Case Study Report on:

Climate Impact Assessment of Bagmati Irrigation System

Submitted by

Crish Basnet

Institute of Engineering, MSc. Water Resource Engineering, 2nd year

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Abstract

The Bagmati River Basin is the most water-stressed basin in Nepal as evidenced by increasing shortages in available water resources (surface and groundwater) to meet the basin water demand at key locations and time (mainly dry season). Bagmati Irrigation project is the national pride project of Nepal, which been providing irrigation service to farm land in Terai, Nepal. Project has envisioned to inter basin water transfer through diversion tunnel (67 m3/sec) from Sun-Koshi to Bagmati basin, to provide irrigation service all year around. After completion of project it covers the gross command area of 122000 ha.

CRAWFORD Model has been used to model the Bagmati Basin. Model was calibrated for 2000-2013 in NSE 0.81 PBIAS 11.38 and 0.92 and validated 2010-2013 had 0.501, PBIAS 40.36 and R 0.60.The study has employed warm-dry scenario of CMIP6 projection from the NESM, Global Climate Model (GCM). Hindcast data from 2000-2013 and Forecast data from 2030-2050 has been used for study. For future performance water surplus/deficit to irrigation system was assessed. Total number of water deficit month in climate of 2030-2050 is found to be increased from baseline period. However, Reliability score was found to be 92.06 and 92.46 was found for SSP 245 and SSP 585 scenario.

1. Introduction

1.1 Background

(Kafle, 2021) Concludes that the diversion of constant discharge of 67 m3/sec from Sun Koshi to Bagmati River may meet crop water requirements and provide year-round irrigation facility to 122000 ha of command area. Climate Impact on the Irrigation system has not been assessed in his study.

The Bagmati River Basin is the most water-stressed basin in Nepal as evidenced by increasing shortages in available water resources (surface and groundwater) to meet the basin water demand at key locations and time (mainly dry season. Degradation of the river environment, watershed and wetlands, floods and landslides in middle basin, and flood risks in the lower basin (Terai) are evident (Shrestha, 2013). Study in 2005 found that current trend is likely to lower the power production from the Kulekhani hydropower, plant is going to be reduced by 4% in every 10 years. Production of rice which is directly related to the monsoon season flow is going to be decreased but the production of the wheat may slightly be increased. The flood magnitude in the Bagmati River basin is decreasing but the duration of each flood and the frequency of the flood are increasing (Raj Hari Sharma, 2005).

To better study the future climate scenario and hydrological flow of basin and study will be vital to study the impact on the Bagmati Irrigation System.

1.2. Objective

The broader objective of the case study was to assess the climate impact on the Bagmati Irrigation system. The specific objectives are:

- Calibrate hydrological model
- Bias-correct GCM to assess flow in Bagmati watershed at the warm-dry scenario
- Simulate discharge at Bagmati watershed (2030-2050)
- Impact assessment of simulated discharge on Irrigation system

2. Study Area

The study area lies in the Bagmati Watershed of Nepal. River originates from Shivapuri hills at Kathmandu Valley and lies between Gandaki and Koshi Basin at West, East respectively.The catchment area is delineated taking padhadovan hydrological station as basin outlet. Hydrological station is located at (27 09 06, 85 29 30). Bagmati Irrigation project head works lies near downstream to Padharodovan having catchment area 2805 sq. km. Bagmati Irrigation project is the national pride project of Nepal, which been providing irrigation service to farm land in Terai, Nepal. Project has envisioned to inter basin water transfer through diversion tunnel (67 m3/sec) from Sun-Koshi to Bagmati basin, to provide irrigation service all year around. After completion of project it covers the gross command area of 122000 ha.

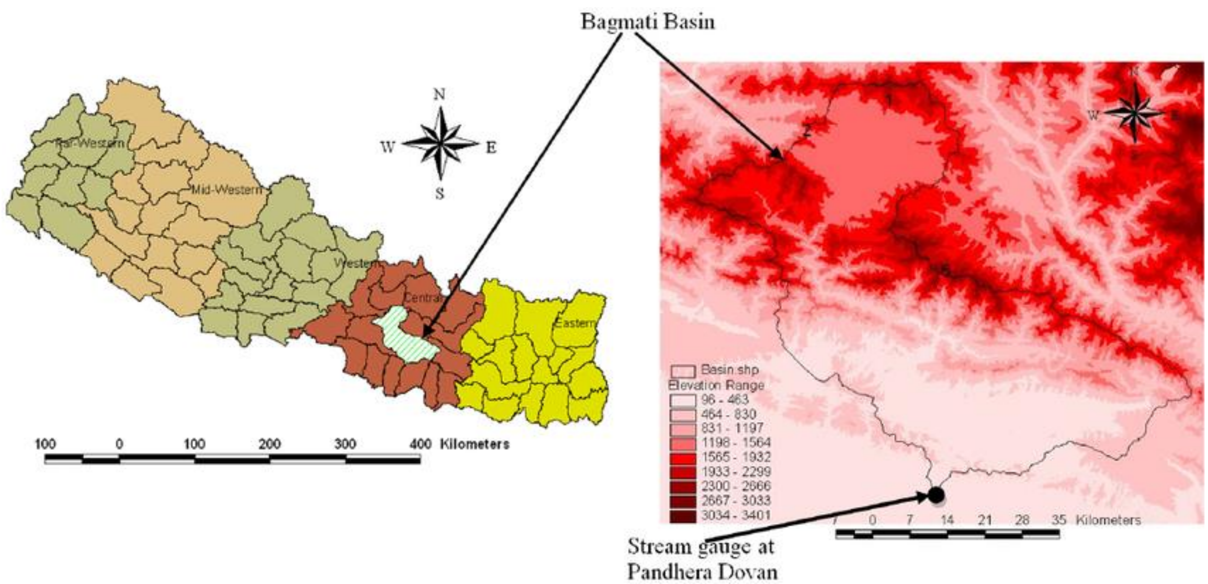


Figure 1 Study Area and Catchment Area of Padharodovan (Source: Sigdel et. al, 2012)

3. Methods

3.1 Hydrological Model

CRAWFORD Model has been used to model the Bagmati Basin. CRAWFOD is the Stanford watershed model developed by Crawford and Linsley in 1966. The model uses parameters to simulate flow: NOMINAL, PSUB, GWF. NOMINAL is the index for total soil moisture, PSUB relates runoff water to recharge of groundwater, and GWF is the time index for ground water to reach the stream. CRAWFORD is lumped model. To setup and simulate the flow from model Climate data; precipitation, temperature are obtained from GPM and the meteorological station of Department of Hydrology and Meteorology (DHM) respectively. Discharge data are also obtained from the hydrological station of DHM. Discharge data from 2000-2013 has been used for study. 2000-2009 for model calibration and 2010-2013 for model validation.

