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# Water Management in the Face of Climate Change: A Good Irrigation Practice as an Adaption Technique towards a Better Streamflow Discharges of Hadejia River System.

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***Keyword:*** *Climate Change, Hadejia River, Stream flow Discharge, Water Resources Management.*

## Abstract

*There is growing concern towards effective water resources management in the face of climate change, phenomena that lead to a mounting pressure on stream flow discharge. Consequently, there is need to identify options towards adapting the phenomena. This paper is set out to serve as an advocate for climate change adaptation technique in sub-Saharan Africa, where it proposed irrigation practices that have a tendency of freeing more water that will increase stream flow discharge for downstream users. A water Evaluation and Planning System (WEAP) was used to model for stream flow discharge along Hadejia River System, Nigeria. The model was ran from 2017-2050 under five different developmental scenarios; Business as Usual scenario (BAU), expanded area scenario (EA), Irrigation Efficiency Scenario (IE), Irrigation Practice Scenario (IP) and Combination of Interventions scenario (COI) representing different irrigation practice. The model results shows average stream flow discharge below Hadejia River head flow to be 40 m*$^3$*/s. The average* *stream flow discharge towards the outflow of the river system was found to be 59.3 $m^3/s$, 58.0 $m^3/s$, 58.3 $m^3/s$, 59.9 $m^3/s$, and 64.8 $m^3/s$ under BAU, EA, IE, IP and COI respectively. The COI demonstrated an ability of increasing stream flow discharge by 11%. The study concludes that adopting an appropriate irrigation practice will result into a better stream flow discharge. Finally, the paper recommends for shifting back to more appropriate irrigation practice.*

## Introduction

Water is under unparalleled pressure as a result of growing population across the globe and various economic needs. There is growing concern towards effective water resources management in the face of climate change concerns that lead to a mounting pressure on stream flow discharge. Practically every development challenge of the 21st century – food security, managing rapid urbanization, energy security, environmental protection, adapting to climate change – requires urgent attention to water resources management (Salami, *et al.* 2014). Arias *et al.* (2014) observed a high vulnerability of stream flow to changes in temperature and rainfall, decrease in stream flow occur as a consequence of increase in temperature and decrease in rainfall. Even though there is an increase in annual runoff in some regions of the word as a result of variation in temperature and precipitation, Bates *et al.*, (2008) documented decrease of runoff in some regions including West Africa. They however observed that many studies have found no trends, or have been unable to separate the effects of variations in temperature and precipitation from the effects of human interventions in the catchment, such as land-use change and reservoir construction.

Hadejia River system is not immune from such challenges. Sobowale *et al.* (2010) shows that the surface water resources have been over exploited and that most of the irrigation schemes in the area waste a lot of water due to poor operation and management; the farmers tend to over irrigate. Other challenges faced by the river system includes, but not limited to; uncoordinated surface water use; extremely large and small flood; irregular and low flows that affected both small and large irrigation along the river; prediction of the impact of climate change on the rainfall and river flow in the basin; and information on environmental river flow (FMWR-IUCN-NCF, 2005).

This paper analyses the impact of five developmental scenarios on stream flow discharge of Hadejia River based on hydrology water simulation model built in Water Evaluation and Planning System (WEAP) model. The five scenarios are; Business as usual, expanded area, irrigation efficiency, irrigation practice, and combination of intervention scenarios. WEAP operates on the basic principle of water balance accounting and WEAP can address a wide range of issues, e.g., sectoral demand analyses, water conservation, water rights and allocation priorities, groundwater and streamflow simulations, reservoir operations, hydropower generation and energy demands, pollution tracking, ecosystem requirements, and project benefit-cost analyses (Seiber and Purkey, 2015). WEAP have been extensively utilised in addressing different water resources management problems across the globe. Abdullahi *et al.,* (2015) for assessment of climate change on water resources availability; Al-Omari *et al.,* (2015) for irrigation water management; Bhatti and Patel (2015) for irrigation scheduling strategies; Omar and Moussa (2016) for future challenges of water management; Brown *et al* (2019) on water resources and climate change studies; and Salamon-Sirolesi and Farinos-Dasi (2019) on supply and demand management.

