FUTURE CROP WATER REQUIREMENT UNDER CLIMATE CHANGE: A CASE STUDY IN COMMAND AREA OF GHUGERA BRANCH CANAL

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ABSTRACT

Water is the lifeline of agriculture production, and climate change will affect agricultural water needs in the future. Globally, the average earth temperature has risen by 0.65 to 1.08˚C for the period of 1880-2017 years. Additionally, it is anticipated that at the end of the 21st century, the average earth temperature will be raised by 1.5 to 2.0 degrees C as compared to 1850-1900. Crop water requirement (CWR) depends upon many climatic parameters (CPs), any significant or moderate change in these parameters can affect evapotranspiration (ET) and eventually the CWR. Two climatic data sets were made as the Past thirty years' baseline (1988-2017) and the future thirty years (2050-2079) under A2 and B2 scenarios. Past climatic data was taken from the UAF observatory. Future data were obtained from the well-known general circulation model HadCM3. The statistical downscaling model (SDSM) was used for the downscaling of the HadCM3 data. CROPWAT model version (8.0) was used to calculate reference evapotranspiration (ET0) and CWR for crops zone (Cotton-Wheat and Wheat-Maize). It is projected that there will be a 3.120 C and 2.560 C rise in mean annual temperature (MAT), 0.44 mm and 0.30 mm in mean annual ET0, 47.63 mm and 49.74 mm in mean annual rainfall under A2 and B2 Scenario respectively. Projected changes in CWR of cotton-wheat and wheat-maize will be 10.01% and 48.99% respectively under the A2 scenario and in the B2 scenario, CWR changes for Cotton-wheat and

wheat-maize are 7.10% and 44.8% respectively. Thus due to the increasing trend in ET0, crop water requirement (CWR) is also increasing.

INTRODUCTION

Water is essential for sustaining quality of life on earth. Pakistan's irrigation depends mainly on both surface and underground water sources. Around 145 million acres feet per year of water enters the rivers of Pakistan. Of this, water that is transferred annually to canals for irrigation is about 110 million-acre feet (72 percent) and due to lack of storage facilities the remaining 35 million-acre feet flow into the sea. The volume of water that comes out of the canals in irrigation channels is around to 98 million-acre feet per year. There is an estimation of 45 million-acre feet of water annually extracted from 550,000 tube wells for irrigation purposes. Thus, the total quantum of water from canals and tube wells that enters the watercourse is 122 million acres per year. About 28 MAF of water are lost during transit from 145 MAF water that enters the canals every year due to many factors (Hussain *et al.*, 2011).

According to the intergovernmental penal climate change (IPCC AR4), if water availability per capita below 1000 m^3 per year over, the country at water scarcity condition (IPCC AR4). In Pakistan water availability per capita in years 1955 and 1990 were 2490 m^3 and 1672 m^3 respectively, but in 2025 year water availability per capita will be 837 m^3, according to this in 2025 Pakistan will be in water scarcity condition (Kahlown and Majeed, 2003). Climate change is the average changes in long term climatic data such as temperature, GHG's composition in atmosphere, rainfall etc. Climate may change in different way; change at different region and over different time scales (Arnell *et al.*, 2004). Scientist observed Climate is changing according to IPCC fifth assessment report, climate change causes by global warming, global warming due to increase in green house gaseous composition in atmosphere by natural or anthropogenic activities. The average earth temperature has risen by 0.65 to 1.08 degree C for the period of the 1880-2021 years. Additionally, it is anticipated that in the ending of the 21st century, the average earth temperature will be raised by 1.5 to 2.0 degree C more than that for the period of 1850-1900 years (Chavas *et al.*, 2009). Climate Change are disturbing the sequence of life and also disturbing the natural sources. Climate change has adversely affected on fresh water sources, agriculture, humans. Climate change has positive and negative effect on agriculture. Temperature is the main parameter of climate, if temperature increase crop productivity increase but also increase crop water requirement (Zhou *et al.*, 2017). Climate change has adversely effect on water resources; due to increase in temperature fresh water source for short period will increased but after long period will decreased (Bates *et al.*, 2008).

Crop water requirement (CWR) is the quantity of water that water vaporizes through evapotranspiration from soil and land fulfills the requirement of water for crop growth (Chattopadhyay *et al.*, 1997). Evapotranspiration (ET) plays main role in hydrological phase and it is used to estimate the CWR (crop water requirement), crop water need and ET are depend upon several climatic parameters such like rainfall, high and low temperature, speed of wind and its direction and also relative humidity. Rain fall is part of the hydrological phase and contributes to a higher or lower level in gratifying the CWR. Rain fall fulfill the CWR in tropical and semi-tropical region during the rainy season. Effective rain fall is that portion of the rain fall which is efficiently utilized by crop later than rain fall misfortunes due to deep percolation and surface run off have been accounted for. The effective rain fall used to estimate the crop irrigation requirement. Global warming is indicating the climate change, global warming will influence the crop water requirement and demand of water in future (Chowdhury *et al.*, 2016). CROPWAT software is a widely used for the calculation of crop water requirement, cropping pattern, reference evapotranspiration and irrigation scheduling in Africa, USA, Morocco, Turkey, Pakistan and Greece (Lobell *et al.*, 2010).

Climatic data are very important for estimate of ET. General circulation model (GCM) is used to estimate the global climatic data; this data is on large scale and low spatial resolution. Downscaling method is very useful for convert the GCMs data at regional level; downscaling method has two types dynamic and statistical. SDSM is used to observe local climate through various statistics based techniques and SDSM assess relationship b/w large scale climate patterns sort out by GCM. Dynamical downscaling used to convert the high resolution data at large scale into local or regional level (Johns *et al.*, 2003). Agriculture production is one of the most sensitive sector to climate change is experiencing significant changes. Globally water withdrawals accounting is 70% and 90% for India, Pakistan and Mexico for irrigation purpose to improve crop yield (Doria *et al.*, 2011). Globally population growth will be highly increase in future under climate change and also food demand will increase, due to increase in food demand water demand will be increase in future, and this is the serious challenge for agriculture production and food security (Kelleners *et al.*, 1999).