3.2 Climate Data

Future climate data is obtained from the Copernicus Climate Data Store. To assess the watershed response during extreme climatic conditions warm-dry scenario has been opted for the study. The study has employed CMIP6 projection from the NESM, Global Climate Model (GCM). Hindcast data from 2000-2013 and Forecast data from 2030-2050 has been used for study. NESM data is biased corrected from GPM using the Quantile mapping function available at the Weather Generator and Climate Change Scenario Generator for Climate Risk Assessment (WG-CRA). It is developed by Nepal Development Research Institute (NDRI) to produce inputs for climate stress test and it provides an interfaces for weather generating processes and enforcing changes in climatic means to produce climate change scenarios. After quantile mapping the NESM data set the biased corrected data set is fed into the model to generate the future simulation.

3.3 Climate Impact Assessment

Simulated future flow are compared with the total intake water requirement. Total intake water requirement is the water required to irrigate the command area of 122000 ha. Total water required is obtained from the study done by (Kafle, 2021) shown in figure 2. Assessment is done considering 67 m3/sec flow successfully diverted into the Bagmati basin from the Sunkoshi basin. Performance indicator such as reliability, flow deficit has been assessed in the study for baseline years and for future simulation.

Table 7: Diversion requirement from Sun Koshi.

Month		80% reliable flow in Bagmati (m^3/sec)	80 % reliable flow in Sunkoshi (m^3/sec)	Total Intake water requirement (m3/sec)	Marin channel loss and provision for irrigation in Marin basin (m^3/sec)	Total water requirement (m3/sec)	Diversion requirement from Sunkoshi (m^3/sec)	Actual planned diversion (m^3/sec)
		1	2	3	4	5 = 4+1	6 = 5-1	7
January	I	14.75	100.23	54.37	6.1	60.47	45.72	67
	II	13.33	92.84	54.89	6.1	60.99	47.65	67
February	I	12.01	85.57	56.11	6.1	62.21	50.19	67
	II	10.75	80.13	63.55	6.1	69.65	58.9	67
March	I	9.54	76.52	63.55	6.1	69.65	60.1	67
	II	8.78	76.44	60.73	6.1	66.83	58.05	67
April	I	8.47	79.89	68.84	6.1	74.94	66.47	67
	II	10.58	90.2	71.57	6.1	77.67	67.09	67
May	I	15.11	107.38	61.68	6.1	67.78	52.67	67
	II	29.36	164.31	47.69	6.1	53.78	24.42	67
June	I	53.34	260.97	33.84	6.1	39.94	0	67
	II	122.01	485.1	70.77	6.1	76.87	0	67
July	I	235.38	836.71	112.78	6.1	118.88	0	67

Figure 2 Total Intake water requirement adopted from (Kafle, 2021)

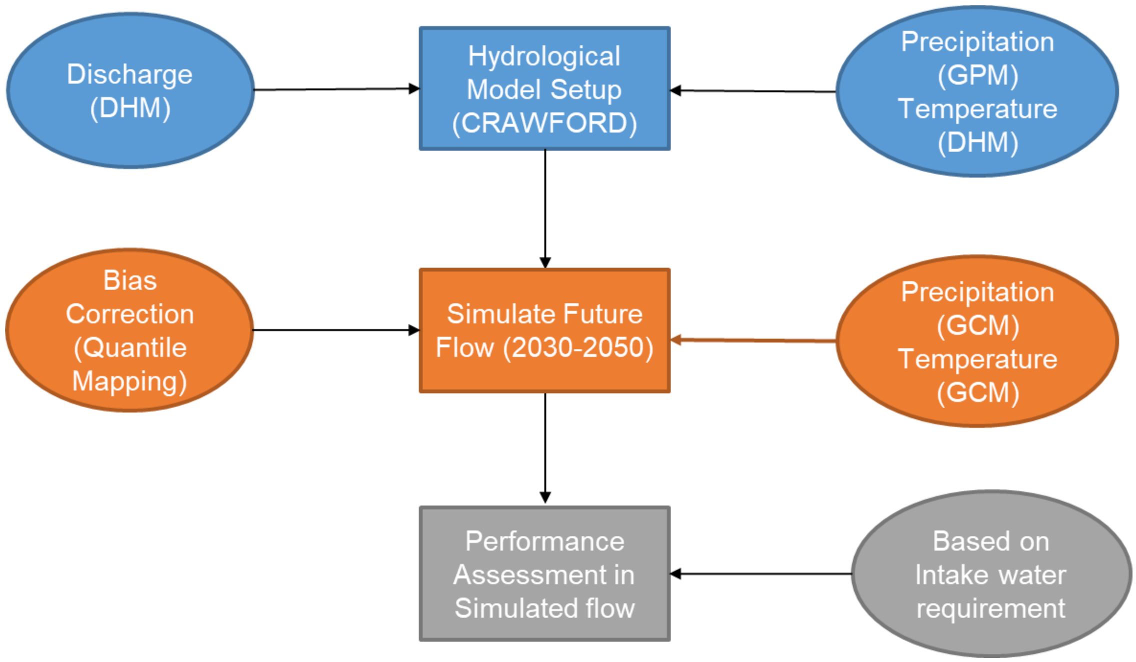


Figure 3 Methodology framework adopted for study

4. Data

4.1 Rainfall

Initially basin is divided into Thiessen polygon as shown in the fugure 2. of area 419.229, 595.625, 606.109, 1183.765 sq. km. and then effective rainfall is calculated for the Basin. Observe data for 2000-2013 was obtained from Department of Hydrology meteorology. Observed rainfall at Kathmandu Airport, Godavari, Haripur, Karmaiya are in figure 3. Effective rainfall of the Basin is given in figure 4.

