ASSESSING THE IMPACT OF CLIMATE CHANGE IN PONNANIYAR BASIN OF TAMIL NADU BASED ON REGCM 4.4 SIMULATIONS

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ABSTRACT:

Climate change induced extreme weather events such as drought and flood condition are likely to become more common and associated impacts on crop production will be more without proper irrigation planning. The present investigation was undertaken for assessing the impact of Climate change on tomato yield and water use efficiency (WUE) using AquaCrop model and RegCM 4.4 simulations. The water driven AquaCrop model was validated based on observation of field experiment conducted with four different dates of sowing (1st November, 15th November, 1st December, 15th December) at Ponnaniyar basin, Tiruchirappalli. Validation of AquaCrop model indicated the capability of AquaCrop in predicting tomato yield, biomass and WUE close to the observed data. Seasonal maximum and minimum temperatures over Tiruchirappalli are projected to increase in the mid-century under both RCP4.5 and RCP8.5 scenarios. Maximum temperature is expected to increase up to 1.7°C/2.5 °C in SWM and 1.9 °C / 2.9°C in NEM by the mid of century as projected through stabilization (RCP 4.5) and overshoot emission (RCP 8.5) pathways. Minimum temperature is expected to increase up to 1.6°C/2.2 °C in SWM and 1.6 °C / 2.1°C in NEM by the mid of century as projected through stabilization (RCP 4.5) and overshoot emission (RCP 8.5) pathways. Seasonal rainfall over Tiruchirappalli is expected to decrease with RCP4.5 and RCP8.5scenarios with different magnitude. Rainfall is expected to change to the tune of -1/-11per cent in SWM and -2 / -14 per cent in NEM by the mid of century as projected through stabilization (RCP 4.5) and overshoot emission (RCP 8.5) pathways.

1. INTRODUCTION

Water is *ess*ential for growing food, for household water uses, a critical input for industry, tourism and cultural purposes, and for its role in sustaining the earth's ecosystems. But this essential resource is under threat. Growing national, regional, and seasonal water scarcities in much of the world pose severe challenges for national governments and international development and environmental communities (Rosegrant *et al*., 2002). In the changing climate, water scarcity is an increasingly important issue in many parts of the world. This is especially the case in arid and semiarid regions, which are exposed to frequent droughts and restricted supply of good quality water limiting crop production. Insufficient water supply for irrigation will be the norm rather than the exception, and irrigation management will shift from emphasizing production per unit area towards maximizing the production per unit of water consumed (the water productivity). There is an urgent need to optimize water use in order to maximize crop yields under water deficit conditions (Fereres and Soriano, 2007). The primary objective of this study is to determine quantitatively the expected changes of water availability and Tomato yield in the Ponnaniyar basin for future climate scenarios. This gives an opportunity to define the degree of vulnerability of water resources in the Ponnaniyar basin.

2. MATERIALS AND METHODS

2.1 Location

The field experiment was conducted in a Farmers field at Ponnaniyar basin, Mugavanur village, Vaiyampatti block of Tiruchirappalli district. The experimental site is situated at 10.51° N latitude and 78.21° E longitude at an altitude of 78.17 m above mean sea level.

2.2 Input requirement for setting up AquaCrop

AquaCrop model uses a relative small number of explicit parameters and largely intuitive input variables, either widely used or requiring simple methods for their determination. Input consists of weather data, crop and soil characteristics, and management practices that define the environment in which the crop will developed.

2.3 Impact of current climate variability on water productivity of Tomato

To understand the impact of current variability of climate on water productivity of Tomato weather data at daily time steps for a period from 1980 to 2010 was obtained from the observatory located at Anbil Dharmalingam Agricultural College and Research Institute (ADAC&RI), Tiruchirappalli. Climate data file was generated with entire dataset of rainfall, maximum temperature, minimum temperature, sunshine hours, wind speed and relative humidity in AquaCrop model. The simulation was performed for 31 years and extracted the required data (fruit yield, ET) from the output file and assessed the impact of climate variability on Tomato crop water productivity. The water driven AquaCrop model was validated based on observation of field experiment conducted with four different dates of sowing (1st November, 15th November, 1st December, 15th December) at Ponnaniyar basin, Tiruchirappalli.

