

# CLIMATE CHANGE IMPACTS ON CROP WATER REQUIREMENT FOR SUKHI RESERVOIR PROJECT

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**Abstract:** Climate can be defined as the “expected weather” and when changes in the expected weather occur, we call these climate changes. With respect to the relations between the hydrological cycle and the climate system, every change on the climate could affect all meteorological parameters and this leads to change in the crop water requirement in agriculture. Considering this, a study was carried out to assess the impact of climate change on crop water requirement for the crops grown in the Sukhi command area of Vadodara district, Gujarat. For this study, daily meteorological data like maximum temperature, minimum temperature, wind speed, sunshine hours and rainfall for the period 2003 to 2009 are used. Cropping pattern data and crop data was used for this study. Future climate data were predicted for the periods of 2011-2030, 2046-2065 and 2080-2099 considering A2 scenario of the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (IPCC SRES) using stochastic weather generator named Long Ashton Research Station Weather Generator (LARS-WG 5.0) considering HADCM3 (Hadley centre Unified Model 3) scenario file. Reference crop evapotranspiration (ET<sub>o</sub>) was determined using mean monthly meteorological data with the help of CROPWAT 8.0 and then crop water requirement (ET<sub>c</sub>) was determined. Results shows the clear effect of climate change on crop water requirement of Rabi and Hot Weather crops. Results shows that crop water requirement of all Hot Weather crops (Millet, Ground nut, Maize, Small vegetables and Tomato) in all future periods is increasing as compared to base period 2003-2009. Crop water requirement of Rabi crops (Wheat, Sorghum, Maize, Small Vegetables, Tomato, Gram and Cowpeas) shows negligible decrease in crop water requirement in the period 2011-2020 but all crops shows considerable increasing water requirement in the period 2021-2030 including the periods 2046-2065 and 2080-2099 as compared to base period 2003-2009. For meeting the increasing water demand and to increase yield, over all water resources should be increased by doing water conservation practices effectively and also farmers’ should be motivated to use drip or sprinkler irrigation system instead of flooding methods.

**Keywords:** Climate change, Future climate data prediction, Evapotranspiration, CROPWAT, LARS-WG, Crop water requirement.

## I. INTRODUCTION

Climate change is becoming the hottest topic to the entire globe. When it comes to defining climate, in general it can be define as “expected weather”. When changes in the expected weather occur, we call these climate changes. Climate may change in different ways, over different time scales and at different geographical scales. Since climate is changing, scientists have become interested in global warming, due to mankind’s impact on the climate system, through the enhancement of the natural greenhouse effect.

Since climate change is likely to have impact on the hydrological cycle and consequently on the available water resources and agricultural water demand, there are concerns about the impacts of climate change on agricultural productivity. Furthermore, industrialization and the extended use of fossil fuels have lead to a great increase in the atmospheric concentrations of greenhouse gases. With respect to the relations between the hydrological cycle and the

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climate system, every change on the climate could affect parameters such as precipitation, temperature, runoff, stream flow, groundwater level, and this leads to not only change in the crop water requirement in agriculture but also industrial and domestic water consumption and demand will also change.

General Circulation Models (GCMs) are used to simulate the present and projected future climate considering various climate change scenarios. A1, A2, B1 and B2 are four main climate change scenarios family. Scenarios are constructed based on the assumptions of future human activities and future technological growth.

LARS-WG (Long Ashton Research Station Weather Generator) is a stochastic weather generator which can be used for simulation of weather data considering various GCM's (General Circulation Model) climate change scenario files. In this literature, LARS-WG is used for generating simulated climate data based on SRES A2 climate change scenario.

Crop water requirement can be defined as "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". In general words, it is the amount of water needed by the various crops to grow optimally.

Paper is organized as follows. Section II gives the detail about study area and types of data collected for this study. Methodology is described in Section III with detail about LARS-WG. Section IV presents results showing results of climate change on water requirement of Rabi and Hot Weather crops of study area. Finally, Section V presents conclusion.

