*Bulgarian Journal of Agricultural Science, 29 (No 5) 2023, 978–993*

# Factors influencing climate change adaptation practices and their impacts on food security dimensions in horticultural crops evaluated using PLS-SEM analysis

**Saeede Sadat Ebrahimi, Farhad Lashgharara*, Seyed Mehdi Mirdamadi and Maryam Omidi Najafabadi**

[1] *Department of Agricultural Development, Science and Research Branch, Islamic Azad University, Tehran, Iran, Postal code: 1477893855, ebrahimi_s84@yahoo.com.*
[2] *Department of Agricultural Extension and Education, Science and Research Branch, Islamic Azad University, Tehran, Iran, Postal code: 1477893855, flashgarara@yahoo.com.*
[3] *Department of Agricultural Development, Science and Research Branch, Islamic Azad University, Tehran, Iran, Postal code: 1477893855, m.mirdamadi@srbiau.ac.ir.*
[4] *Department of Agricultural Development, Science and Research Branch, Islamic Azad University, Tehran, Iran, Postal code: 1477893855, M.omidi@srbiau.ac.ir*
**Corresponding author:* f.lashgarara@srbiau.ac.ir

## Abstract

Ebrahimi, S. S., Lashgharara, F., Mirdamadi, S. M. & Najafabadi, M. O. (2023). Factors influencing climate change adaptation practices and their impacts on food security dimensions in horticultural crops evaluated using PLS-SEM analysis. *Bulg. J. Agric. Sci., 29*(5), 978–993

This study examined the major effective factors on climate change adaptation practices and investigated their impacts on food security in Qazvin province. The population of this study comprised smallholder horticultural farmers, who produced at least two types of horticultural crops during the period 2014-2017. The study sample consisted of 456 farmers, selected through stratified random sampling. A questionnaire was utilized for data collection, and data was analyzed using structural equation modeling (SEM) (Smart-PLS software, version 3.0). The findings showed that the top four climate change adaption practices that can be used by smallholders to improve household food security are (1) using late-flowering and cold tolerant varieties, (2) actively participating in extension training courses, (3) using crop insurance, and (4) covering shrubs and trees with fabric to protect against frost. In addition, the results confirmed that adaptive farming and non-farming practices are positively related to the food security dimensions of food availability, access, stability, and utilization. The findings further showed that farmers' knowledge and skills, as well as the local infrastructure are drivers for food security dimensions through the application of adaptive farming practices. When farmers intend to use adaptive non-farming practices, their attitudes toward the advantages of the climate change adaptation process may stimulate behavioral readiness toward climate change resilience and, consequently, improve food security.

*Keywords:* Climate change; Household food security; Smallholder horticultural farmers; Adaptation practices

## Introduction

Climate change, a global challenge, is a significant threat to food security, especially in developing countries, where agriculture is still a primary means of subsistence for smallholder farmers. These subsistence farmers are more vulnerable to climate change and its possible consequences, such as the probable threat to the welfare and food security of their households (Wiebe et al., 2019). The relationship of climate change and smallholder household food security has been considered due to its impacts on agricultural productivity and production and even scarce resources to continuous food supply (Gregory et al., 2005). According to the FAO (2016), all four dimensions of food security are affected by changing climatic conditions. A range of impacts have already affected crop quantity and quality (*food availability*), agricultural production costs and household incomes (*food accessibility*), calorie intake, dietary diversity, and health (*food utilization*), and the stability of farmers' strategies and production (*food stability*) (Wiebe et al., 2019; Ziervogel and Erikson, 2010).

To reduce the threat of climate change on food security, strategies and practices are needed to ensure the availability, stability, accessibility, and affordability of safe food for farmers' households (Reyes et al., 2014). Farmers will have to learn to adapt to current and future changes (Roesch-McNally et al., 2017) and to choose a set of adaptive farming and non-farming practices for climatic risk management (Alam et al., 2017). To accelerate the learning process and adaptation of farmers, identifying effective factors and providing underlying conditions are urgent priorities for local authorities, farmers' organizations, and even regional research centers in order to help smallholders across the developing world, who are more vulnerable to the consequences of climate change (Sousa et al., 2018; Shi-yan et al., 2018; Alam et al., 2017; Abdul-Razak and Kruse, 2017; Shikuku et al., 2017; Zamasiya et al., 2017; Karami, 2014).

In Iran, like other developing countries, climate change is already affecting the production of agricultural crops, particularly horticultural crops, and risking food insecurity among smallholder horticultural farmers (Crisis Management Center of Qazvin Agri-Jahad Organization, 2017). In Qazvin province, Iran, smallholder horticultural farmers' livelihoods are heavily dependent on the crops they produce annually. According to reports by the Agri-Jahad Organization, grape, cherry, walnut, peach, nectarine, hazelnut, blueberry, and almond comprise most of the horticultural crops in Qazvin. Smallholder horticultural farming in Qazvin generally includes a variety of crops rather than a single crop. Smallholder horticultural farmers meet most of their subsistence requirements by producing and selling crops. In fact, they produce mainly for personal consumption, selling only the small surplus they have (Rola-Rubzen et al., 2010). In recent years, the consequences of changing climates, such as prolonged low temperatures, frequent frost, season creep, unseasonal intensified rainfall and hail, reduced rainfall in the growing season, drought, and increased frequency of pest and diseases, have negatively affected horticultural production in Qazvin (Qazvin Agri-Jahad, 2017). For instance, in 2017, the Crisis Management Center of the Qazvin Agri-Jahad Organization estimated that prolonged low temperatures, frequent frost, season creep, and early blooming of the trees, followed by intense rainfall and hail caused more than $145 million of damage to horticultural farmers in Qazvin. Qazvin province has 73 thousand hectares area under cultivation with horticultural crops. According to the Horticultural Office of the Qazvin Agri-Jahad Organization, 590,000 tons of horticultural crops were produced in this province under normal conditions during the previous year. This figure, dropped to about 500,000 tons in 2017, due to unprecedented frost. Obviously, the welfare and food security of smallholder horticultural farmers was affected most by this situation. Thus, these farmers will have to learn to adapt to changes and to choose the best adaptive practices in order to reduce their vulnerability and the harmful effects of climate change and to achieve food security goals.

Many previous studies on climate change adaptation have focused on identifying strategies and practices to climate change considering all agricultural products (Shi-yan et al., 2018; Shaffril et al., 2018; Alam et al., 2017) rather than horticultural crops, or they have assessed the direct effects of climate change strategies and practices on food security (Wossen et al., 2017; Shisanya and Mafongoya, 2016; Ringler et al., 2010), as a whole without assessing the indirect influences of individual-based and community-based factors related to climate change adaptation on the food security dimensions. Therefore, it seems that the relationships between some individual and community factors that affect climate change adaptation practices (farming and non-farming) and subsequently food security dimensions (food availability, accessibility, utilization, and stability) are still unknown. Research is essential to filling this gap. Thus, this study aimed to explore effective factors on adaptive farming and non-farming practices and their impacts on food security (intended as its four dimensions) using the PLS-SEM approach. The research questions of this study are: (1) In what condition is the farmers' household food security in Qazvin? (2) What factors have significant effects on adaptive farming practices? (3) What factors have significant effects on adaptive non-farming practices? (4) What factors have significant *direct* effects on the food security dimensions? (5) What factors have significant *indirect* effects on food security dimensions?

In this paper, the theoretical background is provided first in Section 2. The research model and hypotheses are described in Section 3, and the methodology and results of the study are presented in Sections 4 and 5. Finally, the discussion and conclusion are presented in Section 6.

## Theoretical Background

***Climate change adaptation practices and effective factors***

Mitigation and adaptation are two main responses to climate change globally. Mitigation addresses the causes of climate change, while adaptation tries to decrease the risks of climate change consequences (UNFCCC, 2007). In other words, mitigation reduces climate change, and adaptation is the response to life in a changing climate and adjustment to the actual, or expected future climate (NASA, 2017). The International Union for the Conservation of Nature (2010) defined adaptation as "the ability to respond to challenges through learning, managing risks and impacts, developing new knowledge, and devising effective approaches" (Shaffril et al., 2018). In the agricultural sector, adaptation to climate change also refers to "adjustments in farming activities or methods to suit the changes in climatic conditions in order to lessen the resultant potential damages" (Zamasiya et al., 2017).