Climate change and agriculture are closely related processes occurring within the global ecosystem (Buragienė *et al.*, 2015). In Pakistan, Agriculture is a main source of income and more than half of the people are attached with this sector directly or indirectly. Agriculture sector of Pakistan primarily comprised of poor farmers and about 75% of the farmers are smallholders and resource-constrained who are becoming the victim of food security due to low productivity and income. About 21% of the gross domestic product has been contributed by agriculture sector and 44% labor is working in this field which elucidates that this income is quite low when comparing with labor market. Most importantly, Agriculture sector is contributing approximately 50% of the total earning of foreign exchange. Furthermore, this is supplying raw material to local agricultural based industries e.g. leather, textiles, sugar and ghee (Davidson *et al.*, 2001). Moreover, the study area falls in the rice wheat and cotton agro ecological zone of Punjab province. Cropping pattern in the area is mixed cropping system including all major crops such as wheat, rice, maize, and cotton. Beside this, the command area of Ghugera Branch Canal is part of the plain of the Indus River. The soil is medium textured and uniform in texture, with a depth of 1 to 4 meters. They are from thick loamy sand to high-quality sandy soil (Kelleners *et al.*, 1999). The organic matter in the soil is generally low and the pH is between 7 and 8.5. Soil is suitable for all kinds of crops. Thus, the only technique to improve agriculture is through the availability of contemporary, adequate irrigation ways and improved water management practices. Considering the present water scenario throughout the globe is an important technique for selecting correct water use. CROPWAT is an FAO-Developed window-based model for determining the ETo for correct irrigation programming and style. The Penman-Monteith Equation of Food and Agriculture Organization is the basis of this application to see ETo, which can even be helpful for increasing crop production. This analysis aims to estimate the Crop Water demand for the varied crops within the city district exploitation CROPWAT 8.0 (Liu *et al.*, 2018). The main purpose of this study was to predict future crop water requirement with and without salinity in the command area of ghugera branch canal.

MATERIAL AND METHOD

STUDY AREA

The study area for this research was conducted in samundari region. Samundari is the district of Faisalabad, Punjab province of Pakistan. It is located at 31.0691^{0}N and 72.9361^{0}E. Soil characteristic of Samundari is clay loam type soil, soil organic matter is 0.62% and PH of soil is 7.5-7.8. Soil contains 34% sand, 26% silt and 40% clay. Major cash crop of samundari is sugarcane. Samundari region is irrigated by ghugera branch canal.

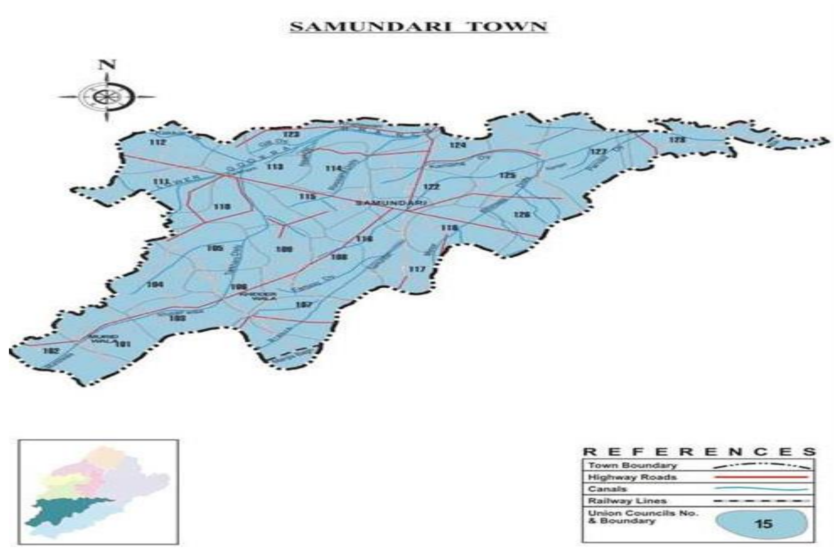


Fig3.1: Map of Samundari, sub-division of Faisalabad

Geographical Description and Climate of Pakistan and Central Punjab, Faisalabad (Study

Area: Command Area of Ghugera Branch Canal)

DATA SOURCE

Past climatic data was taken from Pakistan Metrological Department and UAF Observatory for the year (1988-2017) and future climatic data were predict from GCM HadCM3 under SRES A2 and B2 situations for late century (2050-79).

Data required for input

Climatic Data	Crop Data	Soil Data
Max. Temperature (Tmax)	Date of Planting	Total Moisture Available
Mini. Temperature (Tmini)	Date of Harvesting	Max. Rain Infiltration Rate
Relative Humidity (RH)	Crop Coeff.	Max Plant Rooting Depth
Solar Radiation (SRAD)	Plant Root Depth	Depletion in Soil Moisture
Rainfall (RF)	Plant Height	Initial Moisture Available
Wind Speed		

MODEL SPECIFICATION

Global Circulation Model HadCM3

A coupled climate model called HadCM3 has been frequently utilized for studies on climate sensitivity, detection, and prediction. One of the key models used in the IPCC Third and Fourth Assessments, as well as in the Fifth Assessment, was HadCM3. A significant advancement at the time of its development, its accurate modelling of the current climate without the need of flux modifications and still positions it's highly when compared to other models (Reichler and Kim *et al.*, 2008). Additionally, it has the capacity to record the temporally dependent fingerprint of historical climate change in response to both natural and man-made forcing (Stott *et al.*, 2000). Which has made it a particularly useful tool in research related to the assessment and attribution of past climate changes. A worldwide grid of 96 x 73 grid cells is produced by the atmospheric component, which has 19 levels and a horizontal resolution of 2.5 degrees latitude by 3.75 degrees longitude. At the Equator, this corresponds to a surface resolution of around 417 km by 278 km, which decreases to 295 km by 278 km at 45 degrees of latitude (Pope and Stratton *et al.*, 2000). The horizontal resolution of the oceanic component's 20 levels is 1.25 x 1.25 degrees. It is feasible to portray significant features in oceanic current structures at this level (Gordan and R.A Wood *et* *al.*, 2000). This model used in different biggest projects likes (UK climate projections, the operational decadal forecasting system until 2012, the regional modeling system (PRECIS). That's why this model is very useful for research area to predict the future climatic data (the command area of Ghugera branch canal).

CROPWAT

In this research CROPWAT model version 8.0 was used to determine the reference evapotranspiration ET0, irrigation water requirement (IWR) and crop water demand or crop ET. CROPWAT model version 8.0 calculate the CWR and crop irrigation requirement (CIR) using the FAO Penman-monteith equation. The CROPWAT model was utilized to estimate the crop evapotranspiration for two major crop zones (cotton-wheat and wheat-maize) with salinity.

In which research effective precipitation was calculated according to the method of the USDA soil conservation service. CROPWAT determined the effective precipitation by following equations

$E_p = \frac{T_p(125-0.2T_p)}{125}$ For T_p< 250mm ; $E_p = 125 + 0.1T_p$ ForT_p> 250mm

Crop evapotranspiration was calculated by following equation:

$$ET_{crop} = cropcoeff.(k_c) \times reference(ET_o)$$

Crop irrigation requirement (CIR) was calculated by following equation:

CIR = crop (ETc) - Effective precipitation (PE)

RESULTS AND DISCUSSION

In this portion results and discussion of research showed by necessary comparison performed format such as tables, graphs, maps and charts. Purpose of this research was to predict the impact of climate change on future crop water requirement of two major crop zones. In which study projected future crop water requirement under A2 and B2 scenarios using the climatic data, that climatic data was downscaled by global circulation model (HadCM3).