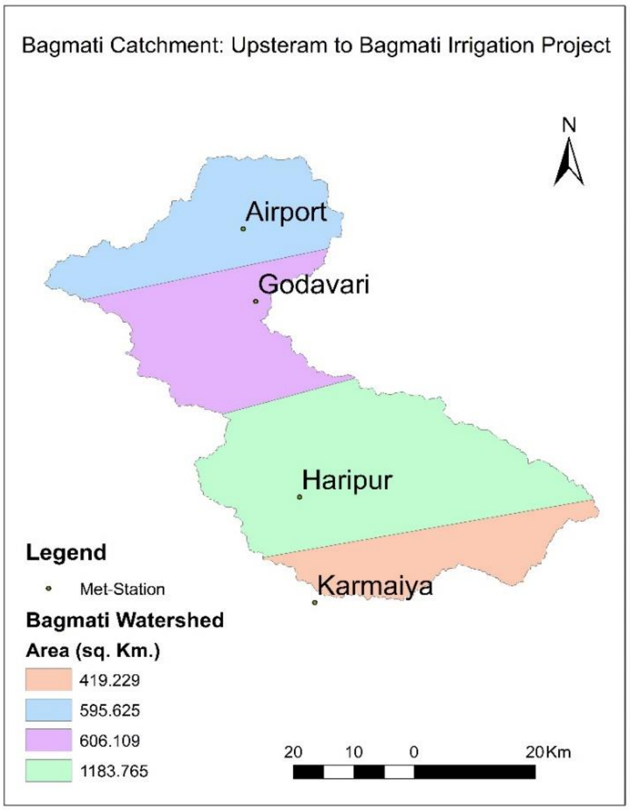


Figure 4 Thiessen polygon in the Bagmati Baisn

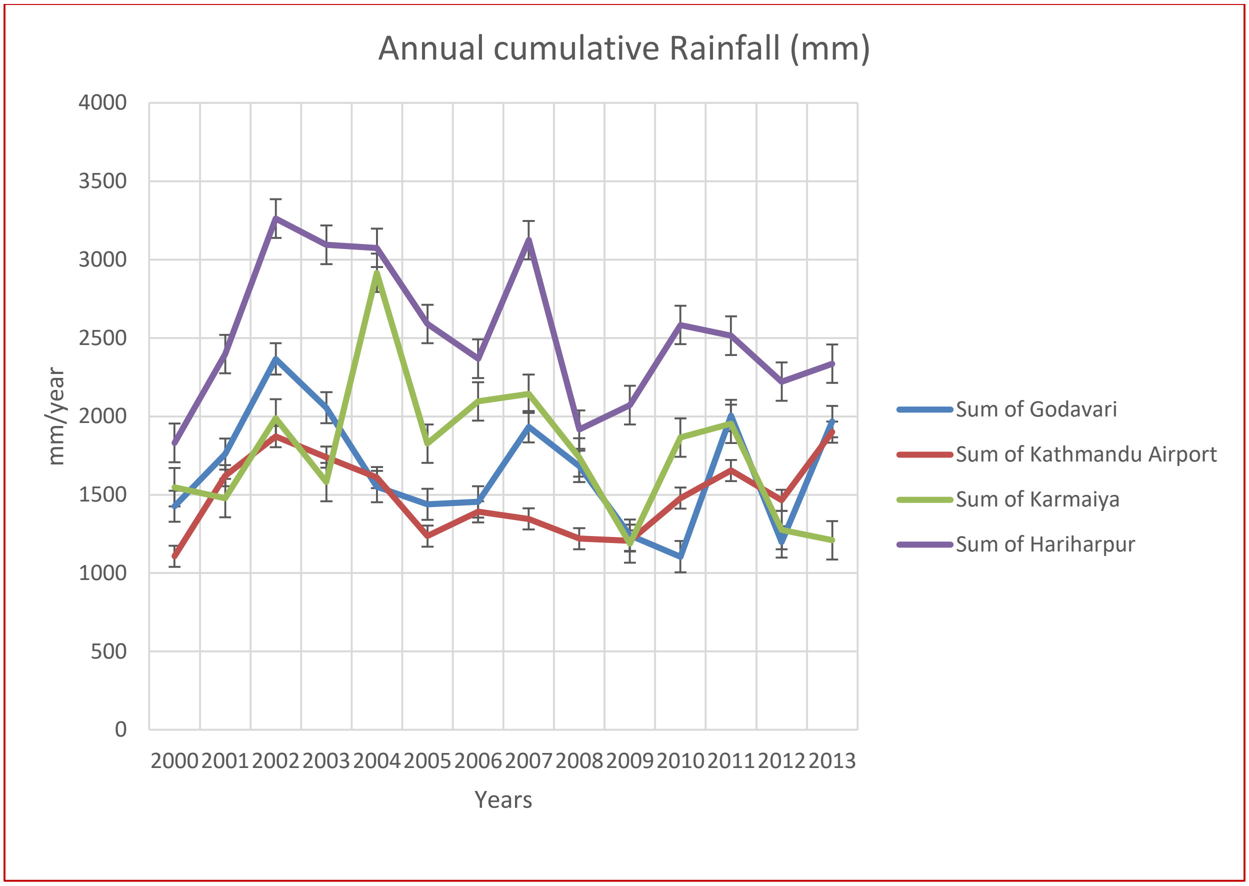


Figure 5 Annual Cumulative Rainfall at four meteorological station

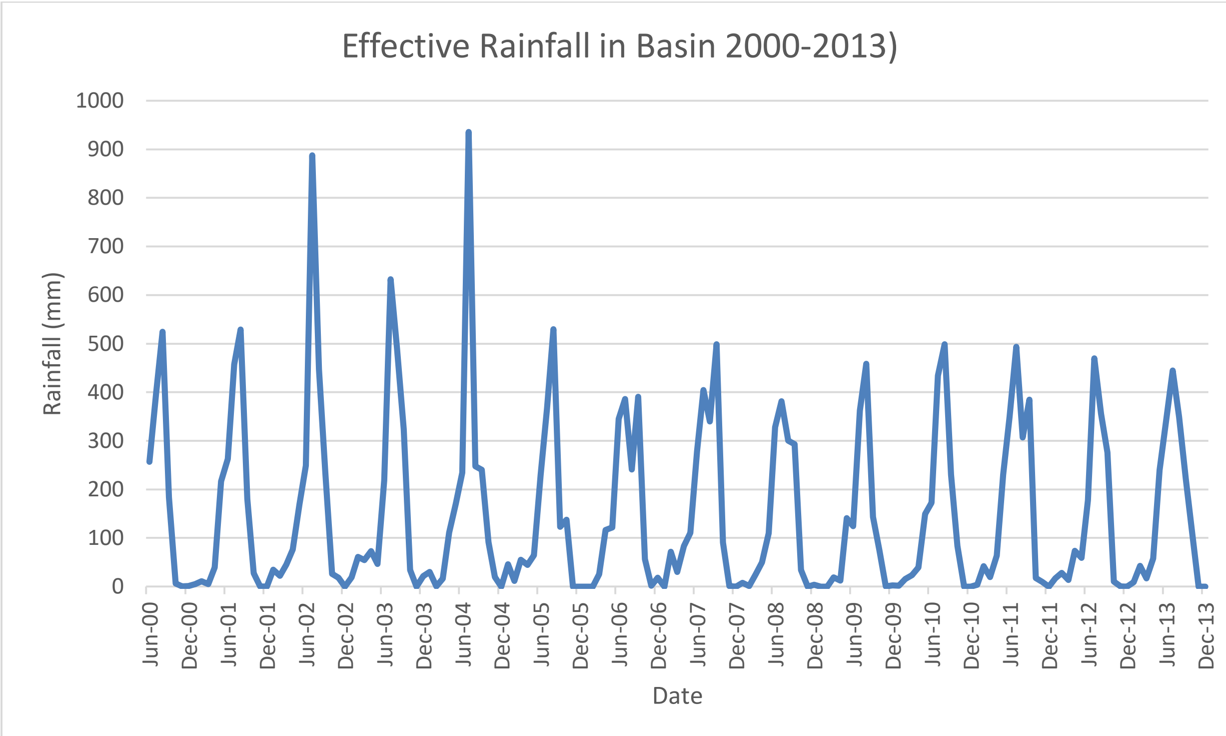


Figure 6 Effective Rainfall in Basin 2000-2013

4.2. Discharge

Observed discharge data for 2000-2013 was obtained from the Department of Hydrology Meteorology. Hydrological station is located at (27 09 06, 85 29 30). Bagmati Irrigation project head works lies near downstream to Padharodovan having catchment area 