## II. STUDY AREA AND DATA COLLECTION

The present study is carried out on the command area of Sukhi Reservoir located in Gujarat state. Sukhi Reservoir Project, one of the major Water Resources projects is envisaged, constructed and developed by Govt. of Gujarat at the confluence of Sukhi and Bharaj River near village Sagadhra and Khos in Pavijetpur and Chhota-Udepur Talika respectively of Vadodara District in Gujarat. Sukhi Reservoir has its total catchment area of 411.81 sq.Km. Among this total area, 25.90 sq.Km. is in Madhya Pradesh and 385.91 sq.Km. in Gujarat. Total 17094 Hectare land of 92 villages of 3 Talukas of Vadodara district and 3607 Hectare land of 39 villages of 2 Talukas of Panchmahal district is benefited due to this project. Figure 1 shows the location of Sukhi dam, catchment area, dam site and command area of Sukhi reservoir.

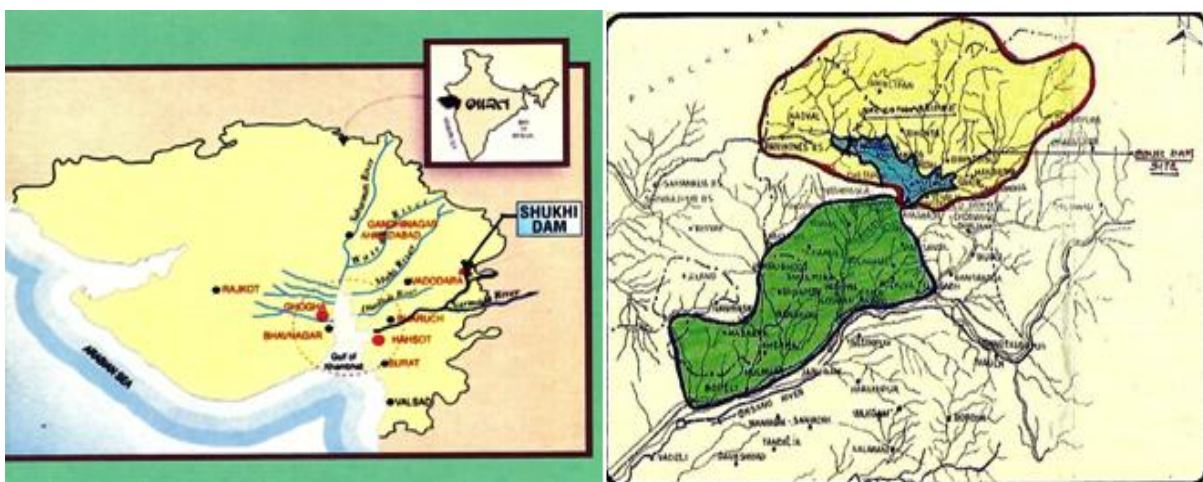


Fig. 1 Location of Sukhi Dam, Catchment Area, Dam Site and Command Area

For this study, meteorological data were acquired from the State Water Data Centre, Gandhinagar which include daily data of maximum temperature, minimum temperature, wind speed, sunshine hours and rainfall for the period 2003 to 2009. Cropping pattern data included season wise crops grown in study area was acquired from Irrigation Department Sub division No. 10, Bodeli. Crop data includes Length of crop development stages in days and crop coefficient (Kc)

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for each crop of all seasons were taken from Food and Agriculture Organization (FAO) Irrigation and Drainage Paper No. 56.

## III. METHODOLOGY

Methodology is divided into three parts: (1) Generation of future climate data using LARS-WG 5.0, (2) ETo calculation using CROPWAT, (3) Calculation of Crop Water Requirement.

