The impact of climatic changes on total horticultural production and food security in agro-ecological zones of Iran

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ABSTRACT

Arid and semi-arid climates, including that of Iran, are more susceptible to environmental changes due to their special ecological structure than other climates. Therefore, climate change in these areas appears to have significant effects on agricultural and food production systems. The present study explores the effect of climatic changes on total horticultural production and food security in agro-ecological zones of Iran. The study was conducted in two steps. In the first step, the effects of climatic parameters on total horticultural production were investigated using time series data (1985–2017) and a regression model. In the second step, due to the important role of horticultural products in per capita food consumption in Iran, the effect of climate parameters on food security was also examined. Results revealed that total horticultural production was influenced by temperature, evapotranspiration, and wind speed at the 0.05 level. With the increase in temperature (at a rate of one unit), total horticultural production is reduced to 0.01 million tons. Evapotranspiration and wind speed have had a negative effect on total horticultural production, and with increasing evapotranspiration and wind speed, total horticultural production was 0.029 and 0.008 million, respectively, tons decreased. Also, food security was influenced by temperature, precipitation, and wind speed.

Key words | climatic parameters, food security, panel data, total horticultural production

INTRODUCTION

Climate change is posed as the greatest threat to agriculture and food security in the 21st century, and this is more so in the poor and agricultural-dependent countries that have little capacity to cope effectively with the crisis (Wang 2010). Considering the widespread and mutual effects of climate with different production sectors, environmental factors, and human societies, today, climate change is considered as one of the most important environmental challenges that has serious economic consequences (Redsma et al. 2009).

Iran is located in the western part of Asia that is grouped in the arid and semi-arid zone by the Intergovernmental Panel on Climate Change. The evidence from historical meteorological data and forecasts of this region’s climate shows that, like other parts of the world, the phenomenon of climate change has commenced in this region in recent decades and will continue in the future (IPCC 2007). IPCC projects that Iran’s mean temperature will rise by 2 °C in the next 30 years and by 3.5–4 °C by the next 100 years, in which case, precipitation will decline drastically. Temperature rise will lead to a remarkable increase in annual evapotranspiration (which has already exceeded annual precipitation in some parts of Iran). The IPCC perceives this problem as a serious challenge for arid and low-rainfall regions like Iran and predicts that, as a consequence of this phenomenon, the production of strategic
grains in Iran will be 30% lower than their present production level in the coming 30 years (Hoseini et al. 2013).

Currently, Iran has over 2.6 million ha of orchards with an annual production of more than 17 million tons of orchard crops. The eminent features of this sub-sector include relative competitive advantage in exports and foreign exchange earnings, job creation, and high economic return of water use. The main threats in the horticultural sub-sector are the constraints on water resources, the drop of underground water levels occurring due to climate change, and the decline of atmospheric precipitation, entailing drought and soil salinity in a large part of the country (Ministry of Agriculture 2016).

Another major aspect of the issue of climate change is its impact on food security (Chang 2002). Events like floods and droughts, which are caused by climate change, lead to the loss of crops, the deterioration of agricultural lands, and threaten food security. Unpredictable global climate changes may bring about a reduced level of crop production and rising food prices (Wiebelt et al. 2013).

Food security is gaining increasing importance for humans and other beings all over the world. Food availability and quality are still among the key challenges for scientists due to climate change (Kang et al. 2009). Global warming has adverse consequences for crop production and trade in developing countries where it will aggravate the risk of hunger. Currently, the number of individuals suffering from chronic hunger has increased from 800 million in 1996 to over one billion. According to the UN’s population statistics, the world’s population will reach 9.2 billion by 2050. A considerable part of this population is projected to be in countries that are already struggling with nourishment problems. Early estimates show 15–30% decline of agricultural productivity due to climate change in most developing countries, for example, in Africa and South Asia, by 2080 (Wolf 2002). The impacts of global warming can be currently observed across the world. The agricultural sector is especially vulnerable to climate change. The rise in average seasonal temperature can shorten the growth period of most crops, causing losses in yields. Climate change, such as the change in temperature, precipitation, and pest and disease outbreaks, adversely influences food production systems, decreases harvest, and jeopardizes food security (Shaemi Barzaki & Habibi Nokhandan 2009).