2805 sq. km. Hydrograph of the 2000-2013 discharge is given at Figure 5. Maximum discharge for the period is observed at 2002, 900 m^3/sec.

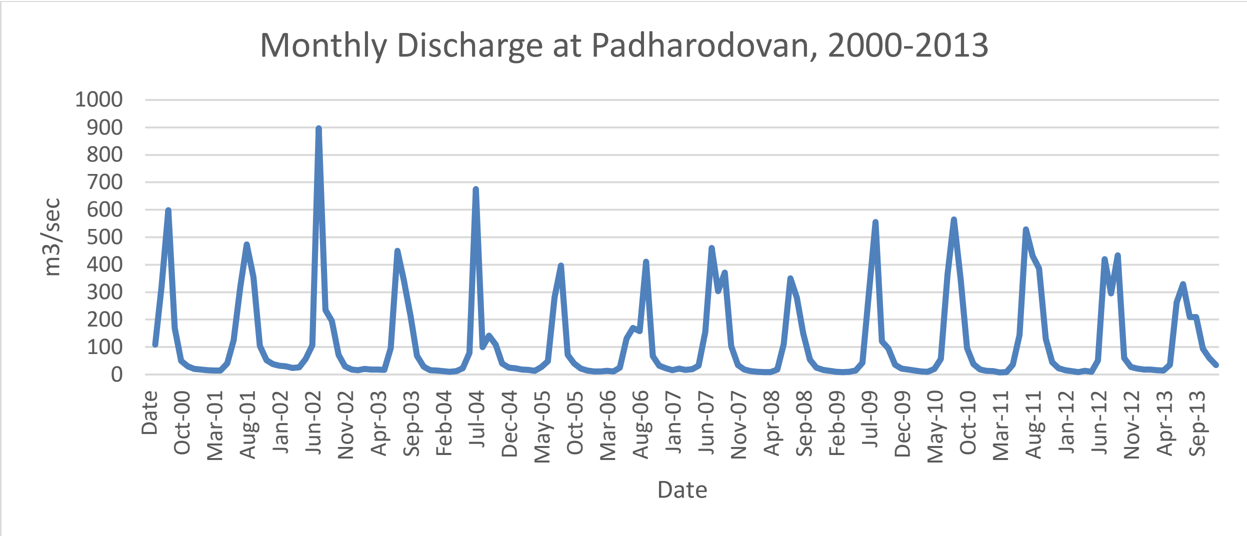


Figure 7 Hydrograph at Padharodovan

4.3 Temperature

Observed temperature data for 2000-2013 was obtained from the Department of Hydrology Meteorology. Station from Hariharpur and Kathmandu Airport was taken for study. The average monthly temperature trend of the basin is given at Figure 6.

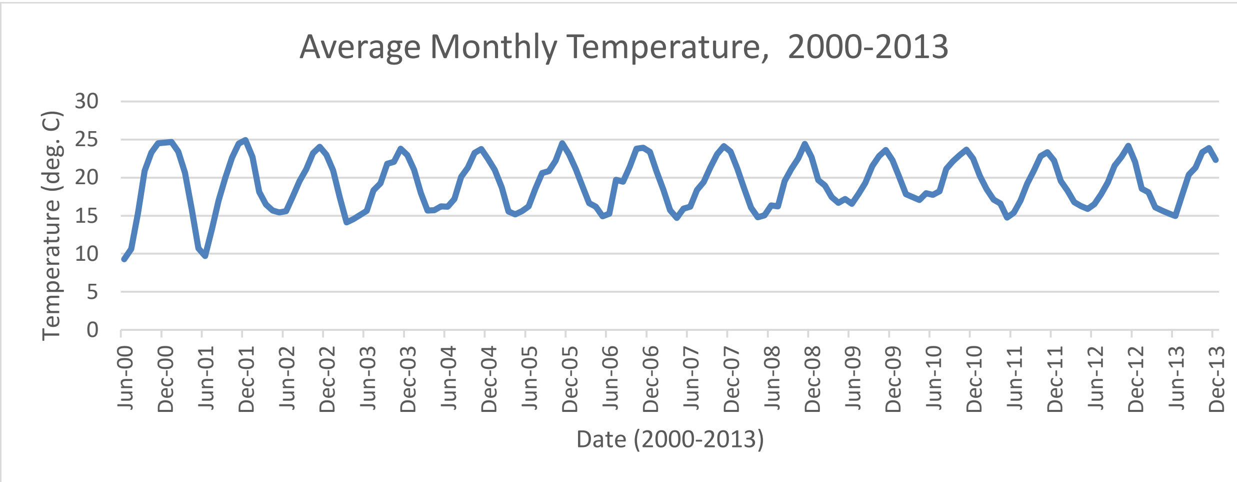
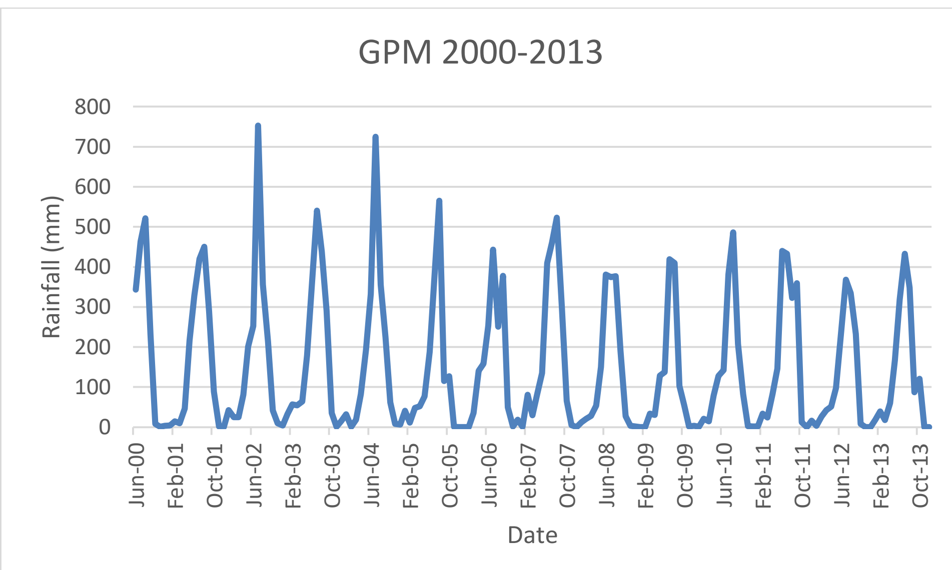


