Effect of Climate Change on Crop Water Requirement in Visakhapatnam District of Andhra Pradesh

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Abstract: Water is important for life and it is becoming a scarce resource in the future owing to climate change. To apply irrigation water efficiently, the water requirement of the crops is to be estimated accurately. The crop water requirements (CWR) may currently be estimated using a variety of computer models. A computer program called CROPWAT 8.0 was created by Joss Swennenhuis and calculates the summarized irrigation water requirements of a complex scenario. In this study, the weather data from 2011 to 2020 was collected from the Regional Agriculture Research Station, and calculated the average weather data for estimating the CWR. CWR for varietal crops in Anakapalle for Paddy (Kharif), Paddy (rabi), Green gram, Maize, Groundnut (Kharif), Groundnut (rabi), Cotton (Kharif), Cotton (rabi), Sugarcane and Small vegetables was 559.5 mm, 460.0 mm, 253.8 mm, 336.6 mm, 301.9 mm, 253.0 mm, 490.3 mm, 469.5 mm, 1284.8 mm and 346.8 mm respectively. The MarkSim weather generator forecasted the weather conditions using models HADGEM2-ES and MIROC-ESM–CHEM for the years 2030, 2040, and 2050. It was observed that there is an increase in crop water requirement with the range of 12.00 to 13.50%, 13.50 to 14.51%, and 14.51 to 15.74 percent for the years 2030, 2040, and 2050.

Keywords: Crop water requirement, CROPWAT, MarkSim weather generator, and water demand

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1. Introduction

Water is an important renewable natural resource in India, with 70% of the surface water precipitation over a three to four-month period. The NCIWRDP estimated the total basin-wise average annual flow inIndian River systems as 1953 km^3, and the annual potential nature of groundwater recharge from rainfall in India is 342.43 km^3. India's entire usable water resources are 1110 BCM, and water is under greater demand as a result of rising population, expanding urbanization, and accelerating industry. The availability of water per person is declining as a result of the inadequate supply compared to the rising demand. For India, managing water effectively and fostering sustainable development is a challenging task.

The riparian area along 12 interstate rivers is lowest in Andhra Pradesh, leading to a deficit monsoon and hazards of floods. Currently, Domestic drinking water use in the state is 3.25 percent, and irrigation uses 96% of the state's water supply, and only 0.6% is utilized by industries. The government of Andhra Pradesh has prioritized increasing water use efficiency to progress towards a more industrial economy. Appropriate water allocations must be set for each industry. By 2029, it is desired to reach a water use efficiency in agriculture of 60%. Planning is aided by estimating the amount of water needed for irrigation, management, and maintenance of irrigation water projects. The climate of the area affects crop water requirements and irrigation. Minimum and maximum temperatures, rainfall, relative humidity, wind speed, evaporation, and sunshine hours are the main climatic factors that affect crop water needs. It is commonly known that the increase in atmospheric greenhouse gases (GHGs) is to blame for the rise in global temperature. Numerous Governmental and Non-Governmental Organizations in India have started studies on how agricultural and water resources are impacted by climate change. In the 2030s, the Indian subcontinent's annual mean surface air temperature is predicted to increase by 1.7°C to 2.0°C, presumably effecting on four important industries: agriculture, water, natural ecosystems, biodiversity, and human health [3].

change has the potential to affect crop production, water needs, irrigation needs, and freshwater availability, making it an important issue worldwide. The International Panel on Climate Change has announced that According to the UN panel on climate change, there would be significant effects on water supply and availability in developing nations, in developing nations, climate change will have a significant impact on water supply and availability., leading to water and food security hazards. It is important to understand the possible impacts of climate change on the water consumption of the agriculture sector.

An accurate estimation of the crops' water requirements is necessary to apply irrigation water effectively. There are now numerous computer models available to calculate the crop water requirements. The computer program CROPWAT 8.0, created by Joss Swennenhuis for the FAO's Water Resources Development and Management Service, determines the distilled irrigation water needs of a complicated situation. According to [2], CROPWAT software is frequently used to forecast CWR, irrigation rescheduling, reference evapotranspiration, deficit irrigation scheduling, and crop patterns. Previous research suggested that the CROPWAT program could be a trustworthy tool for managing irrigation scheduling, planning irrigation, and understanding crop water requirements. The development of drought-resistant crops, agricultural diversification, more effective water usage, and better soil management techniques can all help mitigate some of the negative effects of climate change. In light of the aforementioned information, the current study is intended to assess the impact of climate change in the future on crop water requirements of various crops for the Visakhapatnam district which is located in the North Coastal Region with the following objectives. To analyze the climate data for finding variations in different meteorological factors, Using CROPWAT 8.0, determine the crop water needs of the main crops in the Visakhapatnam district, and research the impact of climate change on crop water needs in the next years.

