POSSIBLE EFFECTS OF CLIMATE CHANGE ON SUGARCANE DEVELOPMENT AND WATER USE IN SOUTHWEST OF IRAN

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ABSTRACT

Water and food security are the key challenges under climate change as both are highly affected by continuously changing climatic patterns. In this study, attempts have been made to study the effects of climate change on length of growing season and water use of sugarcane under RCP scenarios in 4 stations of Khuzestan province, southwest of Iran, namely Abadan, Ahvaz, Bostan and Dezful. The outputs of EC-EARTH global climate model data which are dynamically downscaled by Swedish Meteorological and Hydrological Institute (SMHI) under RCP 8.5 and 4.5 scenarios were used as future projections. The climatic observed data of 4 study stations were collected and used to calibrate the model down-scaled outputs. The changes of precipitation, crop evapotranspiration and length of growing period of sugarcane were worked out. The results showed that except for Dezful station, growing season rainfall would increase comparing to climatic normal. Besides, the length of growing season under RCP8.5 scenario would decrease significantly in all stations. Future trend of evapotranspiration changes was less than 5% and non-significant. Continuous investigation in other climates of the country is undertaken for further scrutiny.

Keywords: Drought Sugarcane, Iran, Climate change, Scenario,CMIP5.

1. INTRODUCTION

The study of climate change effects on crop growth and water use plays a major role in maintaining food security. As a direct consequence of warmer temperatures, the hydrologic cycle will undergo significant impact with accompanying changes in the rates of precipitation and evaporation. Climate change will cause changes in climate variable such as precipitation, temperature, sunshine hours, wind speed and etc. So, as a result of climatic variables change, the related parameters such as potential evapotranspiration and length of growing season will change too. As the soft computing skills increased in recent decades, more number of climate models has been developed for weather and climate predictions which have significantly improved the quality and quantity of projections. This notable increase in number of climate models has enabled the scientists to estimate a wide range of main climate variables such as precipitation and temperature in fine temporal and spatial resolution. Although the uncertainty in model outputs remains a main challenge. Upon release of new scenarios based on Radiative Forcing which are known as Representative Concentration Pathway scenarios (RCP scenarios), by Intergovernmental panel on climate change (IPCC) in fifth assessment report (AR5), a new set of 42 global climate models (GCMs) have been proposed for future climate projections.United Nation Food and Agriculture Organization proposed the new approach of climate smart agrciture in 2010, as a guideline for adapting agriculture to