Our research topic has been the subject of extensive studies, some of which are reviewed below. Fares et al. (2017) examined the potential climate change impacts on citrus water requirement across major producing areas in the world. According to research results, the amount of water needed for citrus growing in the world will decrease in the coming years. Increasing carbon dioxide concentration and precipitation also have a negative effect on the amount of water needed for citrus growth worldwide. Cabbage & McCarthy (2016) focused on the effect of climate change on production time and the quality of grapes in Western Europe. The results showed that climate change had a negative impact on the production and quality of this crop. Tanasijevic et al. (2014) investigated the influence of climate change on olive crop in the Mediterranean region. They reported that as temperature rise and rainfall decline interact, soil water availability might decrease in the root zone and it will be very likely for rain-fed olive orchards to suffer from water stress in future. Thus, we may witness the eradication of rain-fed olive trees in the coming years. Hamid et al. (2014) evaluated the impacts of climate change impacts in a semi-arid watershed in Iran using regional climate models. According to the results of the study, due to the increase in average temperature and reduced precipitation in various emission scenarios, water resources performance will decrease.

In a study on the effect of climate change on fruits and vegetables, Moretti et al. (2010) showed that climate change would, directly and indirectly, influence the production and quality of fruits and vegetables that grow in different climates of the world. Focused on the effect of climate change on horticulture and technology interventions in Japan, Morinaga (2011) concluded that climate change had reduced the yield of some horticultural crops in this country. Wang (2010) studied the relationship between food security, food prices, and climate change in China. The results of the application of a panel data model indicated that climate change influenced food security considerably, but food prices had no impact on food security in China.

Koocheki et al. (2015) examined the impact of climate change on Iranian agriculture. The results showed that the average annual temperature in different regions of the country increased between 3.5 and 4.5°C by the target year, while the mean annual precipitation would
decrease by 7–14%. These changes are sharpening from west to east and from north to south. The results showed that climate change had negative effects on all agricultural indices. The results showed that the most negative effects occurred in the south, east, and center, respectively.

Hoseini et al. (2015) examined the impact of climate change on Iran’s agricultural sector, emphasizing the role of implementing adaptation strategies in this sector. The results show that by the middle of this century climate change will lead to a decrease in precipitation and an increase in the temperature parameters, which will be a direct consequence of the decrease in water resources. The results of the economic model showed that, at worst (not applying matching strategies), the consequence of these changes for the agricultural sector would be a decrease of about 18 and 32% in gross profit for the next 50 and 60 years, respectively. Vaseghi & Esmaeili (2008) examined the economic impact of climate change on Iran’s agricultural sector. Time series data for the period 1983–2004 were used in 17 provinces. The results showed that climate variables have a significant and nonlinear effect on the net income of the country. The results also showed that increasing temperatures and reducing rainfall for the next 100 years would result in a 41% reduction in the yield of strategic crops such as wheat.

As predicted for Iran, it is expected that the occurrence of climate change – which is characterized by the decline of rainfall, the rise in temperature, and the increase in the occurrence of extreme weather conditions – have harmful consequences for agricultural production and the supply of food requirements. Accordingly, it is imperative to develop practical strategies to reduce or remove obstacles against the establishment of agricultural production and food security. The present study aims to explore the effect of climatic changes on total horticultural production and food security in ten-fold agro-ecological zones of Iran and to propose approaches to counteract its negative impacts.

