# Impact of Climate Change on Cropwater Requirement for Sunei Medium Irrigation Project, Odisha, India

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***Abstract***

*The natural process and man-made activities in the watershed have influenced the climate change and induce the hydrology of the watershed along the temporal scale. Increase in emission of greenhouse gas into atmosphere might induce in climate pattern in future. Many researchers have been incorporated climatologicall cycle and its variability into the water resources system modelling in the recent past. Change on climate could affect the metrological parameters and which directly lead to change in irrigation water requirement in agriculture. In this study, an effort has been made to assess the impact of climate change on crop water requirement in Sunei command area (Bhudhabalang Basin) of Mayurbhanj district Odisha, India. For this study, daily meteological data like maximum temperature , minimum temperature, wind speed, sunshine hours, humidity and precipitation data are used. Crops and cropping pattern data are used for the study area. Future climate data predicate for the period 2025, 2050 and 2080 considering both A2 and B2 scenario using GCM HadCM3. Crop evapotranspiration ($ET_o$ ) was calculated using mean monthly climate and rainfall data with help of CROPWAT 8.0. Then crop water requirement (CWR) was determined for each crop of the project area of the study area. Results confirm the clear impact of climate change on crop water requirement of Kharif and Rabi crops. It shows that both H3A2 and H3B2 scenarios crop water requirements increases where as for some Rabi season crops like Dalua rice, Groundnut, Mustard crop water requirements decreases in future for H3B2 scenario. The increase or decrease are consider compared to base period 2010. To meet the increase water demand and to increase yield for future, water resources can be increased by doing water conservation practices, small barrages and farm ponds near command area. Groundwater should be used as conjunctive use at peak requirement period.*

**Keywords***:* *Climate change, Evapotranspiration, Statistical Downscale Model, CROPWAT, Cropwater requirement.*

## I. INTRODUCTION

The natural process in any water can be influenced by changes in climate variable. Climate of a region refers to the average weather conditions in a certain place over many years. The climate in one certain area is called a regional climate. The average climate around the world is called global climate. When scientists talk about global climate change, they are talking about the global climate and the pattern of changes that’s occurring over many years. Scientists are having more interest to know the effect on climate changes due to enhance of greenhouse gases. As climate changes may be great influence on the hydrological cycle and consequently on the available water resources, which also impact on agriculture water demand. Fresh water demand has been increasing rapidly due to population growth day by day and increasing the living standards, increasing the industrial water demand. As a result water shortage has become a great concern for future. With changing the climate to meet food demand and water demand in future is a great challenge. It is necessary to improve integrate technology and multidisciplinary water resources management. From studies it found that about 80% of the available fresh water of the area used in agriculture, of which is less than 30% is effectively utilised by the crop and the rest is consumed by percolation and poor water management. Improving water management boost food production and save water as much as possible, for practice efficient agriculture water management requires reliable estimation of crop water requirement.

Models are developed to replicate the hydrological cycle, the climate influence by considering the variability in the climate influence by considering the variability in the climate parameters.

Intergovernmental Panel of climate change (IPCC) developed a climate model known as General Circulation Models (GCMs) which predict the future climate parameters. When climate variables from GCM is incorporating into the hydrological cycle models will generate the impact of climate change on the system for future scenario. The IPCC has categorised mainly four types of climate scenarios such as (A1, A2, B1, B2) considering on economic development and environmental condition. The impacts of climate change for country like India may faced various problems like fresh water scarcity problems, impacts on agriculture which affect the agriculture and economic of the regions in future. Snow fed rivers may be converted to seasonal rives due to rapid changes in trend of glacial melts.

In the present study General Circular Models (GCMs) are used to simulated present and projected future climate consideration A2 and B2 climate scenario.

The numerical coupled models represents various earth systems including the earth surface, atmosphere, oceans are useful for the study of climate change and variability (Hewitson and Crane 1996; Wilby and Wigley 1997; Prudhomme et al.2003; Crawford et al.2007). These Models are coarser-grid resolution and more accuracy at large spatial scales (Bardossy 1997; Ojha et al. 2010; Hassan and Harun 2012; Mishra et al. 2014). Downscaling offers fine scale data from coarse grids GCMs. For example, the Hadley Centre's HadCM3 model has resolved at a spatial resolution of 2.50 latitude by 3.750 longitude whereas a spatial resolution of 0.1250 latitude and longitude is required for hydrologic simulations of monthly flow in Mountainous catchments (Salath'e, 2003). Hence, various downscale approaches are developed to bridge the gap between the resolution of climate models and regional and local scale process, and tested by many hydrologists and climatologists. (Giorgi and Mearns, 1991; Wilbey et al., 2007; Bardossy et al., 1997). The downscale methods include Multiple linear regression, Canonical correlation analysis, Support vector machines and Artificial neural networks (Lall et al. 2001; Ghosh and Majumdar 2006; Raje and Mujumdar 2009; Kanna and Ghosh 2010; Raje and Mujumdar 2011; Hashmi and Shamseldin 2011; Kodra et al., 2012).

