Case Report
Volume 11:10, 2022

Irrigation & Drainage Systems Engineering

ISSN: 2168-9768 Open Access

Impact of Climate Change on Crop Water Requirement in Kamala River Basin of Nepal

Manoj Lamichhane*[1] Yogendra Mishra[2] and Abin Raj Chapagain[1]

[1]Department of Civil Engineering, Advanced College of Engineering and Management, IOE, TU, Nepal
[2]Ministry of Energy, Water Resources and Irrigation, Department of Water Resources and Irrigation, Lalitpur, Nepal

Abstract

The future climate, which has a crucial role in any hydrological events that occur within the basin, will have more uncertainty. Due to changing climatic variables, the basin's water balance will become more unpredictable. Not only will climatic parameter changes, but it will also adversely affect the water management within the basin. In this study, an effort has been carried out to compare the future River flow of the Kamala basin and the future water demand of the Kamala irrigation command area. The CROPWAT and AQUACROP model, based on climatic, soil, and crop data, was used to estimate the future Crop Water Requirement (CWR), Irrigation Water Requirement (IWR), and Biomass yield. Since the Hydrological station is absent within the basin, the simulation of the future river flow of the Kamala basin using any hydrological model was unworkable. Therefore, the WECS method is used to forecast the future monthly flow of the Kamala River. The two emission scenarios, ssp245 and ssp585, were conducted based on cropping intensity of 170% and 300%, and IWD for each sub-scenario over 12 months was estimated. For the first sixth months, IWR is increased in the future period as maximum and minimum temperature increases, and the IWR for monsoon season is less required due to increases in precipitation, and again for the post-monsoon season, IWR is increased compared to historical IWR. The highest irrigation water requirement occurred in March under ssp245 and ssp585 and CI 300%. In contrast, October and August have the lowest irrigation water demand under ssp245 and ssp585 scenarios. Based on the finding, the production of the crop with an irrigation system is higher than in a rain-fed system. For paddy, the rain-fed system produced a dry yield of 6.58 tons/ha, whereas the dry yield of the irrigated field has 7.05 tons/ha. The future river flow is insufficient to meet the irrigation water demand in the first five months in the near future under both ssp245 and ssp585 scenarios. The magnitude of deficiency in ssp585 is comparatively higher than in ssp245. Therefore, all of these findings suggest that the crop water requirement of KIP is insufficient in the future to provide a year-round irrigation system.

Keywords: Crop water requirement • Irrigation water requirement • CROPWAT • AQUACROP • ssp245 • ssp585

Introduction

Climate change is a major environmental problem around the world. About two-thirds of Nepalese agriculture is strongly reliant on the monsoon, resulting in excess food production imbalance. Climate change has emerged as a significant worldwide issue that has sparked widespread concern at both the national and international levels [1]. According to several studies, Climate change has been linked to a drop in crop yield [2-4]. Climate change has varying degrees of impact on river hydrology worldwide [5,6]. According to the Intergovernmental Panel on Climate Change (IPCC), Assessment Report Six (AR6), increases in monsoon precipitation attributable to warming from GHG emissions were offset by declines in monsoon precipitation due to cooling from human-caused aerosol emissions over the twentieth century in South Asia. Necessary climate conditions in Nepal have considerable seasonal and temporal variations. The temperature and precipitation are affected by the change in height. As a result, there is a wide range of climate variations from tropical in the south to alpine in the north in Nepal [7].

For the future projection of climate change, different sets of SSP/RCP scenarios for Phase 6 of Coupled Model Inter-comparison Project (CMIP6) have been defined by IPCC [8]. Precipitation, like temperature, is a climatic component that changes in amount and pattern. Over the twentieth century, global land precipitation has increased by roughly 9 mm. As per global circulation model (GCM) forecasts, the temperature across Nepal will rise between 0.5ºC and 2.0ºC with a multi-model mean of 1.4ºC by the 2030s and between 3.0ºC and 6.3ºC by the 2090s, with a multi-model mean of 4.7ºC. (UNDP, Nepal). Throughout the century, both the minimum and maximum temperatures, both seasonal and yearly, will rise. The temperature rise in the mountains was found to be significantly higher than in the lowlands. CWR was estimated for four scenarios: current temperature and rainfall (S1), the temperature is 2050 and current state of rainfall (S2), rainfall in 2050 and current state of temperature (S3), and temperature and rainfall in 2050 and current state of temperature (S4). In Al-Jouf, Saudi Arabia a 1°C increase in temperature might raise the overall CWR by 2.9 percent [9]. In the CROPWAT model, the ET¬o was calculated using the Penman-Monteith method, and its impact on other parameters such as sunshine hour, wind speed, maximum and minimum temperature, and rainfall humidity was found [10]. To address these issues, a study was conducted to specify the analysis of rainfall data to determine its contribution to agricultural water requirements.

