Proceedings of 10th IOE Graduate Conference
Peer Reviewed
ISSN: 2350-8914 (Online), 2350-8906 (Print)
Year: 2021 Month: October Volume: 10

Comparative study of Irrigation Water Requirement and available discharge in Kankai river: A case study of Kankai Irrigation System, Jhapa, Nepal.

Manoj Lamichhane [a], Yogendra Mishra [b], Pawan Bhattarai [c]

[a,c] *Deparrtment of Civil Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[b] *Ministry of Energy, Water Resources and Irrigation,Department of Water Resources and Irrigation, Lalitpur, Nepal*
Corresponding Email: [a]ermanoj12lmc@gmail.com , [b]yogendra.1047@gmail.com , [c]pawan.bhattarai@ioe.edu.np

Abstract

The present study deals with the determination of Crop water requirement (CWR), Irrigation water requirement (IWR), and scheme supply of all cultivated crops between 1990-2010 of Kankai irrigation commanded area in Jhapa district, Nepal. The cultivated crop includes Monsoon paddy, Maize, Wheat, Potato, Pulses, Mustard, Vegetables and Spring rice. Additionally, it even aims at identifying the major climatic factors which bring about a certain change in reference to evapotranspiration (ET_o), CWR and IWR. The CWR, IWR and scheme supply for each crop in the command area were estimated by using Crop Water and Irrigation Requirements Program (CROPWAT) 8.0 Model. Furthermore, the Mann-Kendall test is conducted for the analysis of the temporal trends of climate variables. Temporal trends on climatic factors for the period 1990-2010 showed that maximum temperature and humidity had an upward trend, which eventually results in increasing CWR and IWR. CWR and IWR for every crop during 2000-2010 are in increasing order significantly as compared to 1990-1999. The maximum IWR and minimum IWR were found in the months of February (15.7m^3/sec) and July (0.8 m^3/sec) respectively. The available river discharge in the months of February and March are not enough for fulfilling the irrigation requirement in those months and available river water is fairly satisfactory to fulfill the irrigation demand without reduction of crop yield during the month of June, July, August and September of Kankai irrigation system.

Keywords
Agriculture, Crop Water Requirement, Irrigation Water Requirement, Evapotranspiration, Mann-Kendall test

1. Introduction

Water, in today's world, is becoming a gradually scarce resource as an outcome of the burgeoning demand for multiple uses like water supply, irrigation, hydropower and many more. Over the past decade, due to the alteration of the natural environment, industrialization, haphazard urbanization, population growth, climate change and man-made desertification, water shortage problems will have further aggravated in the future period. Water scarcity has a huge impact on food production. Without a sufficient amount of water, farmers do not have a means of watering their crops and could not produce sufficient food to meet the rapid growth of the population. Economic development, in the context of Nepal, is greatly reliant on agriculture, even though the majority of parts of Nepal have meager irrigation facilities. With the motive of comprehending the variation in climatic parameters along with their consequences for the consumption of agricultural water, this study is brought into practice which aims at analyzing the temporal variability of climatic factors, variation in CWR and IWR during the period 1990–2010 in Jhapa, Nepal.

Kankai irrigation system in Jhapa district is a medium irrigation project whose Command area is approximately about 7000 hectares. Kankai irrigation system irrigates paddy, wheat, maize, pulses, potatoes, mustard in different season likes monsoon, winter and summer etc. The present condition of water in the Kankai irrigation system could not sufficient to irrigate the whole command area. Understanding irrigation water requirements and the present level of water supplies is crucial for better management of available resources and agricultural productions. For irrigation scheduling, methods such as the ratio of irrigation water to cumulative pan evaporation [1], the open pan evaporation rate [2], and soil moisture depletion [3] have been frequently employed. To better estimate crop water requirements, the Food and Agriculture Organization recommends utilizing the CROPWAT software. CROPWAT has been widely used to estimate crop evapotranspiration and IWR [4, 5, 6]. CROPWAT has also been widely used to estimate irrigation scheduling and cropping patterns [7, 8, 9, 10]. A study has been conducted in Samrat Ashok Sagar command area and it sows that between the irrigation demand taken up by the dam authority and calculated by CROPWAT by considering just climatic conditions and by considering climate and soil type combined, there is a discrepancy of 25.39 MCM (19.3%) and 21.06 MCM (16.0%) [11]. As a result, using the CROPWAT 8.0 model, an attempt has been made to compute irrigation requirements for all crops of Kankai commanded area, Jhapa and to develop a scheme water supply.