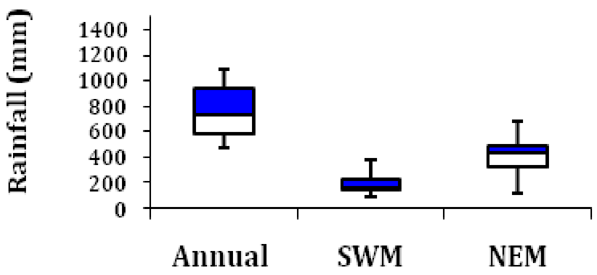
2.4 Impact of future climate projection on water productivity of Tomato

For the impact analysis, future climate data obtained from the GCM (CCSM 4) with regional climate model namely RegCM 4.4 was used for the mid-century (2040 – 2069) time slice based on RCP4.5 and 8.5 scenarios. AquaCrop model forced with the future climatic data and other input files were used similarly which were used with current climatic runs. In the model, the data on the CO2 concentration respective to RCP4.5 and RCP8.5 are available in the file name of RCP4-5.CO2 and RCP8-5.CO2. In.CO2 file the CO2 concentration is given based on IPCC data from 1902 to 2100. In the model, defined the CO2 concentration for future scenarios by choosing.CO2 files corresponding to RCP4.5 and RCP8.5 scenarios. The data were extracted from the model simulations and analysed for evaluating the impact of climate change on water productivity in tomato.

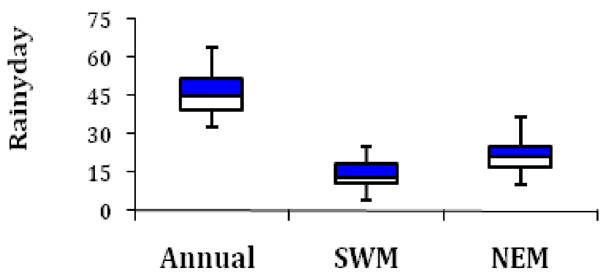
3. RESULTS AND DISCUSSION

3.1 Current climate data analysis

Weather parameters of Tiruchirappalli region were analysed for the base period from 1980 to 2010 to understand its climatology. Annual normal rainfall of Tiruchirappalli is found to be 766 mm and this rainfall is received through 46 rainy days. Among the monsoons. Northeast monsoon (NEM) had higher amount of rainfall 412 mm received in 21 rainy days followed by Southwest monsoon (SWM) with 196 mm of rainfall received in 14 rainy days. Comparing the boxplots depicted in (Fig. 1). SWM shows less variability than NEM. But the quantity of rainfall received in SWM is not sufficient for crop production while NEM receives enough rainfall for raising the crops successfully.



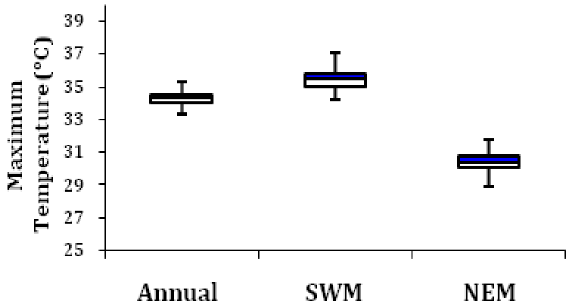
A) Baseline rainfall of Tiruchirappalli



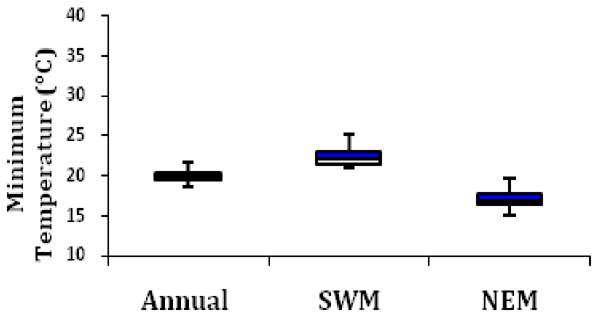
B) Baseline rainy days of Tiruchirappalli

Figure 1. Baseline rainfall and rainy days of Tiruchirappalli

Normal annual maximum temperature of Tiruchirappalli is 34.3°C and during SWM it is 35.5°C followed by NEM 30.4°C. Normal annual minimum temperature is 20.0°C and that of SWM is 22.3°C followed by NEM 17.2°C. In both maximum and minimum temperature. SWM has higher temperature range than NEM (Fig. 2).