MATERIALS AND METHODS

Explanation of the regression model

The choice of the type of statistical method for analysis depends on the type of data measurement and the objectives of the research work to be done. One of these methods is the analysis of time series and cross-sectional combination data, which is used as an effective way in applied analyses of the field of economic and social sciences. In general, economic statistics are divided into three types, cross-sectional, time series, and combination (panel). Meanwhile, the use of combined data in econometrics has many advantages over the use of cross-sectional and time series data. Because not considering some variables in the model structure leads to inefficiencies in estimating econometric models, the combined data methods (consisting of time series data and cross-sectional data), the effect of the not considered variables, controls better than cross-sectional data or time series data (Karami & Mardani 2015).

The set of panel data includes all observations that are made for multiple sections and are collected over time. These data are used when time series or cross-sectional data cannot be applied alone. Panel data contain more information, wider diversity, and less collinearity among variables, so they are more efficient (Baltagi 2008). To analyze panel data, we first assume a certain section (e.g., country, region, province, etc.) and then, the characteristics of the variables are examined for all N sections in the desired period T. The equality of data number between the sections is not necessary (unbalanced panel data model). Also, one may have variables that are constant in a certain section for the studied time period (Abrishami 2004).

The scope of the research

The scope of the research is composed of ten agro-ecological zones of Iran as defined by FAO in terms of climatic similarities (precipitation and temperature), soil type, crop type, and geographical associations. They are described and presented in Table S1 (supplementary material) and Figure 1.

Research steps

The present study was conducted in two steps. In the first step, the effects of climatic parameters (precipitation, temperature, evapotranspiration, relative humidity, wind speed) on total
horticultural production were investigated using time series data (1985–2017) and a regression model (panel data).

The experimental model of the first step

Equation (1) describes the analytical model used to study the impact of climate change on total horticultural production:

$$Y_{it} = \beta_1 + \alpha_0 + \alpha_1 T + W_1 MT_{it} + W_2 P_{it} + W_3 H_{it} + W_4 W_t + W_5 E_{it}$$

(1)

in which $t$ represents the observations for a certain time period, $Y$ shows total horticultural production in region $i$ in year $t$. $MT$, $P$, $H$, $W$, and $E$ represent the means of the variables temperature, precipitation, relative humidity, wind speed, and evapotranspiration in the region $i$ over the year $t$, respectively. $T$ represents the trend variable, and $\alpha_0$, $\alpha_1$, $\beta_1$, $W_1$, $W_2$, $W_3$, $W_4$, and $W_5$ are the estimator parameters of the model.

The experimental model of the second step

In the second step, due to the important role of horticultural products in per capita food consumption (indicator for measuring food security) in Iran, the effect of climate parameters on food security was also examined.

The overall form of the panel data model to explore the relationship of climate change with food security is defined as Equation (2):

$$Y_{it} = \beta_1 + \alpha_0 + \alpha_1 T + W_1 MT_{it} + W_2 P_{it} + W_3 H_{it} + W_4 W_t + W_5 E_{it}$$

(2)

in which $t$ shows the observations for a certain time period, $Y$ shows per capita food consumption in region $i$ in year $t$. Again, $MT$, $P$, $H$, $W$, and $E$ represent the means of the variables temperature, precipitation, relative humidity, wind speed, and evapotranspiration in the region $i$ over the year $t$, respectively. $T$ represents the trend variable, and $\alpha_0$, $\alpha_1$, $\beta_1$, $W_1$, $W_2$, $W_3$, $W_4$, and $W_5$ are the estimator parameters of the model.
\( \beta_1, W_1, W_2, W_3, W_4, \) and \( W_5 \) are the estimator parameters of the model.

**Stationarity tests in panel data**

Most econometric models used in the early decades were based on the assumption of the reliability of time series. After the most unstable issue of most time series was revealed, the use of variables was dependent on carrying out Stationarity tests. Unit root tests of the panel data were established by Quah (1994) and Breitung (1994). These studies were completed by Levin & Lin (1992) and Im et al. (1997). Among these tests, we can mention Levine and Lin (LL), IPS, Fisher and Dickey-Fuller tests (CADF) tests (Abrishami 2004).

