the same and thus are referred to as components (Field 2009 cited in Hyland et al. 2016). Our analysis showed the Kaiser–Meyer–Olkin measure of sampling adequacy to be greater than 0.6 (0.799), thereby verifying that the dataset was appropriate for PCA. Moreover, we determined using Bartlett's test of sphericity that our data were significant and adequate ($\chi^2 = 1,193.620$, $P < 0.0001$). These statistical values indicate that correlations between our selected variables were sufficiently large for factor analysis and for us to proceed with PCA (Pallant 2010). The three extracted components were FPP, FFM, and GPI. Taken together, these three components accounted for 42.74% of the variance. Table 1 shows the factor loadings before rotation. We interpreted factors with factor loadings at an absolute value that was equal to or greater than 0.4 (Hyland et al. 2016). While our PCA revealed only three categories instead of the four introduced by Smit & Skinner (2002), the

variables included in each category were synonymous with the items in the categories presented by them. Furthermore, Cronbach's alpha was used to test the reliability and internal consistency of the derived factor loadings (Pallant 2010). Cronbach's alpha $>0.0.5$ is considered acceptable as evidence of a common factor underlying the responses (Nunnally 1967). It is important to note that while we had expected to list the sale of livestock in the FFM category, our analysis deemed it more suitable for the GPI category. These emerged components were used as different behavioral responses in our regression analysis.

RESULTS

Descriptive statistics

Descriptive analysis of our data revealed that the age of the participants ranged from 25 to 84 years, with a mean of 48.67 years (S.D. = 12.47). The sample consisted of 13 female farmers (3.7%) and 337 male farmers (96.3%). The small number of women in our sample is the result of a low proportion of females in the farming population, and the random sampling approach employed did not focus on obtaining a sample representative of female farmers. Approximately 39% of the participants have non-farm jobs outside of agriculture. About 79% of the respondents were married, and about 53% had access to extension services. The farmers' agricultural experience, that is how long they had been farming at the time of data collection, was distributed across a 4–70 year range, with an average length of farming experience of 24.90 years (S.D. = 14.54). Most of the participants (26.6%) had a high school degree or equivalent. Some (25.1%) had some primary education, 19.4% had some high school education, 8.6% had a college degree, and 20.3% had no education. The mean farm size for rain-fed crop farmers and arable farmland farmers was 7.49 and 2.59 hectares, respectively.

Adaptation behavior

Our finding revealed that almost all farmers had undertaken some form of adaptation measures at the time of data

collection. As shown in Table 1, the most common adaptation strategies employed by farmers in our sample were to decrease the size of cultivated land, practice crop rotation, seek help from others, and use meteorological information. The least commonly employed strategies were to rent agricultural land and to purchase insurance for agricultural production. Only six farmers in our sample had not tried to decrease the size of cultivated land. Three farmers had not attempted crop rotation. Five farmers had not sought help from others and used meteorological information, respectively. The least popular measures among the farmers sampled were the renting of agricultural land and insurance of agricultural production; 73 and 84 farmers had not attempted these strategies, respectively. Our analysis revealed that these two strategies are unusual for farmers in the region.

Factors that influence farmers' adaptation choices

Next, we used multiple linear regression analysis to assess the relative influence of the factors on the farmers' adaptation behavior (Table 3). We performed a three-step multiple regression analysis to determine the extent to which our selected variables predicted behaviors that we could group into the FPP, FFM, and GPI categories, respectively.

Our analysis results are shown in Table 3. We found that the explanatory variables that influenced the farmers' decision to implement adaptation measures are different for different adaptation categories, and that the same variable may have different effects for attributes in different categories. The first regression analysis revealed that physical distance to extension service centers ($P < 0.0001$, $\beta = -0.254$), access to non-farm jobs ($P < 0.034$, $\beta = -0.100$), membership in rural organizations ($P < 0.001$, $\beta = -0.170$), soil fertility ($P < 0.0001$, $\beta = 0.172$), number of relatives present in the same village ($P < 0.002$, $\beta = 0.147$), risk perception ($P < 0.016$, $\beta = 0.123$), and self-efficacy ($P < 0.007$, $\beta = -0.137$) accounted for 50.4% of the variation in FPP ($F = 14.138$, $P < 0.0001$). The second regression showed that the use of rain-fed land ($P < 0.011$, $\beta = 0.315$) and access to non-farm jobs ($P < 0.010$, $\beta = -0.150$) accounted for 25.2% of the variation in FFM ($F = 4.675$, $P < 0.0001$). The third regression revealed that the use of