### LARS-WG 5.0

LARS-WG developed by Semenov and Barrow, is a stochastic weather generator model that has no limitations on the size of the watershed and can be used for simulation of weather data at a single site (synoptic station of the study area), under both current and future climate conditions. These data are in the form of daily time series of climate variables including precipitation (mm), maximum and minimum temperature (°C) and sunshine hours (hr).

#### (1) PROCEDURE TO GENERATE FUTURE CLIMATE DATA

The process of generating synthetic weather data can be divided into three distinct steps:

- 1. Model Calibration - site analysis** - observed weather data are analysed to determine their statistical characteristics.
- 2. Model Validation – Q test** - the statistical characteristics of the observed and synthetic weather data are analyzed to determine if there are any statistically-significant differences.
- 3. Generation of Synthetic Weather Data - generator** - Synthetic data corresponding to a particular climate change scenario are generated by applying global climate model-derived changes in precipitation, temperature and solar radiation to the LARS-WG parameter files.

#### (2) ETo CALCULATION USING CROPWAT

In order to calculate reference evapotranspiration (ETo), using the Penman-Monteith method, monthly mean data are required, including Maximum and minimum temperatures (°C), Sunshine hours (hour), Wind Speed (km/day), Relative Humidity (%). Wind speed and Relative humidity could not be simulated using LARS-WG. In order to incorporate wind speed in estimation of ETo, long term observed monthly average wind speed in the period of 2003 to 2009 are used and it is assumed that the wind speed would not significantly change in the future. Monthly relative humidity (RH) is assumed to be a function of temperature, sunshine hours (Sun) and rainfall of the same month (Rain) as presented here.

$$RH = f(T_{min}, T_{max}, Sun, Rain)$$

Minitab software is used to fit the multivariable linear regression function to find Relative Humidity for future years (i.e 2011-2030, 2046-2065, 2080-2099)

$$\text{Humidity} = 118 + 2.46 T_{min} - 3.18 T_{max} - 0.756 \text{ Sunshine Hours} + 0.442 \text{ rain}$$

Finally, reference evapotranspiration (ETo) in (mm/month) is calculated using CROPWAT model, for past (2003-2009) as well as future weather data (2011-2030, 2046-2065, 2080-2099).

#### (3) CALCULATION OF CROP WATER REQUIREMENT

For this study following crops are considered. In sukhi command area crops viz., Wheat, Sorghum, Maize, Gram, Cowpeas, Small Vegetables and Tomato are grown in Rabi season and crops viz., Millet, Groundnut, Maize, Small Vegetables and Tomato are grown in Hot Weather season. Kc curves are drawn for all crops taking standard values of crop development period, crop coefficient from FAO 56 and approximate planting date. Monthly Kc values are calculated for Rabi and Hot Weather crops. Finally crop wise ETc is calculated using the formula given below.

$$ET_c = K_c \times ET_o$$

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## IV. EXPERIMENTAL RESULTS

The statistical characteristics of the observed and synthetic weather data are analyzed to determine if there are any statistically significant differences between observed and simulated data using t-test (a t-test is any statistical hypothesis test in which the test statistic follows a Student’s t distribution, if the null hypothesis is supported). Table 1 shows t test results

**Table 1 Results of T Test and p-value**

MONTHLY RAIN												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
t-calc	0	0	0	0	0	0.209	0.292	0.038	0.294	-0.715	0	0
p-value	1	1	1	1	1	0.834	0.77	0.969	0.769	0.475	1	1
MONTHLY MINIMUM TEMPERATURE												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
t-calc	-2.942	1.243	0.741	-0.053	0.048	-1.873	-0.883	-1.993	-0.312	0.918	0.353	-0.679
p-value	0.003	0.214	0.459	0.958	0.962	0.062	0.378	0.047	0.755	0.359	0.725	0.497
MONTHLY MAXIMUM TEMPERATURE												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
t-calc	-3.62	-0.082	-0.116	2.222	2.854	-2.129	-2.143	-0.797	-1.44	-1.108	1.66	-1.517
p-value	0	0.935	0.907	0.027	0.004	0.034	0.033	0.426	0.15	0.269	0.098	0.13
MONTHLY RADIATION												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
t-calc	-3.044	3.738	-0.68	-0.701	-1.34	-1.938	-2.058	-1.004	-0.225	-0.721	-0.261	-1.88
p-value	0.002	0	0.497	0.484	0.181	0.053	0.04	0.316	0.822	0.471	0.795	0.061