Variation in Temperature, Rainfall, Reference ET_o (A2 Scenerio)

Relationship amongst time and temperature, rainfall and reference evapotranspiration appear by Table 1. The table 1 demonstrate the correlation between past period (1988-2017) and future period (2050-2079) of time and temperature, rainfall and reference evapotranspiration under A2. In future period (2050-2079) temperature will increment in all long stretches of years aside from May, June, July, August and September when contrasted with the base time frame (1988-2017) under A2 scenarios as indicated by the below table 1, In future the mean yearly normal temperature anticipated to increment up to 2.53 degree Celsius under A2 scenario. The results of projected temperature also showed similar trend comparative to Webb and Barlow (2007), Cubasch (2001), Argueso and Bormann (2014). The precipitation happens sporadically and changes throughout the year. The precipitation happens generally in summer season and winter season, in summer season from July to September and in winter season from December to March. The precipitation does not happen during the time in samundri area. Examination between precipitation of base period and precipitation of future period exhibits in below table 1, as indicated by the table precipitation anticipated to increment in all long stretches of years aside from July, August and September in future under A2 scenerios. In future anticipated normal precipitation increment up to 47.63 mm under A2 Scenarios. The projected rainfall similar results were found by Byakatonda and D. Moalafhi (2018), Kitoh and Kamiguchi (2005). Evapotranspiration is an imperative piece of hydrological cycle and it is utilized to evaluate the water required to crop. Climatic Parameters are input parameter which causes the change in reference evapotranspiration and crop water requirement. The table 1 demonstrate the mean monthly reference evapotranspiration ET and correlation of past and future information. The average reference evapotranspiration was projected rise in Jan, Feb, March, Oct, Nov and December in future period (2050-2079) under A2 scenario. Some months average reference evapotranspiration likes (April, May, June, July, Aug and September) was projected decrease in future duration (2050-2079) under A2 scenario and 0.35 mm reference evapotranspiration will be increases in future period. Mckenney, M.S. and N.J. Rosenberg. (1993) were found the similar kind of results of reference evapotranspiration in his research.

Table 1: Comparison of mean monthly average Temperature, Rainfall, ET_o between (1988-2017 and 2050-2079 under A2 Scenario)

Months	**Average Temp ^{0}C**			**Average Rainfall**			**Average ET_o**		
	1988-2017	**2050-79**	**Changes ^{0}C**	**1988-2017 (mm)**	**(2050-79) A2 (mm)**	**Changes (mm)**	**1988-2017 (mm)**	**(2050-79) A2 (mm)**	**Changes (mm)**
Jan	12.08	33.29	21.21	9.81	81.07	71.25	1.28	5.2	3.92
Feb	15.19	33.12	17.92	19.12	97.77	78.64	1.94	5.08	3.13
Mar	20.26	30.34	10.08	20.52	113.13	92.6	3	4.47	1.46
Apr	26.65	27.31	0.66	20.12	108.92	88.79	4.48	3.75	-0.73
May	32.09	24.11	-7.98	13.35	97.53	84.18	5.79	3.16	-2.63
Jun	33.76	21.48	-12.28	41.66	85.21	43.54	5.82	2.56	-3.26
Jul	32.62	20.44	-12.17	91.09	67.23	-23.85	4.9	2.47	-2.42

Aug	31.84	21.02	-10.82	81.57	57.73	-23.83	4.4	2.76	-1.64
Sep	30.26	23.63	-6.39	51.7	48.29	-3.4	3.99	3.44	-0.54
Oct	25.76	27.07	1.3	5.6	45.21	39.61	3.46	4.12	0.65
Nov	19.53	30.16	10.63	2.88	57.99	55.11	2.03	4.65	2.62
Dec	14.31	32.55	18.23	5.96	74.98	69.01	1.32	5.07	3.75
Average	**24.51**	**27.04**	**2.53**	**30.28**	**77.92**	**47.63**	**3.54**	**3.89**	**0.35**

Variation in Temperature, Rainfall, Reference ET_o (B2 Scenerio)

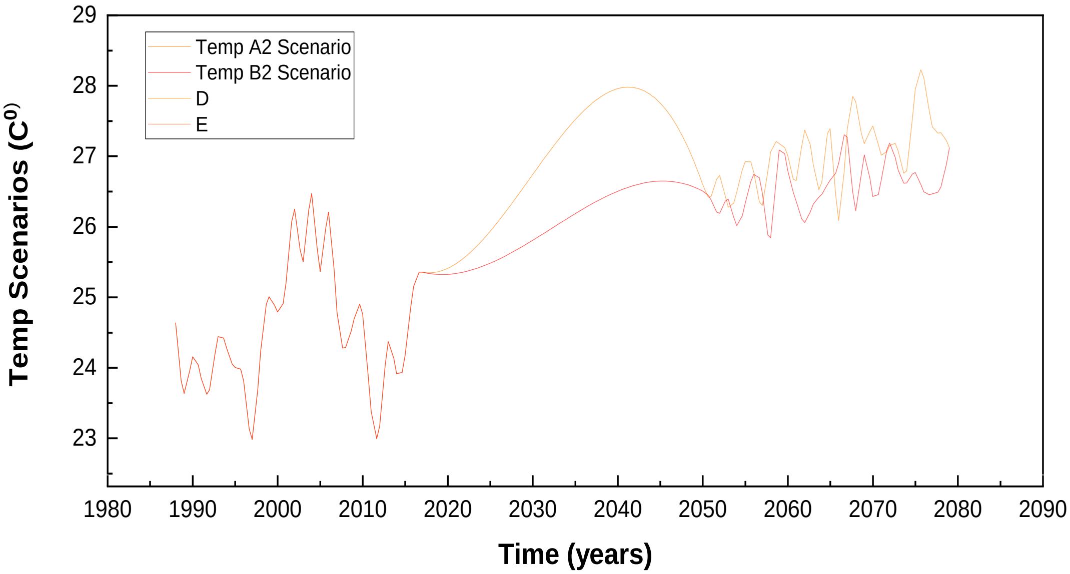
Correlation between past and future period of Temp, rainfall and reference evapotranspiration under B2 scenario demonstrated in table 2. In future period (2050-2079) temperature will increment in all long periods of years aside from May, June, July, August and September when contrasted with the base time frame (1988-2017) under B2 situation as per the below Table In future the mean yearly normal temperature anticipated to increment up to 2.082 ^{0}C under B2 scenario. Comparison between rainfall of base period and rainfall of future period presents in below table according to the table rainfall projected to increase in all months of years except July, August and September in future under B2 scenarios. In future projected average rainfall increase up to 49.74 mm under B2 Scenarios. Average reference evapotranspiration ET0 was projected to increase in Jan, Feb, March, Oct, Nov and December in future period (2050-79) under B2 Scenario. Average reference evapotranspiration ET0 was projected decrease in April, May, June, July, August and September in future period under B2 Scenario.

