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Impact of climate change on the wheat-growing season over Iran

Gholamreza Roshan · Ruhollah Oji · Sultan Al-Yahyai

Abstract The objective of this paper is to derive and analyze the present and future climate projections over the region of wheat production over Iran. In addition, the projected future climate fluctuation results will be used to assist the maximum performance of wheat and to be used as the main basis for planning changes in the farming calendar in Iran. Observed climate (temperature and degree day) changes during the period (1951–2009) will be discussed. Projected future changes up to 2100 based on the MAGICC/SCENGEN 5.3 compound model was utilized. Furthermore, 18 scenarios were used to derive a single GCM model referred to as the United Kingdom Hadley Center Global Environment Model, which will be used to select the worst, best, and average scenario.

Introduction

According to the recent report of the International Panel on Climate Change (IPCC), the global temperature will increase 0.6–2.5 °C within the next 50 years and will increase 1.1–6.4 °C by the end of this century. Significantly higher

G. Roshan (✉)
Department of Geography, Golestan University, Gorgan, Iran
e-mail: ghr.rowshan@gmail.com

R. Oji
Department of Geography, University of Modarres, Tehran, Iran
e-mail: owji58@gmail.com

S. Al-Yahyai
Oman National Weather Service, Public Authority for Civil Aviation, Muscat, Oman
e-mail: s.alyahyai@met.gov.om

increases are expected in regional scale (IPCC 2007). However, the climate change in some of the regions of the globe especially in latitudes higher than 55 north and south will has a positive impact on agriculture (Ewert et al. 2005) but with significant devastating impact on the torrid zones (Gregory et al. 2005; Ghanghermeh et al. 2013; Parry et al. 2004; Sivakumar et al. 2005; Stern 2006). This will bring more temperature and less precipitation for developing countries (Sivakumar et al. 2005; Stern 2006) and higher frequency of uncommon climactic phenomena (draught, heat, cold, and floods) (Tyson et al. 2002; IPCC 2007). An increase in carbon dioxide is responsible for the increase in photosynthesis and consequent increase in the activity of most of farm plants (Burkart et al. 2004; Ainsworth and Long 2005; Kimbal et al. 2002; Fuhrer 2003). However, it seems that different aspects of climate change have different impacts on the production and performance of farm plants which may increase or decrease the farm yield. Thus, the pure impact of climate change on performance will depend on the mutual impact of these factors (Krishnan et al. 2007). Despite the convincing proofs that doubling the carbon dioxide would increase performance of farm plants (Kimbal et al. 2002), studies showed that the expected increase in performance will not take place due to the increase in temperature (Sivakumar et al. 2005; Prasad et al. 2006). Mall and Aggarwal (2002) showed an increase in the performance of rice, assuming an increase in carbon dioxide and a constant temperature. On the other hand, they showed that an increase in mean temperature of about 0.8 °C caused a significant decrease on the performance. Lal et al. (1998) showed a decrease in performance of both wheat and rice due to the increase in temperature. Using general circulation models, Koocheki et al. (2006) predicted considerable changes in the growing season length, precipitation trends, and mean temperature increase in most regions of Iran. Furthermore, they have examined the impact of climate

change on the wheat yield in the northeastern part of Iran including Mashhad Region. Their study was carried out at a regional scale. On the other hand, a national scale study is needed (Ingram et al. 2008) to assist impacts on the production of crops. Recent estimations showed that Iran's demand for wheat will exceed 20 million tons per year by 2050, 65–70 % of which is produced by aquaculture and the remaining by dry land cultivation (Faizabadi et al. 2006). Studies on climate change in global scale reported a decrease of 10 to 40 % and 5 to 20 % in aquaculture and dry land cultivation, respectively, during the next 50 years (Parry et al. 1999; 2004). Other studies such as Nassiri et al. (2006) and Koocheki and Nassiri (2008) showed a decrease in dry land cultivation of wheat about 13.8 and 20.7 % for 2025 and 2050, respectively. Therefore, it seems that global scale assessment lacks conclusiveness and this shows the necessity for national scale studies.

Due to very dry, desert climate, high temperatures, and lack of adequate rainfall, about 37.5 % of food supply of the some Arabian countries such as Bahrain, Qatar, Saudi Arabia, Oman, UAE, and Kuwaitis is imported. Therefore, researches on the effects of climate change on agricultural crops and wheat rarely have been considered in this part of the Middle East. On the other hand, this effect was studied for other countries in the Middle East, including Pakistan, Turkey, and Iran (Hozayn and El-Monem 2010; Haim et al. 2008; Roshan and Grab 2012; Hussain and Mudasser 2007; Nassiri et al. 2006).

Given the regional, cultural, economic, and social characteristics of Iran, wheat is the main source of daily bread and major source of energy. Statistics released by the Food and Agriculture Organization shows that Iran is one of the largest consumers of wheat bread in the world. The per capita consumption of wheat in Iran is than twice the global average.