**Recognize panel or pooled model**

In panel data models, the variables are consecutively measured both between sections of statistical population and over time. Prior to estimation of these models, it is necessary to recognize if the panel or pooled model is suitable for statistical estimation and inferences. To do this, we first estimate the model by integrating data into a pool and the residual sum of squares is then calculated. In the next step, the model is estimated as panel with different y-intercepts for each section, and again the residual sum of squares is calculated. Finally, \( F \)-statistic is used as Equation (3) to test the model:

\[
F = \frac{(SSR_{pool} - SSR_{panel})/q}{SSR_{panel}/(N - K)}
\]

in which \( F \) denotes the test statistic, \( SSR_{pool} \) represents the residual sum of squares in the pool model, \( SSR_{panel} \) represents the residual sum of squares in the panel model, \( q \) shows the number of constraints, \( N \) denotes the number of data, and \( K \) shows the degree of freedom. If the test statistic is greater than critical \( F \) value in the table test significance level (which is 5% here), then the panel model will be more suitable. Otherwise, we should use the pool model.

To test the panel data, we can use fixed effects or random effects. In the random effects model, we have \( E(U_{it}/X_{it}) = 0; \) that is, \( \mu_i \)'s are independent from \( X_{it} \). But this assumption does not hold true in a fixed effects model because \( \mu_i \) is correlated with \( X_{it} \). A way to test is the model proposed by Hausman (1978), which is based on the difference between fixed effects and random effects estimators. The null hypothesis of this model follows Equation (4) (Baltagi 2008).

\[
E\left(\frac{U_{it}}{X_{it}}\right) = 0
\]

(4)

If the model is not of the type of random effects, then Equation (5) holds true.

\[
E\left(\frac{U_{it}}{X_{it}}\right) \neq 0
\]

(5)

**Research data**

The data required for this study consist of two groups of climatic and economic data. Data on climatic variables including mean temperature, mean precipitation, mean relative humidity, mean wind speed, and mean evapotranspiration were required annually for a period of 33 years (years 1985–2017) and were obtained from the Iranian Meteorological Organization. The amount of agricultural production in the subdivision required the existence of data on the time series of product performance, which was used from data available at the Ministry of Jihad-e-Agriculture of Iran. The econometric functions applied in the panel data model were estimated by the Eviews software package.

**RESULTS AND DISCUSSION**

Table 1 presents the amount of horticultural production in the ten agro-ecological zones in 2017. Iran's horticultural production amounts to about 22 million tons, of which, 93.7% is produced in irrigated lands and the rest is rainfed. In this year, Southern Zagros Zone was the leading horticultural producer accounting for 17% of total horticultural
production. The next leading producing zones were Caspian Central Plain Zone, Central Zone, and North-Western Zone contributing 16.7, 16.5, and 16.2% of total horticultural production, respectively. These four zones, together, accounted for 66.4% of the total horticultural production of Iran. The lowest amount of horticultural crops was produced in Khuzestan Zone, accounting for as low as 3.2% of the total horticultural production.

The status of some of the climate parameters in the studied zones in 2017 is presented in Table 2. In terms of temperature parameter, the Khuzestan, Southern Coastal Plain and Arid Southern zones with means of 27.3, 27.1, and 19.5 °C, had the highest annual mean temperature. Caspian Coastal Plain, Central Zagros, and North-Western zones had the highest precipitation with 2,590.8, 2,106, and 1,588.2 mm/year, respectively, and the lowest precipitation was related to the Arid Central, Arid Southern and Khuzestan zones with values of 134.7, 233.5, and 266.7 mm per year. In terms of relative humidity, the highest average humidity per year was related to Caspian Coastal Plain Zone with 74.8%, the Southern Coastal Plain Zone with 63.4%, and North-Western Zone with 47.6%, while the lowest humidity was experienced in the Arid Southern, Arid Central, and Southern Zagros zones of 30.6%, 31.6%, and 42.3%, respectively. The highest wind speeds occurred in the Southern Coastal Plain Zone, Southern Zagros, and Central Zagros zones with 40, 32, and 30 m/s, respectively. The lowest wind speed was reported in Khuzestan (16 m/s), Arid Central (24 m/s), and Arid Southern (25 m/s) zones. In terms of evaporation parameter, the Khuzestan zone with a mean of 243.32 mm per year, had the highest annual mean evaporation (Iran Meteorological Organization 2017).

