J. Agr. Sci. Tech. (2023) Vol. 25(1): 1-17

Climate Change, Food System, and Food Security in Iran

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ABSTRACT

There is a growing concern in countries around the world, including Iran, about the effects of extreme climate change, diversification, and events on food production, food security, and livelihoods. The link between climate change and food security in the Iranian food system is the subject of this article. This review, based on the available literature, used the food system approach to achieve a broader view on issues related to food security in Iran. To this end, this study investigated climatic challenges facing food security in Iran with a focus on two essential products in Iranians' food basket, namely, wheat and rice: Decreased agricultural productivity, food losses along production and distribution chains, postharvest loss, low resilience of poor people in rural areas, and the prevalence of malnutrition among children. The results showed that in addition to measures, such as making food production systems resistant to climate change and the necessary changes in existing food systems to adapt to the consequences of climate change, achieving food security requires a long-term vision to transform the Iranian food system. Accordingly, it is necessary to develop a climate-smart agriculture system that encompasses all aspects of food system security. Except for investigating the productivity of some essential components of this food basket, the results showed that there are scant studies on the effects of climate change on the food system of Iran.

Keywords: Climate change, Crop productions, Climate smart agriculture, Food processing, Postharvest loss.

INTRODUCTION

Concerns are growing in Iran about the consequences of climate change, climate variability, and extreme climate events on food production, food security, and livelihoods. Based on the reanalyzed index of global land-ocean temperature, which was prepared by the National Aeronautics and Space Administration (NASA), analysis of the temperature of both the lands and the oceans shows that the level of warming has gone up to nearly 1.35°C between the years of 1880 and 2018. According to the 138-year information that is available, the warmest years have occurred since 2000. The year 2016 is considered the warmest year in the records of a study done (NASA, 2019). The Sixth Evaluation Report of the Intergovernmental Panel on Climate Change, predictions in the West Asian region suggests that by the middle of the 21st century, the temperature will rise by more than 1.5°C, the frequency of hot days will increase, and precipitation rate will decrease (Hijioka *et al*., 2014). According to the studies done in this field and their anticipations, among the West Asian countries, Iran in the next decades will experience an increase of about 2.6°C in its average temperature and also 35% decrease in its rainfall (Mansouri Daneshvar *et al*., 2019).

The agricultural sector of Iran, with 12.2% of the gross domestic product, is still playing an important role in the economy of the country (The World Bank, 2019). Of the total employed population, 17.37% are

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[DOI: 10.52547/jast.25.1.1]

engaged in the production of basic agricultural products (The World Bank, 2021). Iran produces about 83% of its annual food needs domestically (Soltani *et al*., 2020). About 50% of Iran's existing croplands are located in low-quality lands, representing an unsustainable practice. There is little room for cropland expansion to increase production (Mesgaran *et al*., 2017:1). Therefore, this food system is increasingly exposed to climate change, variability, and extreme climatic events. A study showed that climate change harms the gross domestic product and the welfare of families, particularly rural families, by reducing their income. Agricultural productivity decline negatively affects national food security and increases food insecurity among poor rural and urban populations through rising food prices and marring agricultural livelihoods (Esham *et al*., 2018). Moreover, the adverse effects of climate change will be more severe in the long run. Frequent droughts can harm large areas of the country and cause irreparable damage to the economy, if not addressed properly (Saei, 2018).

Although ensuring food security is of the major goals of the Vision Document and National Development Plans of Iran, food security indicators published by various international organizations, such as the Food and Agriculture Organization (FAO), suggest that Iran's efforts to become a food secure country should be accelerated. Despite a declined number of malnourished people from 5.2% in 2004-2006 to 4.7% in 2017-2019 in Iran, it has failed to achieve the Millennium Development Goal (MDG) of halving this rate. The Global Hunger Index, developed by the International Food Policy Research Institute (IFPRI) by integrating three indicators of malnutrition, child underweight, and child mortality, ranked Iran as 39th out of 107 countries. Although Iran has better conditions than its neighboring countries in West Asia, it is worth noting that with a score of 7.9, Iran has a level of hunger that is low (GHI, 2021).

In the light of the stress imposed by climate change, variability, and extreme weather (hereafter collectively referred to as climate change) on local food systems, this article aims to improve the understanding of the implications of climate change for the food system and food security in Iran. Considering the climate change in Iran, the main question is how to increase the security of Iranian food basket? The link between climate change and food security has been mostly explored in relation to impacts on crop productivity or the food availability aspects of food security with little focus on other key dimensions, namely, food access and food utilization (Gregory *et al*., 2005; Ericksen, 2008; Ingram 2011; Ingram *et al*., 2012; Cai *et al*., 2016). This review will adopt a food system approach to gain a wider perspective on food security issues in Iran. Possible links between climate change and dimensions of food security will be emphasized, and vulnerabilities within the food system that can have implications for food security will be identified. This review will also identify key knowledge gaps in the literature, in particular on less emphasized aspects of food systems and their relationships to food security in Iran.

