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ORIGINAL ARTICLE

Simulating Climate change Impacts on Wheat Production in Gorgan, Iran

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ABSTRACT
In order to evaluate the effect of N and P bio fertilizers on yield and yield components was laid out the environment in which crops will be grown in the future will change. Climate change can be expected to impact on agriculture, potentially threatening established aspects of farming systems but also providing opportunities for improvements. This study investigated the impacts of elevatedatmosphericCO2 concentrations and associated changes in climate on winter wheat yields in Gorgan, Iran. The analysis was based on climate change predictions of two global circulation models (GCMs) for two greenhouse gas emission scenarios (A1B and A2) during three time periods in the 21st century (2020, 2055 and 2090). Climate change predictions by two GCMs used in this study suggested a consistent pattern of increase in mean season air temperature and this increase is more pronounced under the aggressive emission scenario. Two models suggest various levels of reduction in radiation, under all scenarios and all time periods and in all cases the amounts of reduction for summer were greater than other seasons. Season precipitation experienced various levels of reduction, although with less variability than air temperature, depending on the model used and the scenario considered. A simple simulation model for wheat (SSM) successfully simulated contemporary wheat yields. Irrigated and rain fed wheat yield change by -2.35 to 9.21% and 17.2 to 82.56% under future climate conditions, respectively. It can be concluded that increase in the amount of carbon dioxide in future climate conditions in Gorgan can compensate the negative effects of rise in temperature.
Keywords: Iran, Wheat, Climate Change, Modeling

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is known as one of the crop rotation components in arid, semiarid and sub-humid environments in the world with total cultivated area ca. 225 × 10^6 ha(1). Wheat is a strategic agricultural production that has important center station rule in production and consumption food in Iran. Despite technological advances, such as improved crop varieties and irrigation systems, weather and climate are still key factors in agricultural productivity [2].It is widely accepted that projected climate changes associated with increasing atmospheric concentrations of greenhouse gases will fundamentally alter the magnitude and the seasonal variations of temperature and precipitation patterns in many parts of the globe(IPCC[1]) [3].Therefore climate change can be expected to impact on agriculture, potentially threatening established aspects of farming systems but also providing opportunities for improvements [4].

Ecophysiological models are widely used to simulate the potential impacts of environmental factors on agricultural and natural ecosystems [5-7]. An especially active area of application is in research on potential impacts of climate change [8].The scenarios for these studies are created by changing the observed data of the current climate, according to doubled CO_2 climate simulations of General Circulation Models (GCMs). Then the responses of crop models to these scenarios are examined (e.g., [9] on rice; [10] on maize; [11] on sunflower and chickpea, [12] and [13] on chickpea and [14] on wheat).

Richter and Semenov [15] simulated wheat production in England and Wales and the results of their study showed that due to increase in CO_2 concentration in 2050, wheat yield will be increased up to 23%. Another example of the potential of climate change impacts on agriculture is illustrated in a study by

[1]- Intergovernmental Panel of Climate Change

Özdogan [14] in which he assessed the potential impact on Turkey wheat production and showed that under climatic change conditions, winter wheat yields were predicted to decline between 5 and 35 percent, depending on the GCM input used.
Increasing CO_2 concentration affects plant processes in two ways: by direct impact on different physiological processes in plant and by indirect impact through changes in temperature and precipitation. The ultimate effect of increasing CO_2 concentrations and related climate change on crops strongly depends on the current environmental conditions at a location Ludwig and Asseng [16].
Wheat yield is very sensitive to inter annual weather variations, because the Eco-physiological factors affecting crop production are less suited to plants growth and development for the most parts of Iran. Wheat yield varies from year to year, largely as a result of highly variable weather condition, and therefore there is an increasing concern about climate change and its effects on wheat production. Hence this study was taken up to assess the impacts of climate change using the scenarios of A1B and A2 for 2011-30 (2020), 2045-2065 (2055) and 2080-99 (2090) climates to investigate the effect of future climate changes on wheat production in Gorgan, Iran.