t-tabulated = 1.960 for  $v = \infty$  ( t-distribution Table of book “miller & Freund’s Probability and Statistics for Engineers”)  $\alpha = 0.05$  (threshold p-value)

Here analysis is done based on t-calc and t-tabulated values and also comparing p-values with threshold p-value (0.05). Here, hypothesis is checked.

Ho = Simulated climate is same as true climate.

H1 = Simulated climate is different from observed climate.

If t-calc > t-tabulated or t-calc < - t-tabulated then, reject Ho.

If p-value < 0.05 , it means that observed and predicted climate are different.

If p-value > 0.05, it means that observed and simulated climate are same.

Here, in table colored months shows acceptance of null hypothesis.

### CROP WATER REQUIREMENT

Table 2 and table 3 shows decade Wise Average Crop Water requirement of rabi Crops and hot weather crops. Figure 2 to 13 shows Decade Wise Average Percentage Variation in ETc of various crops grown in rabi and hot weather season.

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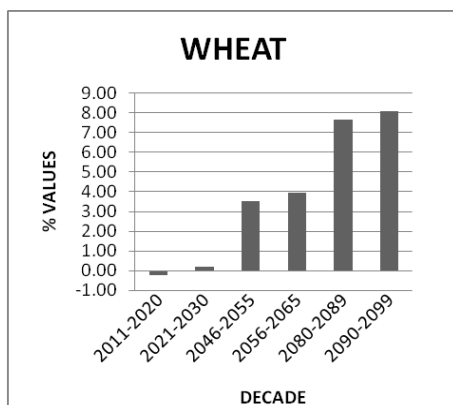
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**Table 2 Decade Wise Average Crop Water requirement of Rabi Crops**

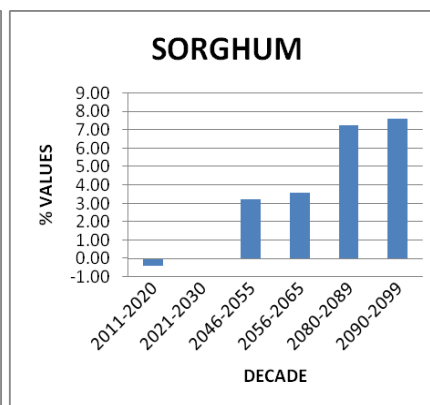
DECADE	RABI CROPS						
	WHEAT	SORGHUM	MAIZE	SMALL VEGETABLES	TOMATO	GRAM	COWPEAS
2003-2009	431.73	412.54	446.82	375.94	991.42	294.55	308.47
2011-2020	430.63	410.98	445.21	375.09	995.60	294.48	308.09
2021-2030	432.49	412.47	447.08	376.95	997.33	296.18	309.87
2046-2055	446.94	425.92	461.67	390.01	1026.86	306.34	320.43
2056-2065	448.82	427.44	463.57	391.87	1028.78	308.07	322.24
2080-2089	464.92	442.53	479.90	406.52	1062.35	319.38	334.00
2090-2099	466.75	444.00	481.76	408.27	1063.88	321.05	335.76