Statistical downscaling model (SDSM) tools (Wilby et al., 2007) which employ the multiple liner regression approach to downscale GCMs outputs from global scale to local scale for assessment the future climate scenario on hydrological process of the Sunei command area ( Bhudhabalang Basin) of Mayurbhanj located in Odisha. The tool process through data quality control, data transformation, screening of the predictor variables, model calibration and validation, weather generation, scenario generation, statistical analysis and its representation of climate data (Wilby and Dawson 2007).

Climate variable (temperature) increases, the atmosphere air gets warmers, thus the warm air accelerates the evaporation from soil moisture. Irrigation schedule depends on the frequency and quantity of irrigation water required based on the type of crop and rainfall precipitation over the time period. Evaporation governs the crop water requirement estimation.

## II.MATERIAL AND METHOD

### A. Study Area

In the study, a medium irrigation project is considered named as Sunei Medium Irrigation project for analysis. The project is located at latitude $21^0$-28'-00''(N) and longitude $86^0$-28'-00''(E). The study area is located in Budhabalanga river basin, which rises at an elevation of about 800m of south of Similipal village in Mayurbhanj district, Odisha, India; and flows for a length of 196 km to join the Bay of Bengal. The catchment area of the project comprise 227 Sq. Km and command area of 10,000 ha in Kharif falls under the northern central plateau zone (agro-climate zone) of Odisha in the district Mayurbhanj and Balasore. The catchment area of Budhabalanga basin is about 4741 $km^2$ lies between $21^0$ 28' N to $22^0$ 20' N latitude and $86^0$ 20' E to $87^0$ 4' E longitude. Average annual rainfall in Budhabalanga basin is in order of 1580 mm. About 90% rainfall is received during June to October due to the influence of the South-West monsoon. Annual average runoff is 3.45 BCM. The temperature starts rising from February and peak reached in the month of May touching to $40^0$ C. The location map of the study area is shown Fig.1.1(a) & (b).

***B. Meteorological Data:*** The daily precipitation data for the periods 1961-2001were collected from India Meteorological Department(IMD), Pune. The daily precipitation data were converted to monthly, seasonal and annual time scale for analysis. For Humidity, wind speed, sunshine hours data are collected from NASA website. For calculation of ETo Crop water 75 % dependable monthly rainfall

