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FULL LENGTH ARTICLE

Assessing climate change impacts on wheat production (a case study)

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Abstract Climate change is one of the major challenges facing humanity in the future and effect of climate change has been detrimental to agricultural industry. The aim of this study was to simulate the effects of climate change on the maturity period, leaf area index (LAI), biomass and grain yield of wheat under future climate change for the Sistan and Baluchestan region in Iran. For this purpose, two general circulation models HadCM3 and IPCM4 under three scenarios A1B, B1 and A2 in three time periods 2020, 2050 and 2080 were used. LARS-WG model was used for simulating climatic parameters for each period and CERES-Wheat model was used to simulate wheat growth. The results of model evaluation showed that LARS-WG had appropriate prediction for climatic parameters and simulation of stochastic growing season in future climate change conditions for the studied region. Wheat growing season period in all scenarios of climate change was reduced compared to the current situation. Possible reasons were the increase in temperature rate and the accelerated growth stages of wheat. This reduction in B1 scenario was less than A1B and A2 scenarios. Maximum wheat LAI in all scenarios, except scenario A1B in 2050, is decreased compared to the current situation. Yield and biological yield of wheat in both general circulation models under all scenarios and all times were reduced in comparison with current conditions and the lowest reduction was related to B1 scenario. In general, the results showed that wheat production in the future will be affected by climate change and will decrease in the studied region. To reduce these risks, the impact of climate change mitigation strategies and management systems for crop adaptation to climate change conditions should be considered.

1. Introduction

In the recent years, visible changes in temperature and rainfall in both the global and regional aspects were known as climate change phenomenon in terms of amount and time of occurrence and consequently have exerted different impacts on the inputs and agricultural production (Wolf, 2002). Researchers of the related sciences have disagreements in the area of causes

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and nature of climate changes, but it seems that in the past decades the climate change impacts and especially its ecological consequences have been so apparent that many of these contradictions have been resolved. The main factor in increasing the greenhouse effect, is the increase in the concentration of gases CO_2, CH_4 and N_2O and types of Halo-Carbons (like CFC) due to the human activities; these gases have an essential role in absorbing the solar radiation that the climate system is also affected by this issue (Tubiello et al., 2000).

Although the climate change in some areas of the world, particularly the areas located within the northern widths above 55°, will have positive effects on agricultural production (Ewert et al., 2005), but the negative impacts of these changes will be so severe in hot and dry areas (Parry et al., 2004; Gregory et al., 2005), so in developing countries the rise in temperature and the decrease in rainfall have been more severe (Sivakumar et al., 2005), and moreover the frequency and intensity of the occurrence of rare climatic phenomena (drought, heat, coldness and flood) will also be intensified (IPCC, 2007). Undoubtedly, any change in climatic condition will affect the agricultural production systems of the world.

Although in recent years, experiments conducted in controlled environments, have provided a lot of information about the impacts of rise in temperature degree and carbon dioxide concentration on plants' growth and development processes, but these studies are very costly and their implementation depends on the exact instruments (Koocheki et al., 2001). Development of modeling techniques is a suitable and low-cost substitute for these types of studies that has already been considered by researchers. General circulation model (GCM) is the right and accurate tool for the prediction of future climatic condition and provides necessary data to run simulation models of the crops' growth and development under climate change condition (Jones and Thornton, 2003). The work of these models is based on global warming and the impact of rise in greenhouse gas concentration and the climatic subsequent consequences are predicted on the basis of the rise of land surface temperature. Because the future climate change depends on the intensity of global warming, predicting the future temperature of the earth is of special importance (Morison, 2006). Global circulation model is a mathematical estimation of the natural climate systems which offer on atmospheric circulation and energy exchange between the main components of the climate systems as a model.

Obtaining more precise information about the phenomenon of climate change in Iran requires further studies on a regional scale and the prediction of agricultural production systems' response to these changes in each region. Our country belongs to the arid and semiarid areas which are more sensitive to environmental changes and more vulnerable due to their special ecological structures. So it seems that the occurrence of probable climatic changes in these regions has a significant impact on agricultural production systems (Fisher et al., 1994). However despite the world's most arid and semiarid areas have been located in developing countries, studies and scientific researches related to climate change impacts in these areas are very limited. The results of studies related to climate changes that have been done in recent years in Iran, all have confirmed the occurrence of this phenomenon in the country. Koocheki and Nassiri (2008) have studied the climate change impact on the water yield of the country by using a growth simulation model and on the basis of various scenarios of climate change and reported that on average the wheat yield in the country will be reduced in the range between 14% and 21%.

Prediction and premonition of how climate change acts and its impact on agricultural department can help the human to deal with these changes. By predicting the extent and intensity of climate change, the crop production changes can be specified in different regions and it can also affect the sustainability of agricultural production especially in arid and semiarid areas. So the purpose of this study is to evaluate the performance of CERES-wheat model and the simulation of the climate change impacts on phonological stages, leaf area index (LAI), biomass and grain yield of wheat plant in the studied region.

2. Material and methods

2.1. Study area

Sistan and Baluchestan region covers an area of about 178,502 km^2. The province is located in the southeast of Iran, within 2503 and 31027 north latitude and and 631021 east longitude.

2.2. Data set and climate model

The IPCC has defined standard greenhouse gas emission scenarios for use in the evaluation of projected climate change based on various socioeconomic, technological and energy use factors (IPCC, 2007). The SRES-A2 scenario indicated very heterogeneous world conditions with high population growth rate, slight economic development and slow technological change (Prudhomme et al., 2010). The SRES-B1 defines a convergent world with a global population that peaks in mid-century and rapid changes in economic structures toward a service and information economy (Wetterhall et al., 2009) and the SRES-A1B scenario describes a world of rapid economic growth, a global population that peaks in mid-century and more efficient technologies based on a balanced energy mix (Olesen et al., 2011). Two GCM models under three scenarios were used to project climate change effects on wheat in this study. Daily climate data including, solar radiation, maximum and minimum air temperature (°C) and precipitation (mm) were obtained for the period of 1975–2010 for studied region meteorological station. The GCM models include the United Kingdom Met Office Hadley Center (HadCM3) (Mitchell et al., 1995) and Institute Pierre Simon Laplace (IPCM4) (Semenov and Stratonovitch, 2010) and scenarios were SRES-A2, SRES-B1 and SRES-A1B.

In this study, LARS-WG was used to produce daily climatically parameters as one stochastic growing season for each projection period. This one year data included radiation, maximum and minimum air temperature and precipitation of location for four projection times (1975–2010 (baseline), 2020, 2050 and 2080). LARS-WG is a stochastic weather generator based on the series approach (Semenov and Stratonovitch, 2010). LARS-WG produces synthetic daily time series of solar radiation, maximum and minimum temperature and precipita-