## MATERIALS AND METHOD

### The Study Area

The Hadejia River is a river in northern Nigeria and a tributary of Yobe River. The River is substantially controlled by Tiga and Challawa Gorge Dams as well as Hadejia Barrage. The River feed Kano River Irrigation Project (KRIP), Hadejia Valley Irrigation Project (HVIP) and contributes to Kano City Water Supply.

The study area does not cover the entire River system. The study started from Hadejia Barrage that feeds HVIP and terminated where the river meets Jamma'are River system and drains into River Yobe. Figure 1.0 shows map of the study area

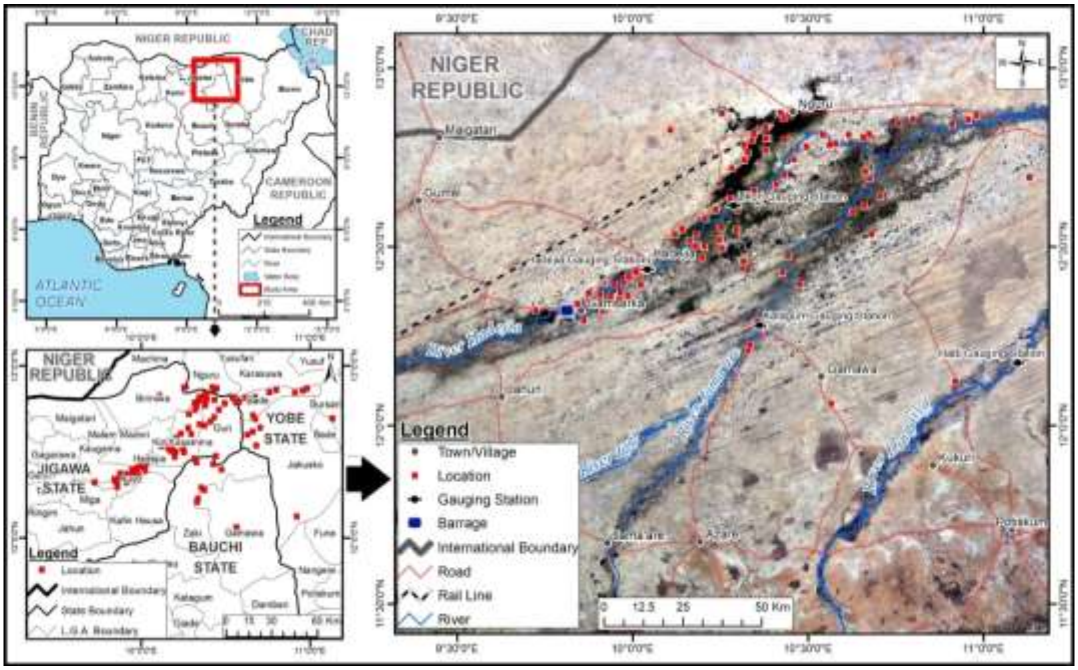


Figure 1.0: Map of the study area
Source: Earthstar Geographics

**Model Development**

A model was developed to simulate irrigation and domestic water demand of the study area. After the simulation, the stream flow of the river was assessed and presented by this paper.

**Area Setting**

Upon opening WEAP, a project area called “Weaping River Basin” appeared. This area was used in creating a new blank area that is used in setting up the development of this model.

A new blank area was created in WEAP window. The area was created by choosing an option (from a popped window) to be initially set blank. After creating the area, a geographic area of the study was then set by setting boundaries of the area on the appeared world map.