***Address for Correspondence:** Manoj Lamichhane, Department of Civil Engineering, Advanced College of Engineering and Management, IOE, TU, Nepal, E-mail: ermanoj12lmc@gmail.com*

Date of Submission: 02 October 2022, Manuscript No. idse-22-74256; **Editor assigned:** 04 October, 2022, PreQC No. P-74256; **Reviewed:** 16 October 2022, QC No. Q-74256; **Revised:** 21 October 2022, Manuscript No. R-74256; **Published:** 28 October, 2022, DOI: 10.37421/2168-9768.2022.11.351

Database and Methods

Study area

The Kamala Basin, almost 2,100 km^2 in area, is located in the southeast of Nepal, the southern tip of the catchment boundary being the international border with India. The Kamala River is a tributary of the Ganges, the principal river of India. Geographically the Kamala Basin comprises three defined landscape types in Nepal: The Middle Mountains, Chure, and Terai. The unstable, often steep slopes of the Chure (or Siwalik) region throughout southern Nepal present particular challenges. Consequently, it has been the focus of special conservation and development requirements, though terrace agriculture is widely practiced. The Chure region covers almost two-thirds of the Kamala Basin. The gently sloping to flat Terai is where the population and agriculture are more concentrated, as is the economic activity of the Basin (Figure 1).

Data collection

The various data types required during this research will be collected from respective sources. The following topics elaborate the list of data required for the whole study. Observed historical data like daily maximum temperature, minimum temperature, precipitation, humidity, sunshine hour, and wind speed for meteorological and climatology stations inside and near KIP are collected from the Department of Hydrology and Meteorology (DHM), Babar mahal for the period of 1985 to 2014. Among those stations, precipitation data for all 5 stations were collected, but data from only three stations were taken due to the unavailability of temperature data from all 5 stations. Similarly, data from only one station is used for humidity, sunshine hour, and wind speed (Tables 1 and 2)

Methodology

GCMs selection for the raw GCMs collection

For the study of climate change in KIP using CMIP6 GCM models, we selected 10 GCM models that participated in Coupled Model Intercomparison Project Phase 6 (CMIP6) for the pool of raw GCMs. These models are selected based on research conducted in South Asian countries [11-13].

Downscaling and extraction of GCMs data

The historical (1985-2014) precipitation, maximum, and minimum temperature data of each GCM model are downloaded from the CMIP6 database website (https://esgf-node.ilnl.gov/search/cmip6). The downloaded data were in netCDF format and on a global scale. First, we merged the data from the year (1985-2014) into a single netCDF file format for each GCM model and each variable, i.e., tmax, tmin, and pr. Next, we down scaled the data for our study area from the merged file by providing a limit of latitude (22.56°N to 34.158°N) and longitude (75.965°E to 42.223°E). The merge and clip operation is performed using the climate data operator tool (CDO) available in the Linux operating system Ubuntu. Then we extracted the gridded data to point data from netCDF file format to comma delimited text (CSV) format for five stations of the study area for all variables using the python codes.