The objective of this paper is to derive and analyze the present and future climate projections over the region of wheat production over Iran. In addition, the projected future climate fluctuation results will be used to assist the maximum performance of wheat and to be used as the main basis for planning changes in the farming calendar in Iran. The rest of the paper is organized as follows: "Methodology" section describes the methodology and used data. Results are presented and discussed in the "Results and discussions" section. Finally, "Conclusions" concludes the paper.

Methodology

Climate change trends

Climate data were obtained from the Iran Meteorological Organization for 25 synoptic and climatological stations within Iran's wheat-producing regions (IRIMO 2013). These regions were subdivided into north (Rasht, Ramsar, Anzali, Babolsar,

and Gorgan), south (Fassa, Kerman, Shiraz, Bushehr, and Bandar-abbas), west (Tabriz, Hamedan, Kermanshah, Khoramabad, and Dezful), east (Mashhad, Birjand, Sabzevar, Zabol, and Zahedan), and center (Esfahan, Tehran, Shahrud, Arak, and Yazd), as shown in Fig. 1. Normalized annual and monthly maximum, minimum, and mean temperatures were calculated for each region, based on the collective data of the regions. The study analyzes 58-year (1951–2009) air temperature records to determine the overall trends.

The trend tests were classified into parametric and nonparametric groups. The presupposition of the parametric tests is that the data are random and outcomes of a normal distribution. However, the presupposition of normality of the data does not exist in the nonparametric tests. Thus, where the normality of the data is not reliable, it is better to use nonparametric tests. On this study, it is assumed that temperature is a linear function of time (Masoudian 2005; Roshan et al. 2011; Borna 2011; Shakoor 2011). Therefore, the temperature change model would follow Eq. (1):

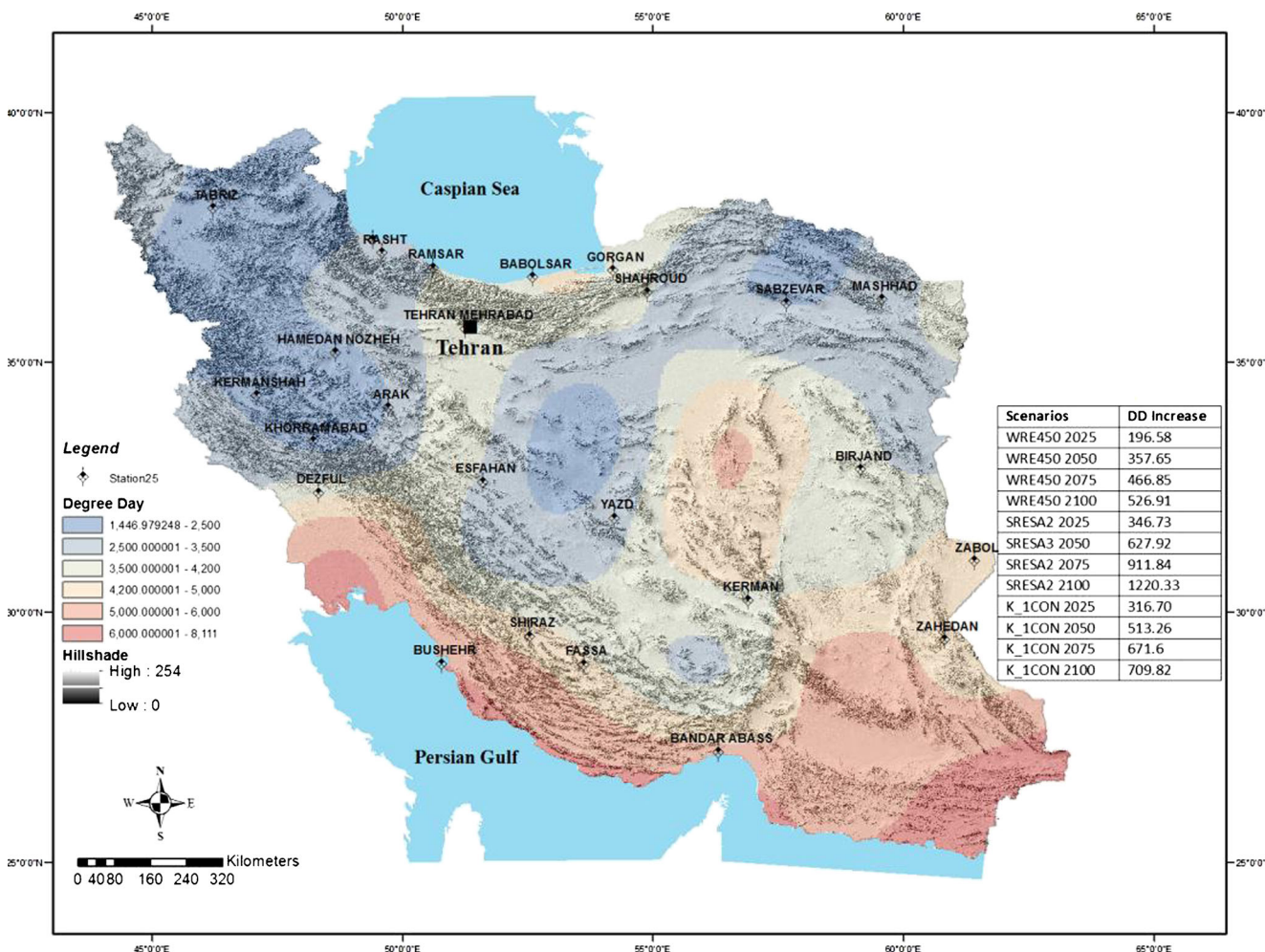$$\text{Temperature} = \alpha + \beta \, \text{Time} \tag{1}$$