Upon setting the boundaries for the study area, a catchment delineation mode, from schematic view of WEAP, was activated and WEAP automatically defined the basins by delineating the catchment and rivers within the study area. A MABIA method was chosen in the process and daily Climatic data of 62 years (1948 – 2010) was downloaded and loaded in the delineated catchment to set up the model. Digital Elevation Data (DEM) for the delineation was obtained at 90 meters (3 arcseconds), as recommended by the developers. The Model's HydroSHEDS digital elevation data is based on high-resolution elevation data obtained during a Space Shuttle flight for NASA's Shuttle Radar Topography Mission (SRTM). ESA-CCI-LC land cover data comes from the Medium Resolution Imaging Spectrometer (MERIS) satellite and PROBA-V and a combination of AVHRR and SPOT-VGT data to create a complete land cover classification sequence that covers the period between 1992 and 2015 (24 years) with a spatial resolution of 300m. Daily Climatic data was based on The Princeton historical climate dataset blends reanalysis data with observations to create global daily and monthly data of temperature, precipitation and wind speed for 1948-2010, at a 0.25 degree spatial resolution.

**Setting General Parameters for the Model**

After setting up of the study area, a set of parameters were set. The setting up of these parameters started with setting years and time steps for the study after which units was set for the model and SI units were adopted. Basic parameters were then set under the assumption that all branches within a demand site have the same variation and all branches within catchment have the same climate data. The MABIA water balance that uses two "buckets" is chosen for the study.

**Current Account**

Current Account was chosen to serve as the base of the model. Year 2016 was chosen as the Current Account year of this study. All system information, data on demand and supply, are inputted into the Current Account which become a dataset upon which scenarios is built.

As presented in Figure 2.0, networks of hydrologic and infrastructural linkages are created on WEAP interface to represent different domestic demand site, irrigation catchments, and supply source. Red circles represent domestic demand sites and green circles represent irrigation catchments. Each demand site and irrigation catchment was connected to supply source (river) using transmission links (green lines). A runoff/infiltration links (dotted green lines) were used to return runoff from catchment to river and infiltration to ground water node (green squares). Each catchment was provided with the groundwater node for infiltration from the catchment to take care of irrigation loss to groundwater. A reservoir (green triangle) was placed to represent Hadejia Barrage Reservoir and diversion (yellow lines) was also created to divert water from the barrage to Hadejia Valley Irrigation Project (HVIP) Catchment and into the river for downstream users.

Communities that fall under the same local government areas are merged and represented as one domestic demand site named after the local government and irrigation schemes that fall under the same local government area are considered as one catchment with the exception of the only formal irrigation in the area, HVIP.

WEAP allocate water to demand site and catchments based on demand priorities and supply preferences. In developing this model, consideration is given to irrigation catchment over domestic demand sites because irrigation is major user of surface water in the study area. All irrigation catchments are allocated demand priority and supply preference 1 and demand sites are allocated 2 implying that demand and supply of irrigation catchments would be satisfied first before that of domestic demand sites.