Figure 8 Average monthly temperature, 2000-2013

4.4 Global Precipitation Measurement

Bias corrected GPM data set for 2000-2013 was provided by Nepal Development Research Institute. Rainfall data shows very similar trend with observed data from DHM.



5. Results

5.1 Hydrological Model

Calibrating hydrological model from 2000-2010 had NSE 0.81 PBIAS 11.38 and 0.92 and validating 2010-2013 had 0.501, PBIAS 40.36 and R 0.60. Optimized parameters of model are:

1 Calibrated parameters of CRAWFORD

Calibrated Parameters	
NOMINAL	**150.00**
PSUB	**0.10**
GWF	**0.50**

The hydrograph of the calibration period 2000-2013 of observed and simulated flow is given in figure 7 and validation hydrograph at figure 8.

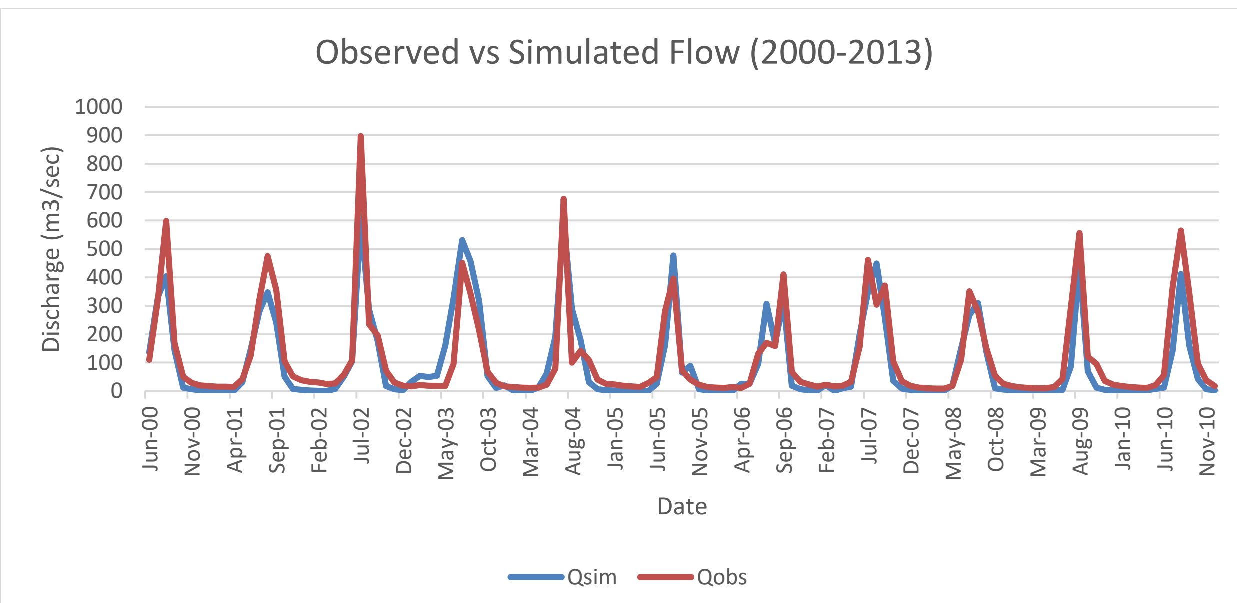


Figure 9 Observed vs Simulated calibrated hydrograph

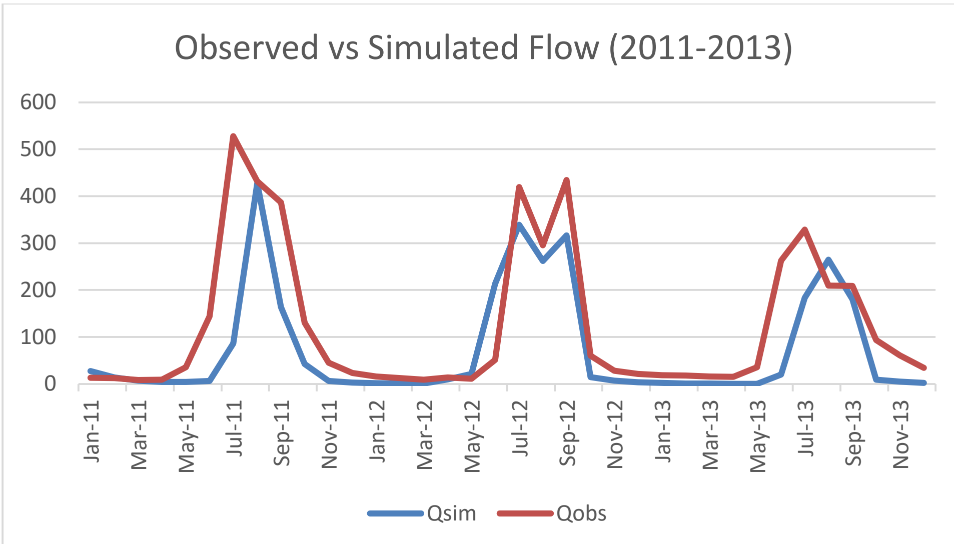


Figure 10 Observed vs Simulated valifated hydrograph

5.2 Global Climate Model Data

GCM data for the warm-dry scenario was taken from the NESM model for historical data set 2013 and forecasted data set 2030-2050. The historical data were used for Bias-correction of future data using the quantile mapping technique from the GPM data set. Figure 9 contains the Bias corrected temperature (ºC) trend for 2030-2050 SSP scenario 245 of NESM GCM data. Similarly figure 10 has for SSP 585. Figure 11,12 has Rainfall data set from same GCM of SSP 245 and SSP 585.