A) Maximum temperature of Tiruchirappalli



B) Minimum Temperature of Tiruchirappalli

Figure 2. Maximum and Minimum temperature of Tiruchirappalli

3.2 Anticipated changes in future climate of Tiruchirappalli

3.2.1 Temperature: Maximum and minimum temperature of was projected to increase by the model studied. Though variation in magnitude exist between the scenarios (RCP4.5 and RCP8.5). both projected an increment for maximum and minimum temperatures during mid-century time scale. probably due to increased concentration of greenhouse gases in the atmosphere as indicated by IPCC (2014).

Both. the stabilization scenario RCP 4.5 as well as the overshoot scenario RCP 8.5. projected an increase in temperature. Among the monsoons. increase in SWM is (RCP 4.5:1.7°C and RCP 8.5: 2.5°C) maximum temperature. which is comparatively lesser than that of NEM (RCP 4.5: 1.9 °C and RCP 8.5: 2.9°C) for projections through both the scenarios (Table. 1). For minimum temperature. the range of increase projected for SWM (RCP 4.5:1.6°C and RCP 8.5: 2.2°C). which is comparatively higher than that of temperature projections for NEM (RCP 4.5: 1.6°C and RCP 8.5: 2.1°C). A similar higher range of increase during SWM period was also reported by Kothawale and Rupakumar (2005); Rupakumar et al. (2006) over parts of India.

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The appreciable difference in the temperature projection between the monsoon seasons could also be attributed to the seasonal wind shifts during monsoon period and the nature of orography in Tamil Nadu (Jegankumar et al. 2012). Relative change in the magnitude of maximum and minimum temperature was compared. Interestingly. both the RCP scenario has projected a higher range of increase for maximum temperature than that of minimum temperature over Tiruchirappalli during mid-century.

3.2.2 Rainfall: Monsoon rainfall projection over Tiruchirappalli was studied as it plays vital role in rain fed agriculture of Tamil Nadu. Among the monsoons. irrespective of the scenarios. SWM is projected to have a decrease (RCP 4.5: -1 % and RCP 8.5: -11 %) and NEM is also projected to receive a decreased rainfall of 2 (RCP 4.5) and 14 per cent (RCP 8.5). The appreciable difference in the rainfall projection between the monsoon seasons could be attributed to the seasonal wind shifts during monsoon period and the nature of orography in Tamil Nadu (Jegankumar et al. 2012).

Time scale	Change in Maximum (°C)		Change in Minimum (°C)		Precipitation Change (%)	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP8 .5	RCP 4.5	RCP8 .5
SWM	1.7	2.5	1.6	2.2	-1	-11
NEM	1.9	2.9	1.6	2.1	-2	-14

Table 1. Future climatic projection based on RCP4.5 and RCP8.5 scenarios

3.3 Assessing the impact of Current climate variability and future climate projection On Water Use Efficiency of Tomato

Tomato productivity during *Rabi* season ranged from 31.4 to 42.2 with mean of 35.1 t ha^{-1} under current climate. WUE was varied from 54.7 to 73.9 kg ha^{-1} mm^{-1} with the mean of 63.3 kg ha^{-1} mm^{-1}. In RCP 4.5 scenario the tomato productivity and WUE is expected to decrease and tomato productivity was ranged from 24.7 to 37.1 with mean of 31.7 t ha^{-1}. WUE was varied from 47.2 to 67.5 kg ha^{-1} mm^{-1} with the mean of 59.90 Kg ha^{-1} mm^{-1}. In RCP 8.5 scenario the tomato productivity and WUE is expected to decrease and tomato productivity was ranged from 25.3 to 36.9 with mean of 30.6 t ha^{-1}. WUE was varied from 46.4 to 71.5 Kg ha^{-1} mm^{-1} with the mean of 54.30 Kg ha^{-1} mm^{-1}. (Table 1.) These results are in harmony with the finding of Weiguang *et al*. (2012). Tomato and WUE was varied over 30 years. Tomato yield varied between -9.6 to -12.8 per cent and WUE varied between -5.3 and -14.2 per cent. (Table 2.) Different climatic conditions prevailed during cropping between the years might have influenced yield and WUE of tomato. Climate variability has been principal source of fluctuations in Indian food production. Even though there is no long-term trend. inter - annual variability of Indian monsoon rainfall leading to frequent droughts and floods has profound influence on agriculture (Rajeevan and Pie. 2006)