MATERIALS AND METHODS

Climate in Iran

Temperature and precipitation are two of the most important climatic parameters that influence food production in Iran. Among the West Asia countries, Iran will experience an increase of 2.6 °C in mean temperatures and 35% decline in precipitation in the next decades. Some pieces of evidence show that Iran, like most of the countries in the world, has seen rapid warming over the past few decades. Alizadeh-Choobari *et al*. (2017) have examined the minimum, maximum, and daily near-surface air temperatures of those ground stations. The results indicated that the annual minimum, maximum, and daily near-surface average air temperatures

[DOI: 10.52547/jast.25.1.1]

in most regions of Iran have experienced increasing warming. Temperatures in most regions of Iran have experienced a changing point either in the 1980s or 1990s, and also the average temperature of all regions after the changing point was approximately 1.2 ˚C greater than the average temperature before the changing point. Because of this warming, unfortunately, most of the regions in Iran have experienced decreasing trends in their annual precipitation. On the one hand, considering precipitation, there are some other critical and influential parameters like the quantity and variability of the rainfalls that inevitably influence food production. In Iran, the annual precipitation is decreasing in 67% of the climate stations while the 24-hr maximum precipitation is increasing in 50% of the climate stations. The decreasing amount of annual rainfall is mostly observed in northern and northwestern regions of Iran, while the increasing amount of 24-hr maximum rainfall is mostly seen in arid and semiarid regions of Iran. However, the regional amount of annual precipitation is big, it is not enough for the 24-hour maximum rainfall. As a matter of fact, these decreasing and increasing trends of annual rainfall and 24-hr maximum rainfall began in the 1970s for most of the climate stations. The decreasing amount of rainfall for most of the regions in the country may show the initial stages of climate change that is going to happen in Iran. As expected, the decreasing trend in annual precipitation may eventually lead to a great change in the water supply of Iran, i.e. there will be an increase in the water demand for agriculture and urban drinking water in the arid and semiarid regions of the country. On the other hand, the increasing amount of 24-hour maximum precipitation may cause the soil degradation to become faster and, in the end, it may cause desertification in arid regions of the country (Modarres and Sarhadi, 2009). The decrease in precipitation and the increase in air temperature show that Iran has become drier and more vulnerable to drought over the past few decades.

Recently, rainfall variability and climate changes have become more prevalent in Iran. These great rainfall variabilities eventually lead to frequent floods and droughts. A study was recently done to specify a big increase in rainfall changes in the dry zone in two cultivation seasons. These changes resulted in such moisture conditions during the reproductive stage of crops that influenced both quality and quantity of crop yields (Abeysekera *et al*., 2015). Moreover, extreme changes in precipitation are considered critical elements in how to handle erosion and flood and the method of management strategies to take.

The occurrence of excessive weather changes has increased recently. It could be claimed that, over the last 10-year period from 2013 to 2017, extreme weather conditions that had different impacts on overall crop production increased (rice is considered the main food and constitutes 15% of agricultural production (Maleksaeidi *et al*., 2021). A comparison between 2011-2012 and 2018-2019 shows that agricultural production in Iran was not promising at all and the share of the agricultural sector in the GDP of the country decreased significantly. (Maleksaeidi *et al*., 2021). (Table1)

Climate Change Projections for Iran

Another important project entitled "General Circulation Model" (GCM) was done at the beginning of the twenty-first century and it showed that temperature would go up by 2.84ºC at the end of this century (Cline, 2007). Alizadeh-Choobari in the year 2017 has used national meteorological records of fifteen ground stations across Iran for a 63-year period from 1951 to 2013 and he studied the trends of the minimum, maximum temperatures in these stations and their daily average near-surface air. The Results of his studies showed that the annual minimum and maximum temperatures and daily average near-surface air in most of the stations in

[DOI: 10.52547/jast.25.1.1]

Table 1. Effect of climatic conditions on agricultural products of Iran in 2011-2019.

Year	Average Temperature (˚C)	Rainfall-Altitude (mm)	Weather condition	Impact on agricultural production (%)		Iran GDP share of agriculture (%)
				Changes in horticultural production	Changes in crop production	
2012-2013	18.4	203.9	Favourable	+0.1	+3.1	+ 6.3
2013-2014	17.8	238.6	Favourable in the first half, flood in the second half	+3.9	+7.1	+ 4.7
2014-2015	18.5	217	flood in the first half, Draught in the second half	+8.8	+3.5	+ 3.8
2015-2016	18.8	218.9	First half favourable, drought in the second half	+4	+17.3	+ 4.6
2016-2017	18.3	270.2	Favourable	+7.7	+8.5	+ 4.2
2017-2018	19.0	233.2	Flood in the first half, Drought in the second half	-1.0	+0.1	+ 0.2
2018-2019	18.7	171.1	Draught and floods	-1.2	-2.4	- 0.1

different areas of Iran have experienced increasing trends. So based on what he claims, Iran, like most of the countries in the world, has been warming with a fast pace over the recent decades. It worth to point that Temperatures in most regions of Iran have experienced a point of a critical change either in 1980s or 1990s and the average temperature of these regions after the changing point was approximately 1.2˚C more than the average temperature before the changing point (Alizadeh-Choobari and Najafi, 2017).