**Table 3 Decade Wise Average Crop Water requirement of Hot Weather Crops**

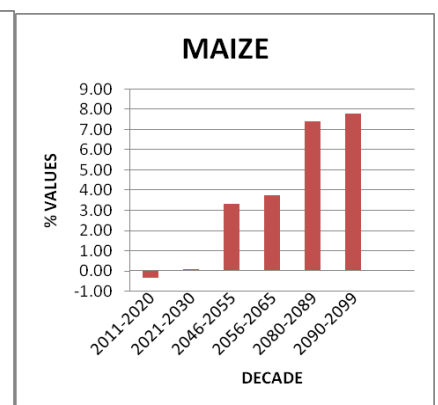
DECADE	HOT WEATHER CROPS				
	MILLET	GROUNDNUT	MAIZE	SMALL VEGETABLES	TOMATO
2003-2009	535.35	815.63	765.97	689.58	1070.01
2011-2020	539.33	833.33	783.62	694.80	1105.63
2021-2030	539.59	833.67	784.05	695.39	1106.70
2046-2055	554.19	856.12	804.97	714.34	1132.73
2056-2065	554.60	856.80	805.74	715.13	1134.85
2080-2089	571.33	881.37	828.69	736.83	1156.96
2090-2099	571.49	881.57	828.97	737.29	1158.20



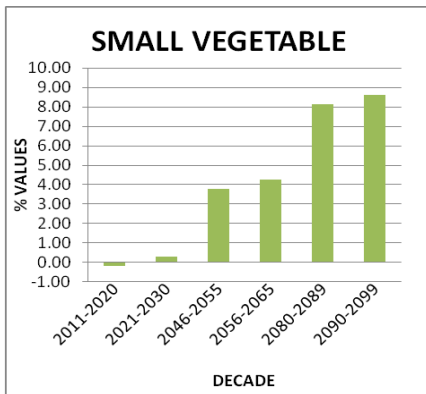
**Fig. 2 Decade Wise Average Percentage Variation in ETc of Wheat (Rabi Season)**



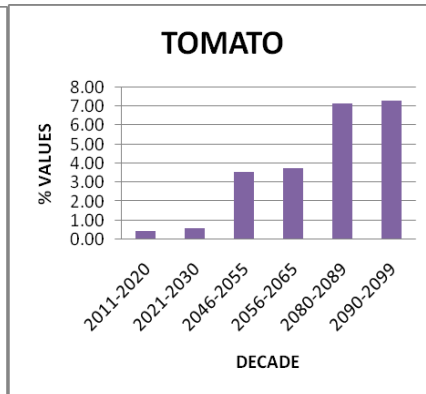
**Fig. 3 Decade Wise Average Percentage Variation in ETc of Sorghum (Rabi Season)**



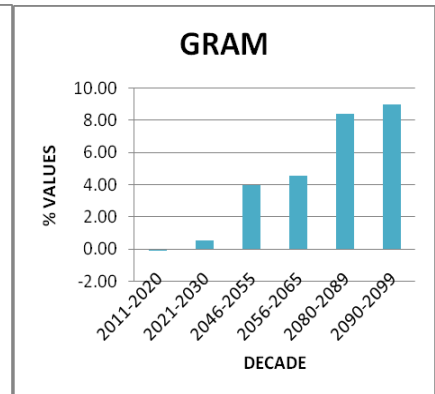
**Fig. 4 Decade Wise Average Percentage Variation in ETc of Maize (Rabi Season)**



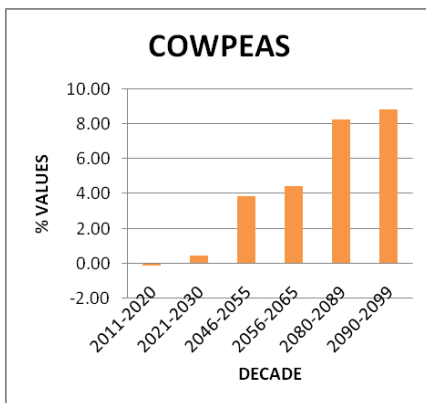
**Fig. 5 Decade Wise Average Percentage Variation in ETC of Small Vegetables (Rabi Season)**