Appropriate local adaptation practices are crucial to reducing the vulnerability of farmers to climate change consequences; historically, farmers have been adapting to environmental variability through culture-based and livelihood-centered practices (Adger et al., 2008; Mugambiwa, 2018). Alam et al. (2017) revealed that smallholder farmers could select a range of adaptive farming and non-farming practices and strategies to alleviate the severity of climate change impacts on agriculture production and food security dimensions. Shaffril et al. (2018) reported that crop management, irrigation and water management, farm management, financial management, physical infrastructure management, and social activities are the most effective farming and non-farming adaptation practices and strategies to climate change. However, according to Alam et al. (2017), effective adaptation practices should be context specific and change over time and place.

Fischer (2018) suggested a framework to realize the impact of climate change in terms of adaptation behavior, which includes a hierarchy of three analytical units of behavior (activities, practices, and strategies). He also stated that understanding adaptation practices and strategies is especially important at the individual level, as well as the community level, because individuals (for example farmers and their families) directly experience climate change impacts. Thus, identifying effective factors on farmers' adaptive behavior is an urgent priority. According to the existing literature, attitude toward behavior is one of the constituent elements of an individual's behaviors (Ajzen, 2005). Therefore, farmers with a strongly positive attitude toward climate change risk alleviation can be expected to select and implement a set of appropriate adaptation practices and strategies (Shikuku et al., 2017). Nonetheless, it should be considered that farmers differ in their ability to select and implement adaptation practices and strategies. George et al. (2007) indicated that only 30% of farmers believe they are competent or very competent to manage climate risk. Meanwhile, it is expected that flexible education and training will improve farmers' knowledge and skills, and as a result, a high level of knowledge and skills will reflect their competency and expertise in adaptive practices toward climate risk management (Abdul-Razak and Kruse, 2017).

Furthermore, Alam et al. (2017) revealed that local agro-ecological systems, socio-economics, and existing infrastructures and capacities are some of the driving factors of enhancing the efficiency of strategies and practices. According to Adger et al. (2009), adaptation to climate change impacts can be affected by different factors, including detailed information about climate change effects; political power in local decision-making; socioeconomic and environmental support; government policies; and research, extension, and education. Abdul-Razak and Kruse (2017) showed that economic resources, awareness and training as well as technological capacities were most relevant for smallholder farmers' adaptive capacity, while infrastructure, social capital, and institutions had the least amount of importance in the adaptive capacity of smallholder farmers in the Northern Region of Ghana.

In the horticulture sector, Williams et al. (2018) examined changing climate, through improving adaptive capacity at the local level to reduce vulnerability. Their results indicated that enhancing households' climate adaptive capacity is dependent on factors, such as improved access to financial resources, climate and production information, market accessibility, farm equipment, storage facilities, and other government and institutional support. Malhotra (2017) indicated that integrating location-specific and knowledge-intensive climate change adaptation strategies is necessary for improving production. They believed that crop-based adaptation strategies are required along with consideration of the nature of the crop, its sensitivity level, and the agro-ecological condition.

***Food security and climate change adaptation practices.*** The link between climate change and food security, is very complex due to the impacts of climate change on crop productivity and food production (Gregory et al., 2005), as well as the socioeconomic issues surrounding food security components (Ziervogel and Erikson, 2010). FAO defined food security as, "when all people at all times have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). Based on the food supply chain, including agricultural production, processing, distribution, and consumption, the components of food security are (i) food availability (with elements related to the production of adequate crops, distribution, and exchange of food); (ii) food access (with elements related to affordability, allocation mechanisms, and preference that enable people to effectively translate their hunger into demand), (iii) food stability (with elements related to continuous food supply and access to food), and (iv) food utilization (with elements related to nutritional value, social value, and food safety) (Gregory et al., 2005; Ziervogel and Erikson, 2010).

Campbell et al. (2018) revealed that most of the studies regarding the impacts of climate change on food security have focused only on quantity of production as one component of food security, while climate change impacts all dimensions of food security. Thus, to reduce climate change risks on food security, all determinants of food security must be considered from the production of adequate crops to food safety. According to Ziervogel and Erikson (2010), to understand the impacts of climate change on food security, the links between climate change, food security, and its drivers should be investigated. From their point of view, cycles for consistency, agricultural management, socio-economic variables, demographic change, cultural and political variables, and science and technology are the drivers of food security that could be directly or indirectly affected by climate changes. Thus, to select and implement accurate adaptation decisions and actions to reduce climate change risks, it is necessary to consider the driver's key role in the link between food security and climate change.

## Research model and hypotheses development

Figure 1 shows the research model of the current study that was formed in four parts (individual factors, community factors, adaptive practices, and food security dimensions).

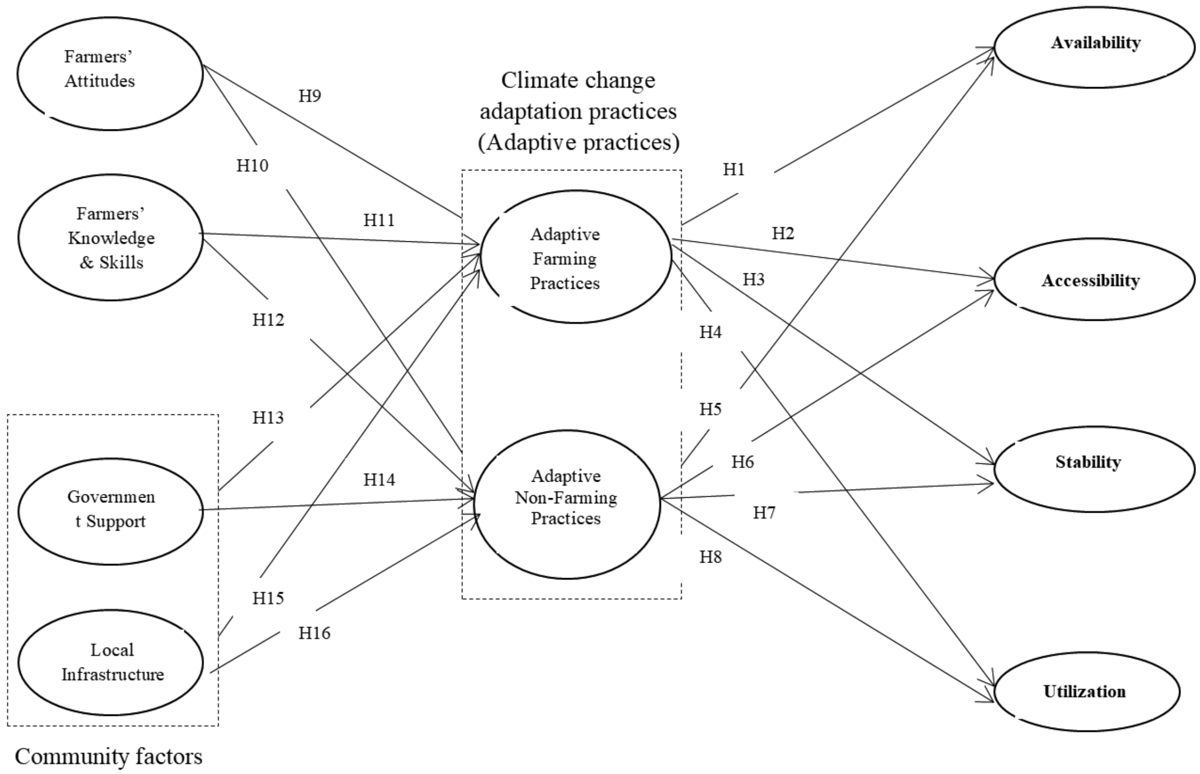


**Fig. 1. Research Model**

Based on the model, adaptive farming and non-farming practices are influenced by two individual factors (farmers' attitudes and farmers' knowledge and skills) and two community factors (government support and local infrastructure). Food security dimensions are directly determined by adaptive farming and non-farming practices and indirectly determined by individual and community factors. The relationships of the constructs in this research model are presented.