As Iran is located in the mid-latitudes, it is influenced by high-pressure weather and blocking patterns in different seasons (Zarrin *et al*., 2010) and can expect that the frequency of these patterns increases because of global warming (Mokhov & Semenov, 2016). Also, irregular periodic variation in winds like the El Niño-Southern Oscillation (ENSO) phenomena can cause intensification of March–April floods in Iran (Saghafian *et al*., 2017), and Blocking patterns cause the change in weather which eventually lead to floods, droughts, unusual temperatures, and other weather extremes. So, the results indicate that by the end of the century, the temperature will increase by about 2-3°C and will experience a 35% decline in precipitation (Cline, 2007; Mansouri Daneshvar *et al*., 2019; Babaeian *et al*., 2015). Also, it is predicted that this climate change will lead to a big water resource shrink in various regions of Iran. Moreover, reduction in precipitation and rising temperature can greatly increase man-made tools to produce water systems for these crops (Table 2).

Food Security, Food System, and the Link to Climate Change

Food security is a high-priority concern on the development agendas of many developing countries. Sustainability in food production and stable food trade are the underpinnings of food security. A number of factors can affect food security including population growth,

[DOI: 10.52547/jast.25.1.1]

Table 2. Consequences of increased drought and flood durations during 2017-2019 for food security and livelihood in Iranian. Source (FAO, 2013; Pakravan-Charvadeh *et al*., 2020).

Consequences	Description
Production	Crop production reduction from +0.1 in 2012-2013 to -1.2 in 2018-2019 Horticultural production reduction from +3.1 in 2012-2013 to -2.4 in 2018-2019
Income	Reduced ratio of agricultural production to GDP in 2012-2013 to -0.1 in 2018-2019 29% reduction of planned income among families working in the agricultural sector The increased poverty rate in Iran from 9.9% in 2016-2017 to 12.9% in 2018-2019
Food Security	Increased rate of food insecurity from 37.6% in 2012-2013 to 42.4% in 2018-2019 Increased rate of malnutrition from 4.8% in 2012-2013 to 4.9% in 2018-2019 Per capita food supply variability (kcal/capita/day) from 34 in 2012-2013 to 29 in 2018-2019

climate change, urbanization and industrialization, land use shifts and water scarcity, income growth and nutritional trends, and trends in global energy supply and food trade (Premanandh, 2011). Among these factors, climate change seems to have a major effect on activities related to the food system and food security of different countries. The food system is a complex web of activities involving production, processing, transport, and consumption. Issues concerning the food system include the governance and economics of food production, its sustainability, the degree to which we waste food, how food production affects the natural environment, and the impact of food on individual and population health.

Food systems are defined as a set of dynamic interactions between and within the bio geophysical and human environments that result in the production, processing, distribution, preparation, and consumption of food.

The food system is conceived as having both determinants and outcomes. The determinants belong to the bio geophysical, social, economic, and political environments that influence the way in which food system activities are carried out, known as food system drivers. Outcomes comprise food security, social welfare, and environmental capital (Ericksen, 2008). According to FAO (1996), food security is achieved ‘‘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.’’ It includes components of availability, access, and utilization. The food system influences all three food security components. Food availability comprises production, distribution, and exchange; food access comprises affordability, allocation, and preference; while food utilization encompasses nutritional value, social value, and food safety (Ingram, 2011) (Gregory *et al*., 2005), (Figure1).

A food system is expected to be efficient in adjusting itself to supply the quantities corresponding to the demand of various food items (Esham *et al*., 2018). Food security is very much dependent on this food system efficiency and, on the one hand, this efficiency could be influenced by different climate changes or other cultural and ecological influences (Gregory *et al*., 2005). Climate change influences all activities of the food system in different ways from production to consumption: From production, markets, and price of food products to other activities and infrastructures of the supply chain to distribution. This study was based on a conceptual framework (Figure 1), derived from the Ericksen food system (2008) for studies on global environmental change.

RESULTS

Consequences of Climate Change for Food System Activities and Food Security in Iran

The consequences that climate change has on the components of food systems and subsequent effects on different aspects of the food system are addressed in this part. This part discusses the components of the food

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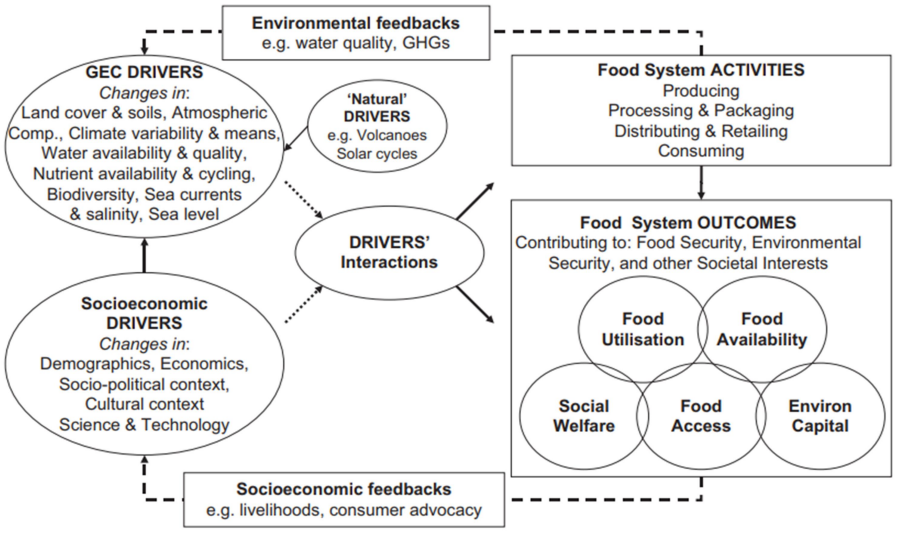

Figure 1. Food system and their drivers (Gregory *et al*., 2005).

system as follows: Food production, Postharvest losses and, Food processing.