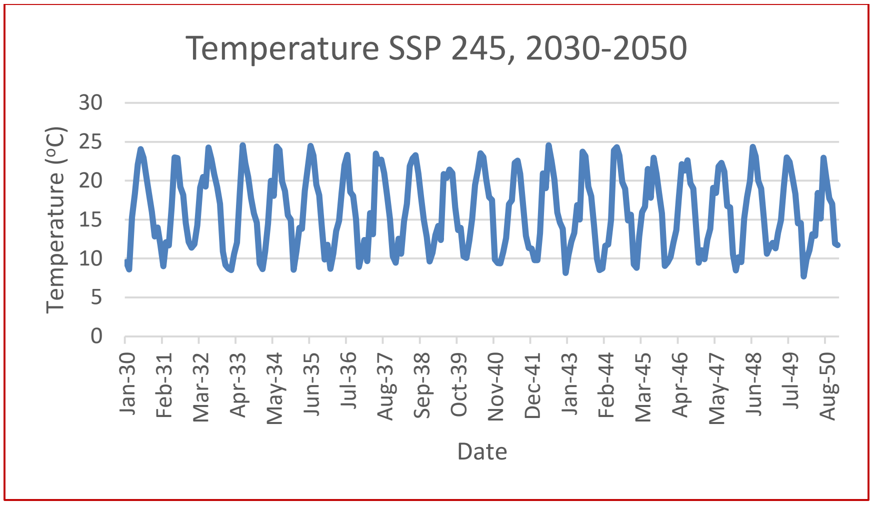


Figure 11 Bias-Corrected Temperature SSP 245

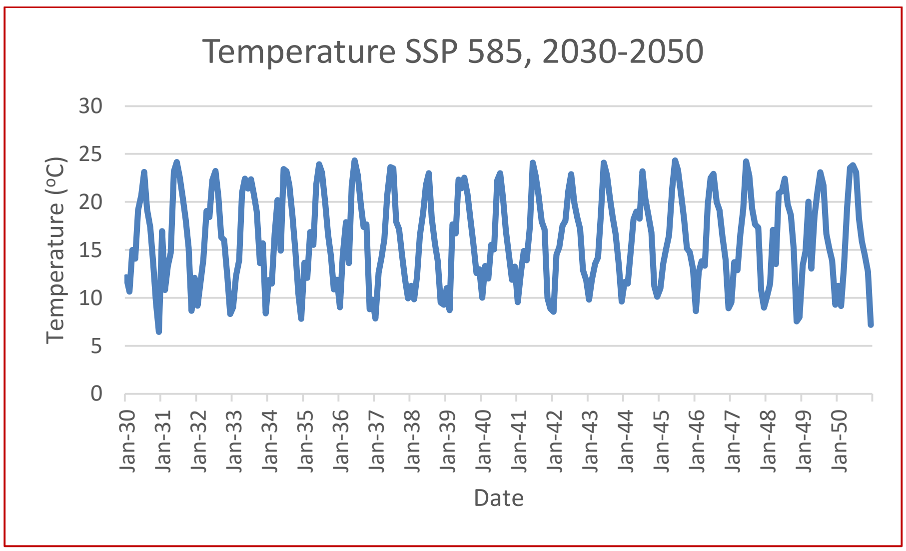


Figure 12 Bias Corrected Temperature SSP 585

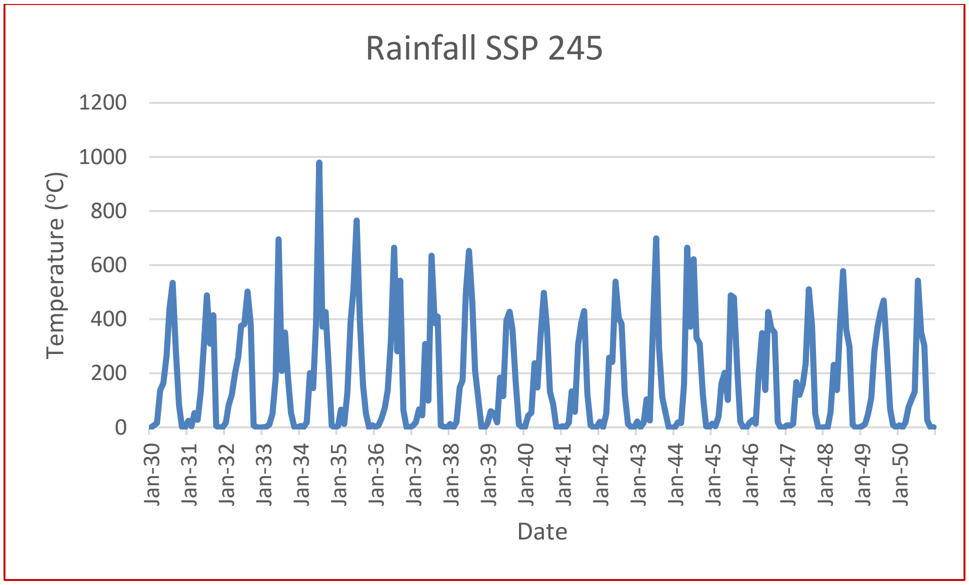


Figure 13Bias Corrected Rainfall SSP 245, 2030-2050

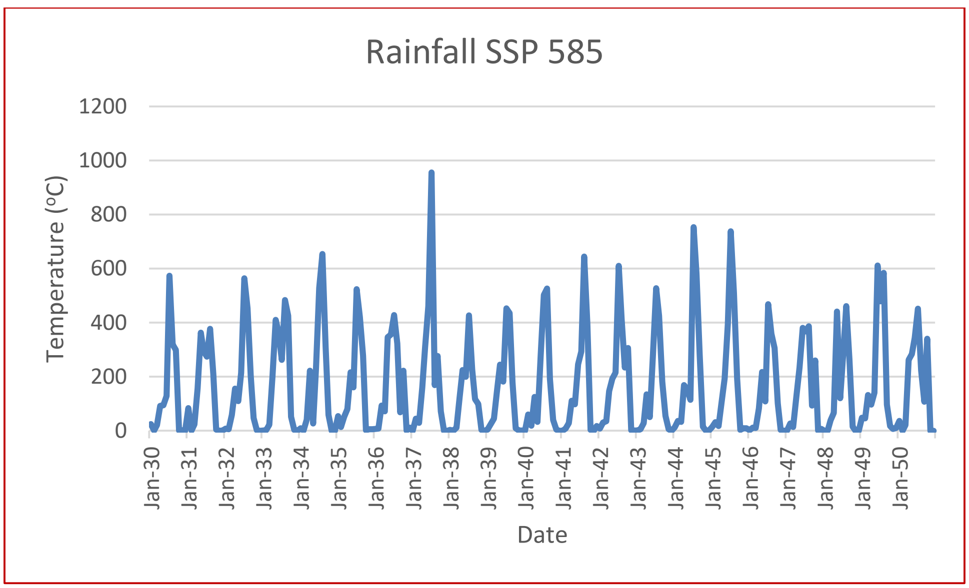


Figure 14 Bias corrected Rainfall SSP 585, 2030-2050

5.3 Simulated Flow

Bias-corrected future climate data of NESM for scenarios SSP 245 and 585 were given input to the calibrated model to generate future hydrological simulation. Simulated hydrograph of SSP 245 and SSP 585 is given in figure below.

