SIMULATION OF CLIMATE CHANGE IMPACT ON WHEAT PRODUCTION IN THE TIARET REGION OF ALGERIA USING THE DSSAT MODEL

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Abstract

It is now commonly accepted that climate changes is expected to have important effects on diverse economic sectors. Agricultural sector is particularly exposed to changes with climate variability and change due to its influence on production. Predicting the potential effects of climate change on crop yields requires a model witch simulate the crop respond to weather variation. Crop models have been used extensively to predict yield response to various SRES (Special Report Emission Scenarios) scenarios of climate change. The main objective of this study is the use of DSSAT model to simulate and to estimate wheat yield prediction under two climate change scenarios (A2 and B1) in the Tiaret region for adaptation measures and mitigation. The simulation results obtained from this study revealed that the use of the model DSSAT provides an efficient method for evaluating impact of changing climate on wheat production. Adaptation measures to mitigate the potential impact of climate change included possible changes in sowing dates and genotype selection.

Keywords: Algeria, Climate change, DSSAT, Wheat

Introduction

Materials and methods

Model Description

The DSSAT model is well known and use wide collection of crop simulation models (for more than 20 different crops) , computer programs integrated into a single software package in order to facilitate the application of crop simulation models in research and decision making (Tsuji et al., 1994 ; Hoogenboom et al., 1999, 2004).

The model simulates, in daily steps, wheat phenology development from presowing to harvest; photosynthesis and plant growth; biomass allocation to root, stem, leaf, and grains; and soil water and nutrient movement. The input data required by model DSSAT include weather records, soil properties, plant characteristics, and crop management. The Output file contains the overview of input conditions and crop performance, summary of soil characteristics and cultivar coefficients, crop and soil status at the main development stages, temporal distribution of crop variables and soil water content.

Simulation experiments

Simulation experiments were performed with experimental factors: (a) Input parameters describing genotype and soil characteristics derived in a previous calibration and testing study, against data from field experiments located in an experimental farm center at Tiaret (Rezzoug et al., 2008); (b) Input parameters describing the crop management file was performed with experimental factors as derived in an earlier study (Rezzoug and Gabrielle, 2009); These experimental factors included cultivar Vitron, planting date was set to day of year (DOY) 330, and plant density to 300 plants. m^{-2} ; (c) Input parameters describing weather file were performed with two climate scenario. The Intergovernmental Panel on Climate Change (IPCC 2001) a scenario defined the climate scenario as ‘‘a coherent, internally consistent and plausible description of a possible future state of the world’’. Two future climate scenarios (A2 and B1) were used to evaluate the impact of future climate change for the period (2021-2050) which was acquired from the ARPEGE climate model, (Déqué et al., 2010). Two emission scenarios were selected to analyze two possible evolutions of climatic characteristics from those proposed by SRES (Special Report on Emission Scenarios): (1) scenario A2, characterized by a medium-high greenhouse gases emission; (2) scenario B1, characterized by low to medium greenhouse gases emission.

Results

Scenario simulations of wheat yield based on past weather data (1986-2005)

Figure 1 compares monthly rainfall data between the historical observation series at Tiaret weather station and the GCM output data for the period (1986-2005). Real observations were lower in few of the cases than the modelled values, especially in the drier months (June and July), and up to 20% higher in April and May. This period are important and corresponds to the wheat grain filling period, during this period wheat is sensitive to water shortage. In our region, rainfall has a high variability.