MATERIALS AND METHODS

Study site and observed climatic data

This study area is located in northern Iran (Gorgan centred at 36° 51′ N, 54° 16′ E and 13 m asl). Gorgan is one of the most productive agricultural regions in Golestan province. Gentle topography, fertile soils, temperate climate, and moisture availability allow significant production, providing yields of 4.6 tha^{-1} (average for irrigated cultivation). Winter wheat is sown in November/December with or without irrigation and harvested in May/June. Wheat yields show significant year-to-year variability associated with the amount and timing of precipitation and cold or warm stress in critical growth stages. The fields are fertilized at least three times during the growing period.
Climate data were obtained from a synoptic weather station (Hashem-Abad) located in the study area. Extracted variables included solar radiation (MJ $m^{-2}d^{-1}$), maximum and minimum temperature (°C) and precipitation (mm). Solar-radiation data were calculated from sunshine hours using a simple program (6). Figure 1 shows long term monthly mean of rainfall, maximum and minimum temperatures based on daily data in Gorgan. Average temperature range from 7.6 °C in January to 24 °C in July with the mean annual precipitation of 537.79 mm. Gorgan is characterized by semi-humid climate. Thirty years [1983 to 2013] of daily observation from Hashem-Abad station considered as baseline period and used to drive simulation model and LARS-WG (17).

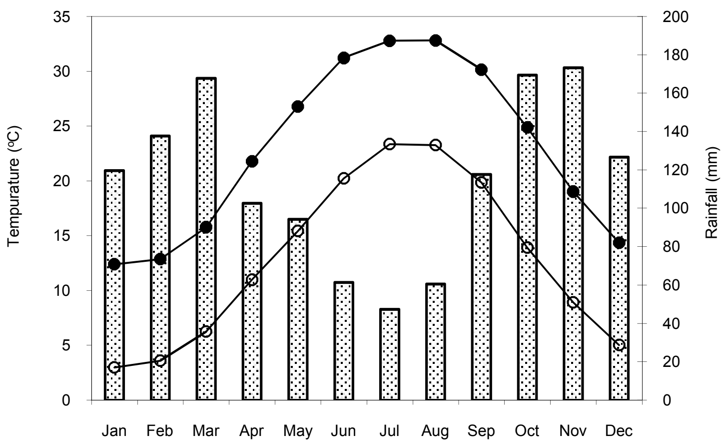


Fig. 1. Long term average monthly of rainfall (bars), maximum (filled circles) and minimum temperatures (open circles) based on daily data in Gorgan

Climate change scenarios

The climate change scenarios were constructed from the output of dailyHADGEM1[2] [18 & 19] for the land grid boxes (1.3° Latitude × 1.9° Longitude) and IPSLCM4[3] [20] for the land grid boxes (2.5° Latitude ×

[2]- Hadley Center Global Environmental Model
[3]- Institute Pierre Simon Laplace

3.75° Longitude). These models were chosen because of their high performance in prediction of climatic data among various GCMs reported by Maddah [21] for Gorgan region.
Using baseline observations, LARS-WG generated synthetic daily weather data under a series of future climate scenarios. For the climate change impact assessment, four time periods were considered: 1983–2013 (baseline), 2011–2030 (2020), 2045–2065 (2055), and 2080–2099 (2090). For emission scenarios, two storylines [3] were selected from the Special Report on Emission Scenarios (SRES). Each storyline describes a different world evolving through the 21st century, with different demographic, economic, technological, and land-use forces leading to different greenhouse gas emission trajectories. The story lines included in this research range from medium-impact (A1B) to high-impact (A2) development. The A1B storyline occurs in a world with very rapid economic growth, a global population that peaks amid-century, and rapid introduction of new and more efficient technologies along with an energy system balanced across all sources. The A2 storyline, in contrast, describes a differentiated world. Economic development is primarily regional, and technological changes are more fragmented in a world of self-reliance and continuously increasing population. Figure 2 shows schematic view illustrations of future climate scenarios used in this study. Finally, each scenario downscaled under A1B and A2 emission scenarios using LARS-WG. Because LARS WG had no database for HADGEM1 model for time period of 2080-99, these period is not investigated in this study by HADGEM1 model.

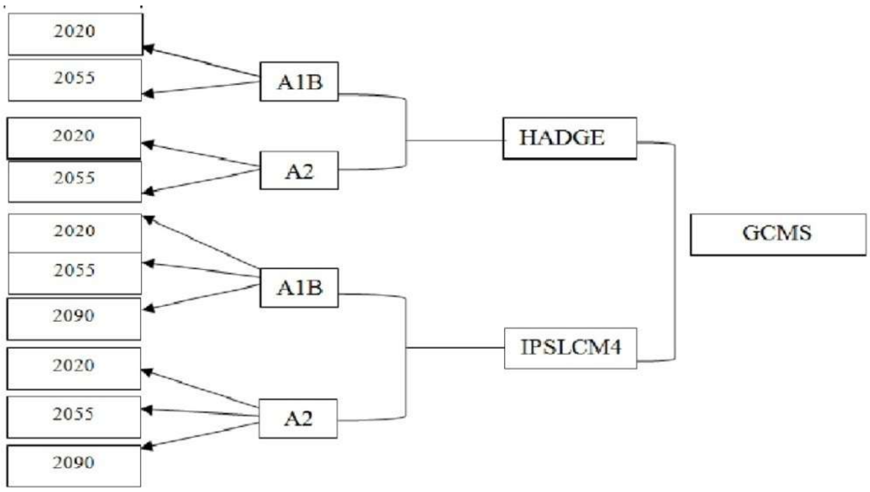


Fig 2. Schematic illustrations view of future climate scenarios (see text for further explanation).