2. Material and Methods

Location of the study area:

One of Andhra Pradesh's nine coastal districts, Visakhapatnam district is situated between 17°42'15" North latitude and 83°17'52" East longitude. It is bordered on the north by Odisha, on the south by the Bay of Bengal, on the east by Vijayanagaram, and the west by the East Godavari. 11,161 square kilometers, or 5.07% of the state's total area, make up the district's overall geographic area. With a maximum temperature of 42°C in the summer and a minimum temperature of 15°C in the winter, the climate is characterized by hot summers and chilly winters. The South-West monsoon provides the district with an average rainfall of 1008 mm per year. The largest river, Sarada, has a catchment area of 2,665 square kilometers. Anakapalle and Yelamanchili are significant cities in the basin.

Climate of the study area:

A meteorological station was established at the Regional Agricultural Research Station. The annual rainfall of Anakapalle collected from 2011 to 2020 and presented in Fig. 2.1. Maximum rainfall observed during 2020 as 1617.7 mm and the lowest rainfall observed during 2017 was 796.1 mm.

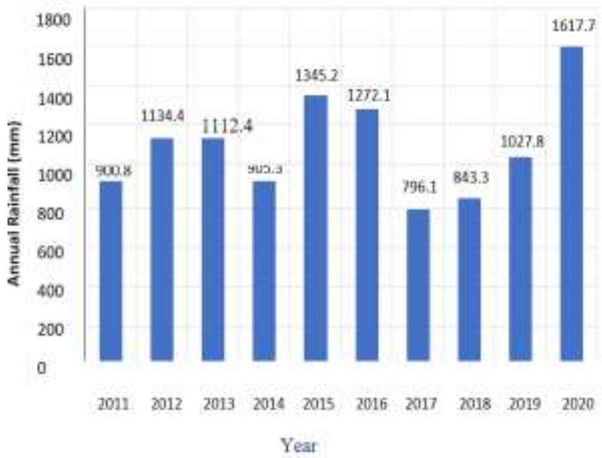


Fig. 2.1 Annual rainfall of Anakapalle of Visakhapatnam district from 2011 – 2020

The daily average maximum temperature and minimum temperature from 2011 to 2020 are shown in Fig. 2.2 with the highest May has the highest average daily maximum temperature while January has the lowest average daily minimum temperature.

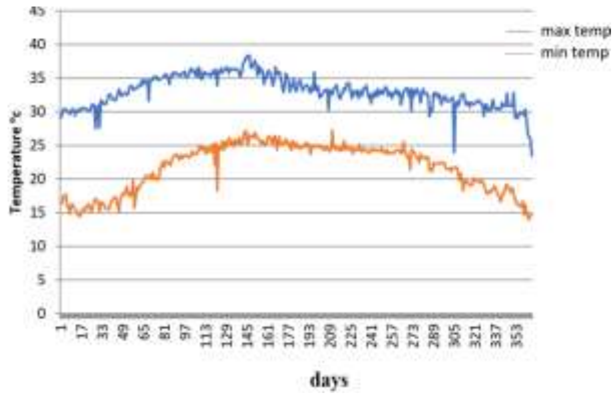


Fig.2.2 Daily average Maximum and Minimum temperatures of Anakapalle of Visakhapatnam district during 2011 – 2020

The average relative humidity has been depicted in Fig. 2.3 and observed that the maximum relative humidity on 10th October was 74.58% and the minimum relative humidity on 20th May was 43.37%

Fig. 2.3 Relative Humidity of Anakapalle of Visakhapatnam district during 2011-2020.

Estimation of crop water requirement:

A computer tool called CROPWAT 8.0 for Windows is used to determine the amount of irrigation and water that crops need based on historical or current climate and agricultural data. Based on the information the user provides, it determines the crop water requirements and irrigation schedules. Data on evapotranspiration (ETO) are required by CROPWAT to calculate crop water requirements (CWR). Using the Penman-Monteith formula, CROPWAT calculates evapotranspiration (ETO) based on inputs of temperature, humidity, wind speed, and sunshine. Alternatively, the user can enter measured evapotranspiration (ETO) values. For various stages of crop development throughout the growing season, these estimations are employed in the calculations for crop water requirements and irrigation scheduling. The following equation of the Penman-Monteith method is used in CROPWAT 8.0

$$ETo = \frac{0.408\Delta(Rn-G)+\gamma T+900273u2(es-ea)}{\Delta+(1+0.34u2)}$$

Where, ET_O= reference evaporation [$mmday^{-1}$], R_n = Net radiation of the crop surface [MJ$m^{-2}day^{-1}$], G = soil heat flux density [MJ$m^{-2}day^{-1}$], T = mean daily air temperature at 2 m height [°C], u_2 = windspeed at 2m height [ms^{-1}], e_s = saturation vapour pressure [kPa], e_a = actual vapour pressure [kPa],

e_s- e_a = saturation vapour pressure deficit [kPa], Δ = slope vapour pressure curve [kPa°C^{-1}], γ = psychrometric constant [kPa°C^{-1}]

Program structure:

Eight separate modules make up the CROPWAT program, five of which are for data input and three of which are for calculations. The modules bar, which is always present to the left of the main window, is a more convenient way to access these modules than through the CROPWAT main menu. This makes it simple for the user to combine various weather, agricultural, and soil data to calculate crop water needs, irrigation schedules, and scheme supplies. General data, weather data (effective rainfall, minimum relative humidity, wind speed data), crop data, and soil data are the initial data that the model needs to determine the irrigation crop water requirements.