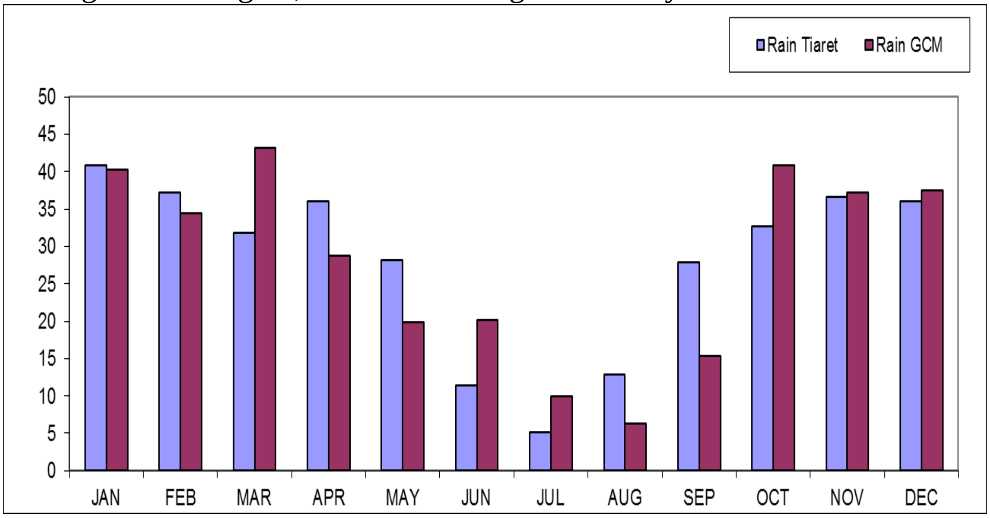


Figure 1: Monthly rainfall data (mm) for Tiaret weather station and GCM output for the period 1986-2005.

The cumulative probability distribution for Tiaret rainfall data and GCM precipitations output data was drawn (Fig. 2). Fitting to the Gamma cumulative probability distributions resulted in good performance relative to correctly producing rainfall amounts across the studied period. Variability of rainfall was also adequate up to the 90th percentile. With a maximum of 544 and minimum of 121. Observed and generated probabilities are in good agreement.

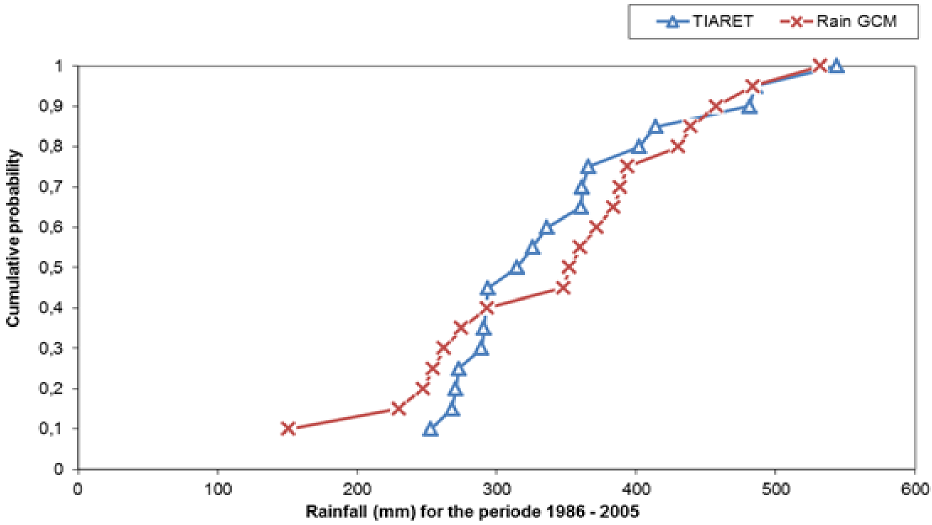


Figure 2: Cumulative probability distribution of rainfall for data derived from GCM and observed at the station of Tiaret (1986-2005).

The cumulative probability distribution of the simulated grain yield using weather data derived from the GCM and ground observations at Tiaret is shown on Fig. 3. The first and third quartiles simulated grain yield with data observed at the station of Tiaret were lower than derived from GCM.

The difference in simulating grain yields was influenced by the variability of the rainfall distribution during the growing season. Thus, correlation analysis was used to quantify the impacts of rainfall on simulated wheat grain yields (Fig.4). The regression analysis results show that the grain yield is positively correlated to the precipitations data.

Three out of 12 generated months were found to have a significantly different distribution from the observed data (Fig.1). These months are: March, June, and October. Such difference distributions explain the difference in simulating grain yields. During these months, growth rates would be altered; for example, March corresponds to the tillering stage and an altered rainfall distribution during this month may lead to an incorrect estimation of grain yield.