Crop model

The SSM wheat simulation model [5] used to simulate the yield of wheat in this study. This model simulates phenological development, leaf development and senescence, mass partitioning, plant nitrogen balance, yield formation and soil water balance. Responses of crop processes to environmental factors of solar radiation, photoperiod, temperature, nitrogen and water availability, and genotype differences were included in the model. The model uses a daily time step and readily available weather and soil information. Detailed description of the model structure, procedures needed for model parameterization and model troubleshooting can be found in Soltani et al [5]. The robustness of the model has been tested by Soltani et al [5] for Gorgan region. For the purpose of modelling implications of elevated CO_2 concentrations, the SSM wheat model was extended with two functions derived from the literature (16 & 5) as follow (Eq (1)):

$$CO_2RUE = ((Ce - t) \times (C350 + 2t)) / ((Ce + 2t) \times (C350 - t)) \qquad (1)$$

Where C350 is the 350 ppm CO_2 concentration, Ce the elevated CO_2 concentration (ppm). The temperature dependent CO_2 compensation point (t)is calculated as t = (163−T)/(5−0.1T) and
t = temperature (°C), according to Bykov et al, (12).
Transpiration efficiency (TEC, g dry matter/(m2 mm water transpired)) modified by a factor that increases linearly from1 to 1.37 when the CO_2 concentration increases from 350 to 700 ppm as follow (Eq (2) and Eq (3)):

$$CO_2TEC = 0.00105715 \times CO_2 + 0.63 \qquad (2)$$

$$TEC = TEC \times CO_2TEC$$

WhereCO_2 is the elevated CO_2 concentration (ppm).The SRES scenarios andtheir associated atmospheric CO_2 concentrations used in this study are provided in Table 1.

Table 1. Atmospheric CO2 concentrations under different IPCC SRES storylines (climatechange scenarios) across a range of model years. The values in the table are partsper million (ppm) equivalent and were obtained from IPCC (2007).

	Current	2020	2055	2090
Baseline	380	-	-	-
A1B	-	418	532	717
A2	-	418	532	856

The mean yields of 1983 to 2011 were taken as baseline yield. Based on the prevailing cropping system, a certain sowing date and plant density were selected (i.e. 31 march and 350 plant.m^{-2} respectively). Soil water and nitrogen attributes were derived from measurements with a volumetric extractable soil water of 0.11 $m^{-3}m^{-3}$and a depth of 120 cm. Yield simulation were performed for both irrigated and rain fed cultivations. For simulation wheat yield in irrigated and rain fed condition parameters of Tajan and Kuhdasht cultivars as a common cultivars in the Gorgan region were used, respectively(Details of these two cultivar parameters has been described in Soltani et al., (5)). After determination of wheat yield, the standard error and coefficient of variation were calculated as follow (Eq (3) and Eq (4)):

$$SE = \frac{Sy}{\sqrt{n}} \qquad (3)$$

$$CV = \frac{S}{\bar{X}} \qquad (4)$$

Where SE is the standard error, Sy is the standard deviation, n is the number of sample and $\bar{X}$ is the average.

The crop model was run for the different years of base period under each scenario by using typical management and soil conditions, and calculated grain yield of the model output was recorded. A randomized complete-block design was used for data analysis in which climate scenarios considered as treatment and years considered as blocks. Mean comparison was done using a Least Significant Difference (LSD) procedure at 5% level.

RESULTS

Expected changes in climatic variables

The predicted means of climatic variables by the two climate models (HADGEM1 and IPSLCM4) under two climate change scenarios (A1B and A2) for three time periods are provided in Table2. The mean radiation show a consistent pattern of change. Two models under A1B and A2 scenarios predict reduction or no significant change across all times. Two models suggest various levels of reduction in radiation, under all scenarios and all time periods and in all cases the amounts of reduction for summer were greater than other seasons. The results showed that two models predict the maximum reduction of ~ 2.5 MJ. $m^{-2}d^{-1}$ for summer relative to baseline, regardless of the emission scenario and time period.