2. Database and Methods

2.1 Study Area

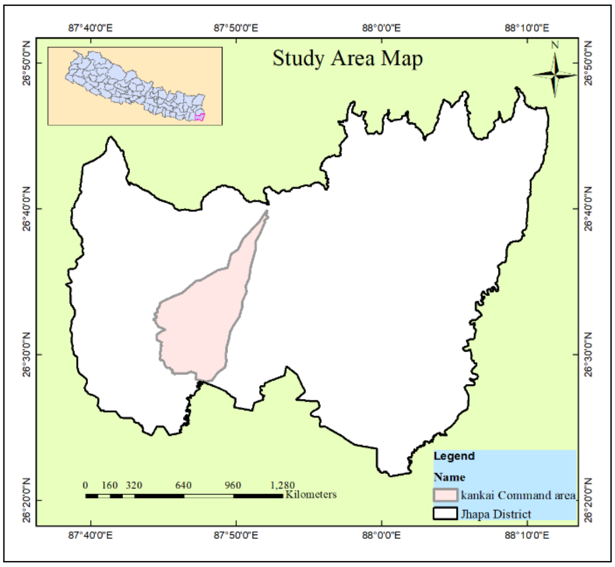

Figure 1: Study Area

Presently the Kankai Irrigation System (KIS) commands 7000 hectares of Jhapa district of Province number 1. The command area is in the flat land of the Terai of Nepal, sloping mildly from north to south as shown in Figure 1. Generally, crops are growing into monsoon, winter and spring seasons. Winter season crops are wheat, maize, mustard, vegetable and pulses whereas monsoon and spring season crops are Rice and spring rice respectively. The water source of KIS is the Kankai River, a perennial river having a catchment area of 1190 square kilometers. The maximum and minimum historical discharges of the Kankai River are 5,200 cumecs and 7.74 cumecs respectively. Figure 2 represents the watershed of the Kanlai river.

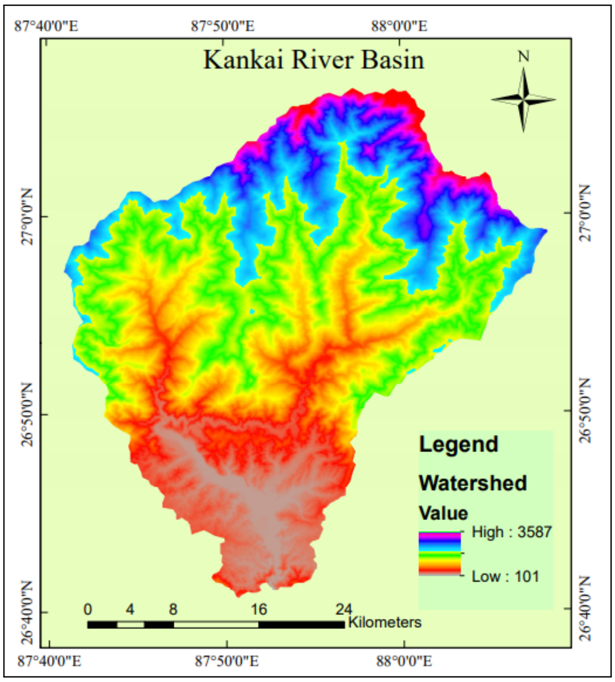

Figure 2: Kankai River Basin

2.2 Data collection

In this study, two meteorological stations (Gaida & Kechana) and one hydrological station (Mainachuli) were taken. Meteorological data (precipitation, temperature, humidity, sunshine hours, wind speed) and hydrological data (River Discharge) were collected from the Department of Hydrology and Meteorology (DHM). The Soil data and all other its properties for the analysis were collected from SOTER Map. The crop data required for the CROPWAT model were collected from The Food and Agriculture Organization of the United Nations (FAO) Irrigation and drainage paper number 56 and the crops calendar of Kankai irrigation command area were taken from Kankai irrigation management division.