Table 3 | Summary statistics for regression of variables

Explanatory variable	Farm production practices (FPP)			Farm financial management (FFM)			Government programs and insurance (GPI)		
	B	Beta	Sig.	B	Beta	Sig.	B	Beta	Sig.
Gender	-0.514	-0.018	0.696	-0.121	-0.006	0.918	-0.781	-0.041	0.427
Age of the head of household	0.028	0.062	0.554	0.015	0.044	0.729	-0.043	-0.139	0.227
Education level	0.004	0.004	0.957	0.050	0.059	0.486	-0.112	-0.143	0.064
Household size	-0.114	-0.031	0.502	0.029	0.011	0.849	-0.235	-0.093	0.064
Farming experience	0.039	0.097	0.317	0.039	0.133	0.261	0.019	0.071	0.502
Farmland ownership (rain-fed)	0.192	0.167	0.097	0.262	0.315	0.011	0.554	0.713	0.0001
Farmland ownership (irrigated)	-0.038	-0.026	0.861	0.085	0.079	0.661	0.449	0.444	0.006
Livestock ownership	-0.008	-0.031	0.499	0.010	0.053	0.349	0.013	0.076	0.135
Farm income	0.009	0.032	0.826	0.005	0.026	0.883	-0.110	-0.594	0.0001
Distance to extension service centers	-0.133	-0.254	0.0001	-0.030	-0.078	0.256	-0.011	-0.032	0.601
Access to non-farm jobs	-1.207	-0.100	0.034	-1.312	-0.150	0.010	-1.497	-0.183	0.0001
Access to credit	-0.660	-0.056	0.230	-0.415	-0.048	0.395	-0.554	-0.069	0.178
Distance to input and output markets	0.016	0.028	0.613	-0.004	-0.011	0.878	-0.011	-0.029	0.642
Membership in rural organizations	-2.097	-0.170	0.001	-0.749	-0.084	0.159	-0.409	-0.049	0.359
Soil fertility	2.333	0.172	0.0001	0.525	0.053	0.355	0.139	0.015	0.771
Number of relatives in the same village	4.308	0.147	0.002	1.880	0.089	0.120	1.497	0.076	0.141
Awareness towards climate change	0.095	0.082	0.130	-0.067	-0.080	0.231	0.148	0.189	0.002
Risk perception	0.082	0.123	0.016	-0.028	-0.058	0.355	-0.066	-0.146	0.010
Self-efficacy	-0.224	-0.137	0.007	-0.067	-0.057	0.359	0.029	0.026	0.639
Constant	23.959			14.218			15.262		
R	0.710			0.502			0.629		
R ²	0.504			0.252			0.395		
R ² _{Adjust}	0.469			0.198			0.352		
F	14.138 (0.0001)			4.675 (0.0001)			9.088 (0.0001)		

rain-fed land ($P < 0.0001$, $\beta = 0.713$), the use of irrigated land ($P < 0.006$, $\beta = 0.444$), farm income ($P < 0.0001$, $\beta = -0.594$), access to non-farm jobs ($P < 0.0001$, $\beta = -0.183$), awareness towards climate change ($P < 0.002$, $\beta = 0.189$), and risk perception ($P < 0.010$, $\beta = -0.146$) can explain 39.5% of the variation in GPI ($F = 9.088$, $P < 0.0001$). Our findings conform to those of previously published studies on climate change.

DISCUSSION

This study contributes to the growing body of literature on farmers' adaptation behavior and factors affecting their

responses to climate change. We grouped these responses into different categories, and analyzed factors that affect farmers' adaptation behavior both conceptually and empirically. Our findings provide new insights into how farmers adapt their agricultural practices to climate change. Following the idea presented by Smit & Skinner (2002) regarding diversity in adaptation responses, we were able to group the responses we received into three different categories. These categories were FPP, FFM, and GPI.

First, we determined how often the farmers in our sample employed each of the listed adaptation strategy. While the FPP category focused on farm activity, the other categories mostly focused on activities outside the farm. There are eight items in the FPP category. In this category,

the lowest mean obtained was 3.38 out of a maximum value of 5. Since the mean value indicates how often the farmers implement a given strategy, this reasonably high mean value suggests that the strategies in this category are commonly employed. The FFM category focuses on financial management and includes five items. In this category, asking others for help, either in the form of financial aid or assistance with farm work, was the most common strategy, while the renting of agricultural land was the least common. Finally, the GPI category focuses on government programs to support farmers and to reduce impact of climate change. As shown in Table 1, strategies in this category were less common, with the exception of livestock sales. The highest mean in this category was 2.87 out of 5, which we obtained for the strategy of using the knowledge, information, and training provided by agricultural experts and relevant agencies. To the best of our knowledge, while Smit & Skinner (2002) introduced four different adaptation categories, we are the first to analyze and confirm the variables in three of these categories empirically.