A general data file for CROPWAT contains information like the nation, station, altitude, latitude, and longitude as well as the weather characteristics of minimum and maximum temperatures, humidity, wind speed, and daylight hours. Monthly weather parameters were taken for the present year, wet year, dry year, and normal years for the period during 2011-2020.

To a greater or lesser extent, rainfall helps to satisfy CWR. The rainfall data used for CROPWAT was collected for Anakapalle for during 2011 to 2020. The effective rainfall was calculated using the United States Department of Agriculture, Soil Conservation Service (USDS-SCS) algorithm using the daily rainfall data from Anakapalle.

Data on crop length, rooting depth, crop coefficients for various growth phases, and planting and harvesting dates were submitted as input for the crop file in CROPWAT. The information was utilized to calculate crop evapotranspiration. The total accessible water, maximum rooting depth, initial soil moisture depletion, and drainable porosity of the soils were provided to CROPWAT based on the kind of soils in the Visakhapatnam district.

Generation of future weather data:

MarkSim, a tool that generates simulated daily weather data specifically designed for use in the tropics, such as rainfall, maximum and minimum temperatures, and solar radiation, was used to forecast weather data. There are 17 models available in the MarkSim, out of which 2 models are described below.

HadGEM2-ES is a linked AOGCM with an ocean resolution of 1 0 (rising to 1/3 0 at the equator) and 40 vertical levels and an atmospheric resolution of N96 (1.875 0 1.25 0) for the atmosphere. With the flexibility to specify either atmospheric CO2 concentrations or anthropogenic CO2 emissions and simulate CO2 concentrations, HadGEM2-ES additionally represents interactive land and ocean carbon cycles and dynamic vegetation. Additionally, a simulation of the evolution of atmospheric composition and interactions with atmospheric aerosols is provided using an interactive tropospheric chemistry method.

The "MIROC-ESM" ESM is based on the MIROC (Model for Interdisciplinary Research on Climate) global climate model. Using a version of MIROC-ESM (MIROC-ESMCHEM) without the connected atmospheric chemistry. It is possible to evaluate the significance of chemistry-climate interactions on the transient climate system.

The climate forecast model has been selected from the drop window. Two models mainly HADGEM2- ES and MIROC-ESM-CHEM were identified with scenarios 4.5 and 8.5 to generate the future climatic data. The model was run with 50 replications to minimize the errors in the simulation.

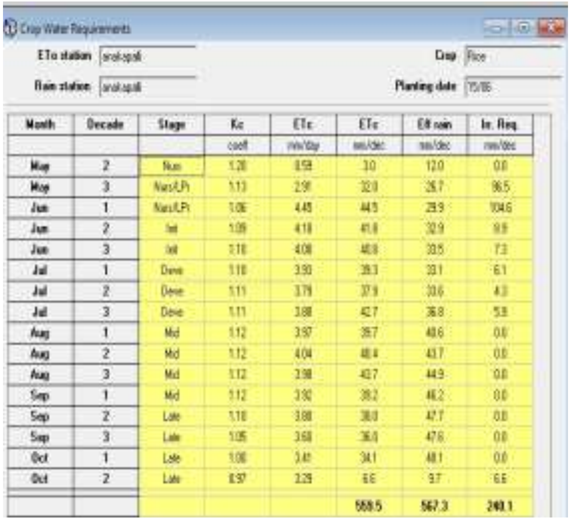
Fig.2. 4 Generation of weather data in MarkSim DSSAT weather generator

The anticipated climate data for the years 2030, 2040, and 2050 was generated using the weather generator, along with the future rainfall maximum temperature, minimum temperature, and radiation.

3. Results and Discussion

3.1 Crop water requirement

Rainfall and climate data from 2011 to 2020 was collected and estimated the monthly average rainfall, maximum and minimum temperature, relative humidity, and solar radiation. Further dry and wet years were identified to calculate the water requirements for crops. Additionally, irrigation water needs were calculated by deducting effective rainfall from crop water needs. The CROPWAT model was given the climate, rainfall, crop, cropping pattern, and soil data as input.



Crop Water Requirements

ETo station: anakapalli | Crop: Rice

Rain station: anakapalli | Planting date: 15/05

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
May	2	Nurs	1.20	0.58	3.0	12.0	0.0
May	3	Nurs/LPr	1.13	2.91	32.0	26.7	96.5
Jun	1	Nurs/LPr	1.06	4.45	44.5	28.9	104.6
Jun	2	Init	1.09	4.18	41.8	32.9	9.9
Jun	3	Init	1.10	4.08	40.8	33.5	7.3
Jul	1	Deve	1.10	3.93	39.3	33.1	6.1
Jul	2	Deve	1.11	3.79	37.9	33.6	4.3
Jul	3	Deve	1.11	3.88	42.7	36.8	5.9
Aug	1	Mid	1.12	3.97	39.7	40.6	0.0
Aug	2	Mid	1.12	4.04	40.4	43.7	0.0
Aug	3	Mid	1.12	3.98	43.7	44.9	0.0
Sep	1	Mid	1.12	3.92	39.2	46.2	0.0
Sep	2	Late	1.10	3.80	38.0	47.7	0.0
Sep	3	Late	1.05	3.60	36.0	47.6	0.0
Oct	1	Late	1.00	3.41	34.1	48.1	0.0
Oct	2	Late	0.97	3.29	6.6	9.7	6.6
					558.5	567.3	240.1