Years (1980-2009)	Current climate		Years (2040-2069)	RCP 4.5		RCP 8.5	
	Yield	WUE		Yield	WU E	Yiel d	WU E
1980	32.6	57.4	2040	35.8	67.4	30.1	50
1981	33.4	60.6	2041	33.8	67.5	29.7	54.2
1982	32.6	64.5	2042	24.7	47.2	25.3	48.9
1983	38.2	70.2	2043	33.8	58.1	32.9	57.2
1984	38.2	62.1	2044	30.6	59.6	35.3	55.1
1985	31.4	57.8	2045	30.9	62.1	27.7	51.1
1986	33.0	62.4	2046	30.1	57.4	26.9	50.9
1987	33.0	54.7	2047	37.1	67.1	30.9	51.8
1988	35.0	60.8	2048	34.9	62.7	29.7	46.4
1989	37.0	68.1	2049	29.3	57.0	31.3	57.4
1990	33.0	57.9	2050	29.3	58.1	30.9	50.4
1991	35.8	67.3	2051	27.4	52.1	30.5	54.7
1992	37.4	73.7	2052	33.3	62.5	30.5	56.2
1993	32.2	62.0	2053	28.1	52.5	31.3	60.3
1994	33.0	58.1	2054	32.0	54.5	28.9	51.5
1995	36.2	63.3	2055	36.6	64.6	27.3	49.1
1996	38.6	66.9	2056	31.4	60.0	32.9	54.4
1997	34.6	61.6	2057	32.1	56.1	30.5	57.4
1998	37.8	64.2	2058	33.1	60.8	31.3	54.3
1999	32.6	57.7	2059	32.6	65.4	30.5	52.8
2000	35.4	68.6	2060	27.5	54.8	29.3	55.6
2001	35.8	61.5	2061	35.6	59.8	33.3	58.2
2002	31.4	57.8	2062	28.0	56.7	27.7	48.6
2003	33.0	61.3	2063	26.2	66.3	28.5	51.5
2004	36.2	68.7	2064	31.6	60.4	28.1	50.7
2005	36.2	64.4	2065	35.1	62.4	32.9	60.2
2006	36.6	66.0	2066	34.7	64.0	31.3	57.3
2007	37.4	64.5	2067	35.0	62.0	32.5	56
2008	42.2	73.9	2068	28.0	59.0	32.1	54.7
2009	34.2	60.4	2069	31.3	59.3	36.9	71.5
Mean	**35.1**	**63.3**		**31.7**	**59.9**	**30.6**	**54.3**

Table 2. Tomato productivity and WUE for the current (1980-2009) and future (2040 – 2069) climate (RCP 4.5 and RCP 8.5) in *Rabi* season

Results showed that future climate would negatively impact the tomato productivity and WUE. As per future projections tomato yield is expected to decrease in the range of 9.6 to 12.8 per cent with the mean decrease of 11.2 per cent. WUE is expected to decrease between 5.3 and 14.2 with the mean of 9.7 per cent. In the future WUE reduced might be due to higher crop water requirement (ET) with fewer yields under warming conditions. These results are in harmony with the finding of Weiguang *et al.* (2012). Doll (2002) found increases in evaporative demands lead to increase the need for irrigation worldwide, with relative changes in total, about +5–8 per cent by 2070. Studies undertaken by Chattopadhyay and Hulme (1997) for Indian sub-continent indicated likely increase of potential evapotranspiration for future warming. The current investigation indicates that extreme rainfall situations such as deficit and excess conditions are affecting the tomato yield and water productivity. Optimization of irrigation through analysing the response of tomato to deficit and excess rainfall conditions could improve the yield and WUE of tomato.

4. Conclusion

Future climate would negatively impact the tomato productivity and WUE. As per RCP 8.5 scenario, tomato yield is expected to decrease in the range of 12.6 to 19.4 per cent with the mean decrease of 13 per cent. WUE is expected to decrease between

3.3 and 15.1 with the mean of 14.3 per cent. In the future WUE reduced might be due to higher crop water requirement (ET) with fewer yields under warming conditions.

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