Food Production

Food production is an important component of food system activities, which contributes to food security. Agricultural systems are managed ecosystems, which depend largely on climate conditions and subsequently are very sensitive to climate change, which affects agricultural production mainly because of precipitation variability, increasing temperature, and increasing CO_2 concentration (Gitz *et al*., 2016). Iran produces about 83% of its annual food needs (Soltani *et al*., 2020) and 17% through imports. Wheat and rice are two of the most important import items in Iran's food basket. In this section, the climate change impacts on the production of two important crop productions (i.e., wheat and rice), horticultural production, and citrus production will be covered.

Wheat

The Constitution of the Islamic Republic of Iran has obliged the government to adopt strategic policies and provide facilities to achieve objectives concerning self-reliance in wheat production (Hoseini and Torshizi, 2009). Moreover, macro-level documents of Iran, such as the 20-Year National Vision of the Islamic Republic of Iran and the general policies of the resistance economy have repeatedly emphasized self-sufficiency and stability in basic agricultural production, particularly wheat production. Therefore, it seems that in proportion to an increasing rate of population growth and consequent demands for wheat in the country in the coming years, supplying sufficient wheat crops will face more challenges.

However, Iran produces a significant portion of the wheat it needs, as one of the most important elements in the Iranian food basket. A study showed that the self-sufficiency rate in wheat production in Iran was 73 and 81% in 2019 and 2020, respectively (Alipour *et al*., 2019). However, given population growth and also during inhospitable climate periods in the country, it is necessary to import wheat to address the shortage and control rising prices. The highest amount of wheat imports in Iran's history (7,249,000 tons) dates back to 2014-2015 (Table 3).

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Using a Ricardian Model, the results of a study to measure the economic effects of climate change on wheat production in Iran predict that climatic variables, such as rising temperatures and declining precipitation, will cause 41% reduction in wheat crop yields in the next 100 years (Vaseghi and Esmaeili, 2008). A study showed that the area under cultivation of dryland wheat and irrigated wheat in the climates and sub-climates of hot, cold, arid, and semi-arid in Iran will decrease in 2025, because of climate change. Moreover, the irrigated and rainfed wheat yields in the temperate climate and sub-climate for 2025 will decrease compared to the current rate. This study showed that climate change would increase the price of wheat and the income of farmers working in wheat fields in arid climates by 2025. Moreover, climate change would also increase the income of farmers in areas with arid-hot, arid-cold, and semi-arid climates and sub-climates by 2025 (Alibakhshi *et al*., 2020). They concluded that due to climate change, Iran would remain an importer of this strategic product by 2025. The results of the study of Zarakani *et al*. (2014) showed that climate change occurred in the past 30 years and there was a significant relationship between the logarithm of maximum and minimum temperature and annual precipitation with wheat yield. Using the resulting equation for yield and income of wheat and the results from numerical climatic model showing 0.5 degree Celsius increase in the minimum and maximum temperature and decreasing 25 mm of precipitation in the region, from 2010 to 2039, would increase wheat yield (10 kg ha^{-1}) and income (785$.$t^{-1}$) in this region (Zarakani, 2014).

Rice

Rice, as one of the main elements of the food basket in Iran, has an important role not only in food security but also in people's health by providing adequate calories and protein (41.8 and 35.5%) needed by the human body (Stat FAO, 2013). Rice consumption in Iran was 2.63 million tons in 2018 and it comes second after wheat in Iran`s food consumption economy (Feizabadi, 2011). Furthermore, together with growth in production and national gross income of the country, per-capita income and also demand for rice has been increased at national and international level (Chizari *et al*., 2013). (Table 4).

A study showed that climate change in Iran reduced rice yield by 1.182% in the past 20 years (Karimifard *et al*., 2018). In two main production regions in Iran, namely, Ghaemshahr and Nowshahr (Ramazanipour, 2019), another study on rice yield used daily precipitation, minimum temperature, maximum temperature, sunny hours, WG-Lars for simulation of meteorological parameters, and multivariate regression equations to predict rice yield in 1995-2029. Results showed that climate change would decrease rice yield in Ghaemshahr by 1.9% in 2020-2029 compared to 1995-2009. Due to climate change, the rice yield in Nowshahr would decline by 0.7% in the period 2020-2029 compared to the period 2009-2010 (Figure 2).

In general, the consequences of climate change in recent years, including changes in precipitation pattern and increase in maximum temperature and its repetition, have affected the planting and harvest calendar and productivity of agricultural products, which can also affect the wheat

Table 3. The amount of wheat production and import in 2012-2019 (Thousand Tons).