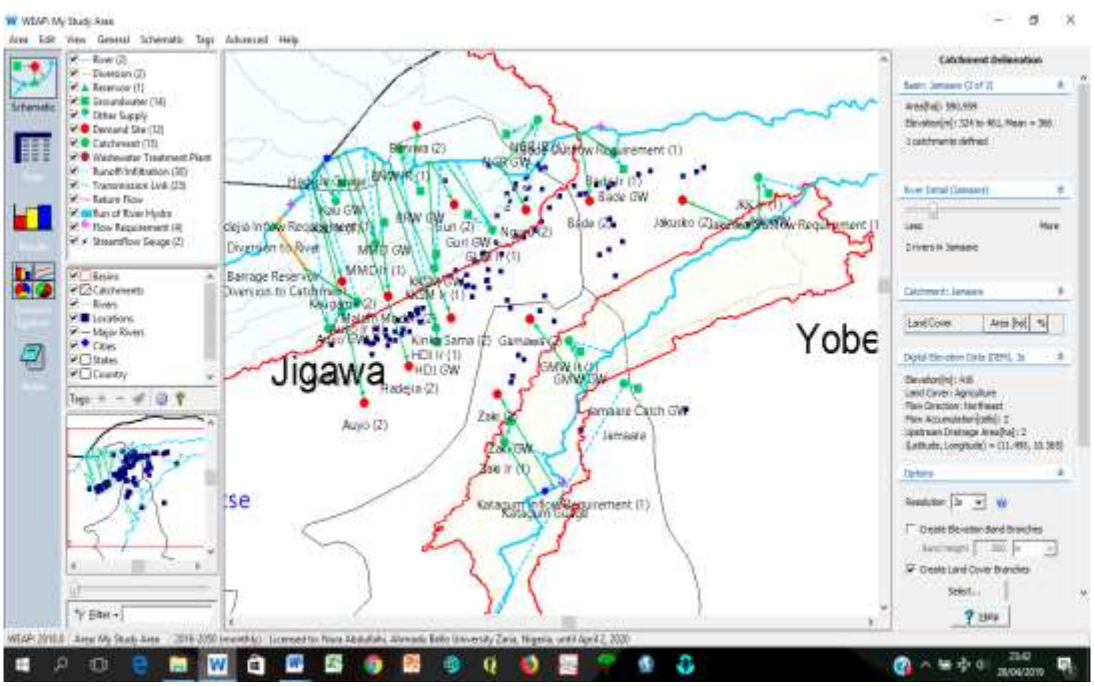


Figure 2.0: WEAP Interface Showing Schematic Representation of the Study Area

**Current Account Data:**

**i) Domestic Water Use Activity**

Annual activity level represents population of communities in each demand node

Annual water use rate represent the average annual per capita consumption of an individual in the demand site. This study adopts the per capita consumption of FMWR/JICA, 2014 that is based on settlement categorisation. Settlement with greater than 20,000 people (urban area) was given per capita consumption of 120 l/cap/day, 5000 – 20,000 people (semi-urban) given 60 l/cap/day, and less than 5000 people given 30 l/cap/day.

A loss rate of 30% as given by FMWR/JICA, 2014 is applied to demand sites.

The model was built under assumption that whatever comes to supply source is consumed and there is no water re-use (from demand sites) in the system. Monthly variation is assumed to be proportional to number of days in month.

**ii) Irrigation Catchment**

**Area**: Area and share of crop under cultivation under each irrigation sub-catchment was entered

**Crops**: Characteristics such as crop development stages and respective coefficients (Kc), yield response and depletion factor, crop height and rooting depth were obtained from Doorenbos and Pruitt, (1977); Allen *et al.*, (1998); and Steduto *et al.*, (2012) all of which are FAO Irrigation and Drainage papers and entered for respective crops

**Soil Water Holding Capacity**: soil properties (particle size, bulk density, and organic carbon content) was obtained from Harmonised World Soil Data Base and was utilised in modelling the water holding capacity of the soil using in-built Pedotransfer Function developed in 2006 by Jabloun and Sahli.

**Maximum Infiltration Rate**: The average maximum infiltration rate of the basin was obtained from technical report on surveys and investigation for Transforming Irrigation Management in Nigeria (Umolo and Babayo, 2016).

**Climate**: The model was loaded with 62 years (1948 – 2010) daily climate data of precipitation, minimum temperature, maximum temperature and wind speed downloaded during catchment delineation.

**Irrigation**: Irrigation Schedule: The irrigation scheduling practice in the area is best described as "fixed interval trigger and fixed depth amount" irrigation. Irrigation schedule is set for each and every crop.

The schedule was set through physical examination by the researchers and series of discussion with stakeholders in the area.

Irrigation Efficiency: 40% efficiency was adopted form (Sluimer *et al*., 2016)

**Supply and Resources:** 40 CMS Cumulative average releases from Tiga and Challawa Gorge Dams was utilised as releases of the reach below the dams. Data on releases from Hadejia Barrage was utilised as flow below the barrage.