One should examine the multi-collinearity between explanatory variables. One way to detect severe multi-collinearity is to calculate the correlation coefficients between the explanatory variables. If the absolute value of the correlation coefficients between the variables is significantly different from 1 (less than 0.6), we find that there is

### Table 1: The statistics of horticultural production in 2017 (tons)

<table>
<thead>
<tr>
<th>Agro-ecological zone</th>
<th>Production level</th>
<th>Percent of total production</th>
</tr>
</thead>
<tbody>
<tr>
<td>North-Western Zone</td>
<td>3,211,684</td>
<td>16.2</td>
</tr>
<tr>
<td>Caspian Coastal Plain Zone</td>
<td>3,509,600</td>
<td>16.7</td>
</tr>
<tr>
<td>Central Zagros Zone</td>
<td>3,717,093</td>
<td>6.5</td>
</tr>
<tr>
<td>Central Zone</td>
<td>3,462,061</td>
<td>16.5</td>
</tr>
<tr>
<td>Khuzestan Zone</td>
<td>1,345,994</td>
<td>7</td>
</tr>
<tr>
<td>Arid Central Zone</td>
<td>927,055</td>
<td>7</td>
</tr>
<tr>
<td>Khorasan Zone</td>
<td>259,799</td>
<td>3.2</td>
</tr>
<tr>
<td>Southern Zagros Zone</td>
<td>3,577,301</td>
<td>17</td>
</tr>
<tr>
<td>Arid Southern Zone</td>
<td>1,054,436</td>
<td>6</td>
</tr>
<tr>
<td>Southern Coastal Plain Zone</td>
<td>820,898</td>
<td>3.9</td>
</tr>
<tr>
<td>Total</td>
<td>21,885,919</td>
<td>100</td>
</tr>
</tbody>
</table>


### Table 2: Status of climate parameters in agro-ecological zones

<table>
<thead>
<tr>
<th>No.</th>
<th>Agro-ecological zone</th>
<th>Temperature</th>
<th>Precipitation</th>
<th>Relative humidity</th>
<th>Wind speed</th>
<th>Evaporation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>North-Western Zone</td>
<td>13.3</td>
<td>1,588.2</td>
<td>47.6</td>
<td>27</td>
<td>137.98</td>
</tr>
<tr>
<td>2</td>
<td>Caspian Coastal Plain Zone</td>
<td>18.2</td>
<td>2,590.8</td>
<td>74.8</td>
<td>27</td>
<td>99.42</td>
</tr>
<tr>
<td>3</td>
<td>Central Zagros Zone</td>
<td>16.3</td>
<td>2,106.5</td>
<td>43.9</td>
<td>30</td>
<td>168.1</td>
</tr>
<tr>
<td>4</td>
<td>Central Zone</td>
<td>17.8</td>
<td>1,026.9</td>
<td>46.8</td>
<td>27</td>
<td>187.71</td>
</tr>
<tr>
<td>5</td>
<td>Khorasan Zone</td>
<td>16.4</td>
<td>555.1</td>
<td>46.5</td>
<td>25</td>
<td>171.89</td>
</tr>
<tr>
<td>6</td>
<td>Arid Central Zone</td>
<td>19.5</td>
<td>134.7</td>
<td>31.6</td>
<td>24</td>
<td>230.05</td>
</tr>
<tr>
<td>7</td>
<td>Khuzestan Zone</td>
<td>27.3</td>
<td>269.7</td>
<td>46.7</td>
<td>16</td>
<td>243.32</td>
</tr>
<tr>
<td>8</td>
<td>Southern Zagros Zone</td>
<td>15.4</td>
<td>1,192.3</td>
<td>42.3</td>
<td>32</td>
<td>167.88</td>
</tr>
<tr>
<td>9</td>
<td>Arid Southern Zone</td>
<td>18.5</td>
<td>213.5</td>
<td>30.6</td>
<td>25</td>
<td>213.85</td>
</tr>
<tr>
<td>10</td>
<td>Southern Coastal Plain Zone</td>
<td>27.1</td>
<td>424.7</td>
<td>63.4</td>
<td>40</td>
<td>185.11</td>
</tr>
</tbody>
</table>