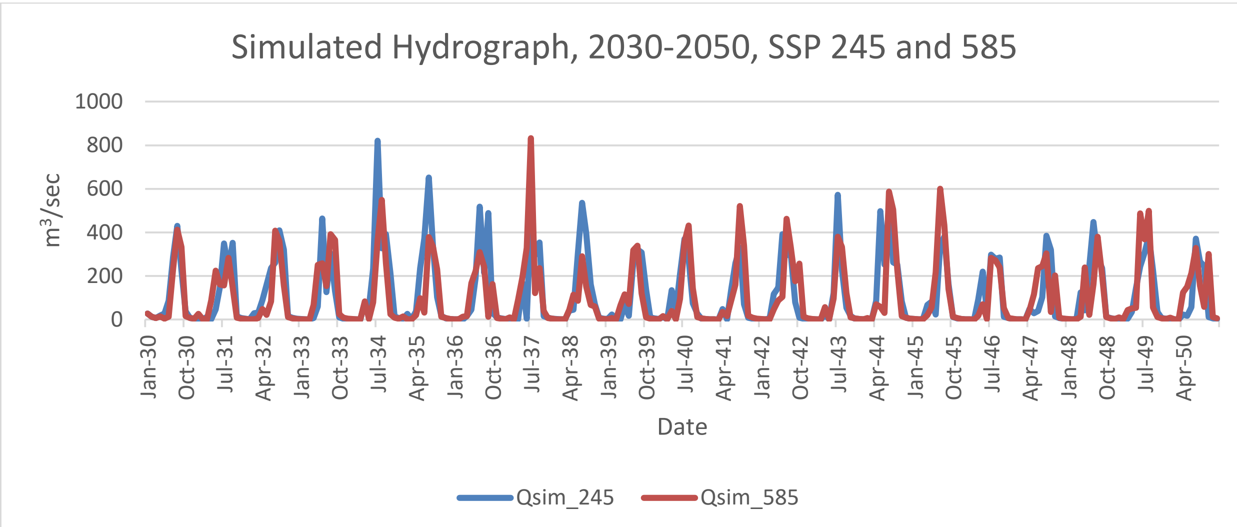
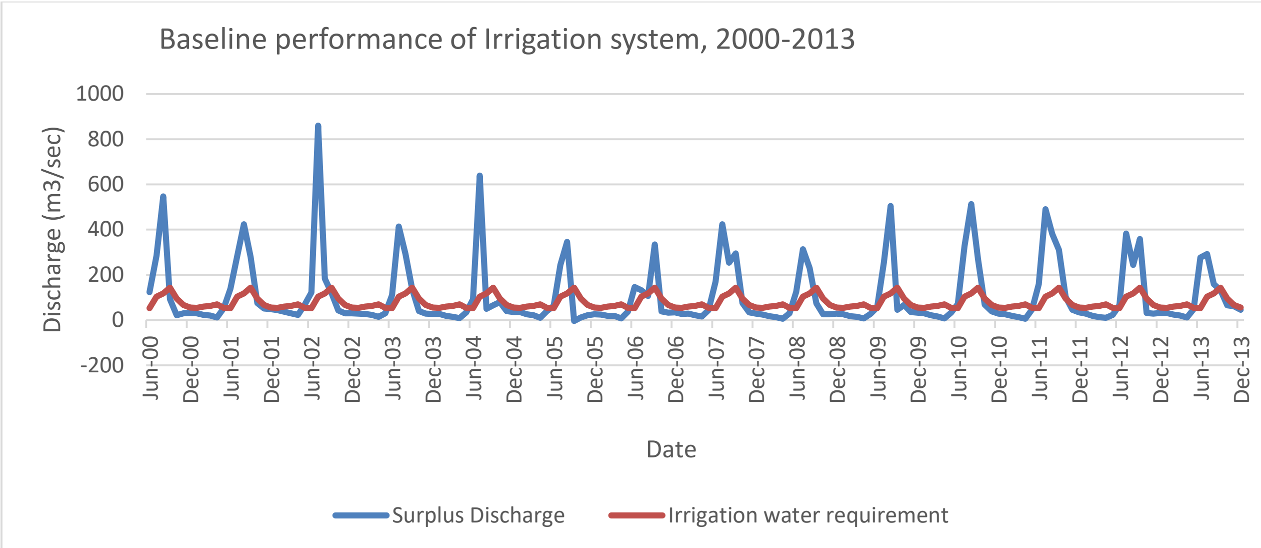


Figure 15 Simulated future hydrograph of Bagmati Basin for SSP 245 and 585

5.4 Performance Assessment of Irrigation System

5.4.1 Baseline Performance

Baseline performance study for 2000-2013 adopting the observed hydrological discharge at Padharodovan, considering after diversion flow scenario at Bagmati River has shown a one month was under deficit in 13 baseline years where deficit discharge was -4.04 m^3/sec.



5.4.2 Performance assessment for future climate and flow scenario

For future performance assessment water surplus/deficit to irrigation system was assessed under warm-dry scenario form NESM model. Total number of water deficit month in climate of 2030-2050 is found to be 47 for SSP 245 scenario and 52 in SSP 585 scenario for total 252 months. Reliability score is 92.06 and 92.46 was found for SSP 245 and SSP 585 scenario.