It is evident that a positive value of β indicates a temperature increase over time, and a negative value for β indicates a temperature decrease over time. If $\beta=0$, the presupposition is not confirmed. However, since the value of β is definite, an estimation of β is obtained from Eq. (2) with a 95 % confidence (Masoudian 2005; Roshan et al. 2011; Borna 2011; Shakoor 2011):

$$\widehat{\beta} = \pm t_{0.025} \frac{S}{\overline{S}} \tag{2}$$

If the upper and the lower limits of β are both positive and both negative, the assumption of temperature trend is not rejected and considered to be increasing or decreasing, respectively. On the other hand, if either the upper or the lower limit is positive and the other is negative, the trend presupposition is not confirmed. This test is performed separately on the time series at both monthly and seasonal scales (Masoudian 2005; Roshan et al. 2011; Borna 2011; Shakoor 2011).

Climate simulation models

Climate change effects in air temperature over Iran are assessed using the publicly available model for the Assessment of Greenhouse Gas-Induced Climate Change (MAGICC; v. 5.3) coupled with a regional climate change scenario generator (SCENGEN), developed by NCAR-CRU based upon over a dozen AOGCMs (Wigley 1995, 2003, 2008). In addition, 18 IPCC scenarios derived by the United Kingdom Hadley Center Global Environment Model are used to select the worst, best, and average simulation for 2025, 2050, 2075, and 2100 and to predict the degree day (Fig. 8).

Scenarios	DD Increase
WRE450 2025	196.58
WRE450 2050	357.65
WRE450 2075	466.85
WRE450 2100	526.91
SRESA2 2025	346.73
SRESA3 2050	627.92
SRESA2 2075	911.84
SRESA2 2100	1220.33
K_1CON 2025	316.70
K_1CON 2050	513.26
K_1CON 2075	671.6
K_1CON 2100	709.82

Fig. 1 Iran's degree day classification based upon total average of degree day from 1961 to 1990 together with transmittance of 25 synoptic stations of the studied regions proper for cultivation of wheat

Degree day of wheat assessment

The index of growing degree days (GDDs) or the corresponding growing season length (GSL) is commonly used in agronomic studies to determine the effect of temperature on crop growth and yields. This approach was considered suitable for this analysis because it would help in determining the GSL for wheat in the study area and assessing the impact of GSL (as affected by climate change) on wheat productivity (Hussain and Mudasser 2007; Elliott et al. 2009). GDDs are also good estimators of wheat growth stages (Pal et al. 1996). The GDD or heat unit was calculated by using the Peterson equation (1965) as shown in Eq. (3):

$$GDD = \frac{T_{max} + T_{min}}{2} - T_{base}. \qquad (3)$$

In this equation, GDD represents the amount of degree day, and T_{max} and T_{min} represent the daily maximum and minimum temperatures, respectively (Shakoor et al. 2010). T_{base} represents the physiological zero of the plant, which

was set to 0 for Iran conditions (Maddah Yazdi et al. 2008; Moini et al. 2008; Rezaei et al. 2008; Sarraf et al. 2009).

The GSL for wheat is then estimated by counting the number of days from the date of planting to the date at which the crop would be able to accumulate GDDs of 1800 (Iranian Ministry of Agriculture 2004; Hussain and Mudasser 2007). This amount is normally required by the existing semi-dwarf wheat varieties for reaching optimal maturity. In this paper, it is assumed that these semi-dwarf wheat varieties will continue to be grown by farmers in the study areas.

Results and discussions

Temperature and degree day trends in Iran (1951–2009)

In accordance with the findings of Ghahraman (2006), a measure of the average annual temperature of 34 stations in different climatic regions of Iran has been analyzed. The analyses of different components of changes in climate in

Table 1 Rates of temperature and degree day changes for south regions of Iran: 1951–2009