Selection of meteorological stations and filling missing data of observed climate data

The data from five meteorological stations inside the KIP command are

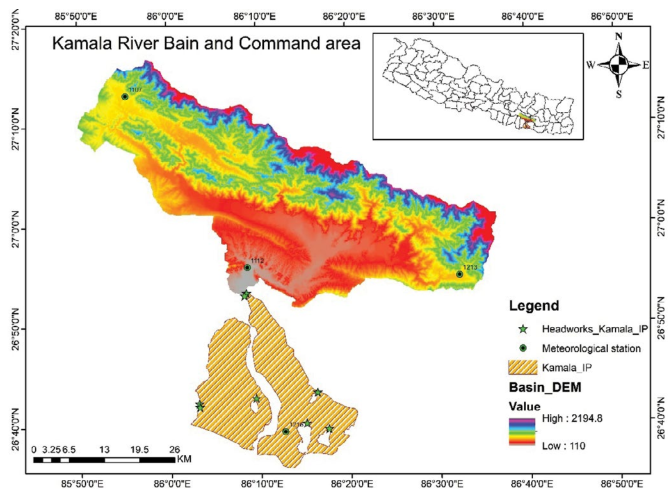

Figure 1. Location map of hydrological station and headworks of different irrigation projects.

taken, and those stations are selected such that it covers the whole command area and represents the overall climatic condition of the study area. The gap of fewer than 10 days in daily observed data obtained from the Department of Hydrology and Meteorology (DHM) was filled using the missing data filling approach of linear interpolation from the nearby stations (Engineering Hydrology, n.d.). The 'POWER Global Downloads NASA' widget, which gives access to Global Climatology 1/2 x 1/2-degree datasets, is used for filling the missing gaps of more than 10 days in the observed climate data.

Historical raw GCMs performance evaluation

The performance metrics of historical raw GCMs were evaluated for each station and each variable using performance evaluation metrics Root Mean Square Error (RSR), Percentage Bias (PBIAS), and Nash-Sutcliff Efficiency (NSE) compared to the observed historical data (1985-2014). The ratings for each performance metric's value are listed in Table 3. In addition, for each precipitation, maximum, and minimum temperature, the average rating for each GCM is determined (Table 4).

Bias correction and selection of the best method of correction

The bias correction method, Quantile mapping (QM) with 13 statistical transformation functions available in the Qmap package in R for bias correction is used. The transformation functions are as follows: Bernoulli Exponential, Bernoulli Gamma, Bernoulli Weibull, Bernoulli Log-normal, Exponential Asymptote, Exponential Asymptote x0, Linear Transformation, Power Transformation, Power x0 Transformation, Scale Transformation, Non-parametric Quantile Mapping, Non-parametric Robust Quantile Mapping, smoothing Spline

Table 1. List of climate stations for precipitation used in this study.

S. No.	Index No.	Station Name	Latitude (Deg)	Longitude (Deg)	Elevation (m)
1	1107	Sindhuli Madhi	85.92	27.21	556
2	1112	Chisapani Bazar	86.14	26.93	127
3	1213	Udaypur Gadhi	86.53	26.91	469
4	1216	Siraha	86.21	26.65	63

Table 2. List of climate stations for maximum and minimum temperature in this study.

S.N.	Index No.	Station Name	Latitude (Deg)	Longitude (Deg)	Elevation (m)
1	1111	Janakpur Airport	85.92	26.71	76

Table 3. Performance Evaluation Criteria of Historical Raw GCMs.

Performance Rating	NSE	RSR	PBIAS	Rating
Very Good	0.75<NSE<=1.00	0.00<RSR<=0.50	PBIAS< 10	5
Good	0.55<NSE<=0.75	0.50<RSR<=0.6	10 <= PBIAS	4
Satisfactory	0.40<NSE<=0.55	0.60<RSR<=0.70	15 <= PBIAS <25	3
Unsatisfactory	0.25<NSE<=0.40	0.70<RSR<=0.80	25 <= PBIAS	2
Poor	NSE<=0.25	RSR>0.80	PBIAS>=35	1

Table 4. Performance Evaluation Criteria of Bias Correction Methods.

Performance Rating	NSE	RSR	PBIAS	Rating
Very Good	$0.85<R^2<=1.00$	0.00<RSR<=0.25	PBIAS< 5	8
	$0.75<R^2<=0.85$	0.25<RSR<=0.50	5 <= PBIAS<10	7
Good	$0.70<R^2<=0.75$	0.55<RSR<=0.60	10 <= PBIAS <12.5	6
	$0.65<R^2<=0.70$	0.50<RSR<=0.55	12.5 <= PBIAS <15	5
Satisfactory	0.57<NSE<=0.65	0.65<RSR<=0.70	15 <= PBIAS<20	4
	0.50<NSE<=0.57	0.60<RSR<=0.65	20 <= PBIAS <25	3
Unsatisfactory	0.4<NSE<=0.5	0.70<RSR<=0.80	25 <= PBIAS <35	2
Poor	NSE<=0.4	RSR>0.80	PBIAS>=35	1

The bias-corrected daily precipitation and maximum and minimum temperature for the baseline period (1985-2014) from the selected GCMs are compared with the observed data obtained from the department of hydrology and meteorology (DHM) to evaluate the performance metrics RMSE, PBIAS, and NSE. The bias correction methods are rated based on the criteria shown in Table 5. The bias correction method with the highest rating is selected for each variable.