Fig. 3.1 Crop water requirement for paddy (*Kharif*) in Anakapalle

The irrigation water requirement (IWR) for paddy *(Kharif)* fields, effective rainfall, and crop water requirements were estimated using CROPWAT and shown in Fig. 3.1

The results on ET_c, effective rainfall, and IWR were presented every 10 days (Decade) in a crop growing season The crop irrigation schedule scheme is shown in Fig.3.2

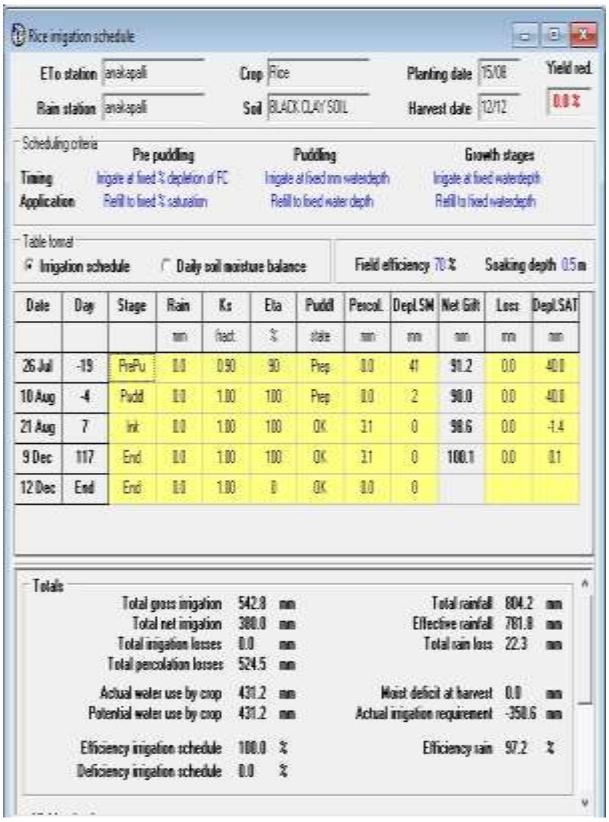


Fig 3.2 Gross irrigation requirement for paddy (*Kharif*) in Anakapalle of Visakhapatnam district

In the Visakhapatnam district's Anakapalle, the crop water demand for paddy (Kharif) was 559.5 mm. The required amount of irrigation water was 240.1 mm. The gross irrigation water requirement was 1382.6 mm. Similarly, the CWR and IWR for paddy, cotton, maize, green gram, groundnut, and small vegetables were estimated and presented in Table 3.1.

A year with average moderate rainfall is considered as a normal year. 2012, 2013, and 2019 are observed as normal years from the last ten years of data (2011-2020). A year with the lowest rainfall is considered as a Dry year. The year 2017 is observed as dry year with 796.1 mm of rainfall. A year with the highest rainfall is considered as a wet year. 2020 is observed as wet year with a rainfall range of 1617.7 mm.

Table 3.1 Crop water requirement, Effective rainfall and irrigation water requirement for different crops in Anakapalle of Visakhapatnam district

Crops	CWR (mm)	Effective rainfall (mm)	IWR (mm)
Paddy (*kharif*)	559.5	567.3	240.1
Paddy(*rabi*)	460	346.5	390.1
Green gram	253.8	71.4	185.3
Maize	336.6	516	13.1
Groundnut(*kharif*)	301.9	452.3	3.7
Groundnut(*rabi*)	253.0	226.4	139.2
Cotton(*kharif*)	490.3	695.2	7.2
Cotton (*rabi*)	469.5	253.4	357.5
Sugarcane	1284.8	875	491.9
Small vegetables	346.8	151.3	192.2

In a normal year, IWR for paddy (*kharif)* was 240.1 mm, and paddy (*rabi)* was 390.1mm. IWR for paddy in the *rabi* season was high when compared to *Kharif* season because there was less effective rainfall. IWR for cotton (*Kharif*), cotton(*rabi)*, sugarcane, groundnut (*Kharif),* groundnut*(rabi*), maize, and green gram were 7.2 mm, 357.5 mm, 491.9 mm,3.7 mm,139.2 mm, 13.1 mm, and 185.3 mm respectively.

In the dry year, IWR for paddy (*Kharif*) was 252.8 mm, and paddy (*rabi*) was 560.9 mm. IWR for paddy in the *rabi* season was high when compared to the *kharif* season because there was less effective rainfall. IWR for groundnut (*Kharif),* groundnut *(rabi*), Cotton (*Kharif*), and Cotton *(rabi)* are estimated as 35.6 mm 233.1 mm, 135.8 mm, and 445.3 mm respectively. The crop water requirement and irrigation water requirement are high for all crops in dry years compared to normal year.

