Indian Journal of Ecology (2022) 49(2): 477-482
DOI: https://doi.org/10.55362/IJE/2022/3548

Manuscript Number: 3548
NAAS Rating: 5.79

Assessment of Climate Change on Crop Water Requirement of Different Crops using CROPWAT model in Bapatla Region

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Abstract: This study investigated possible implications of climate change (in terms of temperature, wind speed, relative humidity) on crop water requirements (CWRs) by 2050s using CROPWAT 8.0 model in Bapatla region. On an average, 1°C rise in temperature may increase the overall CWR by 2-3% in this region. Increase in CWR due to 3°C increase in temperature is observed as 16.59, 0.54 and 1.59 MCM for the crops rice, maize and pulses respectively. For rice crop, the CWR showed 2.3, 6.52 and 8.75% increase from the average CWR (1375.1 mm) due to increase in 1, 2 and 3°C respectively. Similar trend was observed in the case of other major crops in this region such as chillies, maize, cotton, pulses, tomato and vegetables. Similarly change in the wind speed and relative humidity has the demonstrative effects on crop water requirements. This study might be useful in explaining the negative effects of climate change on CWR in Bapatla region and better planning for water resources management.

Keywords: Climate change, Crop water requirement, CROPWAT 8.0 model, Water demand

Water is an important natural resource for all forms of life and it is becoming scarce natural resource in the future owing to climate change, which aggravates the present situation. Water resources are inextricably linked with climate (Rao et al 2011). The population of India is expected to stabilize around 1640 million by the year 2050. The gross per capita water availability in India will decline from ~1820 m^3/yr in 2001 to as low as ~1140m^3/yr in 2050 (IPCC, 2007). Total water requirement of the country for various activities around the year 2050 has been assessed to be 1450 km^3/yr. This is significantly more than the current estimate of utilizable water resource potential (1122 km^3/yr) through conventional development strategies. Therefore, when compared with the availability of ~500 km^3/year at present the water availability around 2050 needs to be almost trebled (Gupta and Deshpande 2004, Babu et al 2014). Almost 60% of India's agriculture is rain-fed, making the country highly dependent on groundwater. In India average temperature may increase 2°C with 1.0 - 4.0°C at extreme ranges by the 2050s. Under 2°C warming, the country may need to import more than twice the amount of food-grain than would be required without climate change. Crop water requirement (CWR) is the depth of water needed to meet the water loss through evapotranspiration of a disease-free crop growing in large fields under non restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment. The amount of water needed by the various crops to grow optimally. The potential evapotranspiration (ET_p) of a crop is the volume of water required by it to meet its evapotranspiration requirements (Raju et al 2016).

Climate change may impose further stress on the availability of water and agricultural productions. Past studies reported that the negative effects from climate change can affect agricultural sector (Ziad and Sireen 2010, Chowdhury and Al-Zahrani 2013, Falguni and Pramodchandra 2013). Increase in temperature, change in relative humidity and wind speed, variable rainfall patterns and interactions of other meteorological parameters may have negative effects on crop water requirements. Increase in temperature by 1°C may change the thermal limits of the crop, which may lead to 5-25% decrease in crop productions (Al Zawad and Aksakal 2010). For better management of available natural water resources and agricultural productions, it is essential to understand CWR, present level of water supplies and possible effects of climate change in future. To apply irrigation water efficiently, the water requirement of the crops is to be estimated accurately. Past studies indicated that CROPWAT software could be a reliable tool to better understand Crop Water Requirement, irrigation planning and manage irrigation scheduling (Kang et al 2009). Keeping in view of the above facts, the present study is planned to evaluate the impacts of climate change on crop water requirements of different crops for the Bapatla region.

MATERIAL AND METHODS

Study area: The study area is Bapatla lies between the coordinates of 15°54′16″N latitude and 80°28′3″E longitude with an average altitude of 6 m above the mean sea level (MSL). It is one of the 57 mandals in Guntur district.

Agro-Climatic conditions: Bapatla comes under humid sub-tropical area and is very close to the coast with very hot summer and cool winter**.** The maximum and minimum temperatures are 38.6^{0}C during May month and 17.6^{0}C during January month respectively with an average air temperature is 28.4^{0}C. The mean relative humidity ranged from 62 to 80 % with an average of 75%. The average wind speed is equal to 8.68 km/hr, while the annual precipitation ranges from 666-1392 mm with normal rainfall 1120mm. The soils in the study area are broadly classified as Black cotton, Red loamy and sandy loamy. The predominant crops grown in the study area are paddy and maize among cereals, blackgram, green gram and red gram among pulses, cotton and chillies among non-food and commercial crops and vegetables including tomato crop. The meteorological data collected from the meteorological station at College Farm, Bapatla and analyzed for the finding variation in meteorological factors.