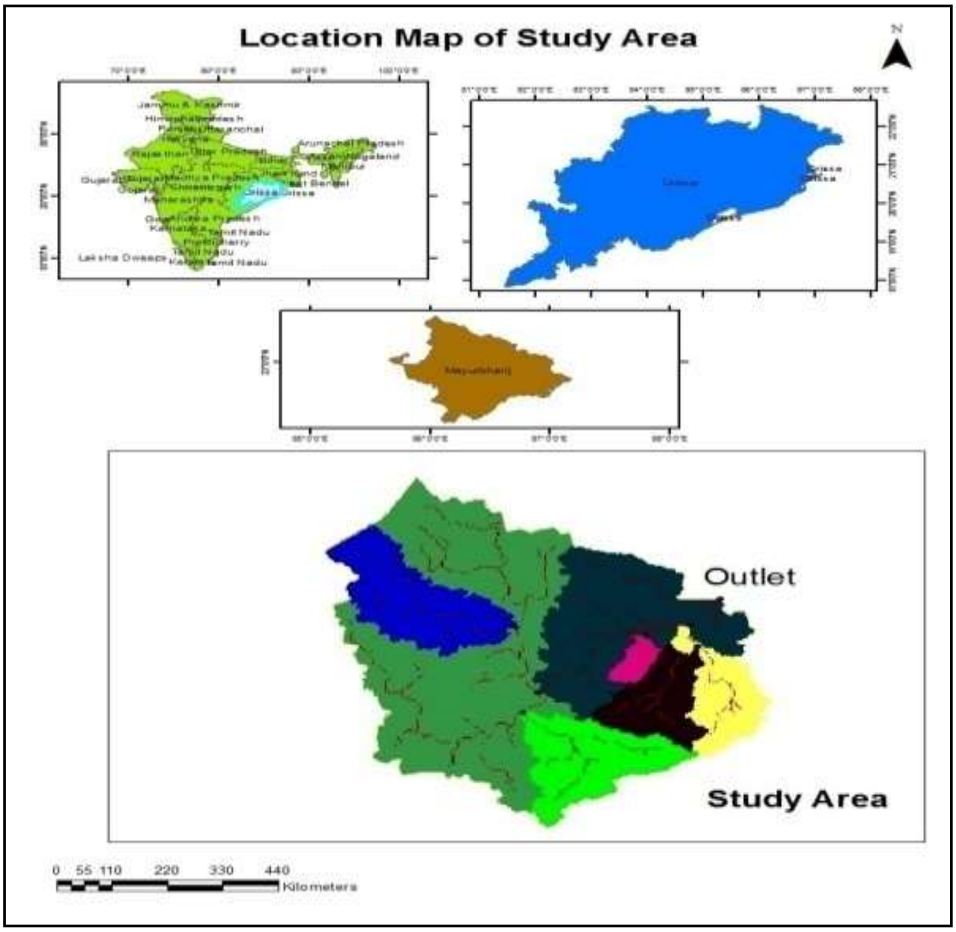


**Fig. 1.1(a) Location map of Sunei Dam and Catchment Area**

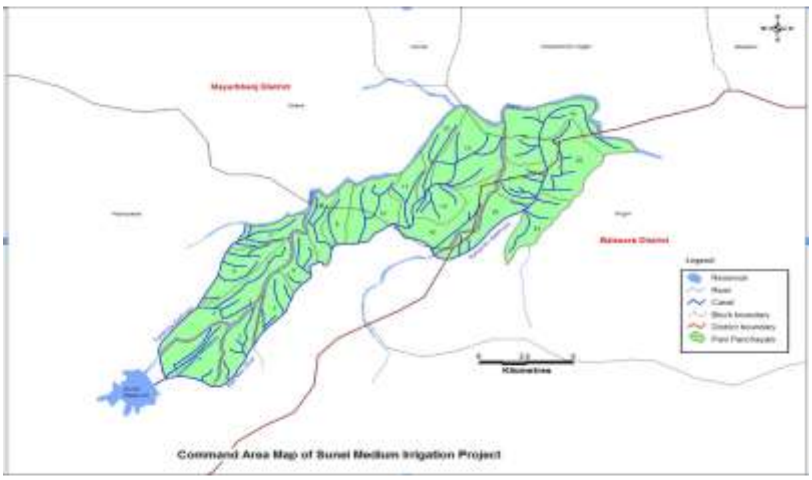


***Fig. 1.1 (b)Location map of Sunei Dam and Command Area***

(period 1987-2010) and monthly mean maximum and minimum temperature (period 2001-2010) is used.

***NCEP reanalysis Data:*** National Centre of Environmental Prediction (NCEP) of $2.5^0$ latitude X $2.5^0$ longitude grid- scale re-analysis data are obtained from Canadian Climate Impacts Scenarios (CCIS) website for the period of 41 years (1961-2001).

***GCM Data:*** The large-scale Hadley Center's GCM (HadCM3) for (HadCM3) A2 and B2 future scenarios data of $3.75^0$ latitude X $3.75^0$ longitude grid-scale for the period of 139 years (1961-2099) are obtained from Canadian Climate Impacts Scenarios (CCIS) website) (http://www.cics.uvic.ca/scenarios/sdsm/select.cgi). HadCM3 has been chosen because of it's wider acceptance in climate change impact. The daily predictor variables from HadCM3 are used for SDSM Model.

***Crop Data:*** Cropping pattern data including season wise crops grown in the study area was acquired from Sunei feasibility project report, DoWR Odisha. Crops data includes length of crop development stages in days and crop coefficient (Kc) for each crop of all season were taken from Food and Agriculture Organization (FAO) Irrigation and Drainage Paper No.56.

**C. Method**

Methodology is divided into three parts (1) Generation of future climate scenario GCM (HadCM3) with statistical down scaling model. (2) ETo calculation using CROPWAT software (3) Calculation of crop water requirement

***Climate Crop water requirement***

To study the influence of variation in climate parameters (temperature, wind, humidity) on the irrigation water requirement on temporal scale, a frame works is developed which is known as climate crop water requirement (CCWR). The CCWR framework integrates the crop water requirement model (CROPWAT) and spatial climate variable downscaling technique developed by Maurer et. al.