Next, we used multiple linear regression to determine factors that influenced farmers' decisions on which strategies to employ. Interestingly, we found the determinants could differ for responses in different categories even when the farmers encountered the same situation. Our regression analysis revealed physical distance to extension service centers as the most accurate positive predictor of adaptation responses in the FPP category. Various studies have reported that access to extension services facilitates decision-making regarding adaptation to climate change. For example, Bryan *et al.* (2013) and Boko *et al.* (cited in Gwimbi 2009) have found access to extension services to be an important determinant of adaptation behavior (also, see, Yazdanpanah & Feyzabad 2017). Farm soil fertility is the second most accurate predictor of adaptation response in the FPP category. Farmers with access to better-quality soil are better equipped to adapt to climate change. This observation agrees with that made by Mudzonga (2011).

On the other hand, we found that membership in rural organizations negatively affects farmers' adaptation response. While other studies have found this variable to promote adaptation behavior, our study yielded results to the contrary. This may be because the farmers in this region feel that the rural organizations of which they are members can protect them

from the negative impact of climate change and hence, they do not need to worry about it. The number of relatives in the same village positively affects adaptation responses in the FPP category. This observation agrees with that in previous studies (Boko *et al.* as cited in Gwimbi 2009; Njuki *et al.* 2008; Tumbo *et al.* 2013).

Self-efficacy, risk perception, and access to non-farm jobs are also predictors for responses in the FPP category. While risk perception had a positive effect, access to non-farm jobs had a negative effect on responses in the FPP category. However, according to Opiyo *et al.* (2016), farmers with non-farm income sources are more likely to implement adaptation measures compared to their counterparts who have no access to additional income sources.

Our second regression analysis showed that the amount of rain-fed land and access to non-farm jobs are the determinants of adaptation responses in the FFM category, an observation that agrees with findings from several previous studies (Maddison 2007; Hassan & Nhemachena 2008; Seo & Mendelsohn 2008; Gbetibouo 2009; Below *et al.* 2012). In this case, access to non-farm jobs had a negative impact.

Our third regression analysis revealed that the type of farmland cultivated, either rain-fed or irrigated, and awareness of climate change positively influenced responses in the GPI category. On the other hand, farm income, access to non-farm jobs, and risk perception negatively influenced these responses. Our findings contradict those of Wood *et al.* (2014), who found that farmers' income has a negative impact on adaptation. Nonetheless, others like Kelly & Adger (2000), Opiyo *et al.* (2016), and Rao *et al.* (2011) have argued that farm income significantly increases the probability that farmers will implement adaptation measures.

Interestingly, we found that while risk perception positively influenced responses in the FPP category, this variable negatively influenced responses in the GPI category. Furthermore, access to non-farm jobs negatively influenced adaptation responses in all categories. This may be because non-farm activities are time-consuming and thus, farmers do not have enough time to implement adaptation measures at their farms. Moreover, farmers with non-farm income are able to support themselves and their families even if disasters strike their farms.

Last, but not least, we found that gender, education level, household size, access to credit, distance to markets,

and livestock ownership are not significantly associated with any adaptation categories.

Findings from our study will help policymakers and agriculture extension researchers implement policies that can help farmers overcome challenges associated with climate change. In this regard, policymakers need to acknowledge the diverse backgrounds of and responses by farmers, which may influence the likelihood of farmers adapting their agricultural practices. Furthermore, policymakers need to pay attention to the various factors that influence farmers' perceptions of and response towards adaptation to climate change.

CONCLUSION

Agriculture is the most vulnerable sector to climate change, particularly in developing countries that rely heavily on their environmental resources. The negative impact of climate change, resulting in changes in weather patterns, precipitation, as well as other related factors, can both lower yields and increase production risks. Consequently, farmers' livelihoods, food security, and health may all suffer. Therefore, research on adaptation in agricultural practices is crucial. The objectives of this study were to evaluate the farmers' ongoing adaptation measures, and to identify factors that influence their choice of adaptation methods in wheat production in the Kermanshah district in Western Iran. PCA revealed that three components play a role in the farmers' decisions on adaptation methods, namely, FPP, FFM, and GPI. Taken together, these components accounted for 42.74% of the variance observed in this study. Our findings also revealed that the explanatory variables affecting the probability of implementing adaptation measures are different for each adaptation category, and that the same variable may have different effects on factors in different categories.

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