Estimation of crop water requirements due to impact of climate change: CWRs were influenced mainly by climate factors and change trends. Changes in the water requirement of different crops affected mainly by meteorological factors, such as temperature, average relative humidity and wind speed. Estimation of the CWR was carried out by the appropriate climate and rainfall data sets, together with soil and crop data files and the corresponding planting dates. Based on the climate data, rainfall data, crop data, cropping pattern data and soil data fed to the CROPWAT 8.0 model, the CWRs were estimated for Bapatla region. The changes in temperature are positive and the temperature will be increased by year 2050s is to be expected 2.0^{0}C. Similarly, the changes in the relative humidity and wind speed expected in the range of 5 to 10% and the CWRs of different crop were estimated under different climate scenarios to find out the impact of climate change on CWR.

RESULTS AND DISCUSSION

Rainfall: The annual average rainfall of Bapatla over 10 years (2006 - 2015) is 1120 mm with the maximum rainfall occurred during the year of 2010 was 1898.4mm and minimum rainfall occurred in the year of 2009 was 666.6 mm (Fig. 1). The effective rainfall was computed using the average annual rainfall data and the average effective rainfall over 10 years is estimated as 839.9 mm with the maximum effective rainfall was 1100.7 mm during 2010 and minimum effective rainfall was 480.7 mm during 2009 (Table 1 and Fig. 2).

Changing trends of meteorological factors: The trend of average temperature increased sharply with the change in the decade is 1.2^{0}C at the rate of 0.12^{0}C per year. It was increased continuously from 32.6^{0}C in the 2006 to 33.8^{0}C in the 2015 (Table 2). Average temperature was the meteorological factor that showed a marked change. The

Table 1. Annual rainfall and their effective rainfall of the study area

Year	Rainfall (mm)	Effective rainfall (mm)
2006	1195.6	760.8
2007	1392.5	805.3
2008	1074.2	817.8
2009	666.6	480.7
2010	1898.4	1100.7
2011	791.2	632.5
2012	1066.9	771.1
2013	1553.5	889.3
2014	676.8	552.9
2015	891.3	587.5
Average	1120.0	839.9

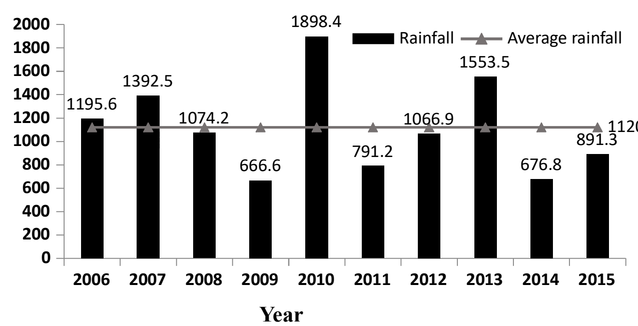

Fig. 1. Rainfall data of Bapatla region from (2006-2015)

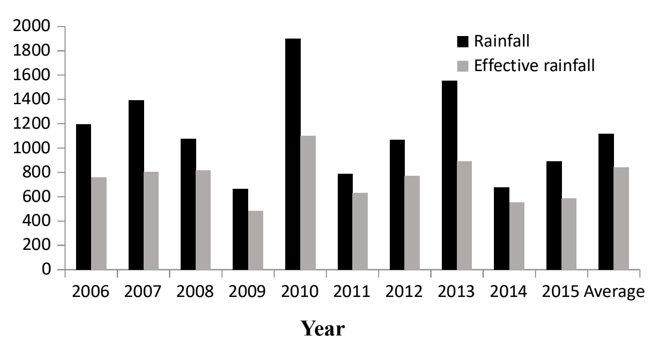

Fig. 2. Rainfall and effective rainfall data of Bapatla region (2006-2015)

effective rainfall was 1100.7 mm during 2010 and minimum effective rainfall was 480.7 mm during 2009 (Table 1 and Fig. 2).

Changing trends of meteorological factors: The trend of average temperature increased sharply with the change in the decade is 1.2^{0}C at the rate of 0.12^{0}C per year. It was increased continuously from 32.6^{0}C in the 2006 to 33.8^{0}C in the 2015 (Table 2). Average temperature was the meteorological factor that showed a marked change. The trend of average wind speeds have many variations with no definite trend during the period 2006 to 2015 and it was decreased from 233 km/hr in the 2006 to 196 km/hr in the 2015 with 10 to 20 % change. Similarly a descending trend in overall average humidity was detected from 78% to 73% with the change in the decade is 5 % and the decline in average relative humidity was consistent with the rise in the temperature. Reference evapotranspiration (ET_o) varies in range of 5.70 to 6.00 mm/day (Table 2). The ET_o increases gradually from 2006 to 2015 approximately at the rate of 0.03 mm/day per year.