Time factors	January	February	March	April	May	June	July	August	September	October	November	December	Annual
T_{min}													
°C/decade	0.01	0.18	0.06	0.2	0.12	0.139	0.14	0.109	0.03	0.09	−0.03	0.08	0.119
R^2	0.004	0.021	0.003	0.14	0.08	0.153	0.14	0.195	0.040	0.043	0.014	0.05	0.179
r	0.07	0.14	0.05	0.374	0.29	0.391	0.37	0.441	0.20	0.21	0.12	0.22	0.423
P	0.62	0.276	0.704	0.004	0.03	0.002	0.000	0.000	0.13	0.11	0.372	0.09	0.001
SE	1.271	1.24	1.501	0.854	0.76	0.669	0.75	0.669	0.84	1.15	1.213	1.49	0.575
T_{max}													
°C/decade	0.07	0.08	0.20	0.325	0.22	0.079	0.02	0.04	−0.06	0.01	−0.10	0.39	0.132
R^2	0.001	0.000	0.001	0.156	0.11	0.17	0.07	0.07	0.002	0.004	0.001	0.11	0.133
r	0.03	−0.02	0.02	0.395	0.33	0.412	0.27	0.264	0.04	0.06	−0.03	0.33	0.364
P	0.82	0.877	0.861	0.002	0.01	0.001	0.04	0.043	0.77	0.63	0.799	0.01	0.005
SE	1.745	1.616	1.531	1.613	1.23	0.601	0.53	0.618	0.65	0.78	1.277	1.83	0.625
T_{mean}													
°C/decade	0.05	0.14	0.12	0.269	0.16	0.124	0.07	0.059	−0.02	0.04	−0.06	0.21	0.118
R^2	0.00	0.00	0.00	0.195	0.13	0.255	0.15	0.15	0.02	0.03	0.01	0.13	0.208
r	0.05	0.07	0.04	0.442	0.36	0.505	0.38	0.387	0.15	0.17	0.07	0.36	0.456
P	0.703	0.612	0.742	0.000	0.01	0.000	0.000	0.002	0.27	0.2	0.576	0.01	0.000
SE	1.227	1.129	1.008	1.076	0.83	0.511	0.51	0.547	0.65	0.78	0.72	1.16	0.484
GDD													
Decade	1.44	3.80	3.87	8.069	5.04	3.713	2.03	1.814	−0.62	1.24	−1.95	6.39	43.24
R^2	0.003	0.005	0.002	0.195	0.13	0.255	0.15	0.15	0.022	0.029	0.006	0.13	0.208
r	0.05	0.07	0.04	0.442	0.36	0.505	0.38	0.387	0.15	0.17	0.07	0.36	0.456
P	0.703	0.612	0.742	0.000	0.01	0.000	0.000	0.002	0.27	0.2	0.576	0.01	0.000
SE	38.05	31.61	31.25	32.3	25.8	15.34	15.8	16.96	19.6	24.1	21.61	36.1	177

SE standard error, *R* liner regression, *P* signification value

Fig. 2 Trend of degree day changes for autumn in 1951–2009
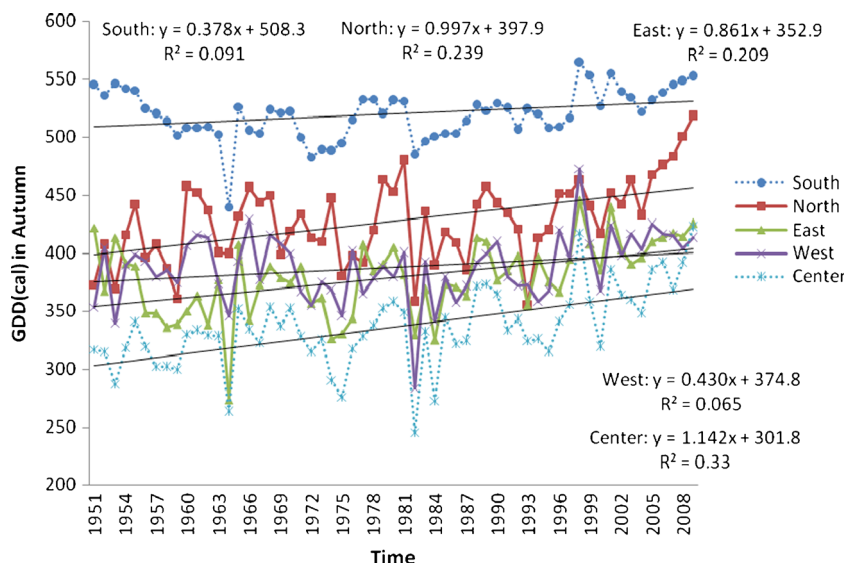
the north show reduction on the mean annual temperature for most of the studies in this part of Iran (Rowshan et al. 2007; Azizi and Rowshani 2008). In this study, the highest maximum temperature rise of 0.597 °C per decade was at Kermanshah Station, and the highest temperature rise for minimum temperature of 0.911 °C per decade was recorded in Ahvaz (Tabari and Hosseinzadeh Talaee 2011). Autumn is the most important season (wet, cool temperature) for wheat cultivation in Iran. Therefore, this study place emphasis on autumn climate trends (October to December).

Southern part of Iran is an important area for wheat production on the country. It recorded peak wheat yield on national scale and known for its arid to semiarid climates where precipitation fluctuates from 152 mm for Kerman to 346 mm for Shiraz. Statistical trend analysis for minimum temperature shows that 83.3 % of the months of the year display significant trends. On the other hand, winter months did not show any significant trends. July (0.14 °C/decade; $P<0.0001$; $R^2=0.14$) and June (0.14 °C/decade; $P=0.002$; $R^2=0.153$) showed highest increase in minimum temperature while December (0.03 °C/decade; $P=0.13$; $R^2=0.040$) showed lowest increase. It was noticed that November (0.03 °C/decade; $P=0.372$; $R^2=0.014$) showed a significant trend of decreasing minimum temperature.