***Adaptive practices (farming and non-farming) and food security.***

To select and implement accurate adaptation practices to reduce the risks of climate change, prior research investigated the role of key adaptive strategies and practices in the link between food security and climate change. Wossen et al. (2017) provided an ex-ante assessment of the impacts of climate on household income and food security in Ethiopia and Ghana to highlight the role of adaptation strategies under climate and price variability. They focused on the availability and access dimensions of food security. They found that a set of adaptive farming and non-farming practices and strategies, such as policy interventions, irrigation facilities, institutional capacity building, access to credit, fertilizer subsidies, and new farming technologies and methods are necessary to allow households to mitigate the negative impacts of climate change. In comparison, Campbell et al. (2018) revealed that most of the studies regarding the impact of climate change on food security have focused only on the quantity of production as one component of food security, while climate change impacts all dimensions of food security.

Shisanya and Mafongoya (2016) reviewed strategies for adaptation to climate change used by smallholder farmers and their impacts on household food security, determined using the Household Food Insecurity Access Scale (HFIAS) in South Africa. Their results showed that 95% of smallholder farmers were aware that the climate is changing and expected severe impacts on their crop production systems. Most of the households indicated that having altered livelihoods systems, government grants, knowledge and information, and appropriate input packages for farmers would play a key role in mitigating the impacts of climate change on household food security. Moreover, householders who were vulnerable to climate change recorded high levels of food insecurity. Toulabinejad et al. (2017) in a similar study investigated the climate change strategies and its impact on the food security of farmer households in Iran using HFIAS and reported that 53% of households had no problem meeting their food needs under usual conditions. According to their findings, 97% of households were aware that climate change has a significant impact on the quality and quantity of products. They also found that the implementation of a portfolio of climate change adaption strategies (composed of soil and crop management strategies) by farmers could reduce climate change risks and food security vulnerability. Ringler et al. (2010) used a comprehensive climate change scenario (CCC) to explore the impacts of climate change on food security in Sub-Saharan Africa. They reported that climate change will lead to changes in yield and area growth, higher food prices and subsequent lower affordability of food, reduced calorie availability, and growing childhood malnutrition.

Therefore, the following hypotheses are proposed:

(H1): The application of adaptive farming practices positively affects food availability among smallholder horticultural farmers.

(H2): The application of adaptive farming practices positively affects food accessibility among smallholder horticultural farmers.

(H3): The application of adaptive farming practices positively affects food utilization among smallholder horticultural farmers.

(H4): The application of adaptive farming practices positively affects food stability among smallholder horticultural farmers.

(H5): The application of non-adaptive farming practices positively affects food availability among smallholder horticultural farmers.

(H6): The application of non-adaptive farming practices positively affects food accessibility among smallholder horticultural farmers.

(H7): The application of non-adaptive farming practices positively affects food utilization among smallholder horticultural farmers.

(H8): The application of non-adaptive farming practices positively affects food stability among smallholder horticultural farmers.

***Individual factors, community factors, and Adaptive practices.***

Alam et al. (2017) revealed that smallholder farmers could select a range of farming and non-farming adaptation practices and strategies to alleviate the severity of climate change impacts on agriculture production and food security dimensions, while effective adaptation practices should be context specific and change over time and place. Therefore, understanding adaptation practices is especially important at the individual level, as well as the community level (Fischer, 2018).

Some of the prior research has focused on individual factors. For example, some studies have suggested that farmers with a strongly positive attitude toward climate change risk alleviation can be expected to select and implement a set of appropriate adaptation practices and strategies (Shikuku et al., 2017; Kaiser et al. 2010). Wheeler et al. (2013) also emphasized the relationship between farmers' attitudes and adaptation practices and strategies. It should be considered that farmers differ in their beliefs and abilities to select and implement adaptation practices depending on their knowledge and skills. George et al. (2007), Abdul-Razak and Kruse (2017), Zamasiya et al. (2017) and Sousa et al. (2018) indicated that a high level of awareness, knowledge, and skills reflect a farmer's competency and expertise about adaptive practices toward climate risks management.

Most of the studies regarding the community level concentrated on various ranges of government, support and local infrastructures to drive the adaptive farming and non-farming practices to enhance resilience to climate change. Important community factors (government support and local infrastructures) that affect local farms and the strategies and practices of smallholder farmers comprised access to information about climate change events and appropriate practices information (Kumasi et al., 2019; Shi-yan et al., 2018; Alam et al., 2017; Adger et al., 2009), government policies in rural areas (Shi-yan et al., 2018; Burney et al., 2014; Adger et al., 2009), promotion of farmer associations (Kumasi et al., 2019; Shi-yan et al., 2018), membership in social groups (Zamasiya et al., 2017), promotion of research, extension, educational services and media (Shi-yan et al., 2018; Zamasiya et al., 2017; Adger et al., 2009), adoption of new crop varieties and changing planting time (Alam et al., 2017), improved access to financial micro-credit services (Alam et al., 2017; Keshavarz et al., 2013b; Keshavarz and Karami, 2014), promotion of insurance services and subsidies (Kumasi et al., 2019; Keshavarz et al., 2013b; Keshavarz and Karami, 2014), new farming facilities and modern technology (Razak and Kruse, 2017; Keshavarz et al., 2013b; Keshavarz and Karami, 2014), institutional support (Burney et al., 2014), provision of local agro-ecological systems (Alam et al., 2017), improvement of the existing infrastructure and capacity (Alam et al., 2017; Razak and Kruse, 2017), allocation of economic resources and credit facilities (Kumasi et al., 2019; Razak and Kruse, 2017), and the establishment of local markets and local storage (Williams et al., 2018).

Therefore, the following hypotheses are proposed:

(H9): Farmers' attitudes positively affect the implication of adaptive farming practices.

(H10): Farmers' attitudes positively affect the implication of non-adaptive farming practices.

(H11): Farmers' knowledge and skills positively affect the implication of adaptive farming practices.

(H12): Farmers' knowledge and skills positively affect the implication of non-adaptive farming practices.

(H13): Government support positively affects the implication of adaptive farming practices.

(H14): Government support positively affects the implication of non-adaptive farming practices.

(H15): Local infrastructure positively affects the implication of adaptive farming practices.

(H16): Local infrastructure positively affects the implication of non-adaptive farming practices.

## Materials and Methods

Based on the objectives, this quantitative paper concentrated on investigating factors influencing the climate change adaptation practices and their impacts on food security dimensions in Qazvin province, Iran. As explained earlier, the research model in this study (Figure 1) includes several endogenous and exogenous constructs: farmers' attitudes (FA) and farmers' knowledge and skills (FNS) (individual factors), government support (GS) and local infrastructure (LI) (community factors) as the main independent constructs, adaptive farming practices (AFP) and adaptive non-farming practices (ANFP) as the mediator constructs, and food availability (Avail), food access (Aces), food stability (Stab), and food utilization (Util) as dependent constructs.

### *Study area*

This study was carried out in Qazvin province, located in northwestern Iran at latitude 35°37' to 36°45' N and longitude 48°45' to 50°50'E. Elevation ranges from 300 to 4000 m, a.s.l. have created differences in topography. Mean annual precipitation is 330 mm (Qazvin Agri-Jagad Organization, 2016). Surface waters flow in both the northern and southern watersheds. According to Agri-Jahad Organization reports, grape, cherry, walnut, peach, nectarine, hazelnut, blueberry and almond are most of the horticultural crops in Qazvin.

### *Participants*

The population of this study consisted of smallholder horticultural farmers involved in the production of at least two horticultural crops (grape, cherry, walnut, peach, nectarine, hazelnut, blueberry, and almond) in Qazvin during the time period of 2014-2017. The criterion for entering this study was having a maximum of three hectares under cultivation of horticultural crops. According to the Qazvin Agri-Jahad Organization, there are about 51,371 smallholder horticultural farmers, who meet this criterion (N = 51,371). The study sample consisted of 456 farmers, based on Cochran, selected through stratified random sampling (n = 456). Some demographic characteristics of the sample are shown in Table 1.