Estimation of crop water requirement: Based on the climate data, rainfall data, crop data, cropping pattern data and soil data fed to the CROPWAT 8.0 model, the crop water requirements were estimated for Bapatla region. The CWR for the cotton, chillies, maize, rice, pulses, tomato and vegetables of the Bapatla region were estimated as 984.3, 604.1, 491.3, 1375.1, 384.6, 868.7 and 617.8 mm respectively (Table 3).

Effect of change in temperature on CWR: Temperature has the demonstrative effects on crop water requirements. The CWR was calculated under different temperatures with increment of 1^{0}C from the average temperature. The effect of change in every 1^{0}C rise in the temperature on the CWR for different crops (Table 4 and Fig. 3). As the temperature increases, the CWR of various crops increases this is due to increasing in the evapotranspiration from soil and crop. For cotton, the CWR increased 2.83, 5.89 and 8.94% increase from the average CWR (984.3 mm) due to increase in temperature was 1, 2 and 3^{0}C respectively. Similar trend was observed in the case of other major crops in the study area such as chillies, maize, rice, pulses, tomato and vegetables.

Effect of Change in relative humidity on CWR: The decreased RH increases the rate of evapotranspiration from soil and crop which leads to decrease in CWR of the crops. The effect of change in every 5 and 10% reduction in RH on the CWR for different crops in the study area shown in Table 5. The decreased RH increases and increased RH decreases the crop water requirements of various crops (Table 5). The 5% decrease in the RH, increased the CWR about 2.79% for the cotton. Similar trend has been identified for other major crops in the study area.

Effect of Change in wind speed on CWR: The higher wind speeds carried away the moisture content from the soil, increases the crop water requirements (Table 6). As the wind speed increases, the crop water requirements of various

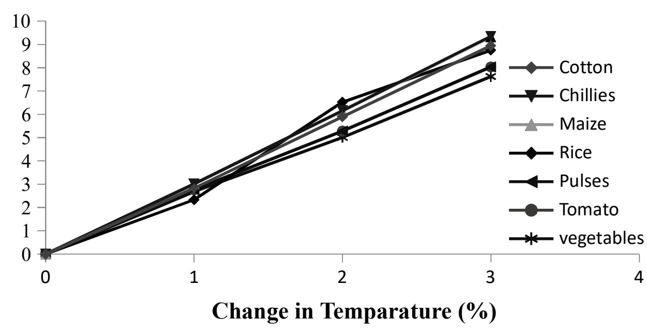

Fig. 3. Effect of increase in temperature on crop water requirement (CWR)

Table 2. Change trends for different meteorological factor means in the study area

Year	Average temperature (^{0}C)		Humidity (%)	Wind speed (Km hr^{-1})	ETO (mm day^{-1})
	Min temp	Max temp			
2006	22.2	32.6	78	233	5.70
2007	22.6	32.7	78	226	5.73
2008	23.3	33.4	75	205	5.93
2009	23.6	34.2	72	228	6.29
2010	23.9	32.5	80	208	5.64
2011	23.1	33.6	76	195	5.92
2012	23.4	33.7	77	204	5.88
2013	23.3	33.2	76	199	5.81
2014	23.4	33.7	72	204	6.12
2015	23.3	33.8	73	196	6.00

Table 3. Monthly crop water requirement of different crops during their crop season

Crop	Crop Water Requirement (ETc) in mm												
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Total
Cotton	-	-	-	-	-	80.7	134.2	216.0	212.6	189.6	117.8	33.7	984.3
Chillies	127.3	123.7	88.1	-	-	-	-	-	-	27.2	107.6	130.3	604.1
Maize	167.5	127.7	14.9	-	-	-	-	-	-	-	50.5	130.7	491.3
Rice	-	-	-	-	410.2	262.8	265.4	242.1	194.1	-	-	-	1375.1
Pulses	143.5	60.4	-	-	-	-	-	-	-	-	57.8	122.8	384.6
Tomato	-	-	-	-	-	138.1	180.9	225.9	205.0	118.6	-	-	868.7
Vegetables	-	-	-	-	-	165.2	219.1	209.8	23.7	-	-	-	617.8

Table 4. Response of crop water requirement to change in mean temperature (T^0C)

Crop	Crop Water Requirement (ETc)						
	Avg. Temp.	ΔT = 1°C		ΔT = 2°C		ΔT = 3°C	
	CWR (mm)	CWR (mm)	Change (%)	CWR (mm)	Change (%)	CWR (mm)	Change (%)
Cotton	984.3	1012.2	2.83	1042.3	5.89	1072.3	8.94
Chillies	604.1	622.3	3.01	641.3	6.16	660.5	9.34
Maize	436.4	449.6	3.02	463.2	6.14	477.1	9.32
Rice	1375.1	1407.2	2.33	1464.8	6.52	1495.5	8.75
Pulses	384.6	396.4	3.06	406.4	5.66	417.8	8.63
Tomato	868.7	892.7	2.76	914.6	5.28	938.5	8.03
Vegetables	617.8	634.4	2.68	648.8	5.01	664.9	7.62