With regards to the mean temperature, except for winter months, all other months other than September and November showed a significant trend of increasing temperature. The central point of significant increase in temperature is more obvious in spring than in other seasons of the year. For mean temperature, the maximum value of temperature increase was recorded on April (0.26 °C/decade; $P<0.0001$; $R^2=0.195$) and the lowest temperature increase on October (0.04 °C/decade; $P=0.2$; $R^2=0.03$). On the other hand, the highest and lowest maximum temperature increase was recorded for October (0.39 °C/decade; $P=0.01$; $R^2=0.11$)

and July (0.01 °C/decade; $P=0.63$; $R^2=0.004$), respectively. Considering all temperature components (maximum, mean, and minimum) for stations in the southern region, the central point of trend of increasing temperature for warm seasons of the year (spring and summer) is more obvious than that in other seasons. It should be noted that some cold months of the year showed a rapid rate of increase in temperature in a decade base from 1951 to 2009 (Table 1).

Among the most favorable regions for agriculture are the northern regions. The annual mean temperature in this part of Iran varies between 15.9 °C in Rasht and 17.8 °C in Groan. According to the statistical analysis, all months showed significant trend of increase in minimum temperature except for February. This 10-yearly trend of increase varies and was maximum in December (0.57 °C/decade; $P<0.0001$; $R^2=0.223$) and minimum in January (0.25 °C/decade; $P<0.05$; $R^2=0.072$). For the maximum, it was noticed that the last month of winter and first of spring showed a significant trend of increase. Maximum and minimum increase was recorded during March (0.55 °C/decade; $P<0.05$; $R^2=0.08$) and April (0.61 °C/decade; $P<0.0001$; $R^2=0.14$), respectively. Finally, summer and fall showed a significant increasing trend for the mean temperature over the region. However, April and June (0.21 °C/decade; $P<0.01$; $R^2=0.12$) in spring and March (0.55 °C/decade; $P=0.002$; $R^2=0.16$) in winter show a significant trend of increasing mean temperature.

The eastern parts of Iran fall into two groups of cold–dry (in northeast) and warm–dry (in southeast). Therefore, northeast stations located in Mashhad, Sabzevar, and Birjand are under the impact of Siberian cold and dry air masses. Based on the statistical analysis, few months showed a significant trend of increasing or decreasing temperature during all seasons. It was noticed that 91.6 % of months showed significant increase for minimum temperature and only 16.6 % of months showed significant increase for maximum temperature.

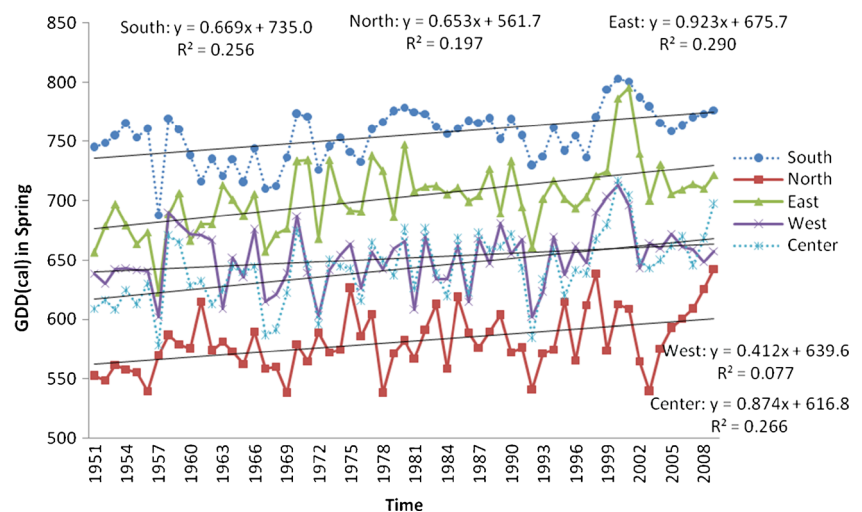**Fig. 3** Trend of degree day changes for winter in 1951–2009
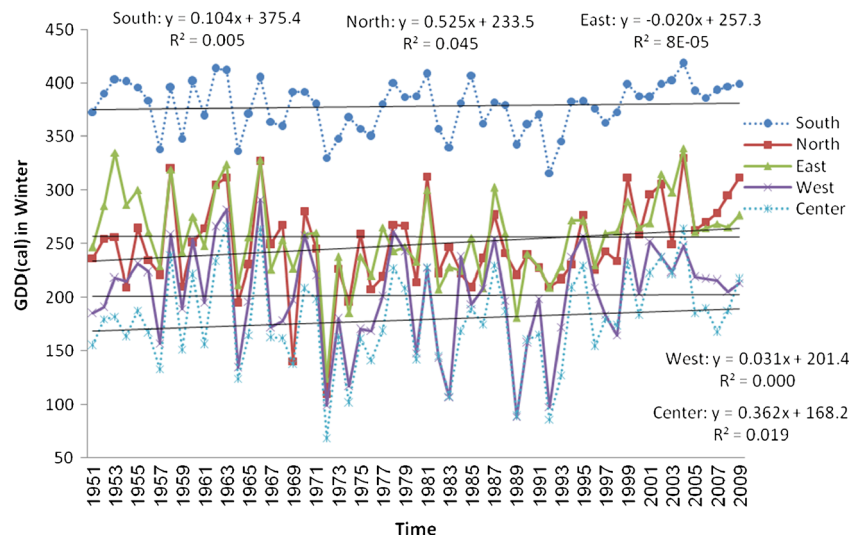
However, for minimum temperatures, the highest increase was recorded during October (0.64 °C/decade; $P<0.0001$; $R^2=0.27$) and lowest increase was recorded during December (0.06 °C/decade; $P<0.05$; $R^2=0.087$). On the other hand, maximum temperature showed its highest increase during April (0.49 °C/decade; $P=0.001$; $R^2=0.116$) and lowest increase during March (0.30 °C/decade; $P=0.94$; $R^2=0.00$). Moreover, the highest and lowest increase was recorded during June (0.47 °C/decade; $P<0.0001$; $R^2=0.42$) and December (0.09 °C/decade; $P=0.078$; $R^2=0.053$), respectively, for the mean temperature.