***Climate Variable downscaling technique***

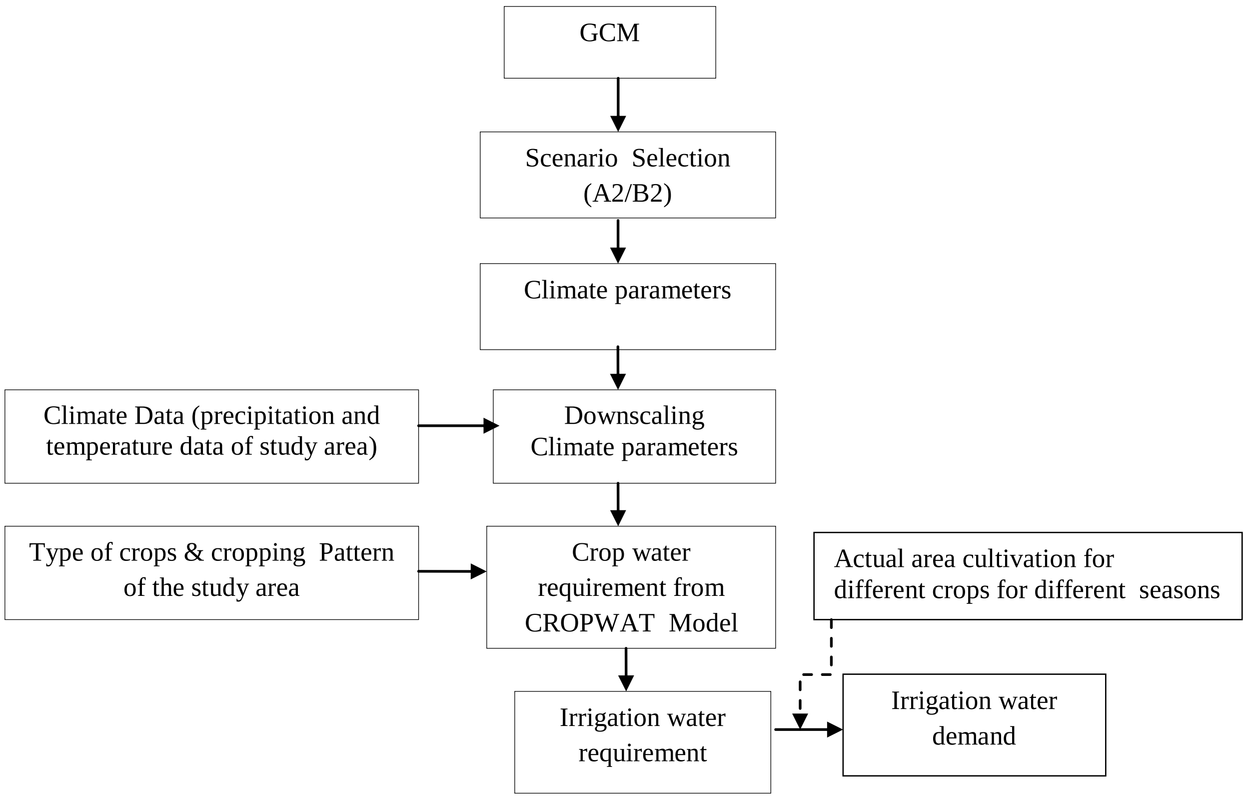


***Fig. 1.2 Flow chart for crop water requirement and Irrigation water demand with changing climate***

***Irrigation water demand for crop***

The irrigation requirements for various crops in the command area have been estimated using the irrigation demand estimation. Mainly four type of data are required for irrigation demand estimation i) rainfall, ii) climate variables iii) cropping pattern including time of sowing and harvesting, iv) Types of soils (field capacity, moisture content).

The process stars with excess rainfall for the rainfall that has occurred in the command area. Then followed by estimation of crop water requirement of the available crop types in the study area. In this research the crop water requirement for the crop types of crop and cropping pattern has been estimated using CROPWAT software. CROPWAT uses FAO Penman-Monteith model for estimating reference Evapo-transpiration.

FAO Penmann-Monteith Model to estimate reference evaporation $ET_o =$

$$\frac{(0.408\Delta(Rn-G)) + (\gamma \frac{900}{T+273} u_2(e_s - e_a))}{\Delta + (\gamma(1+0.34u_2))}$$

The crop water requirement for each crop in the command area has been based on the crop coefficient ($K_c$) and estimated $ET_0$.

$$ET_c = K_c \times ET_o$$

## III. RESULTS AND DISCUSSIONS

### A. Future Scenario Generation

The HadCM3 predictors variables derived from NCEP dataset using Multiple Linear Regression models between the predictand and large-scale predictors are used to generate the future downscaled data for A2 and B2 scenarios. The downscale process has been carried out for the scenario of the current and future time periods, namely 2010, 2025, 2050 and 2080. The result of the downscaled mean daily rainfall, maximum and minimum temperatures for different periods are shown in Fig.1. 3 to Fig.1.5 for A2 and B2 scenarios.