		2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
wheat	Production (T.T.)	8816	9304	10579	11522	14592	12400	13300
	Import (T.T.)	6746	3960	7249	3316	1478	74	0.390

[DOI: 10.52547/jast.25.1.1]

Table 4. The amount of wheat production and import in 2012-2019 (Thousand Tons).

		2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
Rice	Production (T.T.)	4140	4336	4354	4430	4901	5366	4986
	Import (T.T)	1289	1956	1186	745	839	1550	1065

and rice yields. To meet the increase in demands caused by population growth and to achieve self-sufficiency, Iran needs to increase its production, which requires considerable increase in the use of such resources as water and other agricultural inputs, including different chemical fertilizers that, in turn, will have consequences for the environment and national economy of the country.

Postharvest Loss

Ensuring food security requires guaranteeing adequate food availability, accessibility, and utilization along with the sustainability of the food system. Accessibility to food and stability of the food system can be improved by reducing food loss and wastes. Post-harvest loss in the food production chain will have consequences for food security concerning losses in available food for consumption. Moreover, it will reduce the income of smallholder farmers and thus their ability to purchase food. Based on the statistical evidence from Iran, a study showed that an average of 35 percent agricultural crops from product to consumption process is wasted (Rajabi, 2020). The wastes have the potential to feed 15-20 million people in a year. These agricultural wastes occur in the cultivation, pre-harvesting, harvesting, and post-harvesting stages, with the majority of them in the last 2 stages (Asadi *et al*., 2010). The results of the study of Rajabi *et al*. (2020) showed that "management practices and resource and equipment" had a significant effect on the crops' losses.

Post-harvest losses occur in all stages of the supply chain from initial production to consumption. Infrastructural weakness and poor post-harvest marketing in Iran, which is common in many developing countries, contribute to significant post-harvest losses in all sub-branches of agricultural production. For example, it is estimated that each year in Iran, the rice wastes consist of one-third of the whole production of rice, while this is the amount of food that can feed 18 million people. Also, the annual rice wastes indicate an economic loss of 1,403 million U.S. dollars, and waste of water (Ardakani and D'Amico, 2020). Although the considerable post-harvest loss in rice production can be attributed to poor transportation and storage, and badly organized marketing channels, the role of climate change is very important in the loss of agricultural products. Unpredictable precipitation and torrential rain patterns have

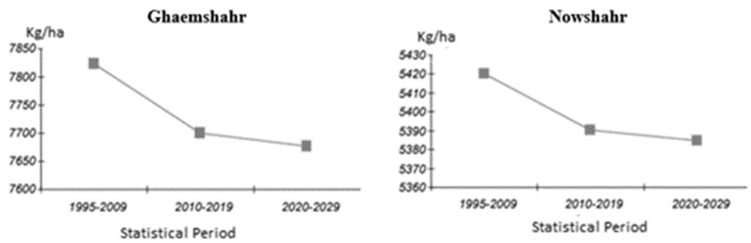

Figure 2. Rice yield in Ghaemshahr and Nowshahr in 1995-2029 (Ramazanipour, 2019).

[DOI: 10.52547/jast.25.1.1]

an important effect on early pre-harvest and post-harvest transportation, threshing, and drying because dry conditions are required for these operations. At the time of harvest, rain can affect grain quality in terms of humidity, which is an important factor in determining the quality of the final product. Although farmers prefer to store unprocessed rice to benefit from higher prices, poor storage management and lack of storage technology can cause the loss of more crops through rodents, insects, and microbial degradation. On the one hand, an increase in temperatures and extreme climate events will exacerbate crop losses, unless storage facilities are improved to withstand the effects of climate change. As a result, degradation of grain quality in storage, shelf life, and processing quality can be reduced by increasing fungal growth and mycotoxin production (Chakraborty and Newton, 2011). Moreover, rising temperatures will accelerate the post-harvest loss of perishable crops. Therefore, it is expected to reduce the shelf life of agricultural products. Generally, the shelf life of agricultural products almost doubles or even triples for every 10°C decreases in temperature (Moretti *et al*., 2010).

Food Processing

The food industry is considered the biggest non-oil industry in Iran, and is the biggest job provider among the industries and provides 16.8% of the total industrial jobs (Helpdesk, 2020). Sustainable food production is a critical matter for a nation survival and security, and to increase its productivity and efficiency, new technologies and modernization of food utilities and more investment in the food systems are needed. As the studies suggest, currently, there exist 11,200 active production units in the food and processing industries in Iran (Helpdesk, 2020). The food processing industry includes the processing of agricultural products. Most food processors in many developing countries use such traditional channels as local markets and contract suppliers to supply basic agricultural materials (Reardon *et al*., 2009). The processors of agricultural products procure required products from smallholder farmers. These smallholder farmers supply agricultural products to the food processing industries through contract suppliers or cash markets (retail/wholesale markets) under contract farming agreements. Nevertheless, these traditional channels are not considered reliable and adaptive food sources because they are largely vulnerable to climatic change. In other words, at the extreme weather conditions and temperature rise, the food processing industry faces serious challenges to ensure a continuous supply of basic agricultural materials. In fact, climate change is a serious threat to the survival of the food processing industry in the long term, which, in turn, will affect the food security and economy of the country (Reardon *et al*., 2009).