Other important region for the wheat production is the west area of the country. This area is identified by its Mediterranean to semiarid climate. The average annual temperature in these regions is approximately 13.5 °C. This area showed the least number of months with significant trend of increasing temperature compared to other regions of the country. For the maximum temperature, the highest increase in a decade was recorded during April (0.36 °C/decade; $P<0.0001$; $R^2=0.22$).

August (0.25 °C/decade; $P=0.01$; $R^2=0.11$) showed the highest increase for the minimum temperature. On the other hand, October (0.42 °C/decade; $P<0.01$; $R^2=0.13$) and June (0.29 °C/decade; $P<0.01$; $R^2=0.12$) showed the highest and lowest significant increases for the maximum temperature, respectively. The highest and lowest significant increase for the mean temperature was recorded during October (0.24 °C/decade; $P<0.05$; $R^2=0.07$) and September (0.14 °C/decade; $P<0.05$; $R^2=0.08$), respectively. Similar to other regions, the highest number of months with a significant trend of increasing temperature was recorded during warm seasons, especially summer.

Finally, the driest region of Iran, which is characterized by its low elevation, is central Iran. Similar to other regions, no significant trend of temperature was observed during winter. However, a significant trend for summer, spring, and fall was recorded. For minimum temperature, the highest increase was observed during both October (0.61 °C/decade; $P<0.0001$; $R^2=0.39$) and July (0.61 °C/decade; $P<0.0001$; $R^2=0.56$).

Fig. 4 Trend of degree day changes for spring in 1951–2009

**Fig. 5** Trend of degree day changes for summer in 1951–2009
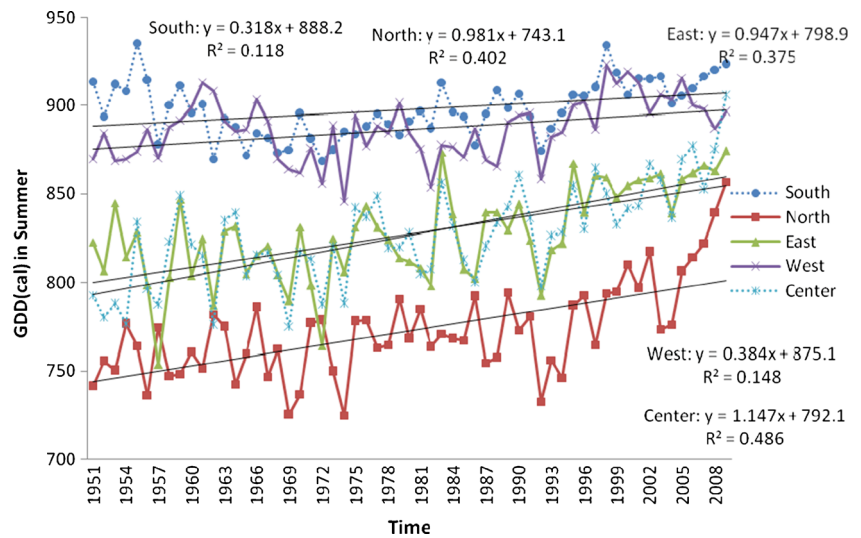
The minimum increase was observed during November (0.32 °C/decade; $P<0.0001$; $R^2=0.25$). For maximum temperature, the highest temperature rise was recorded during December (0.52 °C/decade; $P<0.05$; $R^2=0.087$) and lowest trend increase was for July (0.18 °C/decade; $P=0.085$; $R^2=0.051$). On the other hand, the highest and lowest significant increase for the mean temperature was recorded during December (0.49 °C/decade; $P<0.01$; $R^2=0.15$) and November (0.25 °C/decade; $P<0.01$; $R^2=0.11$), respectively.