**Model Calibration and Validation**

Model calibration was done using the incorporated Model-Independent Parameter Estimation (PEST) interface within WEAP software. The model was validated by comparing modelled and observed stream flow (for 2014-2016) discharge at Hadejia gauging station. The data on observed stream flow discharge from the gauging station was sourced from Komadugu-Yobe Trust Fund.

**Scenario Development**

**i) Business as Usual Scenario**

Business as usual, is created based on the developed current account. The scenario is to simulate the evolution of water resources management (demand and supply) of the study area for thirty three years (2017 to 2050) under the assumption that there are not any changes or intervention to the current account activities.

**ii) Expanded Area Scenario**

This scenario was built based on business as usual scenario. It assessed the impact of government policy of expanding the irrigation facilities of the study area from the current 5300 ha to 11376 ha.

**iii) Irrigation Efficiency Scenario**

The scenario was built based on Expanded Area Scenario. The scenario assesses the impact of increase in overall irrigation efficiency in the area to 65%

**iv) Irrigation Practice Scenario**

The scenario was built based on Expanded Area Scenario. It assesses the impact that a shifting to more appropriate irrigation practice (both in terms of scheduling and cropping pattern). Irrigation in this scenario is based on irrigation schedule triggered at 100% RAW (Readily Available Soil Water) with an application of 100% depletion. The designed cropping pattern that excluded Rice is adopted.

v) **Combination of Interventions Scenario**

The scenario was built based on Expanded Area Scenario. This scenario assessed the combined effect of improvement of irrigation efficiency and change of irrigation practice.

## RESULTS AND DISCUSSION

### Model Validation

The model was validated when there was an agreement between observed and simulated stream flow at Hadejia gauging station. The result of observed versus simulated stream flow at Hadejia gauging station is presented as Figure 3.1