2.3 Methodology

The CROPWAT 8.0 model from the Food and Agriculture Organization was utilized in this study.

The FAO's Department of Land and Water Resources developed CROPWAT. CROPWAT 8.0 is a computer application that combines many models to forecast CWR, IWR, irrigation scheduling and scheme supply [12]. CWR and IWR depend on climatic variables, crop type, soil type, crop cultivation season and crop production frequencies. It uses the Penman-Montieth method, which has been approved by the FAO, to calculate reference evapotranspiration (ET_o), crop evapotranspiration (ET_c) and irrigation water management. ET_c denotes the amount of water lost by the crop owing to evapotranspiration, whereas CWR denotes the amount of water to be applied. The evapotranspiration and irrigation water requirements of crops were modeled using a climatic variable, soil and crop data.The methodological flow chart for estimating CWR, IWR and scheme supply is shown Figure 3

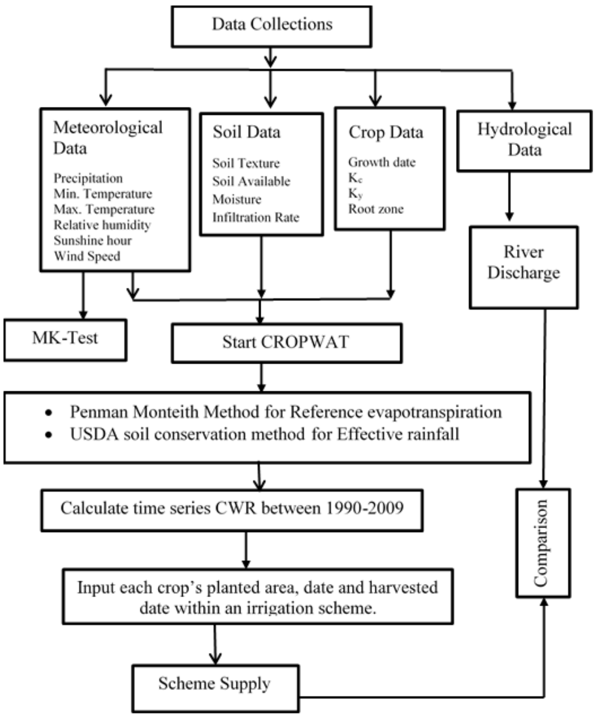

Figure 3: Methodological flow chart

2.4 Crop water requirement

Crop water requirement is the total amount of water needed to mature an adequately irrigated crop, including losses from evapotranspiration (ET), irrigation water application losses, and any additional water needed for special operations. It is expressed in depth per unit time. CROPWAT was used to estimate crop water requirements utilizing inductive, descriptive, and analytical techniques based on measured ET, soil moisture content and crop coefficient.

2.4.1 Reference crop evapotranspiration and effective rainfall estimation

In this study 20 years, meteorological data (precipitation, maximum temperature, minimum temperature, sunshine hour, relative humidity and wind speed) was taken from the Department of Hydrology and Meteorology (DHM) then this data is divided into two decades namely, 1990 and 2000. The data analysis in the CROPWAT model will have done on daily basis. In the CROPWAT model, the reference evapotranspiration were calculate using FAO penman-Montieth method. The equation is expressed as;

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

Where,
ET_o=reference evapotranspiration (mm/day)
R_n=net radiation at the crop surface (MJ $m^{-2}day^{-1}$)
G=soil heat flux density (MJ $m^{-2}day^{-1}$)
T=mean daily air temperature at 2 m height (°C)
U_2=wind speed at 2 m height (m/s^{-1})
e_s=saturation vapour pressure (KPa)
e_a=actual vapour pressure (KPa)
$e_s - e_a$=saturation vapour pressure deficit (KPa)
Δ=slope vapour pressure curve (KPa °C^{-1})
γ=psychrometric constant (KPa °C^{-1})