One objective of this study was to study the effect of the climate change on wheat production over several regions of Iran to ensure maximum performance. Therefore, the comparison between different regions was conducted. The analysis showed that winter recorded the least significant trend while summer recorded the maximum trend. According to the GDD calculation, the center region showed the maximum GDD value (121.8 GDD/decade; $P=0.62$; $R^2=0.379$). The GDD

values for the north, east, and west regions were 120.9 GDD/decade, $P=0.56$, $R^2=0.314$; 85.61 GDD/decade, $P<0.0001$, $R^2=0.29$; and 54.26 GDD/decade, $P<0.05$, and $R^2=0.097$, respectively. The least GDD value was recorded for the south region (43.24 GDD/decade; $P<0.0001$; $R^2=0.20$).

With regards to the degree day statistic, it was noticed that the maximum number of months with a significant trend of increasing degrees was observed for spring (5.61) and summer (1.29) considering all stations in the southern region of Iran. On the northern region, the maximum significant increase was recorded for autumn (13.9) and then summer (11.3). Similarly, the eastern and central regions recorded its maximum increase for autumn and summer with slightly lower grade day values of 9.2 (autumn) and 7.4 (summer) for the eastern region and 12.5 (autumn) and 9.34 (summer) for the northern region. The details of the statistical analysis can be found in Figs. 2, 3, 4, and 5.

Fig. 6 Comparison of annual changes in the process of atmospheric carbon dioxide levels and the degree day in different geographical regions of Iran from 1959 to 2009
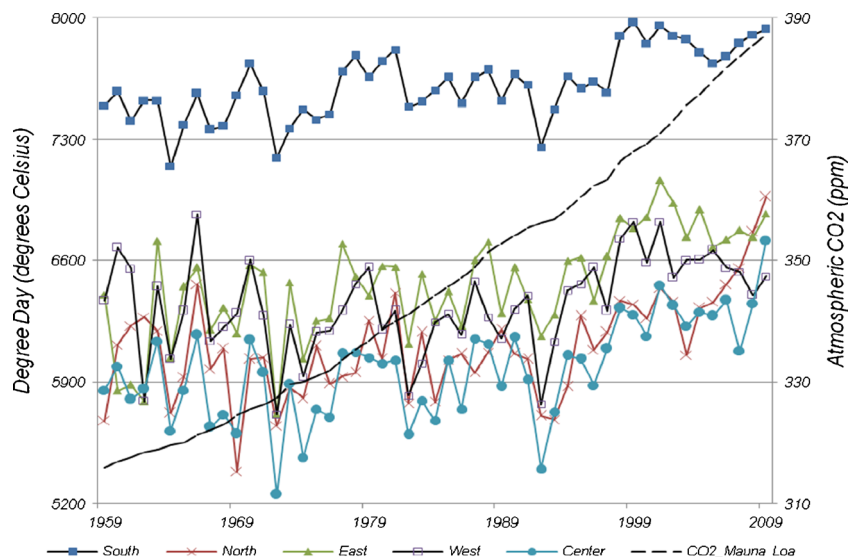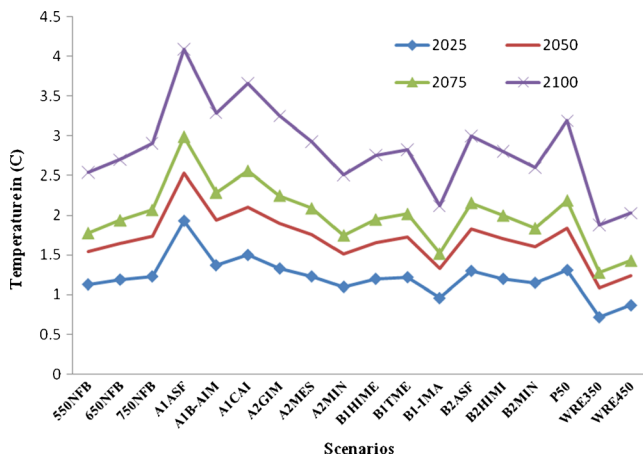
**Fig. 7** Temperature variations of scenarios based on different models to decades MAGICC SCENGEN 2100

Correlation of degree day and temperature with CO_2 in Mauna Loa

It is known that the carbon dioxide measurements from Mauna Loa Station in the Hawaiian Islands are considered as one of the best measurements available with long-term accessible data. In this section, the effectiveness of grade levels—from the days of atmospheric carbon dioxide levels—is compared to the carbon dioxide levels of the Mauna Loa Station as shown in Fig. 6. It can be seen that the carbon dioxide levels of station Mauna Loa showed high effectiveness degree of variation and fluctuation. It also can be seen that the degree day is directly affected by the increase on atmospheric carbon dioxide. Finally, the minimum effect can be seen over the south and west regions.