Table 2: Comparison of mean monthly average Temperature, Rainfall, ET_o between (1988-2017 and 2050-2079 under B2 Scenario)

Months	Average Temp ^0C 1988-2017	2050-79	Changes ^0C	Average Rainfall 1988-2017 (mm)	(2050-79) A2 (mm)	Changes (mm)	Average ET_o 1988-2017 (mm)	(2050-79) A2 (mm)	Changes (mm)
Jan	12.08	33.01	20.93	9.81	92.44	82.62	1.28	5.1	3.81
Feb	15.19	32.42	17.22	19.12	91.88	72.75	1.94	4.89	2.94
Mar	20.26	30.38	10.11	20.52	115.61	95.08	3	4.38	1.37
Apr	26.65	26.75	0.1	20.12	118.02	97.89	4.48	3.62	-0.86
May	32.09	23.47	-8.62	13.35	101.55	88.2	5.79	3.07	-2.72
Jun	33.76	21.07	-12.68	41.66	74.7	33.03	5.82	2.48	-3.33
Jul	32.62	20.21	-12.4	91.09	73.55	-17.53	4.9	2.46	-2.43
Aug	31.84	20.49	-11.35	81.57	60.96	-20.6	4.4	2.64	-1.76
Sep	30.02	23	-7.01	51.7	48.54	-3.15	3.99	3.33	-0.66
Oct	25.76	26.53	0.76	5.6	44.56	38.96	3.46	4	0.53
Nov	19.53	29.76	10.22	2.88	61.04	58.16	2.03	4.52	2.49
Dec	14.31	32.05	17.73	5.96	77.42	71.45	1.32	4.97	3.64
Average	**24.51**	**26.59**	**2.08**	**30.28**	**80.02**	**49.74**	**3.54**	**3.79**	**0.25**

Relationship of mean annual temperature (MAT) under A2 and B2 scenario

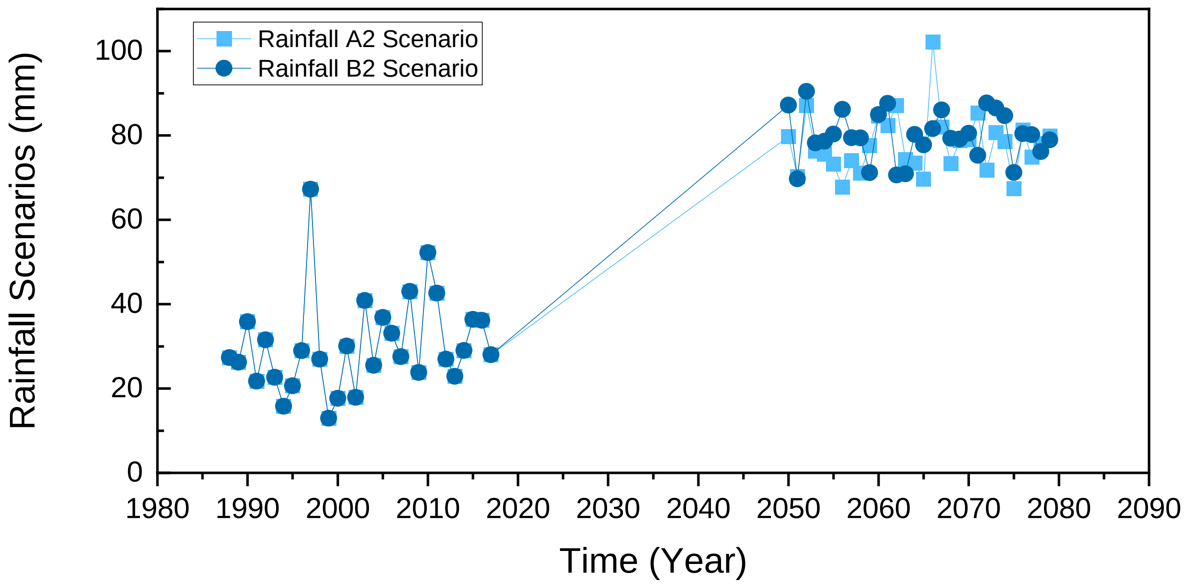
The below bar chart demonstrates the connection between time (years) and Mean every year temperature (MAT) and furthermore demonstrate the temperature drift from 1988-2017, 2050-2079 under A2 and B2 scenario. Orange and red line introduces the mean yearly temperature incline line with deference of time. A2 scenario, as per the straight condition y = 0.0686x + 23.693 temperature anticipated to increments by 0.0686 0C with every multiyear in the period from 1988 to 2079 and catch estimation of pattern line 23.693 shows that there is no adjustment in mean yearly temperature with deference of time. R2 is the Coe-proficient of assurance; the estimation of coefficient assurance 0.70 demonstrates that expansion in temperature is 70% subject to time.
In B2 scenario, as per the linear equation y = 0.0553x + 23.876 temperature anticipated to increments by 0.05530C with every multiyear in the period from 1988 to 2079 and catch estimation of pattern line 23.876 demonstrates that there is no adjustment in mean yearly temperature with deference of time. R2 is the Coe-productive of assurance; the estimation of coefficient assurance 0.76 demonstrates that expansion in temperature is 76% reliant on time.