Precipitation data (daily/decade/monthly) is needed to compute effective precipitation. For this study, USDA Soil Conservation Service method has been decided for the figuring of effective precipitation; the following standards must be followed.

$$ER = TotalR * (125 - 0.2TR)/125 \quad (2)$$

(For Total Rainfall < 250mm)

$$ER = 125 + 0.1 * TotalRainfall \quad (3)$$

(For Total Rainfall > 250mm)

2.4.2 Crop evapotranspiration (ET_c) estimation

The application includes a cropping pattern that includes the planting date, crop coefficient data files (containing $K_c$values, stage days, root depth, depletion fraction), and the area planted (0-100 percent of the total area) as well as a collection of typical crop coefficient data files. The crop coefficient values (K_c) will be obtained from FAO Paper 56 on Irrigation and Drainage. By multiplying reference evapotranspiration by the crop coefficient, crop evapotranspiration can be estimated. The CROPWAT model estimates CWR and IWR using the formula below.

$$CWR = ET_o * K_c \tag{4}$$

$$IWR = ET_o * K_c – ER \tag{5}$$

2.4.3 Calculation of Irrigation water requirement

It is vital to distinguish between IWR and CWR. The CWR means the water needed by the crops for cell construction and transpiration, whereas the IWR means the crop receives the water through irrigation system to ensuring the full growth of the crops.If irrigation is the plant's primary source of water, the irrigation requirement must be at least equivalent to the crop's water requirement, and in most cases, it will be higher to account for irrigation system inefficiencies. If the crop gets some of its water from other sources (rainfall, soil water, underground seepage etc), the irrigation demand can be much lower than the crop water requirement. The Net Irrigation Requirement (IR_n) does not account for losses that occur during the application of water. The field balance equation is used to calculate the net irrigation demand.

$$IR_n = \sum_{t=0}^{T} (ET_o * K_c - P_{eff}) \tag{6}$$

Where,
IR_n= Net irrigation requirement (mm)
K_c= Crop Coefficient
ET_o= Reference evapotranspiration (mm)
P_eff = Effective dependable rainfall (mm)
T = Total Growing Period of Crop
To calculate the effective rainfall, the USDA Soil Conservation Method is employed and IWR is calculated using the CROPWAT model. CROPWAT model uses the following formula for the calculation of effective rainfall and IWR.

$$ER = TotalR * (125 - 0.2TR)/125 \tag{7}$$

(For Total Rainfall $<$ 250mm)

$$ER = 125 + 0.1 * TotalRainfall \tag{8}$$

(For Total Rainfall $>$ 250mm)

$$IWR = ET_o * K_c – ER \tag{9}$$

2.5 Trend analysis of climatic variables

The Mann-Kendall (MK) test is used to determine if the variable of interest has a monotonic upward or decreasing trend across time. The term "monotonic upward (downward) trend" refers to a variable that continuously rises (falls) through time, regardless of whether or not the trend is linear. The MK test can be used instead of parametric linear regression analysis to see if the predicted linear regression line has a slope that differs from zero. The residuals from the fitted regression line must be normally distributed in regression analysis; however, the MK test is a non-parametric (distribution-free) test, therefore this assumption is not required.

3. Results and Discussion

3.1 Crop water requirement and irrigation water requirement

In this study, CWR and IWR are calculated in two decades, i.e., 1990-1999 and 2000-2009. From analysis, CWR is increased from 1990-1990 to 2000-2010 for every crop of command area. Similarly,IWR also increased from 1990-1990 to 2000-2010 for every crop of command area. The CWR and IWR during 1990-1999 and 2000-2010 are shown in Figure 4 and Figure 5 respectively.