Crop Evapotranspiration (ETc): ETo is multiplied by an empirical crop coefficient (Kc) to produce an estimate of crop Evapotranspiration (ETc), ETc =Kc X ETo

Crop Water Requirement (CWR): Effective rainfall (Eff. rain) is subtracted is from ETc to get actual CWR. CWR= ETc- Eff. Rain

Estimation of IWR and CWR

The Crop Water Requirement (CWR) is the total quantity of water required for the plant throughout the life period. It is the compensation of water to the crop, which the plant loses through evapotranspiration. There are various methods by which plants get compensation, such as water from the soil, which is stored as moisture, rainfall, irrigation, etc. The CWR can be said crop evapotranspiration (ETc). It can be calculated by the equation;

$$ETc = Kc \times ETo$$

Where,

ETc = Crop evapotranspiration

ETo = Reference evapotranspiration

Kc= Crop coefficient

The value of Kc varies mainly on the specific crop type and somehow depends on the soil evaporation and climate condition. The value of Kc also varies within the life period of the plant. There is different value in the growing, maturity, and harvesting periods. It converts the reference evapotranspiration to crop evapotranspiration. Kc approach is accepted universally. Scheme water requirement was calculated by using CROPWAT8.0. For that, the first step is to calculate the ETo. As described in equation 4.1, ETo can be calculated by the CROPWAT model. There are different methods to calculate ETo, but the Penman-Monteith method was used in this study. After that, the effective rainfall was calculated. Effective rainfall (Peff) was calculated by the USDA soil conservation method, where effective rainfall was calculated as per the following equations:

$$Peff = (P^* (125-0.2^*3^*P))/125 \text{ for } P<=250/3$$

$$Peff = 125/3+0.1^*P \text{ for } P> 250/3$$

The subsequent step is to define the cropping pattern. The cropping pattern of the study area was collected from the past report and field visit. Data were collected from the field or district level office or the literature. The software calculates the CWR of each crop. Then after deducting the effective rainfall from the CWR, irrigation water requirement was obtained for each crop. Finally, after summing up the all-water requirement in the corresponding time period, the total scheme water requirement can be obtained. After applying efficiency-coefficient in scheme water requirement, the total water required in the source can be obtained. For this study, the cropping pattern was obtained from the field data. All climatic data were obtained from DHM, Nepal. Figure 2 shows the steps to calculate the irrigation water demand. During the field survey, the cropping pattern and the corresponding cultivated area were taken from the field. The scheme water requirement or water required in the source was calculated using the scheme efficiency of 30%. The present water requirement will be calculated using the present cropping system and current climate scenario, whereas the future crop water requirement will be calculated using the future cropping pattern.

The study assumes that the climatic parameters, such as wind speed, sunshine hour, and humidity, will be the same in the future under different analysis scenarios. In the case of the Kamala irrigation project, there are no meteorological stations inside the command area, so the nearby Janakpur Airport station data are used. The crop water requirement in the present and future conditions has been calculated by using the Penman equation. The evapotranspiration was calculated by using the Penman-Monteith equation. The meteorological data from the Janakpur Airport stations were used to calculate the crop water requirement in the present condition. The sunshine hour, wind speed, and relative humidity were also taken from the nearby Biratnagar station. Finally, the proposed (future) cropping pattern was used to calculate the crop water requirement during the present and future conditions.

The present cropping pattern is shown in Table 4, in which traditional paddy remains the main monsoon crop, with supplementary irrigation to increase yields. Other major seasonal crops are wheat, maize, pulses, oilseed, potato, seasonal vegetables, etc. The choices of crops are made by analyzing the land use capability, water availability, and preference made by the farming communities and also taking account of market opportunities. The cropping intensity under the proposed plan is 170 to 300%. After confirming the present and future cropping pattern, the irrigation water requirement is calculated. Then, by taking thirty percent of the scheme efficiency, scheme water for the project is calculated (Figure 2).