In the wet year, IWR for paddy (*kharif*) was 225.3 mm, and paddy (*rabi*) was 388.7 mm. IWR for paddy in the *rabi* season was high when compared to the *kharif* season because there was less effective rainfall. IWR for groundnut *(Kharif),* groundnut (*rabi),* Cotton *(Kharif),* and Cotton *(rabi)* were 14.4 mm, 178.8 mm, 213.5 mm, and 266.7 mm respectively. The crop water requirement and irrigation water requirement were less in the wet year compared to the dry year and normal year due to the availability of more effective rainfall. Less in a wet year compared to a dry year and normal year due to the availability of more effective rainfall.

3.2 Generation of future climate data

3.2.1 Generation of future Rainfall data for Anakapalle of Visakhapatnam district

MarkSim tool was utilized to generate future weather data. The climate models, namely HADGEM2-ES and MIROC-ESM-CHEM with 4 RCP scenarios Future climate data were produced using RCP2.6, RCP4.5, RCP6.0, and RCP8.5.

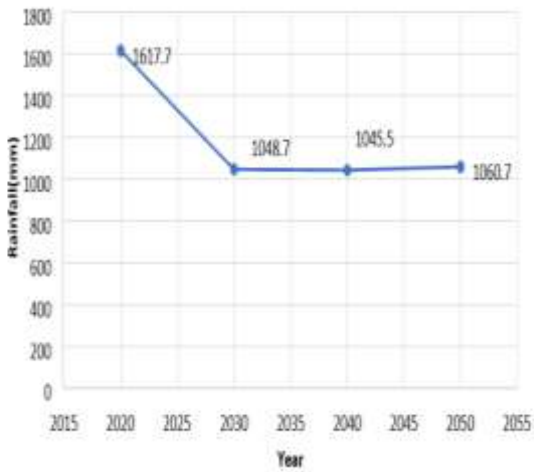


Fig.3.3 Generated rainfall data with HADGEM2-ES and MIROC-ESM-CHEM RCP2.6

It shows maximum rainfall in 2020 year and decreasing trend and during the year 2021, it decreased drastically. The rainfall data generated from HADGEM2-ES and MIROC-ESMCHEM with RCP 2.6 scenario for the period 2020 to 2050 was shown in Fig. 3.3, the rainfall values decreased from 1600 mm to 1000 mm. The rainfall data generated using four RCP scenarios and shown in table 3.2

Table 3.2 Generated rainfall data with different RCP models

YEAR	RAINFALL (mm)			
	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
2020	1617.7	1617.7	1617.7	1617.7
2030	1048.7	1098.9	1085.0	1085.1
2040	1045.5	1077.0	1072.1	1046.0
2050	1060.7	1065.3	1073.3	1052.9

3.2.1 Generation of the maximum temperature of Anakapalle of Visakhapatnam district in future years.

The maximum temperature generated HADGEM2-ES and MIROC-ESM-CHEM with RCP 2.6 scenario was presented in Fig. 3.4 for the period 2020 to 2050.

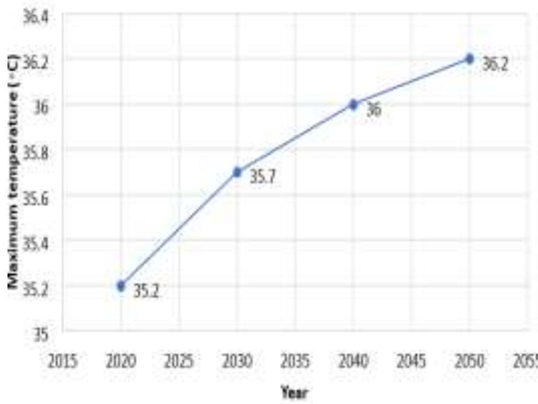


Fig 3.4 Generated maximum temperature data with HADGEM2-ES and MIROC-ESMCHEM with RCP 2.6

Maximum temperature data was generated using four RCP scenarios and shown in table 3.3. Both models predicted an increase in temperature from 2020 to 2050. Maximum temperatures were generated and found highest during the year 2050 at 36.6˚C and lowest during the year 2020 at 32.5˚C.

Table 3.3 Generated rainfall data with different RCP models

YEAR	RAINFALL (mm)			
	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
2020	1617.7	1617.7	1617.7	1617.7
2030	1048.7	1098.9	1085.0	1085.1
2040	1045.5	1077.0	1072.1	1046.0
2050	1060.7	1065.3	1073.3	1052.9

Minimum temperatures were generated using four RCP scenarios and found highest during the year 2050 at 20.8˚C and lowest during the year 2020 at 19.5˚C (Table 3.4).

Table 3.4. Generated minimum temperature data with different RCP models

YEAR	MINIMUM TEMPERATURE			
	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
2020	19.5	19.5	19.5	19.5
2030	19.7	19.8	19.7	20.0
2040	19.9	20.2	20.0	20.7
2050	20.0	20.5	20.2	20.8

3.3 Impact of climate change on irrigation water requirement

3.3.1. Crop water requirement of different crops in Anakapalle of Visakhapatnam district for future years

In HADGEM2-ES and MIROC-ESM -CHEM models with RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5 the CWR increased from 2030-2050 for paddy, sugarcane, cotton, and small vegetables. For paddy in the *rabi* season the crop water requirement (CWR) increases year to year from the year 2030-2050 (Tables 3.5 to Table 3.8).