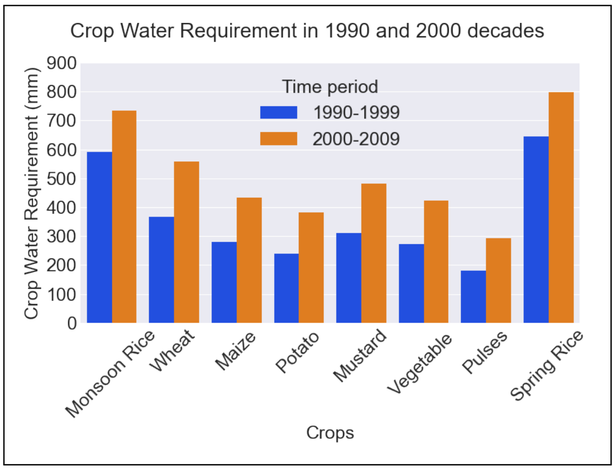

Figure 4: Crop Water Requirement in 1990 and 2000 decades

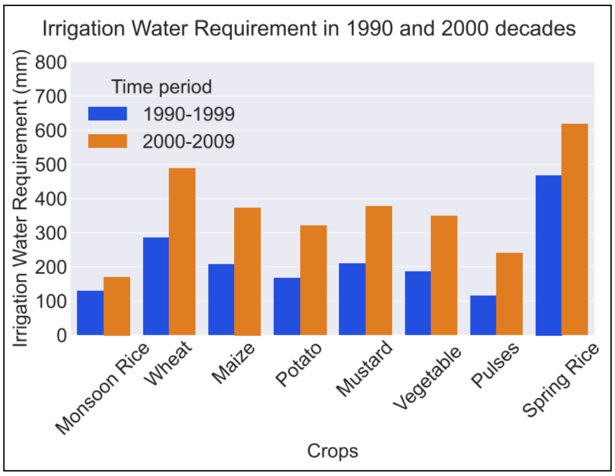

Figure 5: Irrigation Water Requirement in 1990 and 2000 decades

3.2 Temporal variations of climatic factors

Table 1 shows the descriptive statistics of climatic variables as well as the results of the MK test for yearly and seasonal patterns. Figure 3 depicts the temporal patterns of yearly climate variables. Over the research period, the climatic variables of minimum temperature (Min. Temp) and maximum temperature (Max. Temp) showed a rising trend, Whereas annual rainfall and humidity have downward trend.

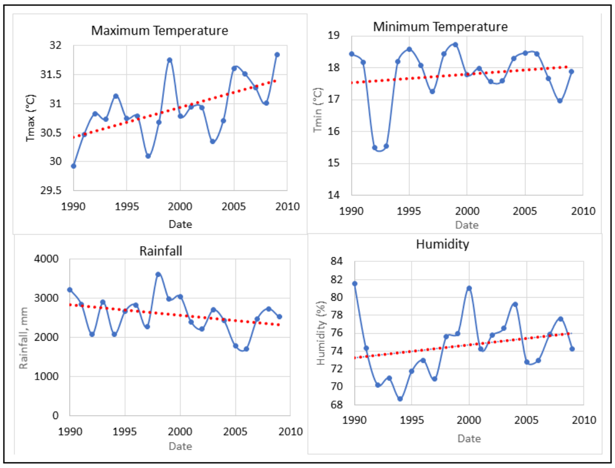

Figure 6: Trend of climatic variables

After analyzing 20 years period of climatic variables, the trends of maximum temperature and humidity were found to be statistically significant ($p < 0.05$). As we mentioned above, CWR and IWR are increasing in trend from 1990 decades to 2000 decades. From the trend analysis of climatic variables, maximum temperature and relative humidity are significantly upward trends during the past 20 years. Here we concluded that the rise in CWR and IWR from 1990 decades to 2000 decades is due to rise in maximum temperature and relative humidity whereas other climatic variables such as rainfall, minimum temperature, wind speed are not responsible for the rise in CWR and IWR.