Relationship mean annual rainfall (MARF) under A2 and B2 scenario

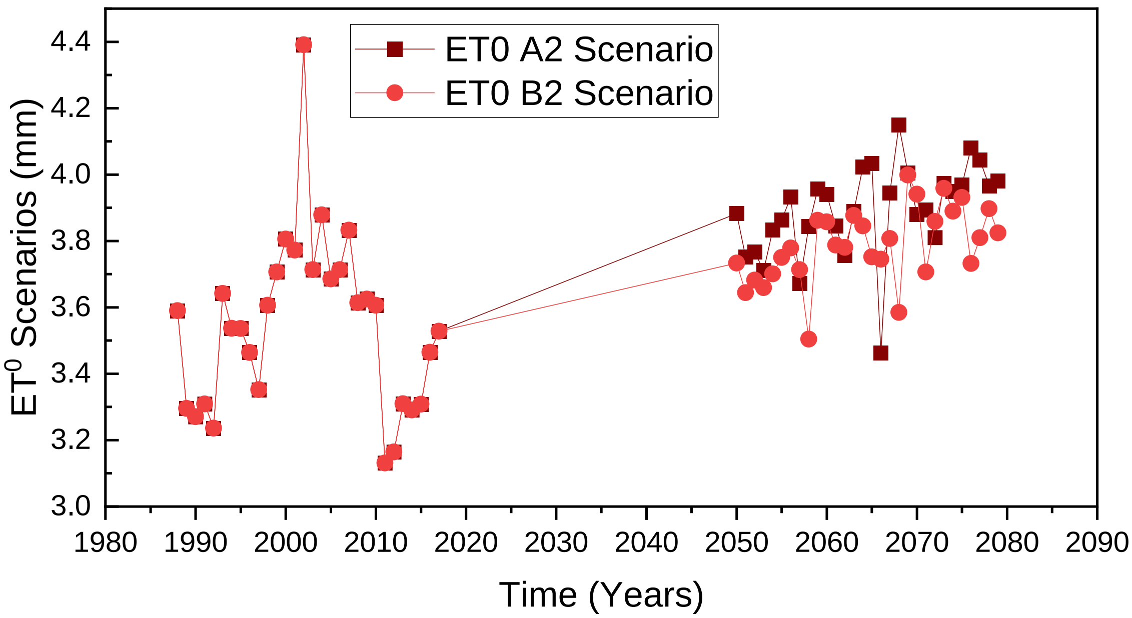
The below bar graph demonstrates the connection between time (years) and Mean every year Rainfall (MARF) and furthermore demonstrate the precipitation incline from 1988-2017 to 2050-2079 under A2 and B2 scenario. Sky blue and dark blue line displays the mean yearly precipitation drift line with deference of time. According to A2 scenario the linear equation y = 1.2329x + 16.501 precipitation anticipated to increments by 1.2329 ^{0}C with every multiyear in the period from 1988 to 2079 and capture estimation of pattern line 16.501 shows that there is no adjustment in mean yearly precipitation as for time. The estimation of coefficient assurance 0.69 demonstrates that expansion in precipitation is 69% subject to time. According to B2 scenario,

as per the direct condition y = 1.2329x + 16.501 precipitation anticipated to increments by 1.23290C with every multiyear in the period from 1988 to 2079 and capture estimation of pattern line 16.501 shows that there is no adjustment in mean yearly precipitation as for time. The estimation of coefficient assurance 0.69 demonstrates that expansion in precipitation is 69% subject to time.



Relationship Mean annual reference ET ($MAET_0$) under A2 and B2 scenario

The below graph demonstrates the connection between time (years) and Mean every year reference evapotranspiration (ET_0) ($MAET_0$) and furthermore demonstrate the reference evapotranspiration (ET_0) incline from 1988-2017, 2050-2079 under A2 and B2 scenarios. Maroon and orange line shows the mean yearly reference evapotranspiration (ET_0) drift line with deference of time. According A2 scenario the straight condition $y = 0.0095x + 3.4297$ reference evapotranspiration (ET_0) anticipated to increments by 0.0095^0C with every multiyear in the period from 1988 to 2079 and capture estimation of pattern line 3.4297 shows that there is no adjustment in mean yearly reference evapotranspiration (ET_0) with deference of time. R^2 is the Coe-productive of assurance; the estimation of coefficient assurance 0.72 demonstrates that expansion in reference evapotranspiration (ET0) is 72% subject to time. According to B2 scenario reference ET projected to increase by 0.0068 mm for the tenure from (1988 to 2079) and intercept value of trend line is 3.4606 is constant according to linear equation. R2 is coefficient of determination, this graph shows the R^2 is 69 percent it means rise in reference ET 69% dependent on time.



CHANGES IN CROP WATER REQUIREMENT

Crop water requirement depend upon climatic parameters like temperature and solar radiation etc., if huge changes in the parameters then crop water requirement will very and its effect on water demand in future. This study projected crop water requirement of cotton-wheat and wheat-maze zones will increase 10.01% and 48.99% respectively under A2 scenario (1988-2079). In B2 scenario (1988-2079) the crop water requirement of cotton-wheat and wheat-maize zones will increase 7.10% and 44.80% respectively. The similar kind results of projected change in crop water requirement showed by the Arshad and Gujree, (2019), Diaz, and E. Camacho (2007), Behera, and S. Sahoo. (2016).

Percentage increment in crop water requirements of Cotton-Wheat and Wheat-Maize zones between 1988-2017 and 2050-79 in Samundari under A2 and B2 scenarios

Period	Cotton-Wheat (%)	Wheat-Maize (%)
1988-2079 (A2)	10.01	48.99
1988-2079 (B2)	7.10	44.80

Relationship of Mean annual crop water requirement (Cotton-Wheat) under A2 and B2 scenario

The above graph shows the relationship between time (years) and Mean annually crop water requirement (MACWR) of cotton-wheat zone and also show the crop water requirement trend from 1988-2017 to 2050-2079 under A2 scenario. Blue line presents the mean annual crop water requirement trend line with respect to time. As indicated to the equation equation y = 0.005x + 2.5085 crop water requirement projected to raise by 0.005^0C with each one year in the period from 1988 to 2079 and intercept value of trend line 2.5085 indicates that there is no change in mean annual crop water requirement with respect of time. R^2 is the Coe-efficient of determination and represent the results are efficient or not. The value of coefficient determination 0.71 shows that increase in crop water requirement is 71% dependent on time.

The above chart shows the relationship between time (years) and Mean annually crop water requirement (MACWR) of cotton-wheat zone and also show the crop water requirement trend from 1988-2017 to 2050-2079 under B2 scenario. Blue line presents the mean annual crop water requirement trend line with respect to time. As indicated to the equation y = 0.0032x + 2.5275 crop water requirement projected to raise by 0.0032^0C with each one year in the period from 1988 to 2079 and intercept value of trend line 2.5275 indicates that there is no change in mean annual crop water requirement with respect of time. R^2 is the Coe-efficient of determination and represent the results are efficient or not. The value of coefficient determination 0.72 shows that increase in crop water requirement is 72% dependent on time.

Relationship of Mean annual crop water requirement (Wheat-Maize) under A2 and B2 scenario

The above bar graph shows the relationship between time (years) and Mean annually crop water requirement (MACWR) of wheat-maize zone and also show the crop water requirement trend from 1988-2017 to 2050-2079 under A2 scenario. Blue line presents the mean annual crop water requirement trend line with respect to time. As indicated to the equation y = 0.0193x + 1.3664 crop water requirement projected to raise by 0.0193^0C with each one year in the period from 1988 to 2079 and intercept value of trend line 1.3664 indicates that there is no change in mean annual crop water requirement with respect of time. R^2 is the Coe-efficient of determination and represent the results are efficient or not. The value of coefficient determination 0.66 shows that increase in crop water requirement is 66% dependent on time.