Table 5. Response of crop water requirement to change in relative humidity (RH)

Crop	Crop Water Requirement (ETc)				
	Avg. RH	ΔRH = -10%		ΔRH = -5%	
	CWR (mm)	CWR (mm)	Change (%)	CWR (mm)	Change (%)
Cotton	984.3	1038.8	5.53	1011.8	2.79
Chillies	604.1	631.4	4.52	617.9	2.28
Maize	436.4	455.7	4.42	446.1	2.22
Rice	1375.1	1482.7	7.82	1444.6	5.05
Pulses	384.6	401.5	4.39	393.2	2.23
Tomato	868.7	921.4	6.06	895.3	3.06
Vegetables	617.8	659.6	6.76	638.9	3.41

Table 6. Response of crop water requirement to change in wind speed (W)

Crop	Crop Water Requirement (ETc)				
	Avg. RH	ΔW = +5%		ΔW = +10%	
	CWR (mm)	CWR (mm)	Change (%)	CWR (mm)	Change (%)
Cotton	984.3	991.3	0.71	998.3	1.42
Chillies	604.1	608.3	0.70	613.3	1.52
Maize	436.4	439.5	0.71	443.3	1.58
Rice	1375.1	1383.6	0.62	1392.0	1.23
Pulses	384.6	387.2	0.68	390.2	1.45
Tomato	868.7	874.4	0.66	880.0	1.30
Vegetables	617.8	622.2	0.71	626.6	1.42

Table 7. Excess water demand in Bapatla region due to increase in temperature

Crops	Avg.CWR (mm)	CWR (mm) at 3°C temp. raise	Increase in CWR (mm)	Area under crops (ha)	Increased water demand (MCM)
Rice	1375.1	1495.5	120.4	13782	16.59
Maize	436.4	477.1	40.7	1326	0.54
Pulses	384.6	417.8	33.2	4790	1.59

Table 8. Excess water demand in Bapatla region due to decrease in relative humidity

Crops	Avg.CWR (mm)	CWR (mm) at decreasing 10% relative humidity	Increase in CWR (mm)	Area under crops (ha)	Increased water demand (MCM)
Rice	1375.1	1482.7	107.6	13782	14.83
Maize	436.4	455.7	19.3	1326	0.26
Pulses	384.6	401.5	16.9	4790	0.81

Table 9. Excess water demand in Bapatla region due to increase in wind speed

Crops	Avg.CWR (mm)	CWR (mm) at increasing 10% relative humidity	Increase in CWR (mm)	Area under crops (ha)	Increased water demand (MCM)
Rice	1375.1	1392.0	16.9	13782	2.33
Maize	436.4	443.3	6.9	1326	0.09
Pulses	384.6	390.2	5.6	4790	0.27

crops increases. For cotton, the CWR increased about 0.71 and 1.42% with increase in wind speed was 5 and 10% respectively. Similar trend was observed in the case of other major crops in the study area.

Increase in water demand: The effect of climate change on the CWR is observed and increase in temperature, decrease in relative humidity and increase in wind speed and interactions of other meteorological parameters may have negative effects on CWR and higher crop water requirements is observed in the study area. Increased CWR leads to high water demand for the agriculture. Excess water demand for some of the crops in the study area is given in (Table 7). Excess water demand due to decrease in relative humidity and increase in wind speed (Table 8, 9). Similarly the other crops also have the excess water demand due to climate change and the excess water demand can be met from the groundwater exploration which leads another problem i.e. the ground water depletion.

CONCLUSIONS

The major findings of the present research had clearly demonstrated that the estimation of CWR for various crops for different changes in climatic parameters. In order to save water resources and efficient use of water resources for future generations, keeping in view of this climate changes there is a need to improve the water use efficiency through estimation of the accurate CWR. The change in every 1ºC rise in the temperature has 2 to 3 % increases in the CWR in the study area. Similarly change in the wind speed and relative humidity has the demonstrative effects on crop water requirements. Excess water demand due to 3°C increase in temperature observed as 16.59, 0.54 and 1.59 MCM for the crops rice, maize and pulses respectively. Similarly the other crops also have the excess water demand due to climate change. Due to climate change there is a necessity to apply efficient water management practices at the field level, so therefore there is a need to create the awareness on the effective utilization of available water resources to the farmers.

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Received 25 September, 2021; Accepted 21 February, 2022