Table 1: The MK test for climatic factors: statistical description and results

Climatic Variables	Tmin	Tmax	Rainfall	RH
Minimum	15.5	29.9	1697.3	68.7
Maximum	18.7	31.8	3761.4	81.5
Mean	17.8	30.9	2652.6	74.7
Standard deviation	0.5	29.9	506.5	3.5
CV (%)	5.0	1.7	19.1	4.6
MK-Value (P)	1.0	0.04	0.48	0.02
Sen's Slope	-0.01	0.05	-26.48	0.21

3.3 Schemes Supply

In schemes supply, monthly irrigation water required by all the crops in the command area was calculated. The average scheme supply of all crops of Kankai command area is shown in Figure 7. From the analysis, it has been seen that Potato required a maximum amount of water (43.4 mm of water) in January month whereas, monsoon rice has zero IWR . The total amount of IWR during the January month was found as 223.3 mm of water. For February month, Spring rice required the maximum amount of irrigation water requirement (236.2 mm of water) whereas, Pulses required only 0.8 mm of water. The total amount of irrigation water requirement during the February month was found as 543.4 mm of water. For March month, the maximum water required by wheat crops (113.3 mm of water) whereas the irrigation requirement of Monsoon rice and Pulses are zero. The total irrigation water requirement in March was found as 397.5 mm of water. Similarly, Spring rice required a maximum amount of irrigation water requirement (105.9 mm of water) in April month whereas, Mustard required only 13.3 mm of water.

The total amount of irrigation water requirement during the April month was found as 211.5 mm of water. Only Spring Rice required 40.9 mm of water in May month whereas all other crops had zero water requirement. All other crops had no irrigation required except Monsoon rice in June month. But monsoon rice required a huge quantity of IWR (214.5 mm of water) due to land preparation and others purpose. Similarly, in July, August and September, irrigation requirement by monsoon rice has 17.7, 140.8, 30.8 mm of water respectively. The maximum portion of crop water requirement is meet by rainfall in July, August and September. Therefore, IWR during this month is comparatively low as compared to other months. Monsoon rice has maximum IWR in October month whereas only 3.7 mm of water is required by Mustard in that month. The total amount of IWR during October month was found as 42.7 mm of water. Vegetable has maximum irrigation demand in November month (37.7 mm of water) and the total amount of irrigation water requirement during the October month was found as 120.3 mm of water. Pulses required the maximum amount of irrigation water demand in December month (49.6 mm of water) and the total amount of irrigation water requirement during October month was found as 188.4 mm of water. The net scheme irrigation requirement calculated using CROPWAT 8.0 model for the Kankai irrigation system was found to be maximum in February month i.e., 543.4 mm/month and minimum for May, July, September and October months.

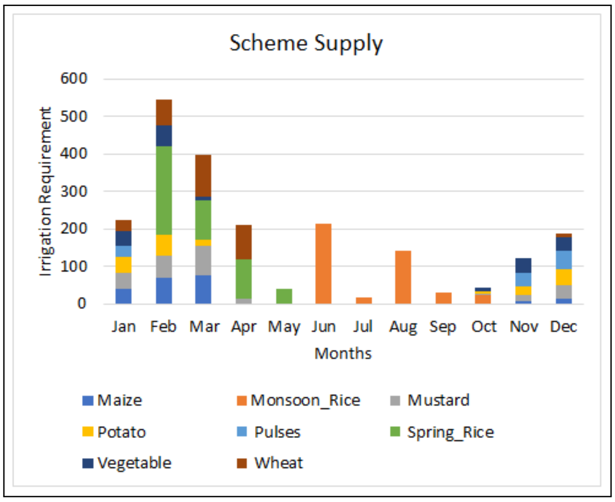

Figure 7: Scheme supply

3.4 Available water and irrigation requirement

The average irrigation water requirement over the study period and river discharge are presented in Figure 8. The maximum irrigation water requirement and minimum IWR were found in February (15.7 m^3/sec) and July month (0.8 m^3/sec) respectively.