Results and Discussion

Bias-corrected daily projections of maximum/minimum temperatures for one station (1111) and precipitation for four stations (1107, 1112, 1213, and

Table 5. Future river flow and IWD under both ssp245 and ssp585 scenarios.

Months	Near future River flow m3/s	Irrigation water demand, m3/s				
			ssp245		ssp585	
		Current	CI=1.7	CI=3.0	CI=1.7	CI=3.0
January	11.2	20	21.6	46.4	24	55.2
February	8.7	32	39.2	72.8	40	91.2
March	20.7	112	123.2	258.4	128	295.2
April	24.5	67.2	67.2	154.4	67.2	154.4
May	38.8	29.6	23.2	67.2	29.6	67.2
June	34.3	6.4	1.6	14.4	6.4	14.4
July	125.1	55.2	57.6	127.2	55.2	127.2
August	172	10.4	0	23.2	10.4	23.2
September	137.2	24	0.8	55.2	24	55.2
October	53.7	52	56.8	120	52	120
November	20.4	22.4	19.2	52	22.4	52
December	13.4	12.8	11.2	28.8	12.8	28.8

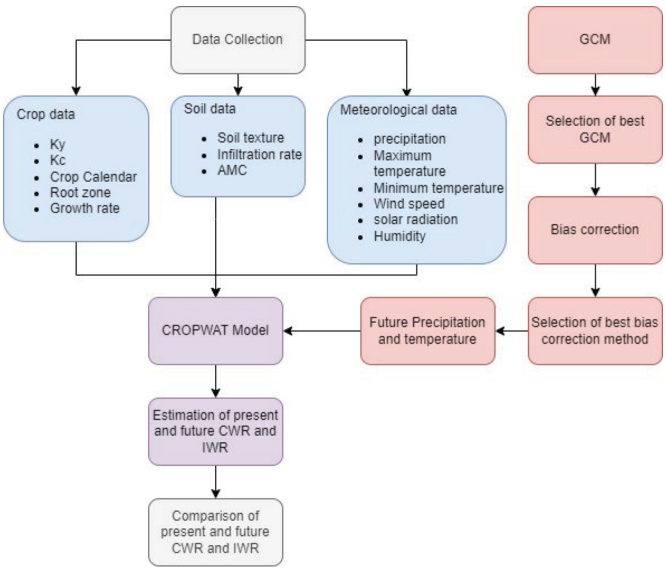

Figure 2. Methodological flow chart.

1216) are developed from the latest CMIP6-GCMs for KIP. The time series plot is available for the observed historical (1985-2014) and future (2015-2100) periods under ssp245 and ssp585 scenarios. The time series plot is done for the four best-performing GCMs and one Multi-model Ensemble (MME).

Precipitation: The latest CMIP6-GCMs have been used to create daily bias-corrected precipitation projections for five meteorological stations for KIP. The projections are accessible for the past (1985-2014) and the future (2015-2100). Precipitation is projected for four GCMs and one multi-model ensemble under two scenarios, ssp245 and ssp585. The long-term annual precipitation of all five stations is presented below. The annual precipitation series of the projected precipitation does not show any significant change in the annual precipitation. The annual projected precipitation ranges from 1000mm to 2000mm under both ssp245 and ssp585 scenarios. The annual projected precipitation under the ssp585 scenario is slightly greater than the ssp245 scenario. Plots that contain the MME ssp245 and ssp585 long-term annual precipitation for all stations can be found in the appendix (Figures 3-5).

Comparison of future river flow and IWD: The hydrological processes of the basin are significantly affected by climate change. The change in precipitation pattern and temperature variation within the basin directly influences the hydrological phenomenon of the basin. Therefore, the future river flow, which changes as time passes, is very important for designing and planning water resources projects. In this study, an effort has been carried out to estimate the future river flow and irrigation water demand in the Kamala River basin and identify the irrigation water deficit months. Since the Kamala basin has no hydrological data measurement stations, an empirical method is carried out to predict the future flow of the River.