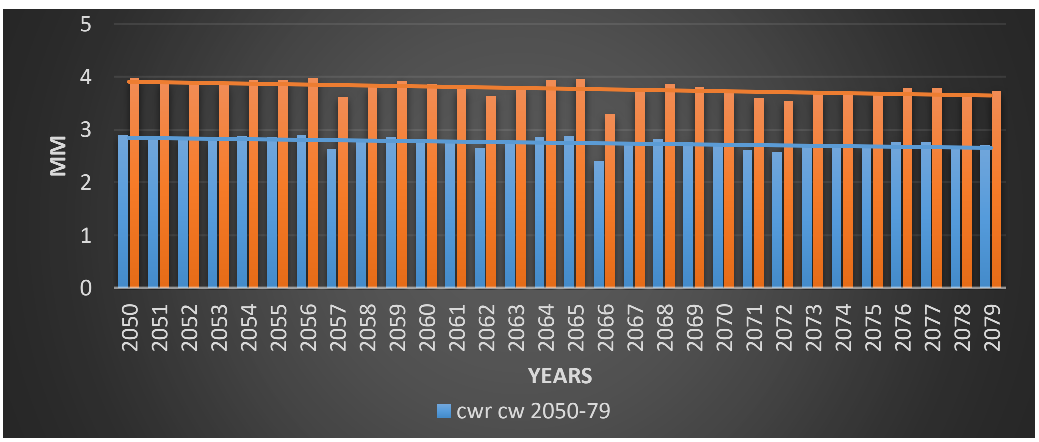
The above graph shows the relationship between time (years) and Mean annually crop water requirement (MACWR) of wheat-maize zone and also show the crop water requirement trend from 1988-2017 to 2050-2079 under B2 scenario. Blue line presents the mean annual crop water requirement trend line w.r.t (with respect to time). Crop water requirement projected to increases by 0.0176^0C with each one year in the period from 1988 to 2079 and intercept value of trend line 1.3857 indicates that mean annual crop water requirement is constant as indicated to the linear equation y = 0.0176x + 1.3857. The value of R^2 is 0.64 shows that increase in crop water requirement is 64% dependent on time.

COMPARISON OF FUTURE CROP WATER REQUIREMENT WITH AND WITHOUT SALINITY

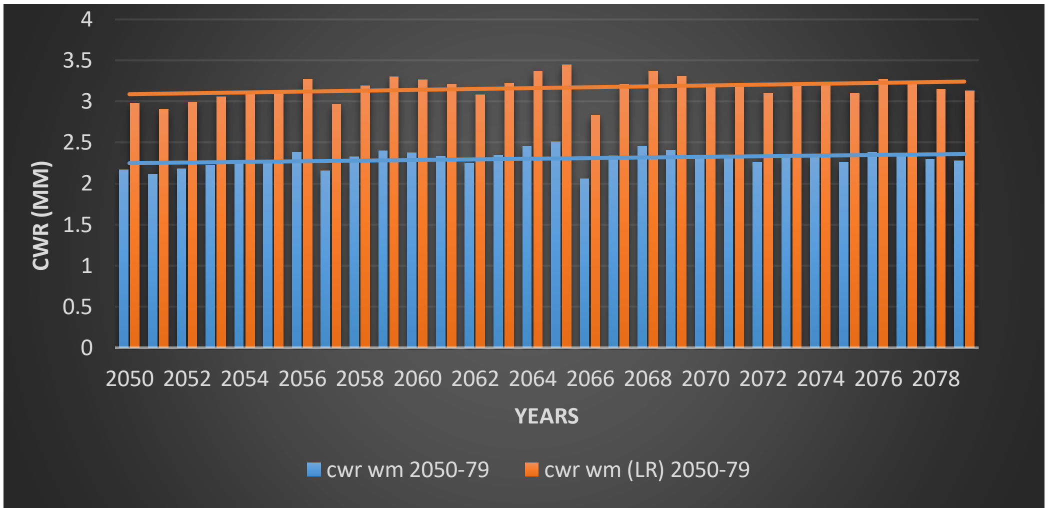
Practically range for Pakistan is under bone-dry Furthermore semiarid climatic zones. Regularly helter smelter evapotranspiration rate done semi-arid in Faisalabad Also bone-dry zones is those fundamental make for salt gathering on the dirt surface. That Normal sunny season temperature clinched alongside Pakistan is regarding 40 degree Celsius also on the different side the base winter temperature between 20 °C will 50 °C. Those imply twelve-month precipitation varies the middle of 100mm to 700mm throughout the particular nation. The vanishing rate may be typically high Also dives Past that of precipitation.

Measurement of LR:

Leaching requirement was determined by the equation, in which electrical conductivity of water (ECw) and electrical conductivity of soil (ECs) used as a parameter. Electrical conductivity of soil 2.335 was taken from the samundari project and report.

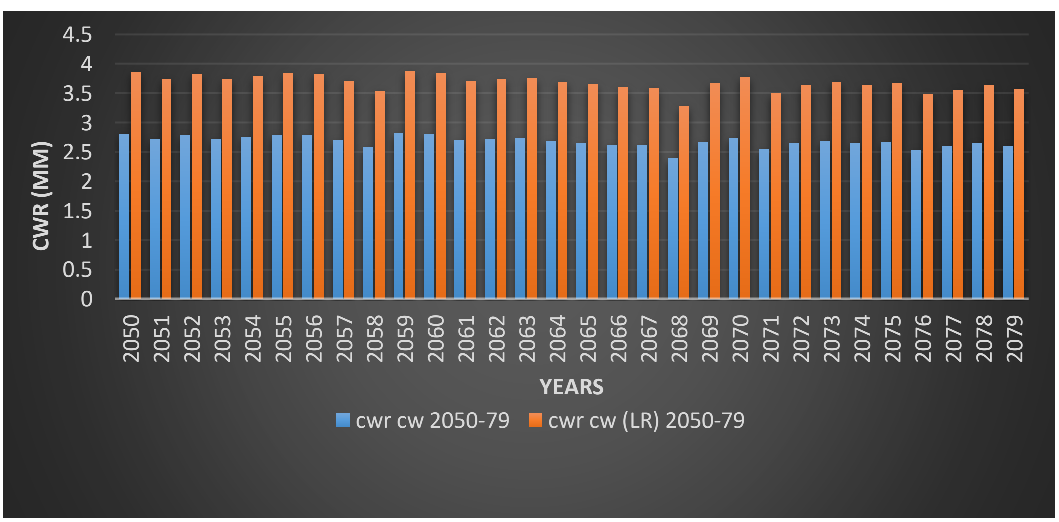


Comparison of future period (2050-79) CWR with and without leaching requirement of cotton-wheat zone under A2 scenario