**Table1. Demographic characteristics of respondents**

| Variables | | Frequency | Percentage | Mode |
|---|---|---|---|---|
| Age (year) | ≤ 30 | 55 | 12.1 | |
| | 31- 40 | 114 | 24.9 | |
| | 41-50 | 157 | 34.5 | 41- 50 |
| | 51-60 | 95 | 20.8 | |
| | ≥ 61 | 35 | 7.7 | |
| Education level | illiterate | 7 | 1.6 | |
| | Primary school | 77 | 16.9 | |
| | Middle school | 56 | 12.3 | Diploma |
| | High school | 93 | 20.3 | |
| | Diploma | 127 | 27.9 | |
| | Academic degree | 96 | 21 | |
| Gardening experience | Until 10 | 172 | 37.8 | |
| | 11-20 | 144 | 31.5 | |
| | 21-30s | 90 | 19.7 | Until 10 |
| | 31-40 | 40 | 8.8 | |
| | ≥41 | 10 | 2.2 | |
| The area under cultivation (ha) | ≤ 1 | 240 | 52.6 | |
| | 1-2 | 192 | 42.2 | ≤ 1 |
| | 2- 3 | 24 | 5.2 | |
| garden's insurance | ≤ 50 | 233 | 51.2 | |
| | 50-75 | 65 | 14.2 | |
| | ≤ 75 | 158 | 34.6 | ≤ 50 |
| Total | | 456 | 100 | |

***Data Collection***

Data was collected with a questionnaire consisting of five sections composed of demographic characteristics, individual and community factors, climate change adaptation practices, food security dimensions, and household food security. The sub-scales of individual and community factors, climate change adaptation practices, and food security dimensions were developed, based on a 5-point Likert scale. The questions of these sections were derived from the research model, confirmed with previous studies, and then modified to fit the nature of this study. According to the research model, independent constructs included farmers' attitudes (FA) (5 items) and farmers' knowledge and skills (FNS) (5 items), government support (GS) (4 items) and local infrastructure (LI) (5 items); mediator constructs included adaptive farming practices (AFP) (5 items) and adaptive non-farming practices (ANFP) (4 items); dependent constructs included food availability (Avail) (3 items), food access (Aces) (3 items), food stability (Stab) (2 items), and food utilization (Util) (3 items). It should be said that to enhance the questions regarding adaptive farming practices and adaptive non-farming practices with actual situations of smallholder horticultural farming in Qazvin province, further information was gathered through in-depth interviews with horticultural experts from the Crisis Management Center and Horticultural Office of Qazvin Agri-Jahad Organization and the Farming Research Center of Qazvin province. After analyzing the interviews, five items for adaptive farming practices and four items for adaptive non-farming practices were achieved.

In these sections, reliability was measured through a pretest. The questionnaire was distributed among 30 horticultural farmers, who were not in the sample of the study. The data was analyzed using Cronbach's alpha to ensure the reliability of measurement items. The results suggested that the Cronbach's alpha (> 0.70) of all the research variables had acceptable reliability. Then, the validity of the scales was modified and confirmed by horticulture experts, professors of the Agricultural Extension and Development Department, and researchers of the Qazvin Agricultural Research Center.

Data on household food security was collected using the Household Food Insecurity Access Scale (HFIAS) (Coates et al., 2007). The HFIAS module yields information on food insecurity (access) at the household level. Coates et al. (2007) stated that "the Access Scale (HFIAS) is an adaptation of the approach used to estimate the prevalence of food insecurity in the United States (U.S.) annually. The method is based on the idea that the experience of food insecurity (access) causes predictable reactions and responses that can be captured and quantified through a survey and summarized in a scale." Four types of indicators can be calculated through HFIAS, including (i) household food insecurity access-related *Conditions,* (ii) household food insecurity access-related *Domains,* (iii) household food insecurity access *Scale Score,* and (iv) household food insecurity access *Prevalence.* In this study, the first two items were assessed. Household food insecurity access-related *Conditions* indicators assess the percentage of households experiencing conditions at any time during the past four weeks, and household food insecurity access-related *Domains* indicators provide summary information on the prevalence of households experiencing one or more behaviors in each of the three domains of anxiety and uncertainty, insufficient quality, and insufficient food intake and their physical consequences in the household in the past 30 days (Shisanya and Mafongoya, 2016). According to Coates et al. (2007), "the questionnaire consists of nine occurrence questions that represent a generally increasing level of severity of food insecurity (access) and nine "frequency-of-occurrence" questions that are asked as a follow-up to each occurrence question to determine how often the condition occurred." This questionnaire, after being translated into Persian and back-translated, was confirmed by the research team and then used to collect data.

***Data Analyzing***

Descriptive analysis was done using SPSS 20. In addition to testing the research model, this study also used the partial least squares (PLS) technique of structural equation modeling using Smart-PLS 3.0 (Ringle et al., 2014) because of its suitability with the exploratory nature of this study. PLS path modeling provides robust solutions, especially when the objective is a prediction, the model is relatively complex, the sample size is small, there are several dependent variables, or the phenomenon under study is new or changing (Chin & Newsted, 1999). A two-step process was applied: first, outer model assessment (measurement model) was done to evaluate the reliability and validity of the variables, and then the inner model (structural model) was assessed to evaluate the relations among the constructs and the significance of the path coefficients in the research model using the bootstrapping technique (Henseler et al., 2009). Finally, the goodness of fit (GoF) index was assessed to provide evidence to support the research model. The GoF index is defined as the geometric mean of the average communality and average $R^2$ for all endogenous constructs that can be used to determine the overall prediction power of the complex model. The GoF represents an index for validating the PLS model globally such as $\chi^2$ and related measures in SEM-ML (Akter, 2011).

## Results

Based on the objectives and research questions of this study and to assess the hypotheses, both descriptive analysis of household food security and structural equation modeling of the research model were conducted.

***Household food security***

Household food security was assessed using the HFIAS structure. According to the results of household food insecurity access-related domains, 89% of households as respondents were anxious and uncertain about food supply, 76% of the households in the study sample had insufficient food quality, and 71% experienced inadequate quantity of food intake and its physical consequences (Table 2).

**Table 2. Percentage of Household Food Insecurity Access-related Domains (n = 456)**

| Household Food Insecurity Access-related *Domains* in the past 30 days | Percentage |
|---|---|
| 1. Anxiety and uncertainty | 89 |
| 2. Households with insufficient food quality | 76 |

Household food insecurity access-related conditions were also assessed, and the frequency of experiencing food insecurity condition in the past four weeks was calculated (Table 3). The results showed that 47% of households often experienced anxiety and uncertainty about household food supply. Moreover, most of the households often consumed poor quality food by eating non-preferred kinds of food (53.5%), a limited variety of food (50.5%), or non-preferred food (51%). Similarly, most of the households sometimes experienced an inadequate quantity of food and used coping strategies, such as eating smaller meals than they needed (52.5%), eating fewer meals in a day (60.5%), experiencing total lack of food due to lack of resources (59.5%), going to sleep at night hungry due to lack of food (49.5%), and going a whole day and night without eating anything due to lack of food (47%).

***PLS-SEM analysis***

In the next step, the model developed based on the research model (Figure 1) in Smart-PLS 3.0 was assessed through a two-step process: (a) measurement model was evaluated to assess the reliability and validity of the constructs, and (b) structural model was evaluated to examine the significance of the path coefficients in the research model. Finally, the predictive relevance and GoF index of the model and constructs were assessed.

**Table 3. Household Food Insecurity Access-related Conditions (n = 456)**

| | The frequency of experience of food insecurity condition in past four weeks (%) | | | |
|---|---|---|---|---|
| Food insecurity conditions | Rarely (Once or twice) | Sometimes (3 to 10 times) | Often (More than 10 times) | Total |
| Anxiety and uncertainty about food supply | 18 | 35 | 47 | 100 |
| Poor quality food consumption coping strategies | | | | |
| Non-preferred kinds of food | 20 | 26.5 | 53.5 | 100 |
| Limited variety of food | 21.5 | 28 | 50.5 | 100 |
| Non-preferred food | 19.5 | 29.5 | 51 | 100 |
| Inadequate quantity of food coping strategies | | | | |
| Ate a smaller meal than they needed | 19.5 | 52.5 | 28 | 100 |
| Ate fewer meals in a day | 20 | 60.5 | 19.5 | 100 |
| Experienced total lack of food due to lack of resources | 18.5 | 59.5 | 22 | 100 |
| Went to sleep at night hungry due to lack of food | 40.5 | 49.5 | 10 | 100 |
| Going the whole day and night without eating anything due to lack of food | 41.5 | 47 | 11.5 | 100 |

***Measurement model***

In the evaluation of the measurement model, initially, confirmatory factor analysis was executed to examine the reliability, convergent validity, and discriminant validity of the constructs for achieving the optimum values of parameters. Smart PLS estimated the construct loading, average variance extracted (AVE) and composite reliability (CR). As revealed in Table 4, all construct factor loadings were higher than 0.5 as the benchmark value (Chine et al., 2014). In relation to AVE and CR values, as shown in Table 5, the AVE scores ranged from 0.5 to 0.9, and the AVE values of all the reflective constructs were higher than the required value of 0.5 (Hair et al., 2011).CR values ranged from 0.5 to 0.9 and were higher than the cut-off value of 0.7 for all constructs (Wong, 2013). Discriminant validity of the constructs was also assessed. To achieve adequate discriminant validity, each square root of the value of AVE was more than the correlation coefficient. In other words, according to Table 5, the diagonal values of the correlation matrix were greater than the off-diagonal values (Barclay et al., 1995; Hulland, 1999). Discriminant validity was also assessed using Heterotrait-Monotrait (HTMT) criterion (Henseler et al., 2015). All HTMT values were below the threshold of 0.85 and confirmed the discriminant validity of the constructs.