Table 3.5 Crop water requirement and Effective rainfall for different crops with HADGEM2-ES and MIROC-ESM-CHEM with RCP 2.6 (2030-2050)

Crop	2030		2040		2050	
	CWR (mm)	Effective rainfall (mm)	CWR (mm)	Effective rainfall (mm)	CWR (mm)	Effective rainfall (mm)
Paddy (*Kharif*)	583.3	568.8	601.0	533.5	605.4	537.2
Paddy (*rabi*)	498.2	115.3	496.9	139.7	497.8	146.7
Green gram	219.8	442.5	232.7	123.2	252.9	130.2
Maize	348.1	510.3	354.7	505.7	373.1	506.2
Groundnut (*kharif*)	379.1	529.2	382.7	527.6	399.6	527.6
Groundnut (*rabi*)	323.6	185.3	325.7	191.8	326.1	198.6
Cotton (*kharif*)	548.1	636.1	553.3	644.0	559.1	652.4
Cotton (*rabi*)	553.3	183.6	557.9	190.3	558.5	197.2
Sugarcane	1313.7	768.0	1325.1	772.3	1328.2	782.1
Small vegetables	303.5	23.9	368.6	103.4	369.4	103.4

Table 3.6 Crop water requirement and Effective rainfall for different crops with HADGEM2-ES and MIROC-ESM- CHEM with RCP 4.5 (2030-2050).

Crop	2030		2040		2050	
	CWR (mm)	Effective rainfall (mm)	CWR (mm)	Effective rainfall (mm)	CWR (mm)	Effective rainfall (mm)
Paddy (*Kharif*)	590.1	573.4	597.1	556.4	602.5	543.4
Paddy (*rabi*)	504.5	125.6	500.5	136.2	506.0	143.9
Green gram	243.2	452.9	210.6	119.9	225.4	40.7
Maize	347.1	531.3	323.0	47.7	354.2	510.4
Groundnut (*kharif*)	375.5	549.8	393.4	518.5	396.5	505.7
Groundnut (*rabi*)	334.6	177.3	333.6	113.2	337.0	121.0
Cotton (*kharif*)	549.1	660.6	551.8	654.4	556.0	651.5
Cotton (*rabi*)	662.4	268.3	671.1	289.3	679.8	282.3
Sugarcane	1314.7	796.9	1321.2	791.6	1334.6	787.3
Small vegetables	364.9	108.7	367.4	109.2	372.0	108.9

Table 3.7 Crop water requirement and Effective rainfall for different crops with HADGEM2-ES and MIROC-ESM-CHEM with RCP 6.0 (2030-2050)

Crop	2030		2040		2050	
	CWR (mm)	Effective rainfall (mm)	CWR (mm)	Effective rainfall (mm)	CWR (mm)	Effective rainfall (mm)
Paddy *(Kharif)*	598.5	548.6	597.7	542.5	603.5	540.5
Paddy *(rabi)*	490.6	150.9	491.4	150.8	492.8	150.8
Green gram	217.9	46.4	218.0	44.5	218.5	42.8
Maize	350.0	517.7	351.1	512.3	355.6	511.6
Groundnut *(Kharif)*	392.0	511.8	393.3	506.6	398.0	505.8
Groundnut *(rabi)*	326.8	126.6	327.4	127.3	328.4	127.7
Cotton *(Kharif)*	547.1	658.1	548.8	653.9	553.8	654.0
Cotton *(rabi)*	665.6	275.9	667.0	279.9	669.2	283.3
Sugarcane	1310.3	797.0	1313.7	791.4	1322.1	789.1
Small vegetables	364.0	106.6	364.7	105.6	365.6	103.3

Table 3.8 Crop water requirement and Effective rainfall for different crops with HADGEM2-ES and MIROC-ESM-CHEM with RCP 8.5 (2030-2050)

Crop	2030		2040		2050	
	CWR (mm)	Effective rainfall (mm)	CWR (mm)	Effective rainfall (mm)	CWR (mm)	Effective rainfall (mm)
Paddy *(Kharif)*	595.5	552.0	602.6	542.9	609.9	535.1
Paddy *(rabi)*	497.5	133.7	500.5	134.9	507.6	135.7
Green gram	221.6	33.9	223.3	117.6	226.4	30.6
Maize	350.6	521.9	354.2	513.2	357.9	509.3
Groundnut *(Kharif)*	392.4	514.3	396.8	505.8	401.5	400.3
Groundnut *(rabi)*	331.6	112.0	333.3	113.0	345.7	110.4
Cotton *(Kharif)*	549.2	652.4	554.4	645.5	561.2	641.4
Cotton *(rabi)*	669.5	288.0	677.6	283.7	682.2	216.1
Sugarcane	1316.5	787.3	1334.9	778.3	1350.4	770.5
Small vegetables	366.0	108.8	370.7	107.5	374.9	104.5

The increase in crop water requirement was observed for the different crops with the range of 12 to 13.5 percent for the year 2030. Similarly, increment in observations of crop water requirements for several crops with a variety of 13.5 to 14.51 percent for the year 2040 and 14.51 to 15.74 percent for the year 2050 (Table 3.9).