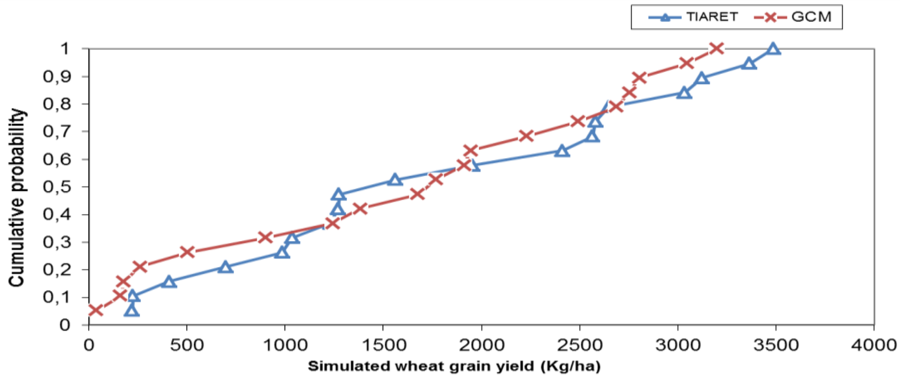
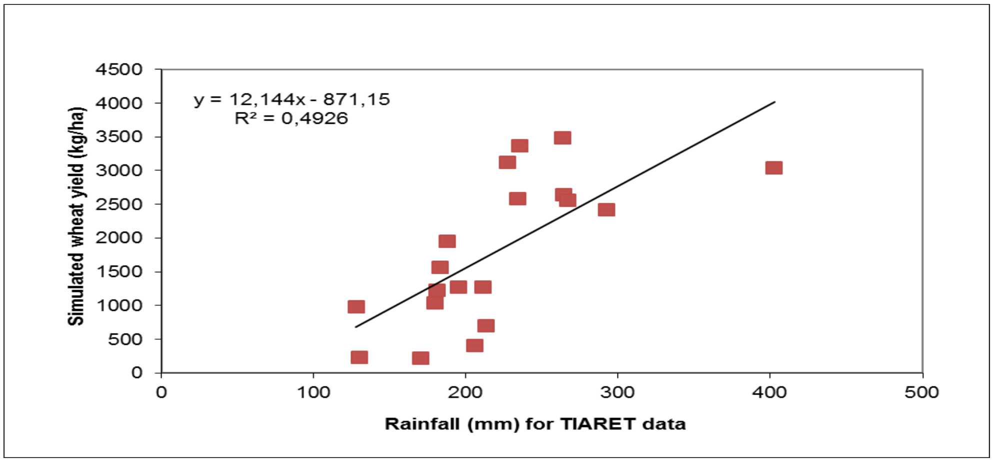


Figure 3: Cumulative probability distribution of simulated wheat grain yield of vitron cultivar and rainfall data derived from GCM for Tiaret (1986-2005).



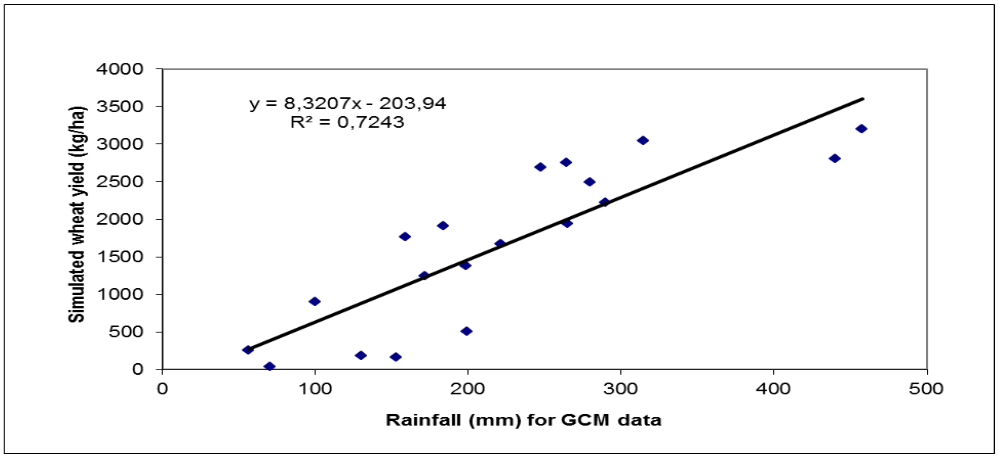


Figure 4: regression line between simulated grain yield (kg/ha) and rainfall GCM data for Tiaret region.