***Structural model***

The hypotheses were tested using the PLS-SEM approach. The structural model was evaluated in order to assess the quality of the model and examine the research hypotheses through the process of bootstrapping, using a two-tailed t-test with a significance level of 5%. The path coefficient was considered significant if the t-value was larger than 1.96 (Ringle et al., 2015). The results of the structural model are shown in Figure 2, along with the coefficients (β) of all the paths and their significance. Based on the results, most of the path coefficients were statistically significant and most of the hypotheses are supported. As shown in Figure 2, the relationship between adaptive farming practices and food availability was confirmed (β = 0.408, t-value = 3.934; p = 0.000); thus, H1 was supported. Furthermore, the relationships between adaptive farming practices and food access (β = 0.392, t-value = 3.035; p = 0.000), adaptive farming practices and food stability (β = 0.444, t-value = 4.381; p = 0.000), adaptive farming practices and food utilization (β = 0.392, t-value = 3.566; p = 0.000), adaptive non-farming practices and food availability (β = 0.426, t-value = 4.143; p = 0.000), adaptive non-farming practices and food access (β = 0.383, t-value = 2.937; p = 0.003), adaptive non-farming practices and food stability (β = 0.415, t-value = 3.910; p = 0.000), adaptive non-farming practices and food utilization (β = 0.432, t-value = 3.800; p = 0.000) were confirmed; thus H2, H3, H4, H5, H6, H7, and H8, respectively, were supported (Table 6).

After evaluating the effects of constructs, IPMA (Importance-Performance Matrix Analysis) was used to further investigate the indicators (or items of adaptive and non-farming practices) and generate additional findings and conclusions. IPMA was used to prioritize and identify the most important adaptive practices to develop resilience against climate change risks regarding enhancing the positive impact on food security dimensions. Smart-PLS computes indicators' importance by using unstandardized total effects. It was found that adaptive practices include (1) use of late-flowering and cold tolerant varieties (AFP1), (2) active participation in extension training courses (ANFP1), (3) use of crop insurance (ANFP1), and (4) covering shrubs and trees in frost with fabric, etc. (AFP2), to be the top four highly important climate change adaption practices that could be implemented by smallholder horticultural farmers to improve household food security.

As shown in Figure 2, the relationships between farmers' knowledge and skills and adaptive farming practices (β = 0.277, t-value = 2.870; p = 0.004), farmers' knowledge and skills and adaptive non-farming practices (β = 0.251, t-value = 2.813; p = 0.005), farmers' attitudes and adaptive non-farming practices (β = 0.314, t-value = 2.922; p =

**Table 4. Results of measurement model based on confirmatory factor analysis**

| Variables | items | | Loadings | AVE | CR |
|---|---|---|---|---|---|
| Farmers' attitudes (FA) | Using adaptive practices increases farm productivity. | FA1 | 0.790 | 0.545 | 0.856 |
| | Using adaptive practices helps decrease farm costs. | FA2 | 0.591 | | |
| | Using adaptive practices enhances stability of resources. | FA3 | 0.645 | | |
| | Learning how to use farming adaptive practices is easy. | FA4 | 0.713 | | |
| | | FA5 | 0.841 | | |
| Farmers' knowledge and skills (FNS) | Awareness of the conditions and terms of crop insurance | FNS1 | 0.382 | 0.555 | 0.857 |
| | Knowledge of how to select appropriate varieties | FNS2 | 0.598 | | |
| | Knowledge and skills of how to protect farm against frost | FNS3 | 0.743 | | |
| | Knowledge and skills of using integrate pest management | FNS4 | 0.669 | | |
| | Knowledge and skills of using modern irrigation equipment | FNS5 | 0.702 | | |
| Government support (GS) | C1Allocate inputs with subsidy price | GS1 | 0.790 | 0.541 | 0.822 |
| | Delivery of information and training programs from media | GS2 | 0.591 | | |
| | Allocate low-interest rate credits | GS3 | 0.645 | | |
| | C3Support and equip farmer associations and cooperatives | GS4 | 0.713 | | |
| Local infrastructure (LI) | Set up stable local markets | LI1 | 0.841 | 0.525 | 0.844 |
| | Set up local agro-meteorology center | LI2 | 0.382 | | |
| | Set up a local storage | LI3 | 0.598 | | |
| | Promote local processing equipment | LI4 | 0.743 | | |
| | Provide safe crop transportation equipment | LI5 | 0.669 | | |
| Adaptive farming practices (AFP) | Use late-flowering and cold tolerant varieties | AFP1 | 0.702 | 0.515 | 0.840 |
| | Cover shrubs and trees in frost with fabric, etc | AFP2 | 0.790 | | |
| | Use sprinklers and garden fog machine for frost protection | AFP3 | 0.591 | | |
| | Conduct integrated management of pests and diseases | AFP4 | 0.645 | | |
| | Use modern irrigation methods and equipment | AFP5 | 0.713 | | |
| Adaptive non-farming practices (ANFP) | Use crop insurance | ANFP1 | 0.841 | 0.542 | 0.825 |
| | Access to timely information | ANFP2 | 0.382 | | |
| | Membership to farmers associations | ANFP3 | 0.598 | | |
| | Active participation in extension training courses | ANFP4 | 0.743 | | |
| Food availability (Avail) | Production of adequate crops | Avail1 | 0.669 | 0.582 | 0.802 |
| | Distribution of crops | Avail2 | 0.702 | | |
| | Exchange of food | Avail3 | 0.790 | | |
| Food access (Aces) | Affordability | Aces1 | 0.591 | 0.732 | 0.891 |
| | Allocation mechanisms | Aces2 | 0.645 | | |
| | Preference | Aces3 | 0.713 | | |
| Food stability (Stab) | Continuous food supply | Stab1 | 0.841 | 0.650 | 0.848 |
| | Access to food | Stab2 | 0.382 | | |
| Food utilization (Util) | Nutritional value | Util1 | 0.598 | 0.696 | 0.821 |
| | Social value | Util2 | 0.743 | | |
| | Food safety | Util3 | 0.669 | | |

**Table 5. Discriminant validity and correlation between constructs**

| constructs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| FNS | 0.745 | | | | | | | | | |
| FA | 0.591 | 0.739 | | | | | | | | |
| GS | 0.645 | 0.628 | 0.735 | | | | | | | |
| LI | 0.713 | 0.522 | 0.671 | 0.724 | | | | | | |
| AFP | 0.641 | 0.587 | 0.611 | 0.677 | 0.718 | | | | | |
| ANFP | 0.582 | 0.422 | 0.577 | 0.483 | 0.489 | 0.736 | | | | |
| Avail | 0.598 | 0.645 | 0.624 | 0.655 | 0.636 | 0.473 | 0.763 | | | |
| Aces | 0.743 | 0.752 | 0.681 | 0.719 | 0.854 | 0.538 | 0.793 | 0.856 | | |
| Stab | 0.669 | 0.663 | 0.709 | 0.737 | 0.702 | 0.569 | 0.652 | 0.790 | 0.806 | |
| Util | 0.702 | 0.550 | 0.599 | 0.785 | 0.642 | 0.437 | 0.691 | 0.721 | 0.732 | 0.835 |

*Correlation is significant at the 0.05 level (2-tailed)
Diagonal values are the square roots of the AVE, and below the diagonal values are the correlations between the construct values.