Future temperature simulation using different scenarios

The expected mean temperature of the entire study areas measured using arithmetic mean was calculated and shown
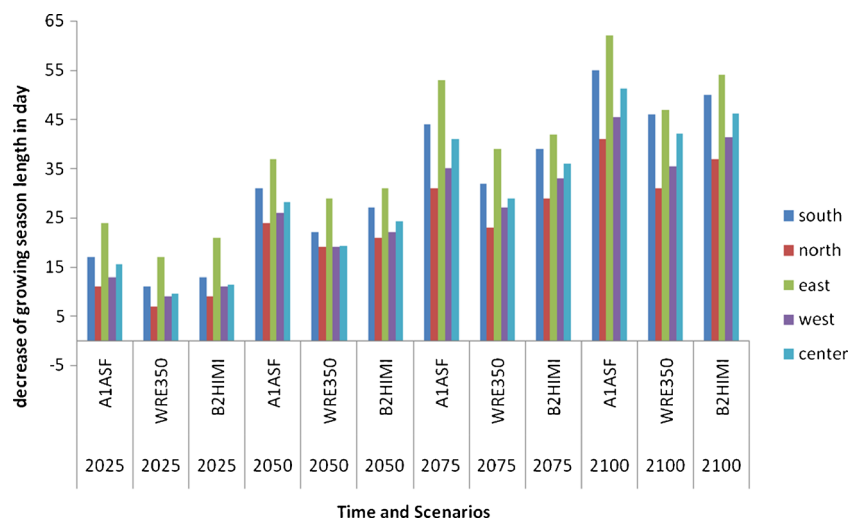
in Fig. 7. It can be seen that the temperature increase predicted by different scenarios range between 0.7 and 2. 0 for 2025, 1.2 and 2.5 for 2050, and 1.4–3 and 2–4.1 for 2075 and 2100, respectively. It can also be seen that scenario "WRE350" was always predicting the lowest change and the highest change was always predicted by the "A1ASF" scenario. On the other hand, scenario "B2HIMI" showed the moderate increase prediction.

Future degree day for wheat production in Iran based on observational and simulated data

Based on the selected three scenarios, namely, WRE350, A1ASF, and B2HIMI, the mean temperature increase over different regions was simulated. An increase trend over all seasons was shown on the simulation. It was simulated that the increase on the western region is expected to be about 2.18 °C. Slightly higher increase was expected for eastern and northern regions of about 2.4 and 2.33, respectively, by 20150. A higher increase of about 4.1, 4.4, 3.7, and 4.2 for western, eastern, northern and southern regions was expected by 2100, respectively. However, increasing the temperature and intensity of the seasonal distribution will definitely affect the crop growth on a global scale. This effect will vary from one region to another (Koocheki and Nassiri 2008).

Seasonally, the temperature increase was expected to vary from one season to another. For 2050, the seasonal variation increase is expected to be 2.02 °C in winter, 2.07 in spring, and 2.11 and 3.84 for fall and spring, respectively. Higher seasonal temperature increase is expected by 2100. It is expected to increase by more than 3 °C during fall and winter. Furthermore, an increase of more than 4 °C and more than 5 °C is expected during spring and summer, respectively.

Based on the simulated temperature increase, the expected degree day was calculated and compared to the

Fig. 8 The reduced growth period of wheat in different regions, using different scenarios to the year 2100

degree day calculated based on the observed temperature during 1961 to 1990 for the wheat growth period (autumn to spring). Using the A1ASF scenario, the expected degree day was 4,316.56 and 5,190.16 for 2025 and 2100, respectively. On the other hand, expected degree day was 4,116.66 and 4,494.76 for 2025 and 2100, respectively, using the WRE350 scenario. Higher values were expected using the B2HIMI scenario. It was expected to be 4,286.53 in 2025 and to be 4,679.65 on 2100.

By comparing the ration for different regions, it was expected to increase by 3.14, 12.98, 10.98, and 9.71 % for the southern, central, western, and northern regions by 2050, respectively. By 2100, the rate increase is expected to be 24.6, 21.8, 17.8, and 14.9 % for southern, central, western, northern regions, respectively. Considering the obtained results, the growth period of wheat until the end of the century is expected to be shorter in duration. The reduction of the wheat growth period for different scenarios is shown in Fig. 8.

It can be seen that the minimum reduction period is expected to be 21.3 days for northern areas. Reduction period of 22.3, 23.9, 26.7, and 32.3 days is expected for the western, central, southern, and eastern regions by the year 2050. Longer reduction periods are expected for all regions by the year 2100.

Conclusions

The objective of this paper was to derive and analyze present and future climate projections over the regions of wheat production over Iran. In addition, the projected future climate fluctuation results are used to assist the maximum performance of wheat and to be used as the main basis for planning changes in the farming calendar in Iran. Using the statistical trend analysis, winter months did not show any significant trends for all the regions. On the other hand, maximum mean temperature increase trend was recorded during summer. With regards to the correlation of degree day and temperature with CO_2 in Mauna Loa, the minimum effect can be seen over the south and west regions.

Using different scenarios, it was expected that the mean temperature increase to range between 0.1 °C by 2025 and 2 °C by 2100 using the most optimistic scenario. On the other hand, the mean temperature increase is expected to reach 4 °C by 2100 using the most pessimistic scenario.

Finally, it was also concluded that the wheat growth period will be negatively affected due to the increase of the temperature. The growth period is expected to be shorter by 21.3, 22.3, 23.9, 26.7, and 32.3 days for the northern, western, central, southern, and eastern regions by the year 2050.

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