Table 3.9 change in the crop water requirement with generated weather data HADGEM2=ES and MIROCESM-CHEM for the years 2020, 2040, and 2050 for Anakapalle of Visakhapatnam district

Crop	Crop water requirement in mm						
	Average	2030	Change in percent	2040	Change in percent	2050	Change in percent
Paddy*(Kharif)*	559.5	591.8	5.45	599.6	7.16	605.3	8.18
Paddy *(Rabi)*	460	497.7	7.57	498.3	8.32	501.1	8.93
Green gram	214.6	226.8	5.68	227.1	5.82	230.2	7.26
Maize	336.6	355.7	5.67	356.7	5.97	360.2	7.01
Groundnut *(kharif)*	301.9	384.7	27.42	391.5	29.67	398.8	32.09
Groundnut *(rabi)*	253	329.1	30.07	330	30.43	334.3	32.13
Cotton*(kharif)*	490.3	550.8	12.33	552.1	12.60	555.5	13.29
Cotton *(rabi)*	469.5	637.7	35.82	643.4	37.03	647.4	37.95
Sugarcane	1284.8	1313.8	2.25	1323	2.97	1333.7	3.80
Small vegetables	346.8	349.6	0.80	364.9	5.21	370.4	6.80

4. Conclusion

The climate change impact on crop water requirements requires rainfall and weather data. So, the Data from the Regional Agriculture Research Station (RARS) in Anakapalle was collected from 2011-2020, using CROPWAT 8.0 software to calculate crop water requirements for major crops in Visakhapatnam district. The crop water requirements for Paddy *(Kharif)*, Paddy *(rabi)*, Green gram, Maize, Groundnut *(Kharif)*, Groundnut *(rabi)*, Cotton *(Kharif)*, Cotton (*rabi)*, Sugarcane, and Small vegetables were 559.5 mm, 460.0 mm, 253.8 mm, 336.6 mm, 301.9 mm, 253.0 mm, 490.3 mm, 469.5 mm, 1284.8 mm, and 346.8 mm respectively. Future weather conditions The following conclusions have been drawn based on the study

1. Crop water requirements of the normal year, wet year, dry year, and present year for paddy *(rabi)* are 460 mm, 462.3 mm, 458.6 mm, and 462.3 mm respectively.
2. Crop water requirement for normal year, wet year, dry year and present year for cotton *(Kharif)* is 490.3 mm, 490.3 mm, 492.6 mm, and 490.3 mm respectively.
3. Crop water requirements for the normal year, wet year, dry year, and present year for cotton *(rabi)* is 469.5 mm, 480.0 mm, 489.3 mm, and 480.0 mm respectively.
4. Crop water requirements for the normal year, wet year, dry year, and present year for green gram is 253.8 mm, 192.7 mm, 192.7 mm, and 192.7 mm respectively.
5. Crop water requirements for the normal year, wet year, dry year and present year for groundnut (*Kharif)* are 301.9 mm, 314.5 mm, 296.4 mm, and 490.3 mm respectively.
6. Crop water requirements for the normal year, wet year, dry year and present year for groundnut *(rabi)* is 253.0 mm, 249.6 mm, 249.4 mm, and 249.6 mm respectively.
7. Crop water requirements for Paddy *(Kharif)*, Paddy *(rabi),* cotton (*Kharif)*, cotton *(rabi),* sugarcane, Groundnut *(Kharif)*, Groundnut *(rabi),* and small vegetables during the year 2030 using HADGEM2-ES and MIROC-ESM -CHEM with 2.6 scenario will be 583.3 mm, 498.2 mm, 548.1 mm, 553.3 mm,1313.7 mm, 379.1 mm, 323.6 mm, and 303.5 mm respectively.
8. Crop water requirements for Paddy (*Kharif)*, paddy *(rabi),* cotton *(Kharif),* cotton *(rabi),* sugarcane, Groundnut (*Kharif)*, Groundnut (*rabi),* and small vegetables during the year 2040 using HADGEM2-ES and MIROC-ESM -CHEM with 2.6 scenario will be 601.0 mm, 496.9 mm, 553.3 mm, 557.9 mm, 1325.1 mm, 382.7 mm, 325.7 mm, and 368.6 mm respectively.
9. Crop water requirements for Paddy (*Kharif)*, Paddy *(rabi)*, cotton *(Kharif)*, cotton (*rabi)*, sugarcane, Groundnut (*Kharif)*, Groundnut (*rabi),* and small vegetables during the year 2050 using HADGEM2-ES and MIROC-ESM - CHEM with 2.6 scenario will be 598.4 mm, 497.8 mm, 552.1 mm, 558.5 mm, 1323.2 mm, 381.6 mm, 326.1 mm, and 369.4 mm respectively.
10. Crop water requirements for Paddy *(Kharif),* Paddy *(rabi)*, cotton *(Kharif),* cotton *(rabi),* sugarcane, Groundnut *(Kharif)*, Groundnut *(rabi),* and small vegetables during the year 2030 using HADGEM2-ES and MIROC-ESM -CHEM with 4.5 scenario will be 590.1 mm, 504.5 mm, 549.1 mm, 662.4 mm, 1314.7 mm, 375.5 mm, 334.6 mm, and 364.9 mm respectively.
11. Crop water requirements of Paddy (*Kharif)*, Paddy *(rabi)*, cotton (*Kharif)*, cotton *(rabi),* sugarcane, Groundnut (*Kharif)*, Groundnut *(rabi),* and small vegetables during the year 2040 using HADGEM2-ES and MIROC-ESM -CHEM with 4.5 scenario will be 597.1 mm,500.5 mm, 551.8 mm, 671.1 mm, 1321.2 mm, 393.4 mm, 333.6 mm, and 367.4 mm respectively.
12. Crop water requirements for Paddy *(Kharif)*, Paddy *(rabi)*, cotton *(Kharif),* cotton *(rabi)*, cotton *(rabi)*, sugarcane, Groundnut *(Kharif)*, Groundnut *(rabi)* and small vegetables during the year 2050 using HADGEM2-ES and MIROC-ESM-CHEM with 4.5 scenario will be 602.5 mm, 506.0 mm, 556.0 mm, 679.8 mm, 1334.6 mm, 396.5 mm, 337.0 mm, and 372.0 mm respectively.
13. Crop water requirements for Paddy *(Kharif)*, Paddy (*rabi*), cotton *(Kharif)*, cotton *(rabi),* sugarcane, Groundnut *(Kharif)*, Groundnut *(rabi),* and small vegetables during the year 2030 using HADGEM2-ES and MIROC-ESM -CHEM with 6.0 scenario will be 598.5 mm, 490.6 mm, 547.1 mm, 665.6 mm, 1310.3 mm, 392.0 mm, 326.8 mm, and 364.0 mm respectively.
14. Crop water requirements of Paddy (*Kharif)*, Paddy *(rabi),* cotton *(Kharif),* cotton *(rabi)*, sugarcane, Groundnut *(Kharif),* Groundnut