The figures exhibits that the mean daily rainfall does not show a constant increase or decrease in rainfall trend for the scenario of the current and future time periods where as the mean monthly temperature increases both scenario except January month for minimum temperature for A2 scenario.

The annual precipitation corresponding to future emission for HadCM3 A2 and B2 scenario is shown in Table 1.1. The result shows that there is an increase in trend of annual precipitation for future for the period 2025 and 2050 for both A2 and B2 scenario compared to present scenario. In the 2025, the simulated rainfall is 2078.75 mm and 2031.47 mm for A2 and B2 scenarios respectively. Similarly for 2050, 2080, the annual mean precipitations are 1932.98 mm, 1805.73 mm for A2 and 1973.22 mm and 1902.24 mm for B2 respectively.

***Crop Water Requirement***

Crop water requirement study has been done considering 100 % Kharif crops and 50% Rabi crops in the study area. In Kharif season crops (Late Rice, Soyabeen, Vegetable) and for Rabi season crops like (Dalua Rice, Groundnut, Mustard, Potato, Moong gram, Sunflower, Wheat and vegetable) are considered.

Table 1.2 and 1.3 show period wise evapotranspiration and average crop water requirements of Kharif and Rabi crop for H3A2 and H3B2 Scenarios. Figure 1.6 to 1.7 shows crop water requirements for H3A2 and H3B2 Scenario. The period wise crop water requirements is shown in figure 1.8.

**TABLE-II**

***Table 1.2 Average Crop Water requirement of Kharif Crops for H3A2 and H3B2 Scenario***

| | | H3A2 Scenario | | H3B2 Scenario | |
|---|---|---|---|---|---|
| **Crops** | **Period** | **$ET_c$ (mm)** | **Irr. Req (mm)** | **$ET_c$ (mm)** | **Irr. Req (mm)** |
| **Late Rice** | **2010** | 886 | 180 | 883.9 | 177.9 |
| | **2025** | 895.1 | 186.8 | 895.7 | 191.1 |
| | **2050** | 911.6 | 221.1 | 895 | 198.9 |
| | **2080** | 931.2 | 256.5 | 904.7 | 220.9 |
| **Soya been** | **2010** | 409.4 | 8.6 | 409.4 | 8.5 |
| | **2025** | 414.8 | 13.5 | 414.8 | 17.7 |
| | **2050** | 422.4 | 27.4 | 415.5 | 20.7 |
| | **2080** | 430.7 | 37.8 | 421.2 | 24.8 |
| **Vege table** | **2010** | 401.3 | 6.2 | 400.5 | 5.9 |
| | **2025** | 405.6 | 11.4 | 405.9 | 12.4 |
| | **2050** | 413.1 | 21.6 | 404.4 | 14.1 |
| | **2080** | 424 | 34.8 | 409.2 | 17.4 |

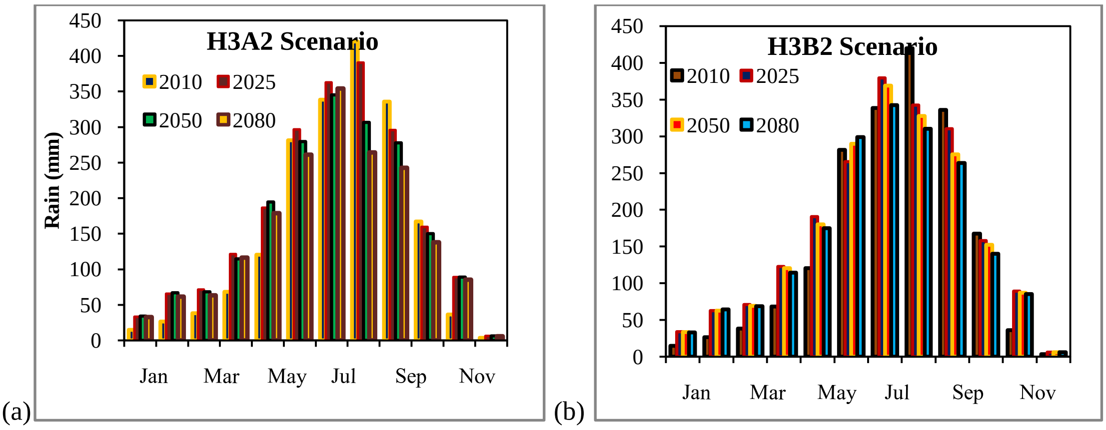


*Fig. 1.3 (a) and (b) General trend of mean daily precipitation for different period corresponding to HadCM3 A2 & B2 scenario*