With respect to mean values of annually temperature, HADGEM1 and IPSLCM4 models show significant increases (α=0.01) under two scenarios and three time periods. In general, HADGEM1 model predicted the highest value of enhancement in temperature for spring (A1B scenario in 2055 ~2.01 °C), and IPSLCM4 model except for the A1B scenario in 2020 conditions that predicted the highest rise in temperature for winter, in other cases (5 remained scenario) showed the highest rise in temperature in summer relative to current condition. In 2090, the highest values of increase in mean temperature under A1B and A2 scenarios will be occurred in summer (~ 4.16 °C) and (~ 4.22 °C), respectively.

The HADGEM1 model predicts the amount of precipitation with no or negligible significant changes under all scenarios and all time periods. In contrast except for the A2 emission scenario under the 2055 conditions, the IPSLCM4 model predicts reduction in precipitation when compared to the baseline conditions and this decrease is larger under the A2 scenario. Details of changes in precipitation are provided in table 3.The IPSLCM4 predicts no significant changes in precipitation values for various seasons by A1B emission scenario under 2090 conditions. This model for A2 emission scenario under 2020 predicts 34 percent decrease for summer and 52 and 25 percent decrease in precipitation for summer and autumn in 2090, respectively.

The results showed that A1B scenario indicated the highest annual precipitation rate across all study scenarios for 2020 (539.67mm) time period (Table 1). However, the highest amount of annual precipitation was obtained under A2 scenario (557.41mm) for 2055. A1B and A2 scenarios showed negligible difference between values of means annual temperatures in all time periods regardless of the model (Table 2). Prudhomme et al (23) reported that mean annual warming under A1B and A2 scenarios was equal and was higher that under B1 scenario in future climate change conditions.

Table 2. Means of seasonal and annually radiation (SR, MJ $m^{-2}d^{-1}$), temperature (°C) and precipitation (mm) and prediction their values by two GCMs (HADGEM1 and IPSLCM4) based on A1B and A2 scenario for 2020, 2055 and 2099.

			Current			
Season	SR		Temp		PR	
	Mean	Sd	Mean	Sd	Mean	Sd
Spring	16.94	3.32	16.04	4.38	150.63	86.08
Summer	21.58	1.98	27.26	1.62	65.78	62.66
Autumn	13.39	2.98	19.51	4.75	166.96	113.09
Winter	9.40	1.36	8.57	1.81	154.42	71.2
Annual	15.35	0.52	17.89	0.73	537.79	90.60
			HADGEM1A1B,2020			
Season	SR		Temp		PR	
	Mean	Sd	Mean	Sd	Mean	Sd
Spring	15.51*	3.51	16.56^{ns}	4.37	152.52^{ns}	96.09
Summer	18.98**	1.39	27.41^{ns}	1.16	56.66^{ns}	69.61
Autumn	12.48^{ns}	2.76	20.13^{ns}	4.37	145.81^{ns}	90.38
Winter	8.347**	1.26	9.017^{ns}	1.11	184.68^{ns}	114.9
Annual	13.85**	0.25	18.33**	0.19	539.67^{ns}	126.0
			HADGEM1A1B,2055			
Season	SR		Temp		PR	
	Mean	Sd	Mean	Sd	Mean	Sd
Spring	15.66*	3.45	18.05**	4.43	137.78^{ns}	87.50
Summer	19.30**	1.55	29.22**	1.396	54.69^{ns}	63.82
Autumn	12.24*	2.82	21.32*	4.641	156.99^{ns}	96.74
Winter	8.22**	1.29	10.09**	1.06	171.40^{ns}	106.31
Annual	13.88**	0.22	19.72**	0.19	520.87^{ns}	110.45
			HADGEM1A2,2020			
Season	SR		Temp		PR	
	Mean	Sd	Mean	Sd	Mean	Sd
Spring	15.99^{ns}	3.49	16.93^{ns}	4.48	133.89^{ns}	77.48
Summer	19.28**	1.52	27.74*	1.20	55.69^{ns}	61.13
Autumn	12.56^{ns}	2.87	19.97^{ns}	4.53	151.03^{ns}	102.51
Winter	8.49**	1.35	9.08*	1.12	166.80^{ns}	114.18
Annual	14.10**	0.21	18.48**	0.16	507.41^{ns}	102.71
			HADGEM1A2,2055			
Season	SR		Temp		PR	
	Mean	Sd	Mean	Sd	Mean	Sd
Spring	15.79*	3.48	17.85*	4.49	138.77^{ns}	93.43
Summer	18.58**	1.33	28.64**	1.25	64.01^{ns}	64.38
Autumn	11.95**	2.80	20.94^{ns}	4.49	167.14^{ns}	113.33
Winter	8.216**	1.23	10.18**	1.20	173.88^{ns}	101.32
Annual	13.65**	0.22	19.46**	0.19	543.80^{ns}	102.38
			IPSLCM4A1B,2020			
Season	SR		Temp		PR	
	Mean	Sd	Mean	Sd	Mean	Sd
Spring	15.62*	3.45	16.68^{ns}	4.42	159.90^{ns}	100.19
Summer	18.97**	1.28	27.68^{ns}	1.27	52.79^{ns}	71.75
Autumn	12.81^{ns}	2.76	20.02^{ns}	4.42	126.01**	78.94
Winter	8.64**	1.26	9.073*	1.12	177.32^{ns}	110.37
Annual	14.03**	0.25	18.42**	0.19	516.02^{ns}	119.20