(*rabi),* and small vegetables during the year 2040 using HADGEM2-ES and MIROC-ESM -CHEM with 6.0 scenario will be 597.7 mm, 491.4 mm, 548.8 mm, 667.0 mm, 1313.7 mm, 393.3 mm, 327.4 mm, and 364.7 mm respectively.

15. Crop water requirements for Paddy *(Kharif)*, Paddy (*rabi),* cotton *(Kharif*), cotton *(rabi)*, sugarcane, Groundnut *(Kharif)*, Groundnut (*rabi),* and small vegetables during the year 2050 using HADGEM2-ES and MIROC-ESM-CHEM with 6.0 scenario will be 603.5 mm, 492.8 mm, 553.8 mm, 669.2 mm,1322.1 mm, 398.0 mm, 328.4 mm, and 365.6 mm respectively.

16. Crop water requirements for Paddy *(Kharif),* Paddy *(rabi)*, cotton *(Kharif)*, cotton *(rabi),* sugarcane, Groundnut (*Kharif)*, Groundnut *(rabi),* and small vegetables during the year 2030 using HADGEM2-ES and MIROC-ESM -CHEM with 8.5 scenario will be 595.5 mm, 497.5 mm, 549.2 mm, 669.5 mm, 1316.5 mm, 392.4 mm, 331.6 mm, and 366.0 respectively.

17. Crop water requirements for Paddy *(Kharif)*, Paddy (*rabi*), cotton (*Kharif)*, cotton *(rabi)*, sugarcane, Groundnut *(Kharif)*, Groundnut *(rabi),* and small vegetables during the year 2040 using HADGEM2-ES and MIROC-ESM -CHEM with 8.5 scenario will be 542.9 mm, 134.9 mm, 554.4 mm, 677.6 mm, 1334.9 mm, 396.8 mm, 333.3 mm, and 370.7 mm respectively.

18. Crop water requirement of Paddy *(Kharif),* Paddy (*rabi*), cotton (*Kharif*), cotton *(rabi)*, sugarcane, Groundnut (*Kharif),* Groundnut (*rabi),* and small vegetables during the year 2050 using HADGEM2-ES and MIROC-ESM -CHEM with 8.5 scenario will be 609.9 mm, 507.6 mm, 518.2 mm, 629.2 mm, 1350.4 mm, 334.5 mm, 268.7 mm, and 374.9 mm respectively.

19. The increase in crop water requirement was observed for the different crops with the range of 12 to 13.5 percent for the year 2030. Similarly, an increment in crop water requirement was observed for the different crops with the range of 13.5 to 14.51 percent for the year 2040, and 14.51 to 15.74 percent for the year 2050. The water demand to meet the crop water requirement in the future will be increased.

Future scope of work

Estimation of future water demand in the agricultural sector and future available water may be useful for planning suitable cropping patterns for sustainable water management.
The data can be generated from different global climatic models are to be verified for realistic predictions on different aspects.
Planning of Irrigation scheduling to achieve maximum production may be tested on projected inter-annual variability of monsoon dry and wet spells.

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