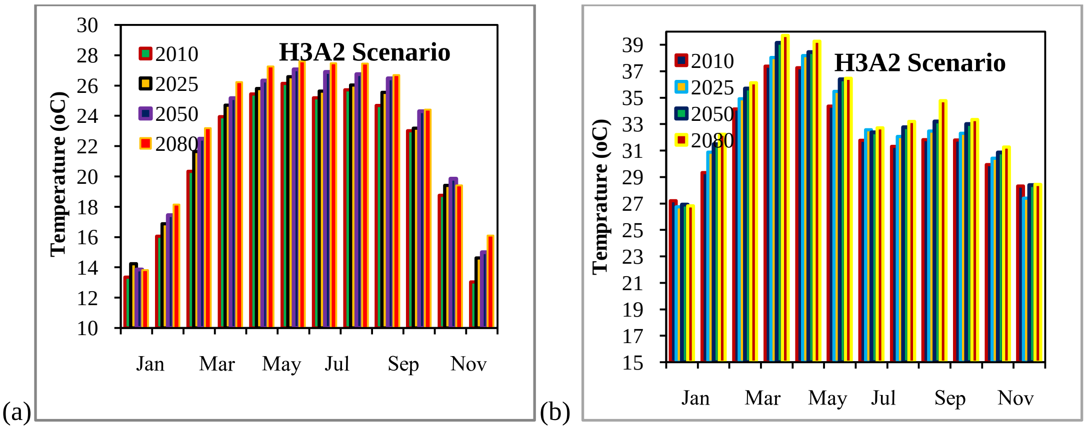


*Fig. 1.4 (a) and (b) General trend of mean daily minimum and maximum temperature for different period corresponding to HadCM3 A2 scenario*

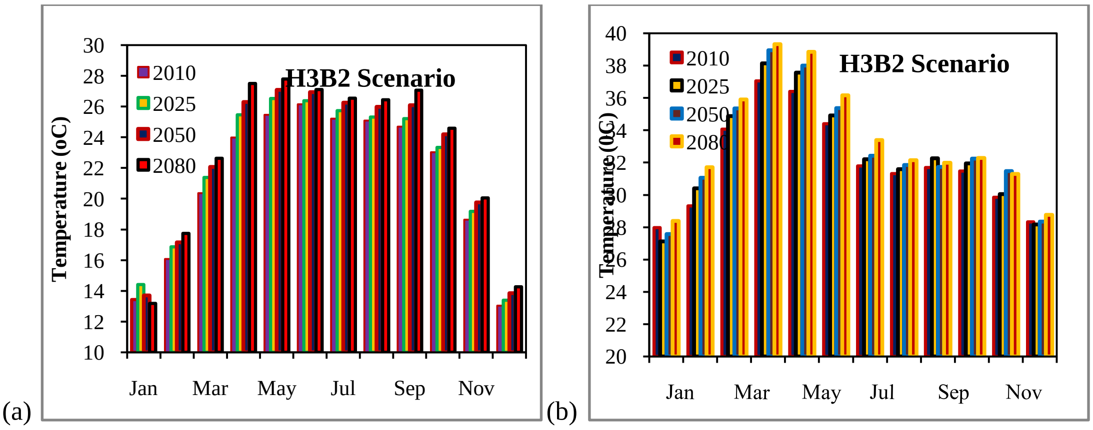


*Fig. 1.5 (a) and (b) General trend of mean daily minimum and maximum temperature for different period corresponding to HadCM3 B2 scenario*

**TABLE-I**

***Table.1.1 Annual average precipitation for present and downscaled precipitation corresponding to HadCM3 A2 and B2 scenario***

| Period | HadCM3 A2 scenario | HadCM3 B2 scenario |
|---|---|---|
| | Annual average precipitation (mm) | |
| 2010 | 1851.76 | |
| 2025 | 2078.75 | 2031.47 |
| 2050 | 1932.98 | 1973.22 |
| 2080 | 1805.73 | 1902.24 |