no coincidence problem (Gujarati 2004). For this purpose, the correlation coefficients matrix between the explanatory variables calculated using Eviews software is presented in Table 3. The coefficients were significantly different from 1, so there is no collinearity between the explanatory variables.

Scatter plots were used to examine the relationship between the independent variables and the dependent variables. This plot is also used to display the data scatter. Usually, the more points along a straight line, the greater the correlation between variables. According to Figure 2, there is a linear relationship between the independent variables and the dependent variable (horticultural production).

Figure 3 shows the linear relationship between the independent variables and the dependent variable (per capita food consumption) through the scatter plot. According to Figure 3, there is a linear relationship between the independent variables and the dependent variable (per capita food consumption).

After examining the linear relationship between independent and dependent variables, there are specific statistics and graphs that make it easier to verify that the distribution is normal. One of these plots is the Q-Q plot. For each data value, the Q-Q diagram shows the observed value and the expected value. If the data belong to a normal distribution, points should be gathered around a straight line. In Figure 4, it is clear that the data are along a straight line and so the variables have a normal distribution.

After reviewing the regression assumptions, it is necessary to first examine the stationarity of the variables and then evaluate the panel’s diagnostic tests. Stationarity tests are necessary to avoid estimating false regression and estimating reliable coefficients. In this study, Levin, Lin and Chu’s, Im, Pesaran, and Shin’s, Fisher-Phillips-Perron’s, and Hadry’s tests were used to examine the stationarity test (Table 4). The null hypothesis of these tests is that there is at least unit root in one of the variables in the study zones. As the results in Table 4 show, all variables

| Table 3 | Collinearity investigation of explanatory variables |
|-------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Variable          | Precipitation | Temperature | Evapotranspiration | Relative humidity | Wind speed |
| Precipitation     | 1.00           | 0.27         | 0.51               | 0.53               | 0.51         |
| Temperature       | 0.27           | 1.00         | 0.43               | 0.06               | 0.29         |
| Evapotranspiration| 0.51           | 0.43         | 1.00               | 0.49               | 0.39         |
| Relative humidity | 0.53           | 0.06         | 0.49               | 1.00               | 0.13         |
| Wind speed        | 0.51           | 0.29         | 0.39               | 0.13               | 1.00         |

Source: Research findings.
are significant at the 5% level. In other words, all research variables are stationary and the hypothesis of non-stationarity for the variables is rejected. All the coefficients have good reliability.

After determining the stationarity variables, Kao and Pedroni tests were used to check for cointegration. Panel cointegration analysis tests the existence of long-term relationships and then estimates it. The basic idea in cointegration analysis is that although many time series are unstable and contain random trends, they may be linear combinations of variables in the long run, static and without a random trend. The null hypothesis of Kao and Pedroni correlation coefficient test is based on non-coefficient variables. The results of Kao and Pedroni tests indicate that in the study zones, the model variables are significant at the 5% level. Therefore, the null hypothesis of non-coincidence of variables is rejected and there is a strong relationship of the climate variables and total horticultural production in the studied agro-ecological zones (Table S2, supplementary material).