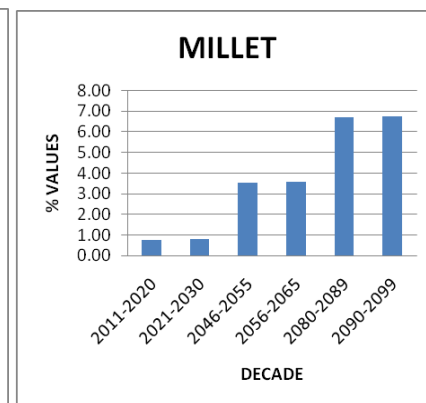
**Fig. 6 Decade Wise Average Percentage Variation in ETC of Tomato (Rabi Season)**



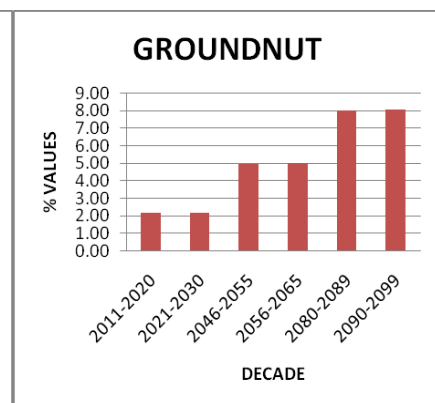
**Fig. 7 Decade Wise Average Percentage Variation in ETC of Gram (Rabi Season)**



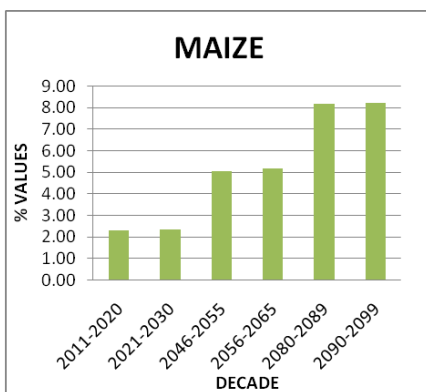
**Figure 8 Decade Wise Average Percentage Variation in ETC of Cowpeas (Rabi Season)**



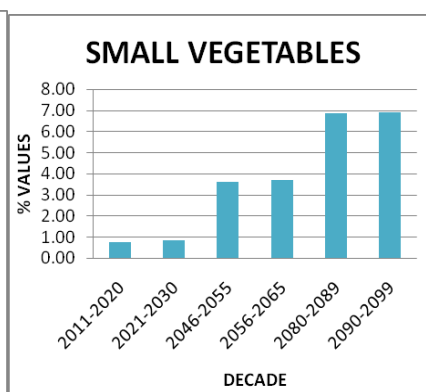
**Figure 9 Decade Wise Average Percentage Variation in ETC of Millet (Hot Weather Season)**



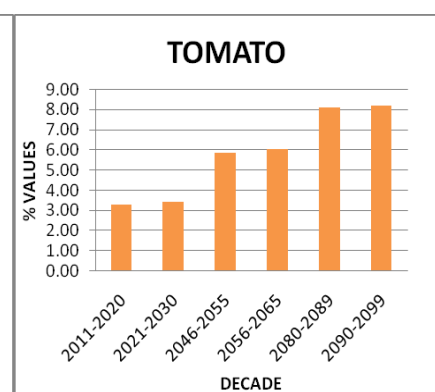
**Figure 10 Decade Wise Average Percentage Variation in ETC of Ground Nut (Hot Weather Season)**