Climate Change, Vulnerable Households and Food Security

The income of families and food prices will determine food affordability for any household to meet nutritional requirements. Here, some of the effects of climate change on the outcome of food prices and the level of their affordability for vulnerable households in Iran are discussed. As a country with a diverse livelihood, 25 percent of Iran's population were rural in 2018 (FAOSTAT, 2020). Rural livelihoods depend highly on agriculture and related industries and are strongly influenced by climatic characteristics and climate change. Iran is highly affected by climate change because it is located in the drought belt, which has prolonged and intensified the drought period. According to study in Iran (Sadeghloo and Sojasi Qeidari, 2014), the rural areas have been most affected by climate change and the consequences of regular precipitation decline and rising temperatures. Moreover, rural areas in arid

[DOI: 10.52547/jast.25.1.1]

and very arid regions of Iran have suffered the most from the consequences of climate change. Fourty-eight percent of income spent on food and other necessities of life in Iran is more than in developing countries such as Pakistan and South Africa, and less than in developed countries (Behzadifar *et al*. 2016). The sensitivity of Iranian households' access to food and their nutritional status to income and price fluctuations should be considered. Although the real income of households in Iran from 20 March 2012 to 20 March 2013 increased from 597 $ to 1255 $, the prevalence of malnutrition and undernourishment was reported from 21 March 2017 to 20 March 2018 as 4.8% by the World Bank (2021) for 20 March 2012 to 20 March 2013 and remained the same on 21 March 2017 to 20 March 2018. Accordingly, Behzadifar *et al*. (2016) showed the overall prevalence of 49% food insecurity among Iranian households (n= 21,856) (Figure3).

A study on food security of rural households in Iran (Ghadiri Masoum *et al*., 2016) showed that 31.73, 43.1, 15.52, and 9.65% of the households had food security, food insecurity without hunger, food insecurity with moderate hunger, and food insecurity, respectively. Salem and Mojaverian (2017) showed that the urban population harmed the food security index and the overall growth of the food security index decreased every year. The results showed that a reduced-calorie distribution coefficient among the poor slows down the growth of the food security index. As a result, improvement of the calorie distribution index is essential for socio-economic development (Salem and Mojaverian, 2017). Literature review showed that although food security is an important issue in both rural and urban areas of the country, calorie intake of families depends on the food price, and urban citizens are the major customers of food products (i.e. food consumption exceeds its production), and the urban areas are more vulnerable than rural areas to rising food price. Hijioka *et al*. (2014) confirmed the relationship between rising food prices and its negative effects on vulnerable sectors in urban areas in South Asia.

A common strategy adopted by urban and rural households to deal with climate change shocks, such as drought, or other economic shocks, such as rising food prices, is to omit one or more meals per day, reduce food intake, or both (IASC, 2009). Evidence from past financial and economic crises showed that reduced food consumption among the deprived sector of society, caused by high food prices, led to their food limitations (Sanogo and Luma, 2010). Although there is no comprehensive study on the relationship between rising food prices and growing population with food insecurity in Iran, Ashktorab, and Nematollahi (2019) showed

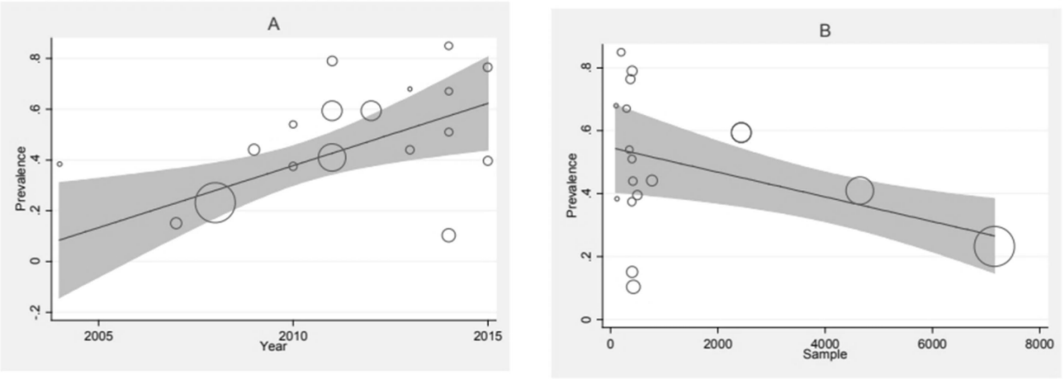

Figure 3. Food insecurity in Iranian households (Behzadifar *et al*., 2016).

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that the number of poor urban families or families below the poverty line increased by 1.98% by increasing food price by 15%. The number of urban households living below the poverty line increased 3.5 and 6.93% by a 25 and 50% increase in food price, respectively (Ashktorab and Nematollahi, 2019). Ghorbanian and Bakhshoodeh (2016) investigated the relationship between increased food price in 2011-2013 and reduced-calorie and protein intake in Iran and found that it had a major role in reduced household calorie and protein intake over that period. The rising bread prices had the greatest effect on food security in all three food groups while chicken and dairy products had the highest impacts on the protein group (Ghorbanian and Bakhshoodeh, 2016).