The Kao test was used to check the cointegration of the studied climate variables with per capita food consumption and results are presented in Table S3. The results indicate that there is a strong relationship between the studied climate variables and per capita food consumption in the studied agro-ecological zones.
After performing unit root and cointegration tests, it is necessary to perform diagnostic tests to determine the estimated model type. To determine the significance of the group of member provinces in the zones, the individual fixed effects test is used. F statistic is used for this purpose. If the test statistic is greater than the critical F value in the table at the test significance level (which is 5%), then the panel model will be more suitable. Otherwise, we should use the pool model. According to the results, since the significance level of the test is set at 0.05, it is more appropriate to estimate the model in panel form (Table S4).

To choose fixed effects or random effects tests for the final estimation of the model, we employed Hausman’s test (1978). In the test, the H0 hypothesis of consistency of random effects estimates is tested against the H1 hypothesis of incompatibility of random effects estimates. If the H0 hypothesis is rejected, the fixed effects method should be used to estimate it. Otherwise, the estimation is done by random effects method. Since the significance level of the test was set at >0.05, the final model was estimated in the form of random effects (Table S5).

Table 5 shows the results of model estimation for the ten studied agro-ecological zones using random effects model. Accordingly, total horticultural production has been significantly influenced by the variables temperature, evapotranspiration, and wind speed (p < 0.05). Temperature has had a negative effect on total horticultural production, and with the increase in temperature (at a rate of one unit), total horticultural production is reduced to 0.01 million tons. Evapotranspiration and wind speed have had a negative effect on total horticultural production, and with increasing evapotranspiration and wind speed (at a rate of one unit), total horticultural production was 0.029 and 0.008 million tons decrease, respectively. Climatic changes through increased temperature, reduced rainfall, and increased evapotranspiration has reduced the amount of irrigation water needed and available for crops and has led to severe water stress conditions in Iran’s agricultural sector. As a result, it has reduced agricultural productivity. Without access to reliable water resources,
many agricultural activities in Iran will suffer greatly. Most of the time, climatic changes in the form of irregular rainfall, incidence of frostbitten plants, has destroyed much of the horticultural crop, thus negatively affecting the food security of the Iranian people. Hailstorms and frostbite are some of the most common weather conditions experienced by Iranian gardeners over the past two decades. One of the phenomena that strongly affects the production of stone fruits is the occurrence of late spring frosts. The proximity of Iran (especially in the east) to the Siberian high pressure system makes the occurrence of frosts in the region inevitable.

Climate change imposes remarkable economic costs on fresh and dried fruit producers. The producers may have to either stop growing these crops or adapt to climate change as far as possible. In most cases, it is not economically feasible for most producers to apply adaptive methods and most of their life aspects are potentially influenced. The results of this section are in line with the results of Cabbage & McCarthy (2016), Tanasijevic et al. (2014), Moretti et al. (2010), and Morinaga (2011). Cabbage & McCarthy (2016) showed that climate change had a negative impact on grape production and quality. The research results of Tanasijevic et al. (2014) showed that as temperature rise and rainfall decline interact, soil water availability might decrease in the root zone and it would be very likely for rain-fed olive orchards to suffer from water stress in future. Thus, we may witness the eradication of rain-fed olive trees in the coming years. Moretti et al. (2010) showed that climate change would, directly and indirectly, influence the production and quality of fruits and vegetables that grow in different climates of the world. Morinaga (2011) concluded that climate change had reduced yield of some horticultural crops in this country.

Also, Table 5 indicates that $R^2$ (showing the potential to account for the total model) was estimated at 0.366. In other words, 0.366% of the variance of total horticultural production is accounted for by the independent variables. As the most important statistic in regression analyses, $F$-statistic shows the significance and reliability of the overall model. $F$-statistic was estimated to be 5.31. Since this is greater than 4, it means that the model reliability can be supported by 100% probability, confirming the hypothesis of overall model significance.