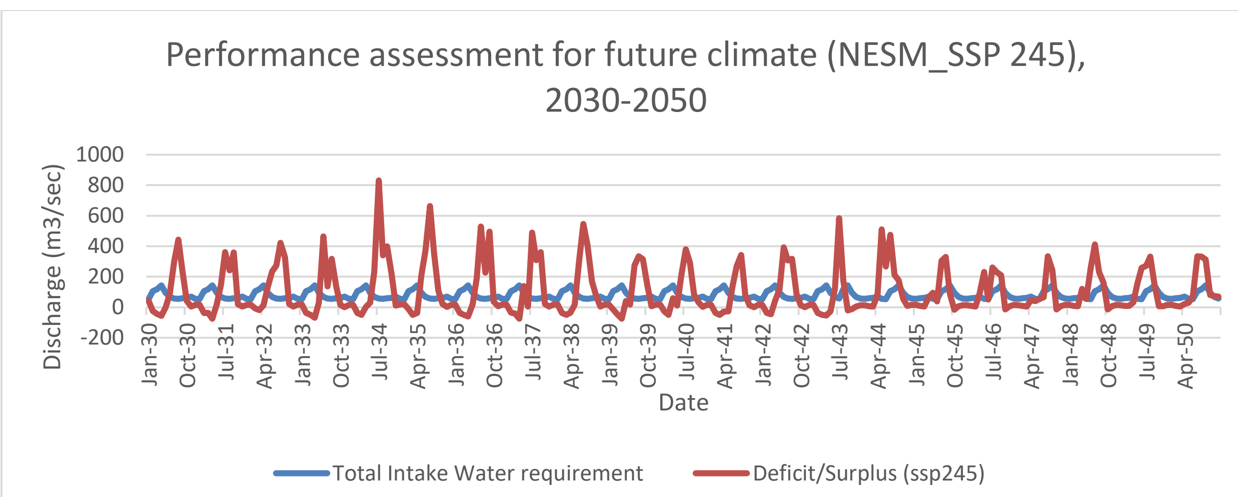


Figure 16 Performance assessment for NESM, SSP 245, 2030-2050

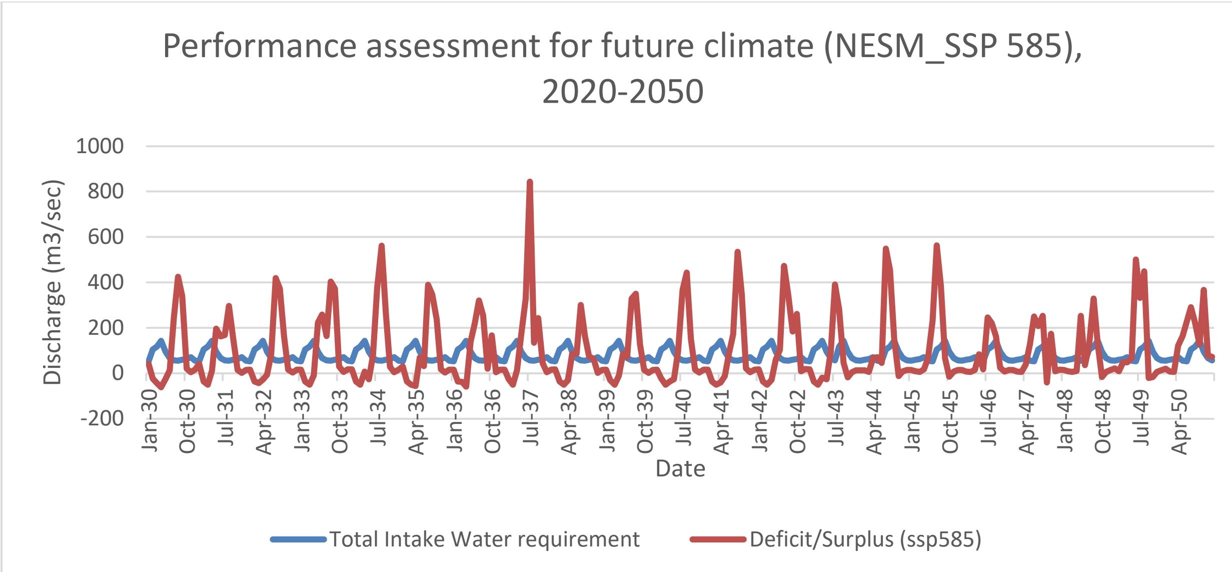


Figure 17 Performance assessment for NESM, SSP 585, 2030-2050

6. Discussion

Hydrological modeling of Bagmati watershed in CRAWFORD model was done for hydrological station at Padharodovan. Model calibrated for 2000-2010 had NSE 0.81 PBIAS 11.38 and 0.92 and validating 2010-2013 had 0.501, PBIAS 40.36 and R 0.60. Calibrated parameter of the model was used to simulate the flow at future using Bias-corrected NESM data. Assessing the warm-dry scenario of NESM it is found that the total number of water deficit month in climate of 2030-2050 is found to be 47 for SSP 245 scenario and 52 in SSP 585 scenario for total 252 months where the reliability score is 92.06 and 92.46 was found for SSP 245 and SSP 585 scenario. Intake water requirement was considered for the study though it won't be the same case in the time being. Whereas baseline performance study for 2000-2013 adopting the observed hydrological discharge at Padharodovan, considering after diversion flow scenario at Bagmati River has shown a one month was under deficit in 13 baseline years where deficit discharge was -4.04 m^3/sec. This shows under a warm-dry scenario it is likely to decrease the flow and thus impact irrigation performance but being in around 92% reliability spells that performance is not affected significantly. It seems diversion of 69 m^3/sec has will make the system climate-resilient providing irrigation to gross command area of 122,000 ha. However, performance slowly decreases creating a flow deficit condition in the future.

References

Abinashi Sigdel, R. J.-S.-H. (2012). pplicability of TOPMODEL in the Catchments ofNepal: Bagmati River Basin. *Geosystem Engineering*.

Kafle, M. R. (2021). GDP Contribution with Optimal Use of Water Resources in Irrigation: A Case of Bagmati Irrigation Project, Nepal . *Journal of Water Resource and Pollution Studies*.

Massoud Behboudian, R. K. (2021). Evaluating the long-term resilience of water resources systems: Application of a generalized grade-based combination approach. *Science of The Total Environment*.

Raj Hari Sharma, N. M. (2005). Hydrological changes and its impact on water resources of Bagmati watershed, Nepal. *Journal of Hydrology*.

Ram Chandra Khanal, P. M. (2021). Approach Towards Building Climate-Resilient Irrigation Systems for Food Security in Nepal. *Water, Climate Change and Sustainability*.

Shrestha, R. R. (2013). *Improving Water Security in Water Stressed Bagmati River Basin, .* High Powered Committee for Integrated Development of Bagmati Civilization (HPCIDBC), Ministry of Urban Development.

7. WECCS-Gen tool

The Weather Generator and Climate Change Scenario Generator for Climate Risk Assessment (WECCS-Gen) tool made it easy for my case study to conduct bias correction through the quantile mapping technique. Climate scenario generator is also useful facility for quick climate impact analysis in the software. The user interface of the tool was simple and easy to understand in the beginning. The user manual for the tool was also comprehensive for the reference.

8. Bio of researcher

Mr. Crish Basnet has completed B. Tech in Environmental Engineering from Kathmandu University in 2022, with the final year project on Flood Hazard and Risk Assessment of Punyamata River, Nepal, and been pursuing MSc. Water resource Engineering in Institute of Engineering, Pulchowk Campus. His interest and working experience lie in water resources, water quality, climate, flood, and Environment.