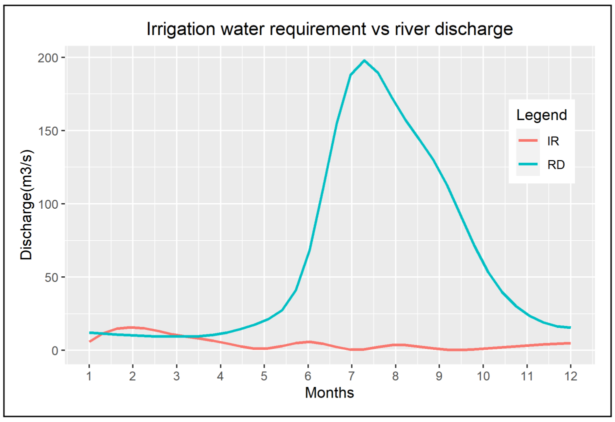

Figure 8: Comparison between Irrigation Water Requirement (IWR) versus River Discharge (RD)

From the analysis of irrigation demand and available monthly discharge in the river, it can be concluded that available water was not sufficient to meet the IWR of the command area in February and March months. The available river discharge in June, July, August and September months is very high and irrigation water demand is very low as compared to other months because the irrigation water is provided by the precipitation. But the base flow of the river during January, February, March, April, May, November and December months is small and irrigation demand is high. Total irrigation water demand is 15.7 m^3/sec in February month and only 10.2 m^3/sec river discharge is available. Similarly, March months has 10.4m^3/sec total irrigation water demand and only 9.4 m^3/sec river discharge is available. Therefore, available river discharge in February and March months are not sufficient to meet the irrigation water requirement. Similarly, available river discharge in January, April and December months are also low as compared to June, July, August and September but irrigation water demand is hardly to meet. The trend of maximum temperature and humidity is increasing in order which led to increasing in evapotranspiration of crop and ultimately increasing in the CWR and IWR of the command area. From this analysis, there is the possibility of an insufficient amount of irrigation demand in January, April and December months if the trend of CWR and irrigation requirement is in increasing in order.

4. Conclusion and Recommendation

An attempt has been made to find out the CWR of major crops in the Kankai irrigation system, Jhapa using CROPWAT 8.0 model. Results revealed that temporal trends on climatic factors for the period 1990-2010 showed that maximum temperature and humidity had an upward trend, which in turn led to increasing in CWR and IWR. The CWR and IWR for every crop during 2000-2010 are in increasing order significantly as compared to 1990-1999. The available river discharge of the Kankai river in the months of February and March are not sufficient to meet the irrigation demand in those months and available river water is sufficient to meet the irrigation demand without reduction of crop yield during the month of June, July, August, and September of Kankai irrigation system.

Therefore, this research can be useful for formulating further alternative sources of water likes the investigation of groundwater resources to meet the full demand of the Kankai irrigation system during the February and March months.

References

[1] Ogbonnaya FC Aiyelaagbe IOO. Growth, fruit production and seed yield of okra (abelmoschus esculentus l.) in response to irrigation and mulching. research bulletin no. 18. 1996.

[2] Singh BP. Effect of irrigation on the growth and yield of okra. 1987.

[3] Panda RK Home PG, Kar S. Effect of irrigation scheduling on water and nitrogen balances in the crop root zone. 2000.

[4] Raghuwanshi N George B, Shende S. Development and testing of an irrigation scheduling model. 2000.

[5] Kerkides P Rizos S Anadranistakis M, Liakatas A. Crop water requirements model tested for crop grown in greecel. 2000.

[6] Zhang Y Feng Z, Liu D. Water requirements and irrigation scheduling of spring maize using gis and cropwat model in beijing-tianjin-hebei region. 2007.

[7] Evett SR Stewart BA Robinson CA. Kang S, Payne WA. Simulation of winter wheat evapotranspiration in texas and henan using three models of differing complexity. 2009.

[8] Nazeer M. Simulation of maize crop under irrigated and rainfed conditions with cropwat model. 2009.

[9] Jamous SA Mimi ZA. Climate change and agricultural water demand: impacts and adaptations. 2010.

[10] Hornbuckle J Song L, Oeurng. Assessment of rice water requirement by using cropwat model. in linea. 2016.

[11] V.K. Pandram T.R. NAYAK, M.K. Choudhary. Modelling the crop water requirement using cropwat: A case study of samrat ashok sagar (halali) project command. 2016.

[12] Rome, Italy. *smith "CROPWAT: Manual and guideline"*, 1991.