0.004), government support and adaptive farming practices (β = 0.312, t-value = 2.556; p = 0.011), government support and adaptive non-farming practices (β = 0.295, t-value = 2.532; p = 0.012), and local infrastructure and adaptive farming practices (β = 0.219, t-value = 3.239; p = 0.001) were confirmed; thus H9, H10, H12, H13, H14, and H15, respectively, were supported. However, farmers' attitudes did not significantly influence adaptive farming practices (β = 0.167, t-value = 1.618; p = 0.106). Thus, H11 was not confirmed. Furthermore, local infrastructure did not significantly influence adaptive non-farming practices (β = 0.104, t-value = 1.311; p = 0.191); therefore, H16 was also not confirmed (Table 6). In addition, all R2 values were higher than 0.50, which indicates good models (Hair et al., 2011).

After evaluating the effects of constructs, IPMA was used to prioritize and identify the most important effective factors on adaptive practices to developing resilience against climate change risks. It was found that indicators including (1) delivery of information and training programs from media (GS2), (2) having knowledge and skills to protect the farm against frost (FNS3), (3) allocating inputs with subsidy prices (GS1), and (4) establishment of a local agro-meteo-

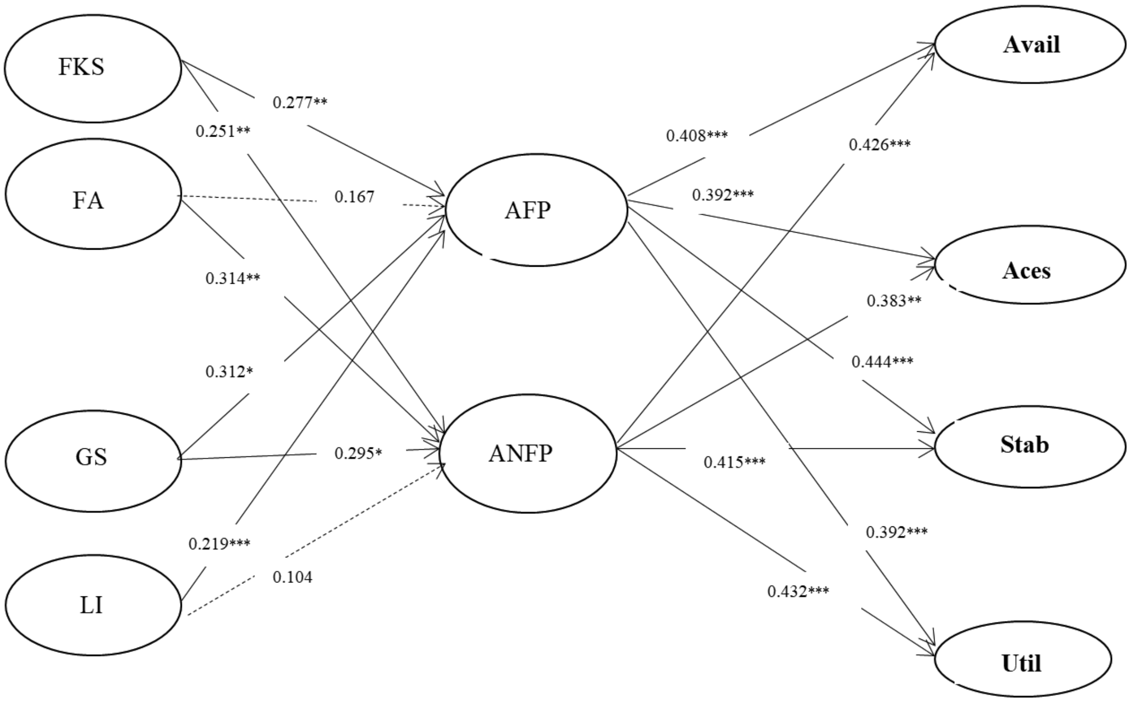


**Fig. 2. Structural model results for research model**

**Table 6. Hypothesis testing, relationships between constructs (direct effect)**

| Hypothesis | | Coef. (β) | SD | t-value | p-value | decision | R2 |
|---|---|---|---|---|---|---|---|
| H1 | AFP → Avail | 0.408 | 0.104 | 3.934 | 0.000 | Supported | 0.602 |
| H5 | ANFP → Avail | 0.426 | 0.103 | 4.143 | 0.000 | Supported | |
| H2 | AFP → Aces | 0.392 | 0.129 | 3.035 | 0.000 | Supported | 0.517 |
| H6 | ANFP → Aces | 0.383 | 0.130 | 2.937 | 0.003 | Supported | |
| H3 | AFP → Stab | 0.444 | 0.101 | 4.381 | 0.000 | Supported | 0.638 |
| H7 | ANFP → Stab | 0.415 | 0.106 | 3.910 | 0.000 | Supported | |
| H4 | AFP → Util | 0.392 | 0.110 | 3.566 | 0.000 | Supported | 0.586 |
| H8 | ANFP → Util | 0.432 | 0.114 | 3.800 | 0.000 | Supported | |
| H9 | FKS→AFP | 0.277 | 0.097 | 2.870 | 0.004 | Supported | 0.758 |
| H10 | FA→AFP | 0.167 | 0.103 | 1.618 | 0.106 | Not-Supported | |
| H11 | GS→AFP | 0.312 | 0.122 | 2.556 | 0.011 | Supported | |
| H12 | LI→AFP | 0.219 | 0.068 | 3.239 | 0.001 | Supported | |
| H13 | FKS→ANFP | 0.251 | 0.089 | 2.813 | 0.005 | Supported | 0.752 |
| H14 | FA→ANFP | 0.314 | 0.107 | 2.922 | 0.004 | Supported | |
| H15 | GS→ANFP | 0.295 | 0.117 | 2.532 | 0.012 | Supported | |
| H16 | LI→ANFP | 0.104 | 0.079 | 1.311 | 0.191 | Not Supported | |

**** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$

rology center (LI2) were the top four, highly important influencing factors to adaptive farming practices that could be implemented by smallholder horticultural farmers to reduce the destructive consequences of climate change. The top four influencing factors to adaptive non-farming practices were (1) increasing farm productivity (FA1), (2) delivery of information and training programs from media (GS2), (3) awareness of the conditions and terms of crop insurance (FNS1), and (4) supporting and equipping farmers' associations and cooperatives (GS4).

In Table 7, the coefficients (β) of all indirect effects of constructs on food security dimensions and their significance are presented. Based on the results of indirect effects, farmers' knowledge and skills through adaptive farming practices as a mediate construct positively and significantly affected food availability (FKS→AFP→Avail: β = 0.113, t-value = 2.129; p = 0.034), food stability (FKS→AFP→Stab: β = 0.123, t-value = 3.333; p = 0.001), and food utilization (FKS→AFP→Util: β = 0.109, t-value = 2.956; p = 0.003), while farmers' knowledge and skills through adaptive farming practices had no significant effect on food access (FKS→AFP→Aces: β = 0.109, t-value = 1.694; p = 0.091). In summary, as shown in Table 7, effective factors on *food availability* through adaptive farming practices as a mediate construct included farmers' knowledge and skills (β = 0.113, p = 0.034), government support (β = 0.128, p = 0.030), local infrastructure (β = 0.090, p = 0.005), while through adaptive non-farming practices, only farmers' attitudes (β = 0.134, p = 0.005) had a significant effect on food availability. The effective factors on *food access*, through adaptive farming practices as a mediate construct included government support (β = 0.123, p = 0.040) and local infrastructure (β = 0.086, p = 0.019), while through adaptive non-farming practices, farmers' knowledge and skills (β = 0.096, p = 0.049) and farmers' attitudes (β = 0.120, p = 0.026) had significant effects on food access. Furthermore, effective factors on *food stability*, through adaptive farming practices as a mediate construct included farmers' knowledge and skills (β = 0.123, p = 0.001) and local infrastructure (β = 0.097, p = 0.011), while through adaptive non-farming practices, farmers' knowledge and skills (β = 0.104, p = 0.021) and farmers' attitudes (β = 0.130, p = 0.004) had significant effects on food stability. Finally, effective factors on *food utilization*, through adaptive farming practices as a mediate construct included farmers' knowledge and skills (β = 0.109, p = 0.003) and local infrastructure (β = 0.086, p = 0.032), while through adaptive non-farming practices, farmers' knowledge and skills (β = 0.108, p = 0.014) and farmers' attitudes (β = 0.135, p = 0.012) had significant effects on food utilization.