**Fig. 11 Decade Wise Average Percentage Variation in ETC of Maize (Hot Weather Season)**



**Fig. 12 Decade Wise Average Percentage Variation in ETC of Small Vegetables (Hot Weather Season)**



**Fig. 13 Decade Wise Average Percentage Variation in ETC of Tomato (Hot Weather Season)**

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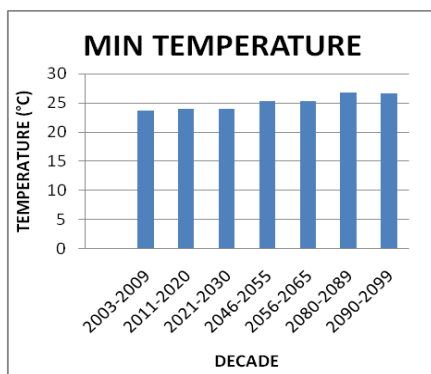
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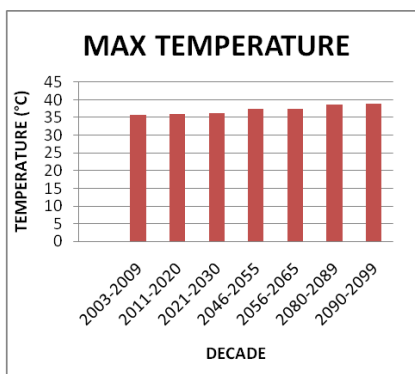
## COMPARISON OF WEATHER PARAMETERS

Various climate parameters like Maximum Temperature, Minimum Temperature, Sunshine Hour, Rain fall and Relative humidity for past and future years are compared. For that year wise average is calculated for each climate parameter and then decade wise average climate parameters are calculated for comparison.

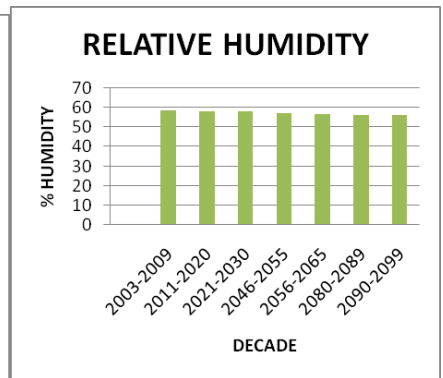
Figure 14 to 17 shows the decade wise variation in Minimum Temperature, Maximum Temperature, Relative Humidity and Rain fall.



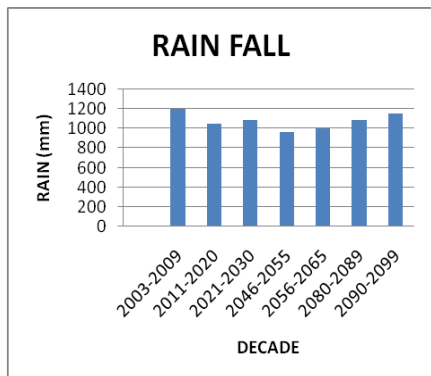
**Fig. 14 Decade Wise Variation in Minimum Temperature**



**Fig. 15 Decade Wise Variation in Maximum Temperature**



**Fig. 16 Decade Wise Variation in Relative Humidity**



**Fig. 17 Decade Wise Variation in Rain Fall**

## V. CONCLUSION

From t-test results we can conclude that for all months the mean of simulated and observed monthly rainfall are same. The mean of simulated and observed monthly minimum temperature are same for all months except January and August. The mean of simulated and observed monthly maximum temperature are same for February, March, August, September, October, November and December. The mean of simulated and observed monthly solar radiation are same for all months except January, February and July.

Results and analysis conclude the effect of climate change on crop water requirement of Rabi and Hot Weather crops. There are both rise and fall in crop water requirement has been seen in this study. All Hot Weather crops (Millet, Ground nut, Maize, Small vegetables and Tomato) shows rise in crop water requirement in all future periods (2011-2030, 2046-2065 and 2080-2099) as compared to base period 2003-2009. In the period 2011-2020, all Rabi crops (Wheat, Sorghum, Maize, Small Vegetables, Tomato, Gram and Cowpeas) shows negligible fall in water requirement,

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whereas considerable rise in water requirement of all Rabi crops has been seen in other future periods (2021-2030, 2046-2065 and 2080-2090).