**TABLE-III**

***Table 1.3 Average crop water requirement of Rabi Crops for H3A2 and H3B2 Scenario***

| | | H3A2 Scenario | | H3B2 Scenario | |
|---|---|---|---|---|---|
| **Crops** | **Period** | **$ET_c$ (mm)** | **Irr. Req (mm)** | **$ET_c$ (mm)** | **Irr. Req (mm)** |
| Dalua Rice | 2010 | 662.7 | 580.1 | 666.4 | 583.9 |
| | 2025 | 670.7 | 501.7 | 669.9 | 500.8 |
| | 2050 | 679.4 | 511 | 670.3 | 501.8 |
| | 2080 | 684.5 | 525.8 | 681.3 | 522.7 |
| Ground Nut | 2010 | 554.8 | 442 | 555.2 | 442.5 |
| | 2025 | 566.1 | 351.2 | 565.1 | 352.3 |
| | 2050 | 575.4 | 364.4 | 552.1 | 341.5 |
| | 2080 | 581.4 | 378.5 | 557.8 | 348.7 |
| Mustard | 2010 | 400.2 | 347.7 | 402.4 | 349.9 |
| | 2025 | 392 | 277.8 | 399.6 | 284.8 |
| | 2050 | 397.8 | 283.9 | 409.4 | 296.9 |
| | 2080 | 397.8 | 286.9 | 414.5 | 303.3 |
| Potato | 2010 | 563.5 | 477.9 | 567 | 481.4 |
| | 2025 | 572.4 | 394.1 | 570.5 | 394.5 |
| | 2050 | 579.2 | 401.4 | 569.3 | 395.5 |
| | 2080 | 583.8 | 416 | 579 | 404.5 |
| Moong Gram | 2010 | 358.1 | 290.8 | 361.1 | 293 |
| | 2025 | 357.6 | 220.6 | 358.6 | 222.8 |
| | 2050 | 361 | 221.5 | 363.9 | 226.8 |
| | 2080 | 362.9 | 226.8 | 371.1 | 233.1 |
| Sunflower | 2010 | 506.1 | 393.3 | 506.7 | 394 |
| | 2025 | 517 | 302.1 | 516.1 | 303.2 |
| | 2050 | 525.2 | 314.2 | 504.4 | 293.8 |
| | 2080 | 530.8 | 327.9 | 510.3 | 301.2 |
| Wheat | 2010 | 578.6 | 464.7 | 580.7 | 466.8 |
| | 2025 | 591.3 | 377.5 | 589 | 376.9 |
| | 2050 | 599.2 | 386.8 | 579.9 | 371.1 |
| | 2080 | 605.1 | 401.4 | 587.9 | 379.2 |
| Vegetable | 2010 | 428.1 | 338.6 | 431 | 341.6 |
| | 2025 | 424.3 | 269.1 | 428.8 | 273.6 |
| | 2050 | 430 | 272 | 436.2 | 280 |
| | 2080 | 431.1 | 276.3 | 442.9 | 286.3 |

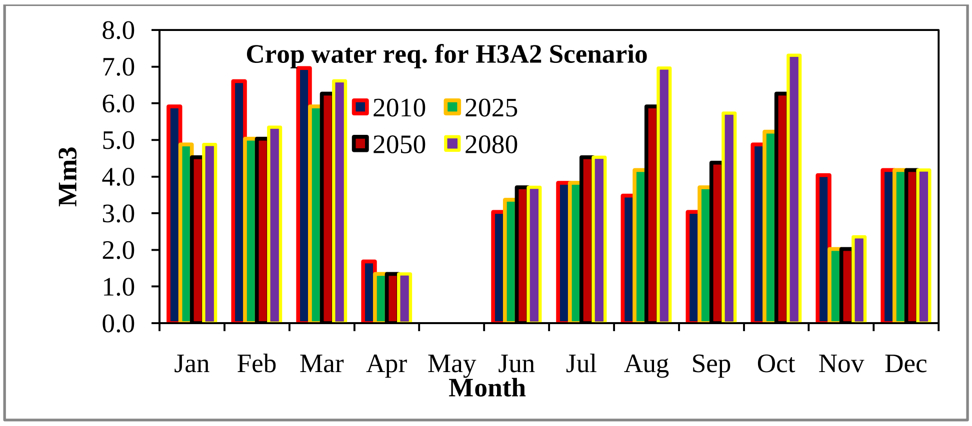


*Fig. 1.6 Monthly Crop water requirement for different period corresponding to HadCM3 A2 scenario*