***Assessment of GoF index***

The GoF index was generated through the standardized root mean squared residual (SRMR), which was 0.071 and the normed fix index (NFI) 0.810, which means that the model fit the empirical data. The GoF index has a descriptive nature, so there are no inference-based criteria to assess its statistical significance (Vinzi et al., 2010). This index is bounded between 0 and 1, and Wetzel et al. (2009) suggested

**Table 7. Relationships between constructs (indirect effect)**

| Hypothesis | Coef. (β) | SD | t-value | p-value |
|---|---|---|---|---|
| FKS→AFP → Avail | 0.113 | 0.053 | 2.129* | 0.034 |
| FA→AFP → Avail | 0.068 | 0.043 | 1.599 | 0.110 |
| GS→AFP → Avail | 0.128 | 0.059 | 1.173* | 0.030 |
| LI→AFP → Avail | 0.090 | 0.032 | 2.811** | 0.005 |
| FKS→ANFP → Avail | 0.107 | 0.055 | 1.944* | 0.052 |
| FA→ANFP → Avail | 0.134 | 0.048 | 2.791** | 0.005 |
| GS→ANFP → Avail | 0.126 | 0.067 | 1.865 | 0.063 |
| LI→ANFP → Avail | 0.044 | 0.036 | 1.214 | 0.225 |
| FKS→AFP → Aces | 0.109 | 0.064 | 1.694 | 0.091 |
| FA→AFP → Aces | 0.065 | 0.048 | 1.374 | 0.170 |
| GS→AFP → Aces | 0.123 | 0.060 | 2.057* | 0.040 |
| LI→AFP → Aces | 0.086 | 0.036 | 2.356* | 0.019 |
| FKS→ANFP → Aces | 0.096 | 0.049 | 1.976* | 0.049 |
| FA→ANFP → Aces | 0.120 | 0.054 | 2.228* | 0.026 |
| GS→ANFP → Aces | 0.113 | 0.066 | 1.712 | 0.087 |
| LI→ANFP → Aces | 0.040 | 0.035 | 1.137 | 0.256 |
| FKS→AFP → Stab | 0.123 | 0.037 | 3.333*** | 0.001 |
| FA→AFP → Stab | 0.074 | 0.048 | 1.580 | 0.115 |
| GS→AFP → Stab | 0.139 | 0.078 | 1.783 | 0.075 |
| LI→AFP → Stab | 0.097 | 0.038 | 2.537* | 0.011 |
| FKS→ANFP → Stab | 0.104 | 0.045 | 2.319* | 0.021 |
| FA→ANFP → Stab | 0.130 | 0.045 | 2.876** | 0.004 |
| GS→ANFP → Stab | 0.123 | 0.073 | 1.671 | 0.095 |
| LI→ANFP → Stab | 0.043 | 0.034 | 1.268 | 0.205 |
| FKS→AFP → Util | 0.109 | 0.037 | 2.956** | 0.003 |
| FA→AFP → Util | 0.065 | 0.047 | 1.405 | 0.161 |
| GS→AFP → Util | 0.123 | 0.067 | 1.835 | 0.067 |
| LI→AFP → Util | 0.086 | 0.040 | 2.156* | 0.032 |
| FKS→ANFP → Util | 0.108 | 0.044 | 2.453* | 0.014 |
| FA→ANFP → Util | 0.135 | 0.054 | 2.520* | 0.012 |
| GS→ANFP → Util | 0.128 | 0.072 | 1.762 | 0.079 |
| LI→ANFP → Util | 0.045 | 0.038 | 1.169 | 0.243 |

**** p < 0.001 ** p < 0.01 * p < 0.05

GoF small (0.10), GoF medium (0.25), and GoF large (0.36) (Akter et al., 2011). For the research model in this study, a GoF value of 0.587 was obtained, which exceeds the cut-off value of 0.36, indicating that the model has very good prediction power.

## Discussion

The current study examined the factors that influence climate change adaptation practices and their impacts on food security, intended as its four dimensions, using the PLS-SEM approach. The results are presented in three sections. First, the findings of this paper show that 89% of households were anxious and uncertain about their food supply, 76% of households had insufficient food quality, and 71% have experienced an inadequate quantity of food intake and its physical consequences. This finding is in close accordance with those of Shisanya and Mafongoya (2016) and Toulabinejad et al. (2017).

Second, the findings of this paper show that government support (Kumasi et al., 2019; Shi-yan et al., 2018; Alam et al., 2017; Adger et al., 2009), farmers' knowledge and skills (George et al., 2007; Abdul-Razak and Kruse, 2017; Zamasiya et al., 2017; Fischer, 2018; Sousa et al., 2018), and local infrastructure (Alam et al., 2017; Razak and Kruse, 2017; Kumasi et al., 2019; Keshavarz et al., 2013b; Keshavarz and Karami, 2014) are the main predictors of adaptive farming practices, respectively, that are supported by earlier research.

In addition, farmers' attitudes (Fischer, 2018; Shikuku et al., 2017; Wheeler et al., 2013; Kaiser et al. 2010), local infrastructure (Alam et al., 2017; Razak and Kruse, 2017; Kumasi et al., 2019), and farmers' knowledge and skills (Abdul-Razak and Kruse, 2017; Zamasiya et al., 2017; Fischer, 2018) are the main predictors for adaptive non-farming practices to climate change. The top four climate change adaption practices that could be implemented by smallholder horticultural farmers to improve household food security are (1) use of late-flowering and cold tolerant varieties, (2) active participation in extension training courses, (3) use of crop insurance, and (4) covering shrubs and trees in frost with fabric. According to the results, the most important influencing factors to applying these adaptive practices are the delivery of information and training programs from media, having knowledge and skills to protect farms against frost, the allocation of inputs with subsidy prices, the establishment of a local agro-meteorology center, a positive attitude toward adaptive practices, awareness of the conditions and terms of crop insurance, and supporting and equipping farmers' associations and cooperatives. These influencing factors should be considered when farmers, government, and other stakeholders want to achieve short-term and long-term goals toward reducing the risks and destructive consequences of climate change.

Third, the results of the current study confirm that adaptive farming and non-farming practices to climate change are positively related to food security dimensions, including food availability, food access, food stability, and food utilization. This finding is supported by earlier research (Wossen et al., 2017; Campbell et al., 2018). The findings further show that farmers' knowledge and skills and local infrastructure are drivers for food security dimensions, through implicating adaptive farming practices. When farmers intend to employ adaptive non-farming practices, their attitudes toward the advantages of the climate change adaptation process may stimulate them into behavioral readiness toward climate change resilience and improvement of food security.

## Conclusion

Climate change, a global challenge, is already affecting the production of horticultural crops in Qazvin. Such changes are negatively affecting both natural and agricultural ecosystems on the one hand and human social systems on the other, because of the lack of some resources, policies, farming skills, and adequate adaptation practices. This paper contributes to the ongoing debate on how to accelerate the drivers to improve smallholder farmers' adaptation behaviors to climate change and, subsequently, to household food security. The results of this study imply the need to facilitate farmers' knowledge and skills, local infrastructures, and farmers' attitudes as influential factors to develop adaptive farming and non-farming practices in order to achieve food security goals.

Providing on-farm extension services by extension agents, persuading farmers to join rural cooperatives and associations, providing the required farming, or gardening equipment and technologies by public and private institutions, facilitating the terms of crop insurance for farmers, providing sprinklers and garden fog machines to rent for frost protection, and facilitating the appropriate conditions for access to financial resources, as the most important adaptation strategies, may be responsible for reducing climate change risks for smallholder horticultural farmers in Qazvin province. In fact, these strategies could be introduced as food security drivers for smallholder horticultural farmers in Qazvin province. It should be said that food security components, especially food stability, food availability, and food access among smallholder horticultural farmers' households, might be aggravated by the implementation of these adaptation strategies. It seems that success in building stable and enhanced food security could be driven through the incorporation of these strategies in plans, aims, and programs of policymakers, researchers, specialists, farmers, and other stakeholders in the horticultural sector of Qazvin.