** significant (p value: 0.01). * significant (p value: 0.05). ns: non significant

Continue of table 2

Means of seasonal and annually radiation (SR, MJ $m^{-2}d^{-1}$), temperature (°C) and precipitation (mm) and prediction their values by two GCMs (HADGEM1 and IPSLCM4) based on A1B and A2 scenario for 2020, 2055 and 2099.

			IPSLCM4A1B,2055			
Season	SR		Temp		PR	
	Mean	Sd	Mean	Sd	Mean	Sd

Spring	16.11^{ns}	3.63	18.20^{**}	4.89	136.76^{ns}	98.61
Summer	19.14^{**}	1.38	29.87^{**}	1.10	40.92^{**}	41.23
Autumn	12.63^{ns}	2.82	21.16^{*}	4.84	139.38^{ns}	95.51
Winter	8.83^{**}	1.21	9.97^{**}	1.14	149.39^{ns}	85.32
Annual	14.20^{**}	0.23	19.86^{**}	0.19	466.45^{**}	82.44
			IPSLCM4A1B,2090			
Season	SR		Temp		PR	
	Mean	Sd	Mean	Sd	Mean	Sd
Spring	16.35^{ns}	3.40	19.64^{**}	4.85	123.07^{ns}	84.97
Summer	19.17^{**}	1.33	31.42^{**}	1.15	26.66^{ns}	29.26
Autumn	12.88^{ns}	2.86	22.63^{**}	4.96	133.99^{ns}	99.94
Winter	9.19^{ns}	1.39	11.04^{**}	1.11	149.99^{ns}	87.71
Annual	14.41^{**}	0.23	21.24^{**}	0.19	433.71^{**}	77.74
			IPSLCM4A2,2020			
Season	SR		Temp		PR	
	Mean	Sd	Mean	Sd	Mean	Sd
Spring	15.88^{ns}	3.63	16.53^{ns}	4.62	161.14^{ns}	109.96
Summer	19.08^{**}	1.38	27.79^{*}	1.17	42.84^{**}	44.04
Autumn	12.66^{ns}	2.85	19.59^{ns}	4.62	139.19^{ns}	95.06
Winter	8.643^{**}	1.21	8.91^{ns}	1.07	166.87^{ns}	95.37
Annual	14.09^{**}	0.23	18.26^{**}	0.19	510.04^{ns}	88.56
			IPSLCM4A2,2055			
Season	SR		Temp		PR	
	Mean	Sd	Mean	Sd	Mean	Sd
Spring	15.88^{ns}	3.56	17.84^{*}	4.72	164.64^{ns}	108.3
Summer	19.09^{**}	1.34	29.17^{**}	1.14	57.00^{ns}	61.02
Autumn	12.67^{ns}	2.80	20.59^{ns}	4.66	162.80^{ns}	95.66
Winter	8.66^{**}	1.19	9.62^{*}	1.16	172.96^{ns}	98.82
Annual	14.09^{**}	0.23	19.36^{**}	0.19	557.41^{ns}	97.21
			IPSLCM4A2,2090			
Season	SR		Temp		PR	
	Mean	Sd	Mean	Sd	Mean	Sd
Spring	16.23^{ns}	3.62	17.85^{*}	4.49	147.84^{ns}	110.48
Summer	19.14^{**}	1.39	31.84^{**}	1.06	31.54^{**}	32.92
Autumn	12.84^{ns}	2.84	22.77^{**}	5.01	124.82^{**}	97.71
Winter	8.956^{*}	1.24	11.34^{**}	1.08	161.03^{ns}	91.95
Annual	14.31^{**}	0.23	21.47^{**}	0.19	465.23^{**}	82.59