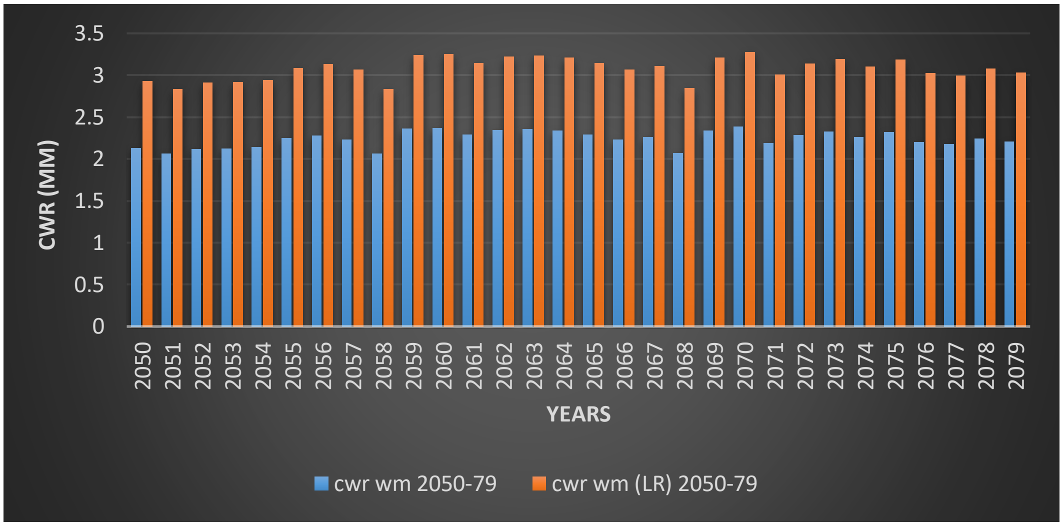


Comparison of future period (2050-79) CWR with and without leaching requirement (LR) of wheat-maize zone under A2 scenario

Above charts shows the comparison of future (2050-79) crop water requirement (CWR) of wheat-maize (WM) zone with and without leaching requirement under A2 scenario. Red line present the CWR of wheat-maize with leaching requirement and blue line present the CWR of wheat-maize without leaching requirement of future period 2050-2079 under A2 scenario. CWR of cotton-wheat and wheat-maize zone was projected increase due to including the leaching requirement according to the all comparisons. Cai, X., and Rosegrant, M.W., (2003) were found the similar results in his research.



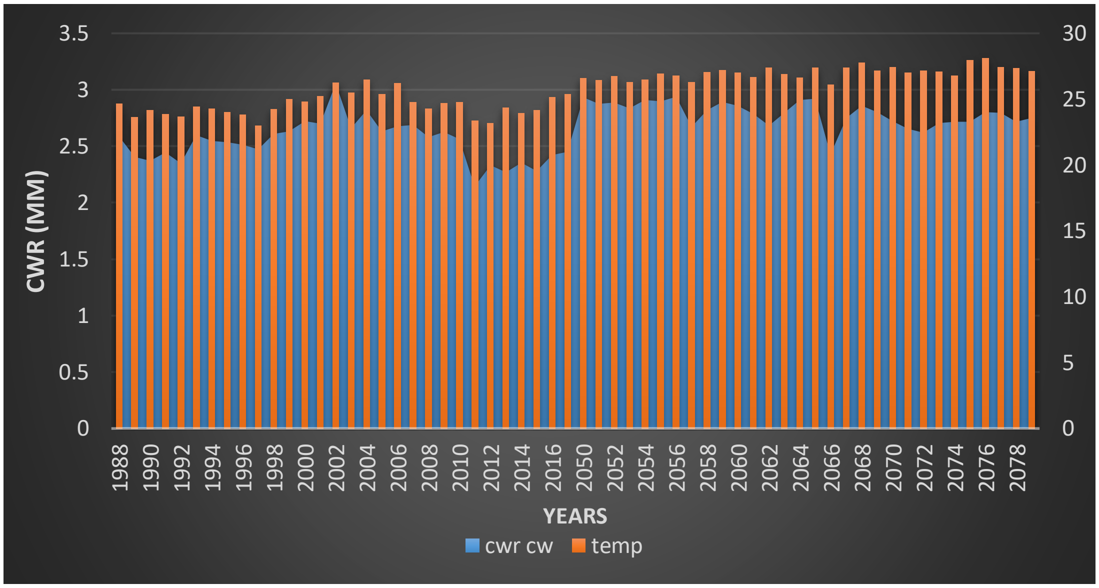
Comparison of future period (2050-79) CWR with and without leaching requirement of cotton-wheat zone under B2 scenario



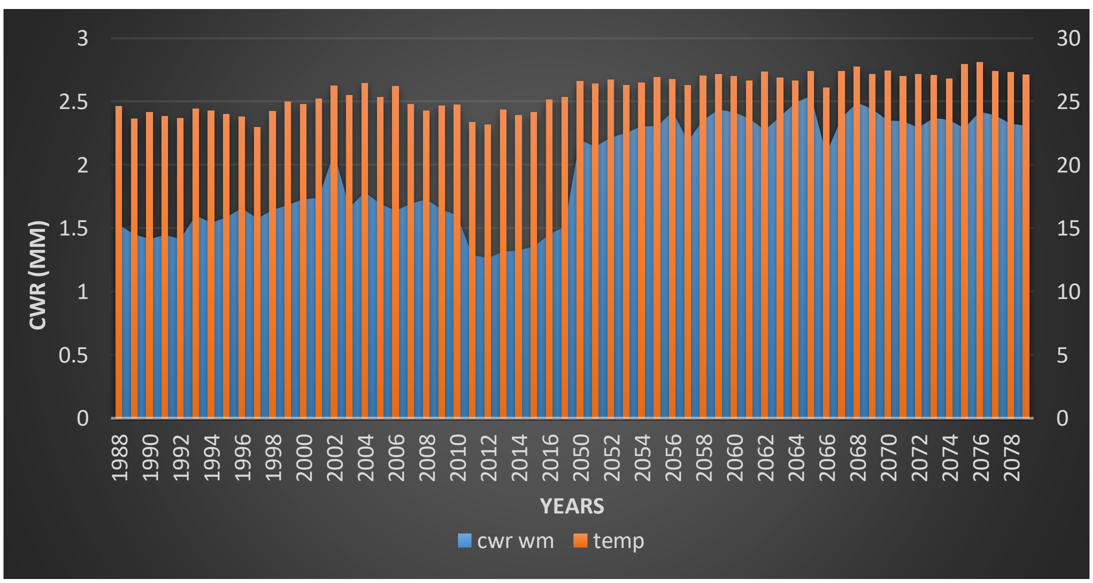
Comparison of future period (2050-79) CWR with and without leaching requirement of wheat-maize zone under B2 scenario