The results of model estimation using random effects model for the ten studied agro-ecological zones are shown in Table 6. The results show that the variables temperature (negative effect), precipitation (positive effect), and wind speed (negative effect) were effective on per capita food consumption (indicator for measuring food security) in the ten studied zones. Also, Table 6 shows that $R^2$ (as an indicator of the potential to account for the overall model) was 0.342. In other words, 0.342% of the variance in per capita food consumption is accounted for by the independent variables. As mentioned, $F$-statistic shows the significance and reliability of the overall model. It was found to be 4.51 and since it was greater than 4, it means that the model is 100% probable to be reliable and the assumption of the overall reliability of the model is supported. The agricultural sector plays a key role in ensuring food security by providing the Iranian people with food and creating employment and income for a large part of the workforce. Therefore, any change in agricultural production due to climate change has a negative impact on food security indicators such as food access. Unpredictable climate change across Iran can reduce agricultural production and increase food prices. As climate change influences the production of the agricultural sector in Iran, the livelihoods of poorer and vulnerable rural families are seriously threatened, resulting in food insecurity. Climate change has created chronic food problems for Iran and has reduced food availability. In fact, climate change is a major threat to food security through influencing the production and income of the agricultural sector in Iran. The crisis in agriculture due to climate change has a
significant impact on per capita food consumption, meaning that climate change will reduce food production and lead to food scarcity and impact on food security. The results of this section are in line with the results of Wang (2010). The results of the study by Wang (2010) showed that climate change influenced food security considerably.

CONCLUSIONS

The vastness of Iran, its geographic location, how to develop mountainous areas, is preventing the region from having full access to the country’s inflow of atmospheric precipitation. The existence of such conditions causes an inhomogeneity in the amount and pattern of precipitation that has crystallized in the temporal and spatial behavior of the climatic factors. This case can be alarming for a country like Iran, which is heavily dependent on rainwater, and will cause the country to face a crisis of water shortage. On the other hand, given that more than 82% of the territory of Iran is located in dry and semi-arid regions, the agriculture sector is always faced with low rainfall and the risk of drought. These climatic conditions have provided major constraints on agricultural production in Iran and made this sector very vulnerable.

Due to the arid and semi-arid climate of Iran, Iran is one of the countries facing water shortage. Obviously, this shortage will greatly affect agricultural production. Climate change has been accompanied by declines in production, cultivation levels, and water resources availability (mostly in the central and southern parts), which is a serious threat to Iran’s food security.

Analyzing the effects of climatic changes on food production systems is essential for future planning of the agricultural sector so that officials and planners can be prepared to reduce the negative impacts on the systems involved in agriculture by increasing their knowledge of the potential impacts.

The present study suggests the need for further studies on greenhouse gas emissions, especially in industrialized provinces, as one of the major causes of climate change. Considering the adverse effects of increasing the temperature variable and decreasing rainfall variability in groundwater level, soil moisture, water level in upper layers of soil, the occurrence of drought, attention to temperature trends, precipitation, along with other climatic factors can be a great help to the economic and agricultural sectors. By supplementary study and seasonal study of climate parameters in the cultivating seasons, suitable planning for agricultural activities in different areas can be done.

According to the results of the research, it is recommended to plan and grant financial facilities, in order to prepare horticultural farmers for climate change, such as the use of modern irrigation technologies and agricultural crop insurance. Also, the impacts of climate change on agriculture and food security can be alleviated by such policies as the maintenance and optimal use of water and soil capacity and assets, increasing investment in sustainable activities, and using advanced technologies in the agricultural sector.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this paper is available online at https://dx.doi.org/10.2166/wcc.2019.139.

REFERENCES

Chang, C. 2002 The potential impact of climate change on Taiwan’s agriculture. Agricultural Economics 27, 51-64.


Karami, A. & Mardani, Y. 2015 The impacts of macroeconomic variables on poverty in rural areas of Iran. *Agricultural Economics Research* 7 (26), 109–123.


Ministry of Agriculture 2016 *Agricultural Statistical Book of Horticultural Crops*. ITC Center, Deputy of Planing and Economics, Tehran, Iran.

Moretti, C. L., Mattos, L. M., Calbo, A. G. & Sargent, S. A. 2010 Climate changes and potential impacts on postharvest quality of fruit and vegetable crops: a review. *Food Research International* 43, 1824–1832.


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