** Significant (p value: 0.01). * significant (p value: 0.05). ns: non significant

Wheat yield results under the climate change scenarios

Irrigated condition

Simulations of irrigated wheat yields revealed moderate increases or decrease under all scenarios for all time periods (Fig. 3a). For example, irrigated wheat yields in 2020 are expected to decrease -0.13 to -0.78 percent depending on the emission scenario and model. Under the medium-impact (A1B) emission, yield decreases are lower than those under the A2 scenario and they did not show any significant differences (α=0.05) related equal CO_2concentrations (Table 3).In time period of 2055, the discrepancy is larger, ranging from -2.35 to 3.62 percent between the moderate to highCO_2 scenarios. For the A1B scenario, this increase in wheat yield increase was not observed, indicating a possible threshold for CO_2related increases, at least as modelled by the IPSLCM4and HADGEM1 models. The SSM model results using the HADGEM1 GCM output under A1B scenario in 2055 suggest the highest decline (-2.35 percent) in yields (Table 3), but SSM simulated the highest value of rising in yield using IPSLCM4 output under A2 scenario for 2090 conditions.Finally, the results showed that wheat yield will not change until to 2020 but HADGEM1 model forecasts slight decrease for irrigated wheat yield in 2055 while the IPSLCM4 considered this significant change will be occurred farther in the future i.e. 2090 (Fig. 3a).Based on this observation, it is possible that further increases in atmospheric CO_2 concentrations beyond year 2080 as predicted by the A1B and the A2 emission scenarios would likely have a significant positive effect on wheat yields.

Table 3. Means of current irrigated wheat yield, simulated irrigated yield (gr m^{-2}) and change in yield (%) with HADGEM1 and IPSLCM4 under A1B and A2 scenario in 2020, 2055 and 2090.

Year	Emission scenario	GCMs	Grain yield (gr m^{-2})	Standard error	CV (%)	Yield change (%)	Standard error
Current	-	-	632.12ab	15.17	10.46	-	-
2020	A1B	HADGEM1	622.42a	8.33	5.83	-0.44a	2.83
2020	A1B	IPSLCM4	624.09a	8.60	6.01	-0.13a	2.95
2020	A2	HADGEM1	621.68a	8.36	5.86	-0.55a	2.83
2020	A2	IPSLCM4	620.87a	7.03	4.94	-0.78a	2.55
2055	A1B	HADGEM1	639.73ab	9.30	6.33	-2.35bc	3.07
2055	A1B	IPSLCM4	629.98ab	7.24	5.00	-0.66ab	2.64

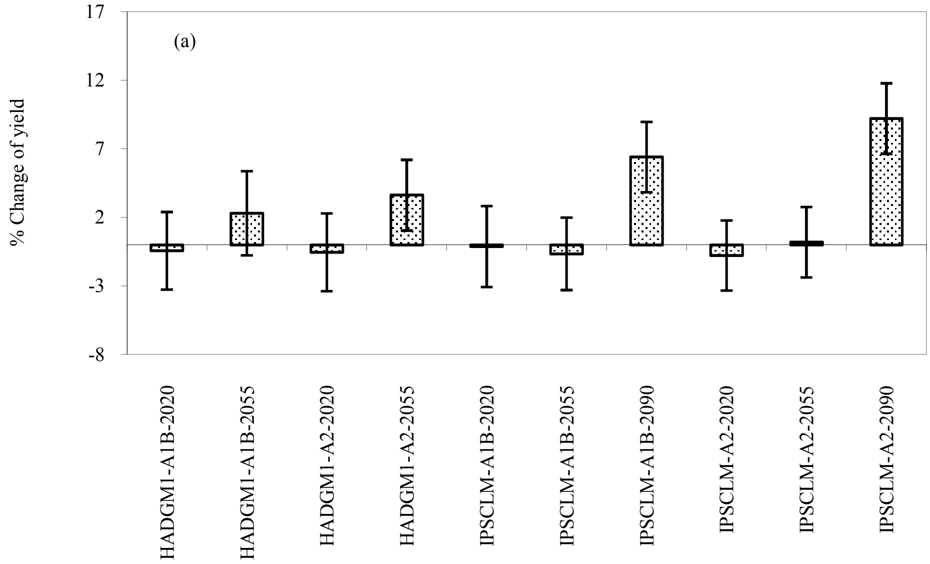
2055	A2	HADGEM1	648.58bc	6.41	4.31	3.62c	2.58
2055	A2	IPSLCM4	627.01a	6.90	4.79	0.19ab	2.56
2090	A1B	IPSLCM4	666.51cd	8.16	5.33	6.40d	2.56
2090	A2	IPSLCM4	684.56d	8.83	5.62	9.21e	2.56

Means with the same letter are not significantly different at 5% level of probability in each column

Table 4. Means of current rain fed wheat yield, simulated rain fed yield (gr m^{-2}) and change in yield (%) with HADGEM1 and IPSLCM4 under A1B and A2 scenario in 2020, 2055 and 2090.