It has been concluded from the results and analysis that in future years crop water requirement will increase in the study area. The reason for this may be due to increase in Maximum and Minimum temperature and decrease in Relative humidity in future years. Also average rainfall of the study area is showing decreasing trend until end of 2065 and showing increasing trend until end of 2090. The results of this study will be useful for policy makers and planners of water resources for the future planning of projects and suggest water saving techniques to satisfy increasing crop water requirement.

### REFERENCES

- [1] Chatterjee, S. K., Banerjee, S. and Bose, M., "Climate Change Impact on Crop Water Requirement in Ganga River Basin, West Bengal, India", DOI: 10.7763/IPCBE, 3rd International Conference on Biology, Environment and Chemistry, IPCBEE vol.46 pp 17-20, 2012.
- [2] Chaudhari, K.N., Oza, M.P. and Ray, S.S. "Impact of Climate Change on Yields of Major Food Crops in India", ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture, pp. 54-60, 2009.
- [3] De Silva, C.S. et al., "Predicting The Impacts of Climate Change—A Case Study of Paddy Irrigation Water Requirements in Sri Lanka", Agricultural Water Management 93: pp 19–29, 2007.
- [4] Kumar, S.N. et al., "Impact of Climate Change on Crop Productivity in Western Ghats, Coastal and Northeastern Regions of India", Current Science, Vol. 101, No. 3, 10 August 2011, pp 332-341, 2011.
- [5] Manekar, V. and Bharadiya, N., "Climate Change Impact on Crop Productivity Using Miami Model for Bardoli Area, Gujarat", International Conference on Chemical, Bio-Chemical and Environmental Sciences (ICBEE'2012) December 14-15, 2012 Singapore, pp 23-26, 2012.
- [6] Masanganise J. et al., "Model Prediction of Maize Yield Responses to Climate Change in North-Eastern Zimbabwe, African Crop Science Journal, Vol. 20, Issue Supplement s2, pp. 505 – 515, 2012.
- [7] Mbaye Diop, "Analysis of Crop Water Use in Senegal With The Cropwat Model", GEF funded project: Regional Climate, Water and Agriculture: Impacts on and Adaptation of Agro-ecological Systems in Africa, CEEPA, pp. 1-18, 2006.
- [8] Molua E. L and Lambi C. M., "Assessing The Impact of Climate on Crop Water Use and Crop Water Productivity: The Cropwat Analysis of Three Districts in Cameroon", GEF funded project: Climate Change Impacts on and Adaptation of Agro-ecological Systems in Africa, CEEPA, pp 1-44, 2006.
- [9] Rehana, S. and Mujumdar, P. P., "Regional Impacts of Climate Change on Irrigation Water Demands", DOI: 10.1002/hyp.9379, Hydrological Processes, 2012.
- [10] Semenov, M.A. et al., "Comparison of The WGEN and LARS-WG Stochastic Weather Generators for Diverse Climates", Clim Res 10: pp 95–107, 1998.
- [11] Tumbo, S.D. et al., "Impact of Projected Climate Change on Agricultural Production in Semi-Arid Areas of Tanzania: A Case of Same District", African Crop Science Journal, Vol. 20, Issue Supplement s2, pp. 453 – 463, 2012.

### BIOGRAPHY



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and its Impact on Water Resources, Rain Water Harvesting, and Low cost Micro Irrigation Systems.

Dr. Parekh is Life Member of various professional bodies like Indian Society of Hydraulics, Indian Water Resources Society, Association of Hydrologists of India and Association of Agrometeorologists and Indian Society of Geomatics. She is chairman of Board of studies of WREMI and member of Faculty Board of Tech. & Engg. She is also joint secretary of Gujarat Chapter of Association of Hydrologists of India. She Worked as Principal Investigator for Research Project funded by Gujarat Council on Science and Technology and completed five institutional consultancy projects. She is recipient of "Prof. S.C. Puranik Young Scientist Award" for the award winning paper in 2004 by Association of Hydrologist of India. She has published 28 Research Papers in various International/ National Journals/ Conferences.



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