The projected precipitation has been used for the prediction of future flow. The future flow is based on the WECS/Department of Hydrology and Meteorology (DHM) method developed by the Department of Hydrology and Meteorology, Nepal. The projected river flow in the near future, including both scenarios, is represented in Table 3. Here, river flow and irrigation water demand are estimated under two scenarios, namely: ssp245 (Middle Road approach) and ssp585 (High emission scenarios). The future hydrology is unpredictable, and IWD changes as the climatic variables change. Therefore, two scenarios, one middle approach, and the other high emission scenario were taken to estimate the future river flow and IWD. Figure 6 depicts the future river flow in the near future and irrigation water demand, including different sub-scenarios. From the analysis, the irrigation deficit occurs in the first five months of the near future under ssp245, and the magnitude of deficiency increases as the

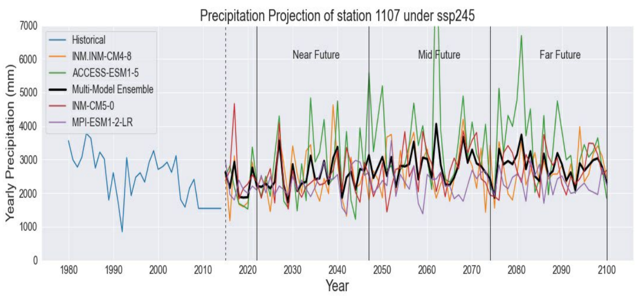

Figure 3. Projected annual precipitation under ssp245 at station 1107.

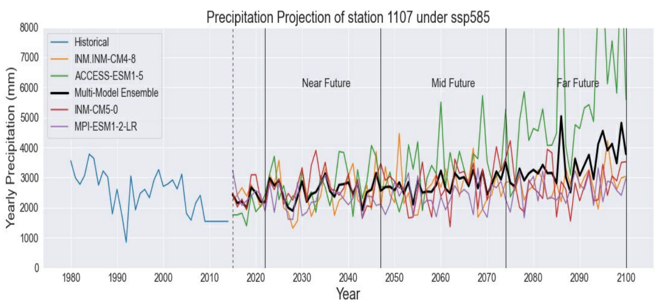

Figure 4. Projected annual precipitation under ssp585 at station 1107.

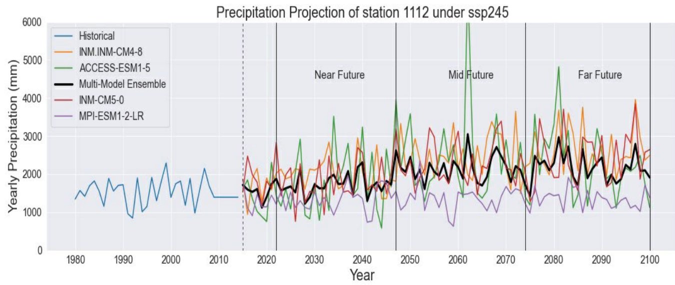

Figure 5. Projected annual precipitation under ssp245 at station 1112.

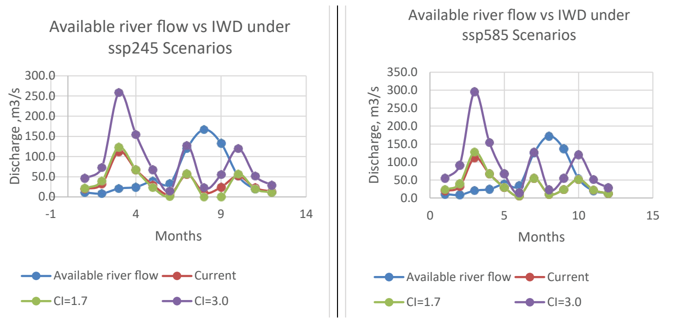

Figure 6. Comparison of future river flow and future IWD under ssp245 scenario.

cropping intensity increases. Therefore, the available river flow is insufficient to meet the irrigation demand of the Kamala irrigation system for five months from January to May in the near future under ssp245 scenarios.