Year	Emission scenario	GCMs	Grain yield (gr m^{-2})	Standard error	CV (%)	Yield change (%)	Standard error
Current	-	-	337.41a	25.11	32.44	-	-
2020	A1B	HADGEM1	370.40abc	14.48	17.04	23.81ab	12.36
2020	A1B	IPSLCM4	381.63bcd	15.74	17.98	27.21abc	12.48
2020	A2	HADGEM1	360.85ab	13.35	16.13	18.78a	10.61
2020	A2	IPSLCM4	357.46ab	14.23	17.36	17.20a	10.30
2055	A1B	HADGEM1	431.37e	15.56	15.72	43.38d	14.11
2055	A1B	IPSLCM4	384.34bcd	11.32	12.84	28.21abc	12.89
2055	A2	HADGEM1	403.35cde	12.13	13.11	34.54bcd	13.41
2055	A2	IPSLCM4	412.69de	15.41	16.28	36.51cd	13.25
2090	A1B	IPSLCM4	484.58f	15.95	14.35	62.51e	16.89
2090	A2	IPSLCM4	545.71g	14.92	11.92	82.56f	18.60

Means with the same letter are not significantly different at 5% level of probability in each column



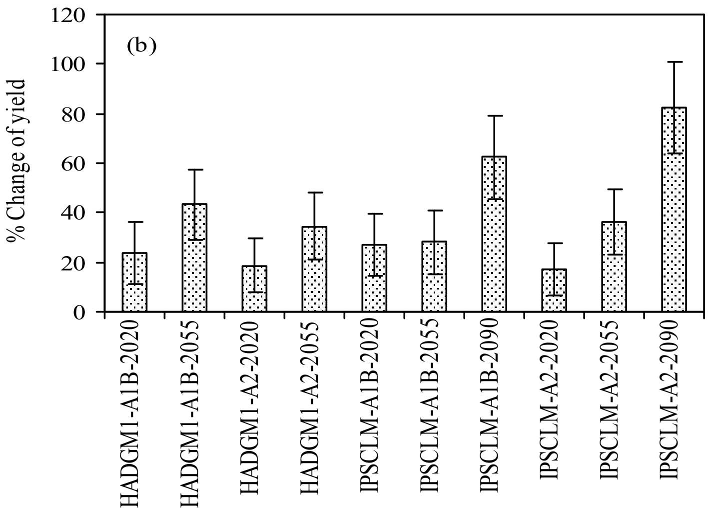


Fig 3. % change from mean yields of 1983-2011 caused by various climate change scenarios under irrigated (a) and rain fed conditions (b). Error bars represent the mean ±SE of the independent scenarios.

Rain fed condition

When changes in climatic variables investigated under rain fed conditions, the modelled wheat yields across all GCMs, emission scenarios, and time periods are consistently higher than the baseline values. However, these increase occur differently across models and time periods (Fig. 3b). For example, the SSM model results using the IPSLCM GCM output under A2 scenario in 2020 suggest the smallest increase (~17 percent) in yields, in contrast this minimum amount of increase occurs under the A1B scenario (~24percent) for HADGEM1 model (Table. 4). The results of simulations for 2055 time period showed that the amounts of rain fed yield did not reveal any significant differences between two models under A2 scenario but in contrast two models showed significant differences in term of yield change under A1B scenario. When the IPSLCM4 derived climate variables under A1B emission scenario are used in the SSM model for 2090, yields show a considerable increase, as much as62.51 percent, from the baseline (Table. 4).The largest increase in winter rain fed wheat yields occurs by more than 80% when the SSM model is forced with variables from the IPSLCM4 climate model under the high-impact (A2) scenario in 2090.The results of grain simulation showed that the percentage of change in rain fed wheat yield were more different than irrigated wheat.