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climate change sequences.The first step in impact assessment studies is selecting suitable climate models from those recommended by IPCC for obtaing required climatic data under ceratin scenarios.Few studies have been done so far in Iran for choosing proper models (Ghahreman *et al.* 2015).The uncertaintity of different models of CMIP5 project which are approved in fifth assessment report (AR5) of IPCC in projection of temperatre and rainfall data have been evaluated .The CSM1.1(m), MPI-ESM-MR, PI-ESM-LR, BCC were found to be the best models for projection of rainfall and MPI-ESM-MR, CESM1(BGC.) models were for projection of temperature respectively, based on bias and RMSE statisitics.The secons step is investigation the the effect climate change on crop growth and developlemnt (length of growth season). Meuller et al (2015) investigated changes in an annual temperature-based index, the growing season length, defined as the number of days with temperature above 5 °C. They showed that over extratropical regions where maize and wheat are harvested, the increase in growing season length from 1956 to 2005 can be attributed to increasing greenhouse gas concentrations.In another study, Downscaled climate model projections from phase 5 of the Coupled Model Intercomparison Project (CMIP5) were used to force a dynamic vegetation agricultural model (Agro-IBIS) and simulate yield responses to historical climate and two future emissions scenarios for maize in the U.S. Midwest and wheat in southeastern Australia. In addition to mean changes in yield, the frequency of high- and low-yield years was related to changing local hydroclimatic conditions. Particular emphasis was on the seasonal cycle of climatic variables during extreme-yield years and links to crop growth. Downscaled climate model projections from phase 5 of the Coupled Model Intercomparison Project (CMIP5) were used to force a dynamic vegetation agricultural model (Agro-IBIS) and simulate yield responses to historical climate and two future emissions scenarios for maize in the U.S. Midwest and wheat in southeastern Australia. (Ummenhofer *et al.* 2015) In addition to mean changes in yield, the frequency of high- and low-yield years was related to changing local hydroclimatic conditions. Particular emphasis was on the seasonal cycle of climatic variables during extreme-yield years and links to crop growth. For southeastern Australia, the frequency of low-yield years rises dramatically in the twenty-first century because of significant projected drying during the growing season. By the late twenty-first century, MMM growing season precipitation in southeastern Australia is projected to decrease by 15%, temperatures are projected to increase by 2.8°–4.5°C, and wheat yields are projected to decline by 70%. Results highlight the sensitivity of yield projections to the nature of hydroclimatic changes. Climate change is expected to have important consequences for sugarcane production in the world, especially in the developing countries because of relatively low adaptive capacity, high vulnerability to natural hazards, and poor forecasting systems and mitigating strategies (Zhao and Li 2015). de Carvalho et al.(2015) reported that based on A1B scenario, the potential yield can be reduced in the near future (2014–2040). The high temperatures in northeastern Brazil will increase the evapotranspiration rates, reducing the amount of soil moisture, making the planting of sugarcane increasingly difficult, which tend to be strongly reduced in drier areas, such as cities located in the , northern state of Pernambuco, Brazil. Similarily, Kumar and Sharma(2014) showed that sugarecane productivity positively get afftect by increasing average temperature in rainy season and winter in India.Previous studies of authors revealed that sugarecane growing season rainfall in southwest of Iran during the next five decades (2021 to 2070) would not significately changed comraing to baseline period of 1991-2005 under RCP4.5 and RCP8.5 scenarios (Ghahreman and Tabatabaei 2015). Few studies on impact assessment of climate change on crop production using RCP scenarios have been performed so far, in Iran, hence the aim of this study is initiation of series of researches on application of models and scenarios recommended in IPCC AR5 for several crops in Iran.

2. METHODS

2.1 Study stations

The four study staions namely Abadan,Ahwaz,Bostan and Dezful are located in Khuzestan province, southweat of Iran (Figure 1). The geograp[hiclal and climatic characteristic of study stations are proived in Table 1.

Figure 1. Geographical location of Khuzestan province in southwest of Iran

Table 1. Geographic and climatic information of synoptic stations used in the study

Station	Rainfall(mm)	Temperature(°C)	Altitude(m)	Latitude(°)	longtitude(°)
Abadan	172.7	26	6.6	30.37	48.25
Ahwaz	242.6	25.8	22.5	31.33	48.67
Bostan	203.8	24.9	7.8	31.72	48
Dezful	338.4	24.8	143	32.40	48.38

Sugarecane is a C4 crop which is grown in tropical and semi tropical climates. Khuzestan province produces about 95 % of coutry's sugarecane .Three different date of sowing and required growing degree days chosen in this study for investigation the effects of climate change on lengrth of growing season are given in table 2.

Table 2. Date of sowing (DOS) ,required GDD and base temperature chosen for study region

Date of sowing (Julian Day)	Upper threshold of Tmax	T_{base}	GDD	Sowing period in the region
270 - 260 - 250	35	12	1300	Sep 15th to October 10th

1.2. Correction of climatic data

The projected values obtained from climate models were corrected based on a propsed method for correction of standard deviation and mean of historical data for baseline period. In this method,the observed and hindcast data values for baseline period are used to correct the projected values of future, as follows :

$$STD_{fut} = \frac{STD_{base}^{obs}}{STD_{base}^{GCM}} \times STD_{fut}^{GCM} \quad (1)$$

Where, STD_{fut} standard deviation of for future period, STD_{base}^{obs} standard deviation of observed data for baseline period. STD_{base}^{GCM} standard deviation of data for bvaseline period, STD_{fut}^{GCM} standard deviation of projected data for future period.Similarily, the mean values were corrected as suggested by deCarvalho et al.(2015):

$$Mean_{fut} = \frac{Mean_{base}^{obs}}{Mean_{base}^{GCM}} \times Mean_{fut}^{GCM} \quad (2)$$