Figure 6 depicts the future river flow in the near future and irrigation water demand, including different sub-scenarios. From the analysis, the irrigation deficit occurs in the first five months of the near future under ssp585, and the magnitude of deficiency increases as the cropping intensity increases. The available river flow is insufficient to meet the irrigation demand of the Kamala irrigation system for five months from January to May in the near future under ssp585 scenarios. Hence, the magnitude of the water deficit under ssp585 is much higher than under the ssp245 scenarios

Estimation of productivity with respect to water (Rain and Irrigation Water)

The production of biomass and dry yield is estimated using Aqua Crop. All the climatic variables (Wind speed, humidity, maximum temperature, minimum temperature, solar radiation, and rainfall) were imported into the model, and simulations were done. There are two scenarios setup: the first is the production of dry yield without irrigation water, i.e., rain fed, and the second is the production of dry yield with irrigation facilities. Based on the finding, crop production with an irrigation system is higher than in a rain fed system. For example, for paddy, the rain fed system produced a dry yield of 6.58 tons/ha, whereas the dry yield of the irrigated field has 7.05 tons/ha.

Conclusion and Recommendation

- The research was conducted to determine the impact of climate change on the Kamala irrigation system's future crop water requirement. Under ssp245 and ssp585 scenarios, the impact of climate change on future water requirements and irrigation water requirements of KIP was quantified. The following is a summary of the key findings.
- The precipitation and temperature projections of the Kamala irrigation project area using the latest model CMIP6 are projected with bias-corrected monthly and annually (2015-2100) for two scenarios, ssp585 and ssp245. This trend analysis was done for the near (2022-2046), mid (2047-2073), and far (2074-2100) future.
- According to the findings, GCM models INM-CM4-8, NorESM2-MM, INM-CM5-0 showed a higher rating for maximum and minimum

temperature, and ACCESS-ESM1-5, MPI-ESM1-2-LR, INM.INM-CM4-8 and INM-CM5-0 showed a higher rating for precipitation. These are the models helpful in assessing the future minimum temperature of the Kamala irrigation project.

- Based on the average combined ratings of all metrics at all selected stations using 13 bias correction methods, the best performing bias correction method for precipitation was the Power x0 Transformation method. Likewise, the maximum temperature and minimum temperature were bias-corrected by nine methods, and the selection of the best bias correction method was made by using the performance rating of past data. Based on the average of combined ratings of all metrics at all selected stations using 9 bias correction methods, the best performing bias correction method for maximum temperature was Linear Transformation and the same for minimum temperature.
- The magnitude of the mean annual trend is 0.011°C per year in NF, 0.021°C per year in MF, and 0.025°C per year in FF for maximum temperature under ssp245. Similarly, 0.0127°C per year in NF, 0.072°C per year in MF, and 0.049°C per year in FF are obtained under ssp585 for maximum temperature. Also, the magnitude of the mean annual trend is 0.045°C per year in NF, 0.04°C per year in MF, and 0.039°C per year in FF for minimum temperature under ssp245. Similarly, 0.0588°C per year in NF, 0.076°C per year in MF, and 0.05°C per year-1 in FF are obtained under ssp585 for minimum temperature. Similarly, for precipitation, the % change of mean annual trend and monthly percentage change was done under ssp245 and ssp585 scenarios. The analysis of above obtained mean annual data of temperature (maximum and minimum) indicated a significant increasing trend for a future period.
- According to the scenarios ssp245 and ssp585, the analysis revealed that both maximum and minimum temperatures would rise significantly in the future. The rise in future temperature with ssp585 was substantially more significant than with ssp245 in both the maximum and minimum temperature cases. According to the findings, both ssp585 and ssp245 are expected to increase both seasonal and annual precipitation. The projected increase for ssp585 was somewhat higher than for ssp245.
- Based on the findings and analysis, it is predicted that precipitation will increase in the study area for a certain period and then decrease, while mean minimum and maximum temperatures will rise in the future. As a result, the requirement for crop water is expected to rise in the future.
- The crop water requirement for the future is increased for all months except October and November. In addition, the percentage change in crop water requirement is highly increased for the first three months (January, February, and March) compared to other months because the percentage increase in maximum and minimum temperature of KIP is higher during those months.
- The irrigation water requirement is decreased in the future period under the ssp585 and ssp245 scenarios in five months, namely, May, June, August, November, and December. But crop water requirement increases in May, June, and August towards different future periods. The increase in crop water requirement is fully met by increased precipitation. At the same time, irrigation water demand increased in six months: January, February, March, April, October, and September.
- ssp 245 and ssp585 were conducted based on cropping intensity 170% and 300%, and IWD for each sub-scenario over 12 months was estimated. For the first sixth months, IWR is increased in the future period as maximum and minimum temperature increases, and the IWR for monsoon season is less required due to an increase in precipitation, and again for the post-monsoon season, IWR is increased compared to historical IWR..
- The highest irrigation water requirement occurred in March under ssp245 and ssp585 and CI 300%. In contrast, October and August have the lowest irrigation water demand under ssp245 and ssp585 scenarios.
- Based on the finding, the crop production with an irrigation system is higher than in the rainfed system. For example, for paddy, the rainfed system produced a dry yield of 6.58 tons/ha, whereas the dry yield of the irrigated field has 7.05 tons/ha.
- The future river flow is insufficient to meet the irrigation water demand in the first five months in the near future under both ssp245 and ssp585 scenarios. The magnitude of deficiency in ssp585 is comparatively higher than in ssp245. As a result, all of these findings suggest that the crop water requirement of KIP is insufficient in the future to provide a year-round irrigation system.