DISCUSSION

According to table 1,in all of 10 cases of investigated scenarios in this study (combination of two models, two scenarios and three time periods) changes in radiation has been reported as decline (for most cases) or no change in the amount of annual mean radiation. In all cases, the maximum reduction of the radiation was in summer. Although no remarkable difference was detected between two models, the IPSLCM4 model offers more reports of statistically non-significant cases about radiation in spring and autumn seasons (in 5 non-significant cases of total 6 cases for spring and in all cases for autumn). In general, it can be concluded that the two models present the reduction in the radiation in future, with greater emphasis on reduction in the summer season. Reduction in the amounts of radiation in all simulated periods illustrate that with this declination, the amounts of grain yield of the crops that grows especially in the winter will decrease. According to the general equation for the production of dry matter in plants (6), it is possible by decreasing in the amount of radiation, the crop yield reduces. However, the positive impact of increased radiation use efficiency under these conditions must be considered.

In cold and cool environments and where crops are grown in winter, plant growth is often limited by low temperatures. Under such conditions, temperature increase due to global warming could potentially have positive effects on crop growth and hence yield (16).

The rise in temperature can also cause the increase in the amount of growing growth degree (GDD).The increases in the amount of GDD can also leads to the increase in speed of the passing development stages. It can increase the yield particularly in Gorgan for the plants that are sensitive to terminal drought stress such as wheat. Gholipour and Soltani (12) stated that the reduction in harvest index in climatic changed condition induced by drought and increased in unfavorable temperature. It seems that consistency of radiation and precipitation values and increment of the amount of temperature during the growing seasons were the main reasons for higher irrigated and rain fed wheat yields under A1B and A2 emission scenarios in 2090 in comparison with base line of wheat. In contrast the lowest irrigated wheat yield simulated under A1B emission scenario by HADGEM1 in 2055. This time period is recognized with reduction in radiation in addition to increment in temperature.

Although in many reviews of climate change effects, the amount of rainfall will be expected to increase (3), in this study, HADGEM1 model did not predict any significant differences between three time periods. Rainfall can effect on the production of crops positively or negatively, that this depends on the area of the study. In arid and semiarid regions an increase in the rainfall could leads to increase in the production. On the other hand the increase in rain fall in areas with high rainfall, with flooding conditions or excessive leaching of the nutrient can have lowering effect on crops (24).

The results of this study were in agreement with the estimates of Koocheki et al (25) that predicted a decrease in irrigated wheat yield in 2050s in Iran. Although they reported reduction of 13 to 28% in wheat grain yield for irrigated condition, they stated that the amount of reduction is depend on location and the GCMs used in each studies.

Although the increase in CO_2 concentration in irrigated agriculture condition with no water limitation can increased the plant biomass and grain yield, the reduction in incident solar radiation and increase in temperature specially in filling grain period can reduce harvest index (26). These factors will cause no change in the amount of yield in irrigated conditions in future. In addition, in case of rain fed wheat production in future we will detect an increase in wheat yield in Gorgan. Enhanced temperature can be lead to early ripening of the wheat and this can help wheat to escape from late season droughts stress. Golipour and Soltani (12) and Hajarpour et al., (13) reported the increase in the chickpea yield in rain fed condition as a result of enhancement in transpiration efficiency in increased CO_2 condition. In fact, they believed that in climatic changed condition, the amount of obtained photosynthesis per consumed water is higher. Moreover, the reduction in stomatal conductance in this condition can enhance the grain yield.

It seems that in Gorgan and in the rain fed condition, negative effects of the shortening of growth period due to increase in temperature, can be compensated by higher value of radiation use efficiency and transpiration efficiency in the reduced radiation condition in future, avoidance of late-season terminal drought and higher level of net photosynthesis. Increase in the wheat photosynthesis and radiation use efficiency due to enhanced CO_2 has been reported by number of evidences (27, 28 & 29).Results of this study is comparable with the results of studies that indicated the increase in wheat grain yield will occur in future climatic condition (30, 31 &32).The results of this study was in contrast to reports of Nassiri et al., (33) that stated reduction in rain fed wheat plant will occur in 2025 and 2055.

CONCLUSSION

This study investigated the impacts of elevatedatmosphericCO2 concentrations and associated changes in climate on winter wheat yields in northern Iran.With change in climate, the crop model predicted positive and negative changes in irrigated wheat yields and positive changes in rain fed wheat yields across all scenarios and all time periods. The main reason for the yield variations appears to be temperature increase that not only shortens the vegetative duration, and more importantly the grain filling period, through speed up the developmental processes. All of these changes are further exacerbated by significant decline in precipitation in some time periods. In contrast, negative effects of the shortening of growth period due to increase in temperature, can be compensated by higher value of radiation use efficiency and transpiration efficiency in the reduced radiation condition in future, avoidance of late-season terminal drought and higher level of net photosynthesis.Results showed that in future climatic conditions of Gorgan, the yield of irrigated and rain fed wheat would be changed between -2.25-9.21% and 17-82%.

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