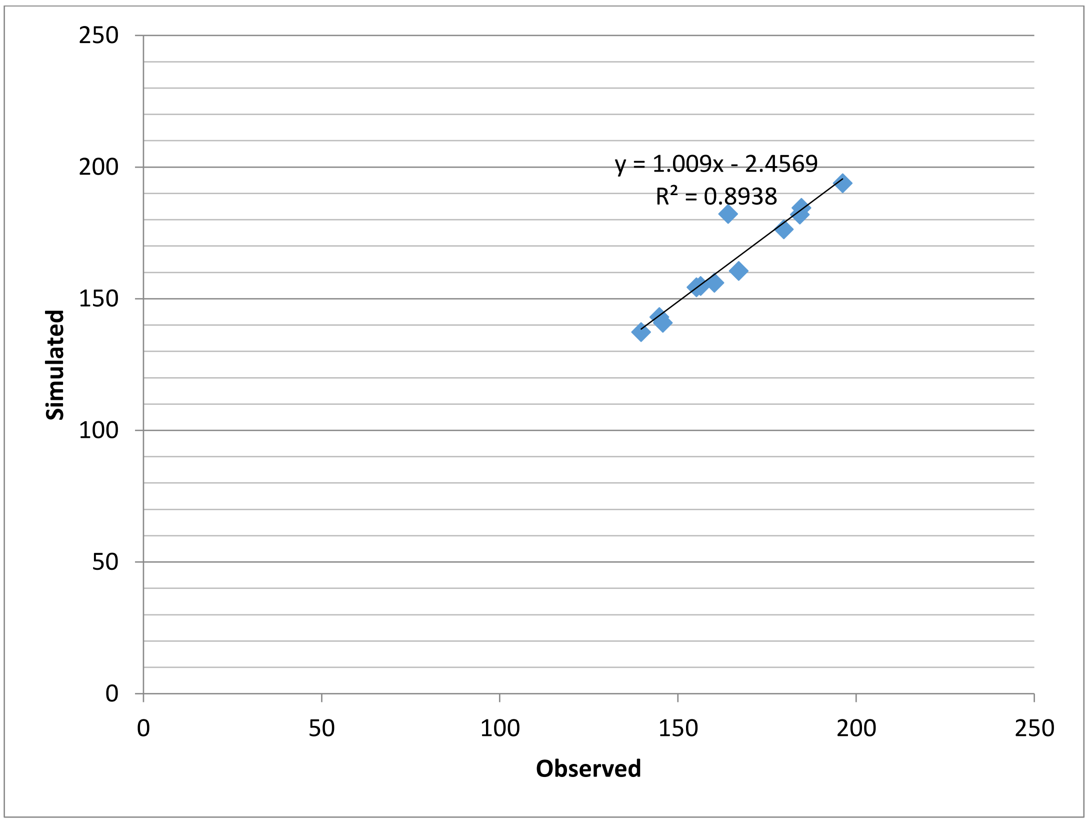


Figure 3.1: Observed vs. Simulated Stream Flow at Hadejia Gauging Station 2014 - 2016

### Stream flow

Stream flow of the river system (monthly average) was assessed at a reach below Hadejia Runoff (i.e. below Hadejia River head flow). The flow was then assessed towards the outflow point of the river, below Bade Ir runoff

return, after water withdrawal by the domestic demand sites and irrigation catchments.
The monthly average of stream flow below Hadejia Runoff was found to be in the range of 97.7 million cubic meters (MCM) to 107.1 MCM across all the scenarios. This translates to a monthly average of 40 $m^3/s$. Figure 3.1 present the stream flow below Hadejia Runoff.

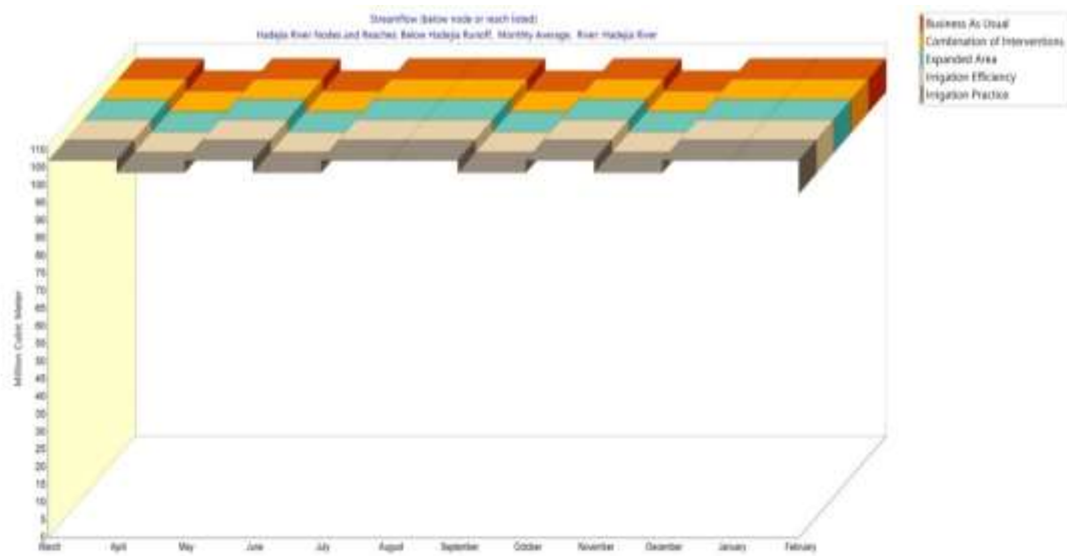


Figure 3.1: Stream Flow below Hadejia Runoff.