References

1. Behera, Satyapriya, Deepak Khare, Prabhash Kumar Mishra and Sangitarani Sahoo. "Impact of climate change on crop water requirement for Sunei medium irrigationproject, Odisha, India." *Int J Eng Trends Technol* (IJETT) 34 (2016): 358-367.
2. Nayak, Tejram, M. K. Choudhary and V. K. Pandram. "Modelling the crop water requirement using CROPWAT: A case study of Samrat Ashok Sagar (Halali) Project Command." (2016).
3. Allen, Richard G., Luis S. Pereira, Dirk Raes and Martin Smith. "FAO Irrigation and drainage paper." Rome: FAO of the United Nations 56 (1998): 156.
4. Birsan, Marius-Victor, Peter Molnar, Paolo Burlando and Martin P. Faundler. "Streamflow trends in Switzerland." J *Hydrol* 314 (2005): 312-329.
5. Bouraima, Abdel-Kabirou, Weihua Zhang and Chaofu Wei. "Irrigation water requirements of rice using Cropwat model in Northern Benin." *Int. J Agric Biol Eng* 8 (2015): 58-64.
6. Ewaid, Salam Hussein, Salwan Ali Abed and Nadhir Al-Ansari. "Crop water requirements and irrigation schedules for some major crops in Southern Iraq." *Water* 11 (2019): 756.
7. Hoekstra, Arjen Y., Ashok K. Chapagain, Maite M. Aldaya and Mesfin M. Mekonnen. "The water footprint assessment manual: Setting the global standard." Routledge, 2011.
8. Jeneiová, Katarína, Silvia Kohnová and Miroslav Sabo. "Detecting trends in the annual maximum discharges in the Vah River Basin, Slovakia." Acta Silvatica et Lignaria Hungarica 2010 (2014): 131-142.
9. Kashyap Kashyap, Durba and Tripti Agarwal. "Temporal trends of climatic variables and water footprint of rice and wheat production in Punjab, India from 1986 to 2017." *J Water Clim Chang* 12 (2021): 1203-1219.
10. M.Smith. "CROPWAT: Manual and guideline." *Rome, Italy* (1991).
11. Memon, A. V. and S. Jamsa. "Crop Water Requirement and Irrigation scheduling of Soybean and Tomato crop using CROPWAT 8.0." *Int Res J Eng Technol* 5 (2018): 669-671.
12. Moss, Richard H., Jae A. Edmonds, Kathy A. Hibbard and Martin R. Manning,et al. "The next generation of scenarios for climate change research and assessment." *Nature* 463 (2010): 747-756.
13. Nakicenovic, Nebojsa, Joseph Alcamo, Gerald Davis, B. de Vries and Joergen Fenhann, et al. "Special report on emissions scenarios." (2000).

How to cite this article: Lamichhane, Manoj, Yogendra Mishra and Abin Raj Chapagain. "Impact of Climate Change on Crop Water Requirement in Kamala River Basin of Nepal" *Irrigat Drainage Sys Eng* 11 (2022): 351.