Despite the lack of exact statistics on the increased food insecurity caused by the recent economic crisis in Iran, it seems that a high increase in food price, such as bread and rice, as the essential products in Iranians' food basket, can increase wheat and rice prices, which worsen household calorie intake, since Iranian households are reluctant to substitute other foods for bread and rice (Abdi *et al*., 2016). Similar to many countries in South and West Asia, it is predicted that the wheat and rice price in Iran will increase by 2040 because of the effects of climate change on food systems (Cai *et al*., 2016). Given that these two important agricultural products supply a major part of the calorie intake of Iranians, this problem can have dangerous consequences for their food insecurity. Despite the better protein intake status of Iran than some of its neighbors in Southwest Asia, a study shows that the rising food prices have reduced consumption of this important item of food security, exposing almost 30% of Iranian households to an insecure level of protein intake. This reflects poor dietary diversity in Iran, which is regarded as an important cause of food insecurity (Tanhaei Zare *et al*., 2015).

DISCUSSION

Achieving food security in Iran requires taking immediate measures with efforts beyond the existing efforts to create and expand sustainable food production systems that are resistant to climate change. To this end, a comprehensive approach to food security should be developed to ensure the flexibility of the entire food system to climate change. Moreover, nutritional concerns from climate change should be addressed. Therefore, the establishment of a Climate-Smart Agriculture system (CSA) addressing all dimensions of food security concerns is essential in Iran. Such an approach should comply with the priority measures on food security set in documents, laws, and national programs, including the National Nutrition and Food Security Document.

In this regard, recent CSA approaches have many opportunities to improve food systems under the new climate change conditions. CSA explains that sustainable food production increases its productivity and also reduces greenhouse gas emissions and enhances the number of national foods of a country (FAO, 2010). The authors believe that CSA is an approach that brings together agricultural practices, policies, institutions, and financing with regards to possible climate changes and needs and considers these needs in national planning processes that implement climate change action plans properly.

Climate-smart agriculture is not a completely new concept in Iran because some of its methods are currently used by farmers at different scales (Ardakani *et al*., 2019). However, CSAs should be applied much more broadly in various areas related to food systems from planting and production to distribution and consumption. This approach should be used in Iran to achieve better nutrition management. By adopting and extending CSA-related policies in a broad range of activities related to Iran's food system, and intertwined chain of food

[DOI: 10.52547/jast.25.1.1]

security activities should be pursued at the local, transnational, and national scales. CSA-compliant strategies and programs are also needed to be extended beyond production to other food system-related activities, including transportation, processing, storage, distribution, and pricing. Such efforts, along with the need for providing food system stakeholders with better access to financial resources, technology, and investment in supply chain infrastructure, require the establishment of an intelligent and integrated management system focused on food security in Iran.

In addition to CSA methods, creating a secure food system in the country and paying attention to adaptation to climate change consequences require a long-term perspective with the aim of transforming Iran's food system. This is because the current measures taken to withstand the predicted increase in temperature and undesired climate may not be adequate. For example, it is expected that the temperature increase exceed the tolerance level of cereal crops, such as wheat and rice, which may force farmers to grow crops in protected spaces and greenhouses and require the development of new planting and production methods (Paymard *et al*., 2018). They proposed that changing planting dates and densities could be beneficial for adaptation of wheat to climate change. In addition to the climate change consequences, such as the global economic crisis in 2008 that led to higher food prices (Cribb, 2010), the recent economic crisis caused by the return of economic sanctions, led to an increase in food prices and, consequently, an increase in the price of agricultural inputs in Iran through declining revenues, devaluation of the national currency, and rising inflation and unemployment (Kokabisaghi, 2018). Such conditions can push smallholder farmers to the brink of poverty and exacerbate food shortages unless the required measures are taken to emphasize the sustainable use of resources as a prerequisite of a climate-friendly approach. This goal can be facilitated by ensuring national self-sufficiency in the production of agricultural products and related inputs.

In spite of meeting the poverty-related Millennium Development Goal (MDG) targets and indicators, a percentage of the Iranian population still remains below the poverty line and would need to receive government benefits (UNDP, 2021). Concerning these rural and urban households, child malnutrition raises questions about their ability to obtain high-quality foods. Long-term interventions should focus on increasing household income by providing opportunities, especially for smallholder farmers, to increase agricultural production using CSA methods. In addition, non-agricultural job opportunities must be expanded so that the poor rural population can diversify their sources of income and improve their livelihoods. The effectiveness of food security training and control programs should be strengthened to help these vulnerable groups, especially in rural areas. The subsidy program, which provides a monthly allowance for low-income households, has not achieved its goals because of failure in setting goals and identification of target population, inefficiencies, and political interference. In this regard, the subsidy program can be improved by setting better goals and reinforcing interventions to help eliminate poverty by participating in income-generating programs and developing family members' skills to address macro-vulnerabilities.

Malnutrition of children with potential long-term consequences for adult health, along with labor productivity is another issue that requires policymakers to intervene. This is because it would jeopardize human capital at a national level. In this regard, a set of cost-effective interventions to overcome child malnutrition and maternal nutritional distress, prescribed by Horton *et al*. (2010), can be very useful. These interventions improve nutritional measures, such as breastfeeding, complementary feeding for infants over 6

[DOI: 10.52547/jast.25.1.1]

months, improved health-related measures, provision of foods enriched with low-consumption elements, and nutrition therapy with special foods for malnourished children.