The stream flow after water withdrawal by domestic demand sites and irrigation catchments was discovered to vary across scenarios. Table 3.1 present the range of monthly average stream flow and average discharge of the river for the different scenarios. It can be seen that expansion of irrigation area under expanded area scenario has reduced average river discharge to 58 $m^3/s$ from 59.3 $m^3/s$ under business as usual scenario. This demonstrated a decrease of 2% discharge. But improvement of irrigation efficiency will relatively increase the average discharge by 1% to 58.3 $m^3/s$. Irrigation practice scenario also show an ability of releasing more water than expanded area. With an average discharge of 59.9 $m^3/s$, the scenario demonstrated a discharge increase of 3.5%. The average discharge under combination of intervention scenario was found to be 64.8 $m^3/s$. When compared with expanded area scenario, it demonstrated an ability of increasing discharge by 11%. The average monthly stream flow of all the months is presented by Figure 3.2.

Table 3.1: Range of Monthly Average Stream Flow and Average Discharge of the river

| SCENARIO | MONTHLY AVERAGE STREAM FLOW (MCM) | | AVERAGE RIVER DISCHARGE ($M^3/S$) |
|---|---|---|---|
| | Lowest | Highest | |
| BUSINESS AS USUAL | 121.4 | 198.0 | 59.3 |
| EXPANDED AREA | 113.5 | 198.1 | 58.0 |
| IRRIGATION EFFICIENCY | 123.2 | 198.1 | 58.3 |
| IRRIGATION PRACTICE | 124.3 | 211.9 | 59.9 |
| COMBINATION OF INTERVENTIONS | 139.1 | 211.6 | 64.8 |

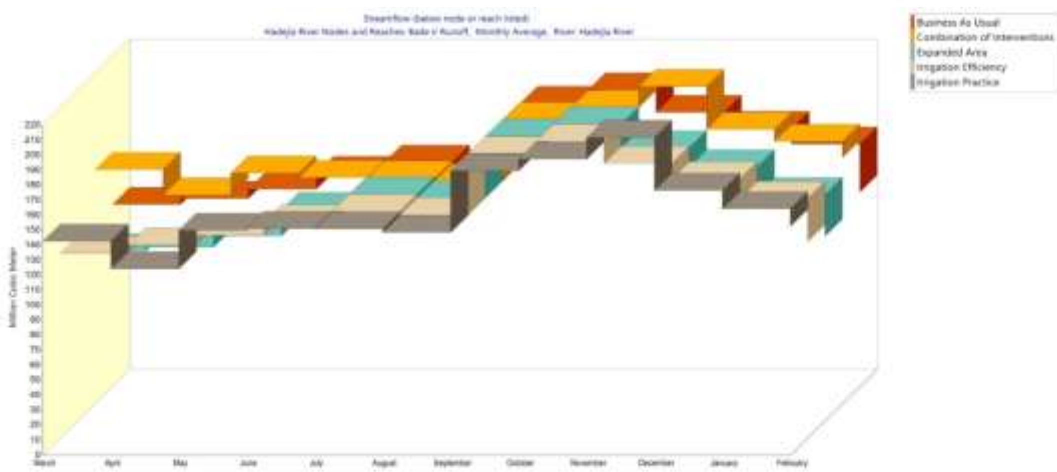


Figure 3.2: Average Monthly Stream Flow of Bade Ir Runoff Node.

## CONCLUSION AND RECOMMENDATIONS

This study assessed stream flow discharge of Hadejia River System after water withdrawal by domestic and irrigation catchments under five different irrigation developmental scenarios. The study found an increase of stream flow with an increase in irrigation efficiency and change of irrigation practice in the study area. Increase in irrigation efficiency demonstrated a tendency of increasing stream flow of the area by 1%, change of irrigation practice will increase it by 3.5%, and the combination of increase in efficiency and change of practice will increase it by 11%.

The study therefore recommends for an overall increase of irrigation efficiency and shifting to more appropriate irrigation practice where irrigation schedule is triggered by moisture content (soil readily available water for crops/plants). The study further recommends that government and other stakeholders must ensure that designed cropping pattern of the area is strictly adhered to.

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