It is further suggested that future studies more thoroughly investigate the role of the main climate change adaptation strategies introduced herein that were found to be the most important households food security drivers in Qazvin province.

***Author Contributions***

Saeede Sadat Ebrahimi and Farhad Lashgarara conceived of the presented idea. Saeede Sadat Ebrahimi developed the theory and performed the computations. Seyed Mehdi Mirdamadi and Maryam Omidi Najafabadi verified the analytical methods. Farhad Lashgarara encouraged Saeede Sadat Ebrahimi to investigate and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

Farhad Lashgarara contributed to the interpretation of the results. Saeede Sadat Ebrahimi took the lead in writing the manuscript. All authors provided critical feedback and helped shape the research, analysis and manuscript.

Saeede Sadat Ebrahimi and Farhad Lashgarara designed the model and the computational framework and analysed the data. Saeede Sadat Ebrahimi and Seyed Mehdi Mirdamadi carried out the implementation. Saeede Sadat Ebrahimi performed the calculations. Saeede Sadat Ebrahimi and

Farhad Lashgarara wrote the manuscript with input from all authors. Seyed Mehdi Mirdamadi and Maryam Omidi Najafabadi conceived the study and were in charge of overall direction and planning.

***Conflict of Interest***

The authors, whose names are listed immediately below certify that they have NO affiliations with, or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter, or materials discussed in this manuscript.

## References

**Adger, W. N., Arnell, N. W. & Tompkins, E. L.** (2005). Successful adaptation to climate change across scales. *Global environmental change, 15*(2), 77-86.

**Akter, S., D'Ambra, J. & Ray, P.** (2011). An evaluation of PLS based complex models: the roles of power analysis, predictive relevance and GoF index. Proceedings of the 17th Americas Conference on Information Systems (AMCIS2011) (pp. 1-7). Detroit, USA: Association for Information Systems.

**Alam, G. M. Monirul, K. A. & Shahbaz, M.** (2017). Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh. *Climate Risk Management*, *17*, 52-63.

**Barclay, D. W., Higgins, C. A. & Thompson, R.** (1995). The partial least squares approach to causal modeling: personal computer adoption and use as illustration. *Technology Studies, 2*(2), 285– 309.

**Campbell, B. M., Vermeulen, S. J., Aggarwal, P. K., Corner-Dolloff, C., Girvetz, E., Loboguerrero, A. M., Ramirez-Villegas, J., Rosenstock, T., Sebastian, L., Thornton, P. & Wollenberg, E.** (2016). Reducing risks to food security from climate change. *Global Food Security*, *11*, 34-43.

**Chin, W. W. & Newsted, P. R.** (1999). Structural Equation Modeling analysis with Small Samples Using Partial Least Squares, in R. Hoyle (ed.), Statistical Strategies for Small Sample Research, Thousand Oaks, CA: Sage Publications, 307-341.

**Coates, J., Swindale, A. & Bilinsky, P.** (2007). Household Food Insecurity Access Scale (HFIAS) for measurement of household food access: Indicator guide (version 3). Washington, D.C.: FHI 360/FANTA.

**FAO**. Rome Declaration on World Food Security. Rome: FAO (1996).

**Feola, G., Lerner, A. M., Jain, M., Montefrio, M. J. F. & Nicholas, K. A.** (2015). Researching farmer behavior in climate change adaptation and sustainable agriculture: Lessons learned from five case studies. *Journal of Rural Studies,* 39, 74-84.

**Gregory, P. J., Ingram, J. S. I. & Brklacich, M.** (2005). Climate change and food security. *Philos Trans R Soc London*, 360, 2139–2148.

**Hair, J. F., Black, W. C., Babin, B. J. & Anderson, R. E.** (2010). Multivariate Data Analysis. Seventh Edition. Upper Saddle River, New Jersey: Prentice Hall.

**Henseler, J., Ringle, C. M. & Sinkovics, R. R.** (2009). The use of partial least squares path modeling in international marketing. *Advances in international marketing*, 20, 277–319.

**IPCC** (Intergovernmental Panel on Climate Change). (2007). Climate Change 2007: Impacts, adaptation and vulnerability: Contribution of Working Group II to the fourth assessment report of the Intergovernmental *Panel on Climate Change*, 4: Cambridge University Press.

**Karimi, V., Ezatollah, K. & Marzieh, K.** (2018). Climate change and agriculture: Impacts and adaptive responses in Iran. *Journal of Integrative Agriculture, 17*(1), 1–15.

**Keshavarz, M., Karami, E. & Vanclay, F.** (2013). Social experience of drought in rural Iran. *Land Use Policy*, 30, 120–129.

**NASA** *(2017).* Responding to Climate Change. Earth Science Communications Team at NASAs Jet Propulsion Laboratory, https://climate.nasa.gov/solutions/adaptation-mitigation/.

**Paramu, Sh., Paramu, S. & Paramu, M.** (2016). Adaptation to climate change and the impacts on household food security among rural farmers in uMzinyathi District of Kwazulu-Natal, South Africa. *Food security, 8*(3), 597–608.

**Ringle, C. M., Wende, S. & Becker, J. M.** (2014). SmartPLS 3, SmartPLS GmbH: Boenningstedt.

Ringler, C., Tingju, Zh., Ximing, C., Jawoo, K. & Dingbao, W. (2010). Climate Change Impacts on Food Security in Sub-Saharan Africa Insights from Comprehensive Climate Change Scenarios. IFPRI Discussion Paper 01042.

**Ringler, C., Bryan, E., Biswas, A. & Cline, S.** (2010). Water and food security under global change. In Ringler C. et al. (eds). *Global Change: Impacts on Water and Food Security,* 3-15.

**Rola-Rubzen, M. F., Janes, J. A., Correia, V. P. & Ximenes, T. D.** (2010). Challenges and constraints in production and marketing horticultural products in Timor Leste. *International Society for Horticultural Sciences*, 895, 245-253.

**Shaffril, H. A. M., Steven, E. K. & Samsul, F. S.** (2018). A systematic review on Asian's farmers' adaptation practices towards climate change. *Science of the Total Environment,* 644, 683–695.

**Shisanya, S. & Mafongoy, P.** (2016). Adaptation to climate change and the impacts on household food security among rural farmers in uMzinyathi District of Kwazulu-Natal, South Africa. *Food Security*, *8*(1), 1- 12.

**Toulabinejad, M. & Tabatabaei, S. A.** (2017).Farmers Adapt to Climate Change and its Impact on Food Security of Rural Households Poldokhtar Township. *Journal of Natural Environmental Hazards*, *6*(13), 67-90.

**UNFCCC** (2007). Climate change: impacts, vulnerabilities and adaptation in developing countries. United Nations Framework Convention on Climate Change, the Information Services of the UNFCCC secretariat, 64.

**Vinzi, V. E., Trinchera, L & Amato, S.** (2010). PLS path modeling: From foundations to recent developments and open issues for model assessment and improvement, in Handbook of Partial Least Squares: Concepts, Methods and Application. Esposito Vinzi, V.; Chin, W.W.; Henseler, J.; Wang, H. (Eds.), Springer, Germany, 47-82.

**Wang, W. W.** (2012). *Three Essays on Climate Change Impacts, Adaptation and Mitigation in Agriculture.* Ph.D.Dissertation,-Texas A&M University,Texas.

**Wood, S. A., Jina, A. S., Jain, M., Kristjanson, P. & De Fries, R. S.** (2014). Small holder farmer cropping decisions related to climate variability across multiple regions. *Global Environ. Change*, 25, 163–172.

**Wossen, T., Berger, T., Haile, M. G. & Troost, Ch.** (2017). Impacts of climate variability and food price volatility on household income and food security of farm households in East and West Africa. *Agricultural Systems*, 163, 7-15.

**Zamasiya, B., Nyikahadzoi, K. & Mukamuri, B. B.** (2017). Factors influencing smallholder farmers' behavioural intention towards adaptation to climate change in transitional climatic zones: A case study of Hwedza District in Zimbabwe. *Journal of Environmental Management*, 198, 233-239.

**Ziervogel, G. & Ericksen, P.** (2010). Adapting to climate change to sustain food security. *WIRES Clim. Change*, 1, 525-540.

*Received:* **May, 24, 2020**; *Approved*: **November, 17, 2020;** *Published:* **October, 2023**