Climate change scenarios

Data presented in (Table 1) showed the historic and the predicted values by year 2050 of some climate parameters temperature (C°), rainfall (mm) and global solar radiation (MJ.m^{-2}).

Results revealed that temperature would increase. The increasing in the temperature concern all the months. While the opposite trend will be noticeable regarding precipitation except for a few months (June, September, and October). Concerning solar radiation, there is a slight difference between the observed data and the GCM Scenarios output values.

Table 1. Mean monthly rainfall (mm), temperature max and min (°C), global solar radiation (Mj.m^{-2}) for historic data collected over the period 1986-2005 at Tiaret and climate Scenarios A2 and B1 data over the period (2021-2050).

	Historic Data (1986- 2005)				Climate Scenario B1 data (2021-2050)				Climate Scenario A2 data (2021-2050)			
Month	Rainfall (mm)	Tmax (C°)	Tmin (C°)	Ray (Mj.m^{-2})	Rainfall (mm)	Tmax (C°)	Tmin (C°)	Ray (Mj. m^{-2})	Rainfall (mm)	Tmax (C°)	Tmin (C°)	Ray (Mj. m^{-2})
1	40.8	10.90	0.00	10.07	34.5	11.66	0.26	10.34	32.4	11.58	0.19	10.34
2	37.2	12.81	0.57	14.45	30.0	14.20	1.80	14.30	38.1	14.12	2.26	13.94
3	31.8	15.76	3.22	18.50	33.9	17.04	4.12	18.84	40.2	17.16	4.62	18.28
4	36.0	19.69	6.37	23.66	39.0	20.56	7.39	23.05	30.0	20.77	7.51	23.61
5	28.2	23.81	10.27	25.78	28.2	25.01	11.70	25.67	23.4	25.03	11.77	25.48
6	11.4	28.77	15.46	27.06	22.2	29.14	16.33	26.89	26.1	29.69	17.28	26.18
7	05.1	32.66	18.56	27.03	11.1	33.71	20.06	26.64	09.0	33.80	20.33	26.24
8	12.9	32.22	18.24	25.86	09.0	33.44	20.07	25.50	08.1	33.20	20.19	25.18
9	27.9	26.93	15.08	19.52	24.9	27.43	16.32	19.01	28.5	27.67	16.71	18.68
10	32.7	20.23	9.46	14.97	35.4	20.76	10.17	14.90	42.3	21.31	11.00	14.89
11	36.6	14.78	3.88	11.13	29.4	15.28	3.95	11.38	38.1	15.23	4.50	10.92
12	36.0	10.79	- 0.43	9.12	27.6	12.09	0.75	9.21	34.8	11.82	1.26	8.86

Scenario simulations of wheat yield based on past weather data (1986-2005) and future weather scenarios (2021-2050)

The potential impact of climate change on wheat production was evaluated by simulating wheat cultivar production based on past weather and future climate (figure 5). Simulation results showed variations in simulating wheat grain yield. The DSSAT model predicted an increased yield of wheat under the two scenarios for the period (2021-2050). Comparing to Giglio et al., (2010) reported, in a temporal-spatial study using the model DSSAT, that durum wheat yields were predicted to increase under different GCMs climate change scenarios, in southern Italy. However, the change in the sowing dates has an effect on simulated grain yield. Using the same sowing date Ventrella et al., (2012) , reported no negative yield effects of climate change were observed for winter durum wheat with delayed sowing (from 330 to 345 DOY) increasing the average dry matter grain yield under forecasted scenarios using the model DSSAT, in southern Italy.