RELATION BETWEEN CROP WATER REQUIREMENT, TIME AND TEMPERATURE

Evapotranspiration (ET) may be a critical a piece from claiming hydrological cycle Furthermore may be used to evaluate the crop water prerequisite (CWR). The A large portion imperative focuses which impact the CWR alternately ET rely on a lot of people climatic parameters. Any huge alternately considerably moderate transform in the parameter encountered with urban decay because of deindustrialization, engineering concocted, and government lodge toward worldwide warm might likewise influence ET or crop water interest. Though the ET are proceeds with improve the water storages in the structure from claiming minute's dams what's more ponds and so forth. Might dry more fast and quick. Because of those effect about worldwide warming, alterability middle of the year and likewise moon quickly precipitation need significantly extended Also glaciers would constantly Dissolving at more quickly over watched prior. The below graphs shows the relation between temperature and crop water requirement of selected crop zones (cotton-wheat and wheat-maize) under A2 and B2 scenario. From the graphs it's clear that the temperature direct link with crop water requirement, according to the result increased in temperature cause the increase in crop water requirement.

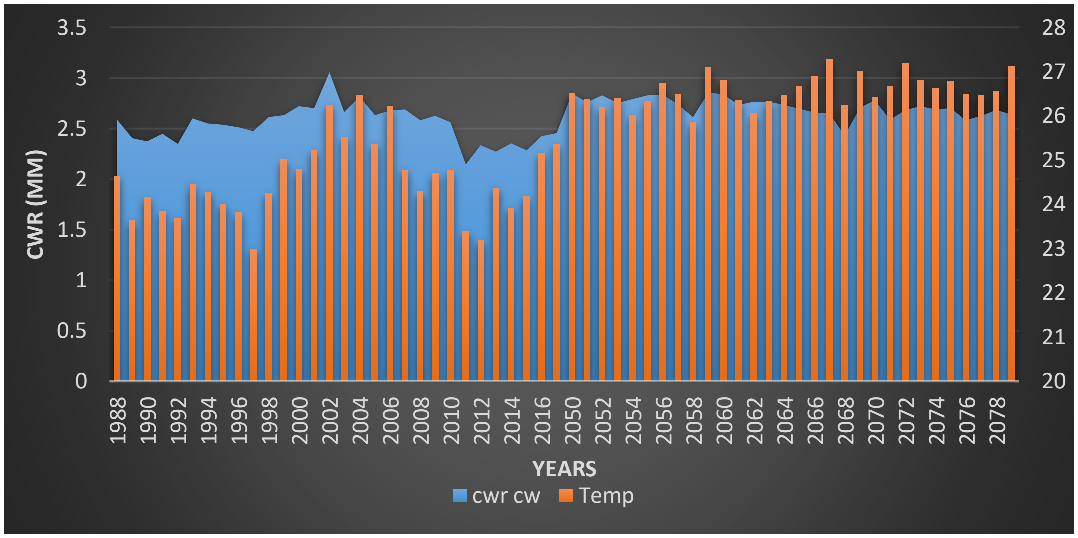


Relation between CWR, time (1988-2017 and 2050-2079) and temperature of cotton-wheat zone under A2 scenario



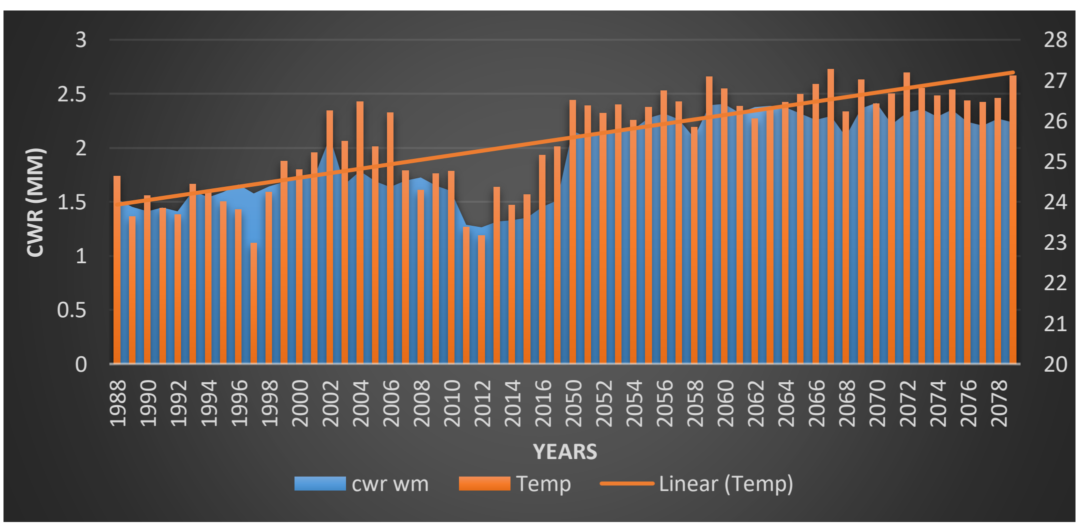
Relation between CWR, time (1988-2017 and 2050-2079) and temperature of wheat-maize zone under A2 scenario

Above chart shows the relationship between CWR, time (1988-2017 and 2050-2079) and temperature of wheat-maize zone under A2 scenario. In which graph red line show the mean annual temperature and blue line show the mean annual crop water requirement. Temperature direct link with crop water requirement clear from the graph, the CWR was projected increase with respect to time due to increase in temperature.



Relation between CWR, time (1988-2017 and 2050-2079) and temperature of cotton-wheat zone under B2 scenario

Above chart shows the relationship between CWR, time (1988-2079) and temperature of cotton-wheat zone under B2 scenario. In which graph red line show the mean annual temperature and blue line show the mean annual crop water requirement. Temperature direct link with crop water requirement clear from the graph, the CWR was projected increase with respect to time due to increase in temperature.



Relation between CWR, time (1988-2017 and 2050-2079) and temperature of wheat-maize zone under B2 scenario

Above graph shows the relationship between CWR, time (1988-2079) and temperature of wheat-maize zone under B2 scenario. In which graph red line show the mean annual temperature and blue line show the mean annual crop water requirement. Temperature direct link with crop water requirement clear from the graph, the CWR was projected increase with respect to time due to increase in temperature.

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