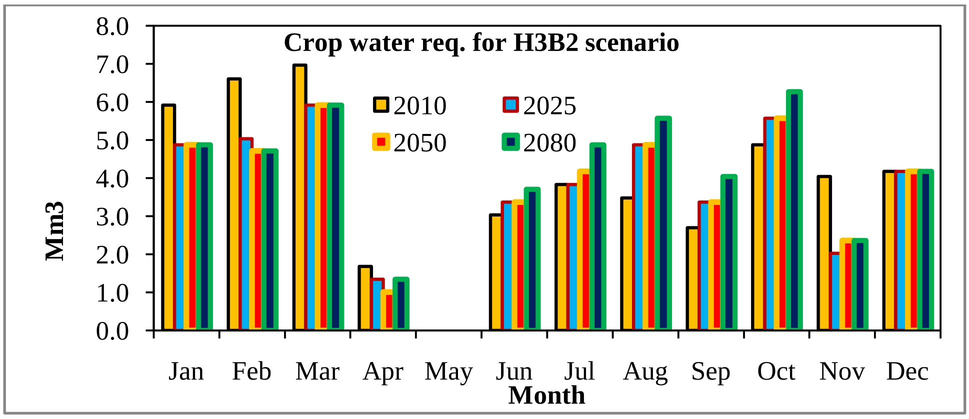


**Fig. 1.7 Monthly Crop water requirement for different period corresponding to HadCM3 B2 scenario**

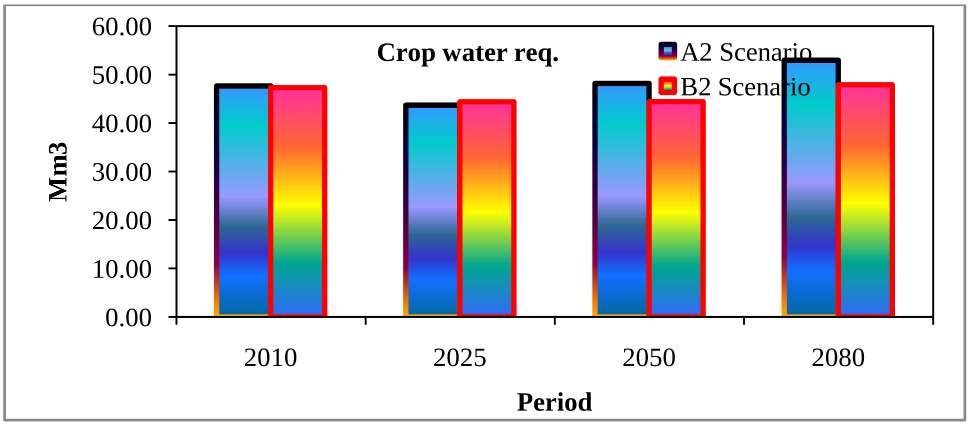


**Fig. 1.8 Crop water requirement for different period corresponding to HadCM3 A2 and HadCM3 B2 scenario**

## IV.CONCLUSIONS

The main fundamental of SDSM is the relationship between predictand (rainfall or temperature) GCMs predictor (HadCM3 A2/B2). GCMs variables selection is the most important factor in the study of climate change, which will affects in the results of climate assessment. The selection of GCMs variables are difficult and tricky. In this study, seven (07) of GCMs variables has been considered. The model calibration and validation has been performed using NCEP reanalysis data for duration 1961-1990 and 1991-2001 respectively and the results indicate that the model can be applied in Sunei irrigation project (Budhabalangaa river basin) to downscale climate change at different temporal and spatial scale. Daily precipitation and temperature data for the study area has been predicated for the periods 2025, 2050 and 2080. The study shows that an increase in rainfall in the study area for the period 2025 and 2050 and temperature increases Sunei command area

Results and analysis conclude the effects of climate change on crop water requirements for kharif and rabi crops. All kharif crops (Late rice, Soyabeen, Vegetable) shows rise in water requirements in all three periods for both scenario. Where as the crop water demand for the rabi crops ( Dalua rice, Ground nuts, Mustard) decreases for future compare to the period 2010. This occurs due to the monthly rainfall pattern change in future. Crop water requirements is more in case of H3A2 scenario compared to H3B2 scenario.

It has been concluded from the above results and analysis that in future precipitation increases for a certain period in the study area and then the trend may be decreased, where as the mean minimum and maximum temperature increases in future. As a results the demand of crop water requirement will be increase in future. To meet the increase water demand and to increase yield for future, water resources management should be necessary, in which policy maker, planner and water user like farmers should participate. Water resources can be increased by doing water conservation practices, small barrages and farm ponds near command area. Groundwater should be used as conjuctive use at peak requirement period.

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