CONCLUSIONS

The decrease in precipitation and the increase in air temperature show that Iran has become drier and more vulnerable to drought over the past few decades. Food security in Iran has been the focus of policymakers and authorities at the national policy level over the past four decades; nevertheless, serious challenges are facing Iran in achieving sustainable food security. Climate change and its consequences, including rising temperature, increased drought intensity, changes in regular precipitation pattern, and increased number of severe events can affect food security. However, this study focused on several climate change challenges facing food security, including declined agricultural production, reduced agricultural productivity, food losses from the production to distribution chains, and poor livelihood resilience of rural and low-income urban families. Although previous studies have examined the relationship between climate change and food security in Iran, this paper sought to examine the impact of climate change on food security in Iran by focusing on the food system in Iran. Contrary to its importance, the contribution of the food system in the effects of climate change on food security in Iran was scantily mentioned in the previous studies. The main emphasis of the article is that, without the transformation of the food system, the food security goals are unattainable. Food is provisioned through a food system that has different sectors. The food system includes all activities related to producing, transporting, trading, storing, processing, packaging, wholesaling, retailing, consuming, and disposing of food. In this article, the consequences of climate change on the components of food systems and subsequent effects on different aspects of the food system were addressed in sections on food production, post-harvest losses, food processing, and drivers of food system activities, such as household income and food prices.

The focus of this article was related to changes in the agricultural sector, which opens a potential window to transform food systems. As food is uniquely connected to many social and environmental challenges besides climate change, this transformation can create synergies that combat climate change and advance many Sustainable Development Goals at the same time. In fact, food production systems need to adapt to climate change to help minimize the economic impacts on the agri-food sectors and consumers, and all this must be accomplished without threatening food security. The results showed that, in addition to measures such as making food production systems resistant to climate change and the necessary changes in existing food systems to adapt to the consequences of climate change, achieving food security requires a long-term vision to transform the Iranian food system. To this end, a comprehensive approach to Iran's food security based on the establishment of a climate-smart agriculture system and transformation in the Iranian food system should be developed to ensure the flexibility of the entire food system to climate change. To understand the impact of climate change on other food system activities and its effects on food security in Iran, further studies are needed on other important foods, including fruits and vegetables. Due to the lack of published studies, this study could not include the other two major food production systems in Iran, namely, livestock and fisheries. Further studies are needed based on the role of livestock and fisheries systems in food security in Iran under climate change.

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تغییر اقلیم، سیستم غذایی و امنیت غذایی در ایران

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چکیده

نگرانی ها در کشورهای جهان از جمله ایران در مورد پیامدهای تغییرات، تنوع و رویدادهای مفرط اقلیمی بر تولید مواد غذایی، امنیت غذایی و معیشت مردم درحال افزایش است. ارتباط بین تغییرات اقلیمی و امنیت غذایی در سیستم غذایی ایرانیان موضوع این مقاله است. سوال اصلی این است که با توجه به تغییرات اقلیمی در ایران چگونه می توان امنیت سبد غذایی ایرانیان را افزایش داد؟ در این بررسی که بر اساس پیشینه‌ی پژوهش‌های موجود صورت گرفته است، از رویکرد سیستم غذایی برای دستیابی به دیدگاه وسیع‌تر در مورد مسائل امنیت غذایی در ایران استفاده شده است. در این مقاله مروری چندین مسئله‌ی اقلیمی چالش‌انگیز برای امنیت غذایی ایران با تمرکز بر دو محصول اصلی در سبد غذایی ایرانیان -گندم و برنج- بررسی می‌شود: کاهش بهره‌وری کشاورزی، تلفات مواد غذایی در طول زنجیره‌های تولید و توزیع، مقاومت پایین معیشت فقرای روستایی و شیوع سوءتغذیه و بدخوراکی در میان کودکان. بررسی ها نشان می‌دهد که رسیدن به امنیت غذایی علاوه بر اقداماتی نظیر ایجاد سیستم های تولید غذای مقاوم در برابر تغییرات اقلیمی و تغییرات لازم در سیستم های غذایی موجود در جهت ایجاد سازگاری با پیامدهای ناشی از تغییرات اقلیمی، نیازمند اتخاذ چشم‌انداز طولانی‌مدت با هدف ایجاد تحول در سیستم غذایی ایران است؛ براین اساس، دستیابی به «کشاورزي هوشمند به اقلیم» که تمام ابعاد امنیت سیستم غذایی را موردتوجه قرار دهد ضرورت دارد. قابل ذکر است برای درک بهتر و روشن تر شدن بیشتر اثرات پیامدهای تغییرات اقلیمی بر اجزای مختلف سیستم غذایی باید طیف گسترده تری از محصولات کشاورزی و زراعی و همچنین تولیدات دامی و شیلات مورد بررسی قرار گیرد تا نتایج تحقیقات در مورد علل ناامنی غذایی ناشی از تغییرات اقلیمی، روشن تر شود.

[DOI: 10.52547/jast.25.1.1]