The corresponding daily values of rainfall and precipitation obtained by equation 1 and 2 were converted to monthly and annual values to be used for calculation of evapotranspiration by Penman –Monteith equation.(Allen et al.2006)

$$PET = \frac{0.408\Delta(R_{net}-G)+\gamma\frac{900}{T_{2m}}U_{2m}(e_s-e_a)}{\Delta+\gamma(1+0.34U_{2m})} \quad (3)$$

1.3. Calculation of GDD

$$\boldsymbol{T_{avg} = (T_{min} + T_{max})/2} \quad (4)$$

$$\sum(\boldsymbol{daily\ GDD}) = \boldsymbol{0}\ \ \boldsymbol{when}\ \ \boldsymbol{T_{avg} \le T_{base}}$$
$$\sum(\boldsymbol{daily\ GDD}) = \sum(\boldsymbol{T_{avg} - T_{base}})\ \ \boldsymbol{when}\ \ \boldsymbol{T_{base} < T_{avg} < T_{up}}$$
$$\sum(\boldsymbol{daily\ GDD}) = \sum(\boldsymbol{T_{up} - T_{base}})\ \ \boldsymbol{when}\ \ \boldsymbol{T_{avg} \ge T_{up}}$$

Where, T_{max},T_{min},T_{base} and T_{avg} are Maximum,Minimum ,base and mean temperature respectively.(Hur and Ahn 2014).

1.4 Crop coefficents

The required crop coeffiecents for calculation of sugarecane evapotranspiration were retrived from FAO 56 publication (Allen et al. 2006).

Table 4. Crop coefficients for different growth stages of sugarecane

Kc	Length of Stage	Stage
0.4	95	intial
1.25	135	Mid
0.75	50	Late season

Projected length of period for entire growing season (LGP) under RCP 4.5 and 8.5 were worked out and compared with baseline values in each study stations.

3. RESULTS AND DISSCUSION

The results of comparison of baseline and projected values of precipitation (Pr), crop evapotranspiration ETc and length of growing seson(LGP) are shown in Table 5 and Figure 2.

Table 5. Percentage of change of different parameters in study station

Station		DOS	Pr		ETc		LGP	
			RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
a	Abadan	Sept 07	0	23	-1	-9	-5	-14
		Sept 17	-2	21	6	-3	-6	-15
		Sept 27	35	-9	5	-1	-6	-16
b	Ahwaz	Sept 07	13	9	-2	-7	-6	-14
		Sept 17	6	1	4	-2	-6	-15
		Sept 27	35	-7	4	-3	-6	-16
c	Bostan	Sept 07	2	6	-5	-8	-7	-15
		Sept 17	-6	-12	4	-3	-7	-16
		Sept 27	11	-9	2	-2	-8	-17
d	Dezful	Sept 07	-2	-4	-6	-5	-7	-15
		Sept 17	-14	-15	0	-3	-7	-17
		Sept 27	2	-22	-1	-4	-8	-20