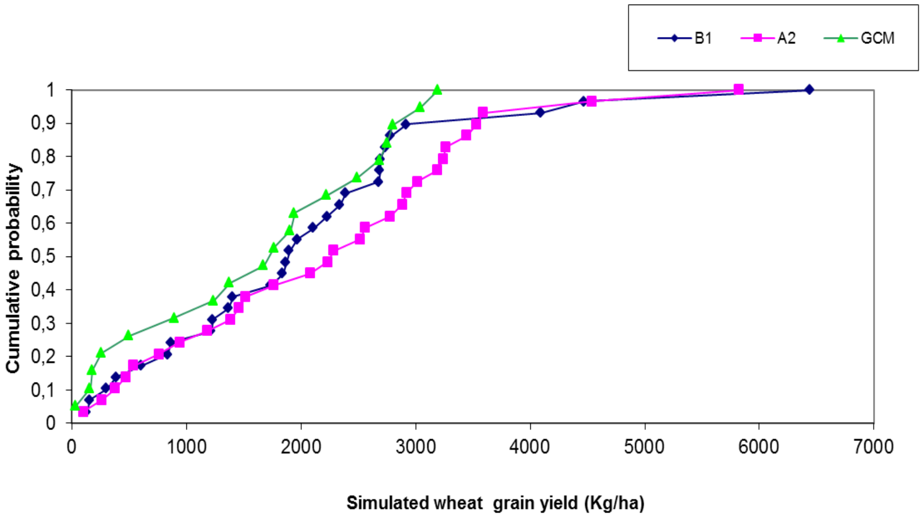


Figure 5: Grain yield (kg ha-1) simulated of vitron cultivar for the period (1986-2005) with data derived from GCM and for data of Scenario A2 and B1 for the period (2021- 2050)

Discussion

Although the effect of climate change on wheat yields in Algeria has not been investigated yet, the results obtained here may be compared with studies from neighboring regions or covering larger areas. Giannakopoulos et al., 2009 reported on climate change over the Mediterranean basin in 2031–2060, when a 2 °C global warming is most likely to occur larger than the trend obtained here with the 2 climate scenarios; however precipitation and surface temperature changes are examined through mean and extreme values analysis, under the A2 and B2 emission scenarios. The same author reported the dry season tends to shift towards autumn, with the exception of the south of France and Algeria where it would start and end 2 weeks earlier on average.

Many of impact studies were aimed at assessing crop development shifts and yield variations under changes in mean climate conditions. These studies showed, changes in yields were not homogeneous and dependent on crop phenology (e.g. summer and winter crops type (e.g. C3 and C4 plants) or environmental conditions (water and nutrient availability) (Giannakopoulos et al., 2009)

In a Mediterranean type environment the correct choice of sowing date and cultivar are critical determinants of yield (Connor et al., 1992; Turner, 2004).

The real challenge under climate change conditions is to use adaptation strategies, which are improved agricultural management practices, to reduce the damage of climate change on the yield.

Finally, the DSSAT model was run introducing adaptation management strategies (Rezzoug and Gabrielle 2009) that may reduce the negative impact of climate change and variability on crop yield, especially in vulnerable regions where agriculture is most sensitive to climatic fluctuation.

Conclusion

Projecting agricultural crop, such as wheat yield under future climate plays a fundamental part in planning for supply and demand, especially in developing countries. The crop simulation model is a suitable tool for evaluating the potential impacts of climate change on crop production. The simulation results obtained from this study revealed that the use of the model DSSAT provides an efficient method for evaluating impact of changing climate on wheat production. The application of IPCC scenarios (A2 and B1) for the period 2021 and 2050 (lower and higher impact scenarios) on wheat production in the Tiaret region of Algerian did not show a major change. It is possible to explain this situation by respecting the selection of optimal management strategies as derived in an earlier study (Rezzoug and Gabrielle, 2009).

Adaptation measures to mitigate the potential impact of climate change include possible changes in sowing dates and genotype selection.

The DSSAT model demonstrated being a powerful tool to simulate the effect of climate change in crop production. It can be considered a good tool for decision support at farm level to test crop management strategies and at global scale to evaluate crop response to climate change.

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