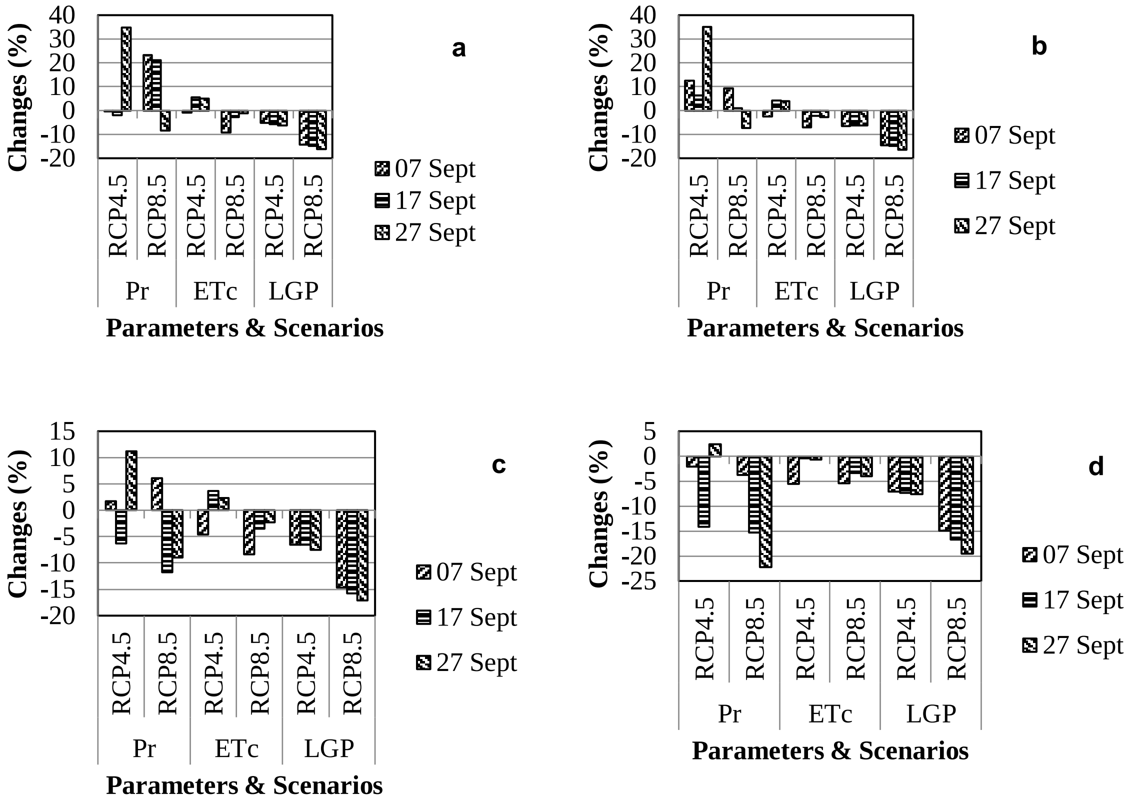

Figure 2. Pecentage of Change of precipitation (Pr), crop evapotranspiration (ETc) and length of growing seson (LGP) for Abadan (a), Ahwaz (b), Bostan (c) and Dezful (d) under two RCP scenarios.

According to results, for Abadan station, the presipitaion would increase significanetly under both scenarios, but crop evapotranspiration does not show a significant change. Length of growing season would decrease under both scenarios.As seen in Fig1.b, in Ahwas under both scenarios, the precipitatin would increase comparing to long term histirical normals,by the end of century, but evapotranspiration would remain almost same.Among the different dates of sowing ,September 7th is the best one,as the most decrease in evapotranspiration and most increase in precipitation would occur during the corresponding growth season.Lenght of season would not affected by change of DOS. The results for Bostan station is almost same to Ahwaz,the LGP would dercrease under both scenarios which the dercrease would be more in case of RCP 8.5. In Dezful station the change of DOS from 7.to 27th September would led to 20 % decrease in LGP.The results are somewhat coincide by findings of previpus studies.(Deresa *et al* 2005, Jones *et al*. 2014). As indicated by Zhao and Li (2015) the yield variations are due to internnnual changes in rainfall and temperature and climate of study region.Most of studies have emphasized on significant effect of temperature on sugarecane development and evapotraspiration. The increase in ETc in the region would somehow compensated by precipitation increase.The significant change of LGP under both scenarios have been confirmed in all stations, so it is recommended to pay more attention to future trend of temperature which mainly governs the LGP.

4. CONCLUSION

In this study, the changes in length of growing season, precpitaiton and evapotranspiration of sugarecane crop under two RCP scenarios in four stations located in south west of iran was examined.In Abadan,Ahwas and Bostan stations, the cropping situation would improve considering the increase in precipitaion and decrease in ET_C. But, in Dezful station, due to significant decrese in precipitation continous cultivation of this crop can not be recommended.More studies using other climate models and correction approaches is recommended for more scrutiny in other regions of the country

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