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CLIMATE VARIABILITY AND IMPACT VULNERABILITY STATUS OF IRRIGATION WATER RESOURCES ON RICE AND TOMATO PRODUCTION DOWNSTREAM OF TIGA DAM, NIGERIA

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ABSTRACT

The focus of this empirical study is to investigate the trends of some hydro metrological parameters and Impact Vulnerability Status (IVS) of irrigation water resources on rice and tomato production in the downstream of Tiga station. Investigation was conducted using data on rainfall, temperature, evaporation and reservoir water level for 30 years in Tiga station. The data collected was used to show the trend fluctuations of each parameter for the period of study. The rainfall data was also used to analyze the Normalized Rainfall Index (NRI) in order to know periods of surplus, deficit and optimal water availability as against the required water for rice and tomato production. The rainfall pattern and water level showed increasing trend while temperature and evaporation showed a general decrease in trend. The NRI used to investigate the IVS in Tiga station downstream revealed that rice and tomato were not vulnerable to drought and flooding for 18 years while every other years were vulnerable or slightly vulnerable. However, only year 1993 appears to be very wet and highly susceptible to flooding. Findings from focus group revealed that 80% of the farmers reported floods occurrences during rainy season and deficit of water between January and March of each year. In conclusion, the IVS of farmers to climate change revealed periods of deficit, optimal and excess water availability for rice and tomato production and their vulnerability status. It was recommended that the government should strengthen laws and policies relevant in addressing climate change.

Keywords: Hydro metrological parameters, Irrigation water resources, Rice, Tomato production and Tiga dam.

INTRODUCTION

Climate variability refers to the climatic parameter of a region, varying from its long term mean every year in a specific time period. The climate of a location may differ as some years have below average rainfall, while some have average or above average rainfall (Ayoade, 2003). In recent times, increasing attention has been focused on the linkages between climate variability and crop production, prompted by concern that the environmental effects of these changes, especially the depletion of natural resources, will create conditions that increase food insecurity (Brown and Crawford, 2009). It is interesting to note that Climate change acts as a 'threat multiplier' that makes existing concerns, such as water scarcity and food insecurity, more complex and intractable.

Rice and tomato are major consumed food crops in Africa whose cultivation could be affected by water scarcity, rainfall, evaporation and temperature. However, Irrigation is a major mitigation strategy to boost yields of these crops (Olaniyan, 2015). Nigeria is African leading consumer of rice, and one of the largest producers of rice in the continent, and simultaneously one of the largest rice importers in the world. Rice is an important food crop and essential cash crop. It is mainly cultivated by small-scale farmers, who commonly sell 80 per cent of total production and consume only 20 percent. It is mostly cultivated within a temperature range of 25 – 35°C, for good yields. Rice generates more income for Nigerian farmers than any other cash crop in the country (Olaniyan, 2015). Similarly, Nigeria was reported to be the second largest producer of tomato in Africa after Egypt and 13th in the world, with a production of 6 million tons annually prior to 1990 (Idah, Ajisegiri and Jiya, 2007). Tomato is grown in Nigeria, in its diverse agro-ecological zones that range from humid in the south to sub-humid in the middle belt and semi-arid and arid in the north. It is mostly cultivated within a temperature range of 25 – 34°C, for good yields (Idah et al., 2007).

Aryal (2013) who worked on rainfall and water requirement for rice and tomatoes during growing periods revealed that the optimal amount of water for rice is 711.45mm and that of tomatoes 786mm in a total growing period. This implies that any excess or deficit from this, will likely affect the yields of these crops. Similarly, the seasonal and long-term variations in the flow of rivers in the area underline the importance of large storage as a means of making optimum use of the water resources. Many researchers have examined floods, climatic challenges, water resources and crop production in different parts of the country, some of whose works include that of

Babatolu and Akinnubi (2016) on smallholder farmer's perception of climate change and variability impact and their adaptation strategies in the Upper and Lower Niger River Basin Development Authority Nigeria.

The works of Umar, Mohammad, Ahmad, Jamil, and Abdulkareem (2018) on runoff, irregularities, trends, and variations in Hadeja river catchment, which used 36 years monthly river discharge data (1980–2015) to study the hydrological trends and variations of surface runoff in the river catchment. The work of Abdullahi (2015) on the influence of weather parameters on the productivity of rice in the Kano River Irrigation Project, which used data on weather and rice yield for a period of 20 years (1994 – 2013).

All these studies aimed at proffering solutions to address climatic challenges, flood and water shortages in order to boost crops yields. However, there seemed to be limited information on the analyses of water requirement and vulnerability status for crops especially on rice and tomato simultaneously in the downstream of Tiga station as high rates of evaporation from the reservoir, persistent droughts, faulty designs and operation of the multipurpose dams have often led to drastic reduction of water availability and sometimes flooding of irrigated wetlands downstream. This therefore necessitates the need for findings in order to proffer lasting solution in attaining crops (rice and tomato) optimal water requirement, limit water deficit and flooding on these crops.

The study aims to assess climate variability and impact vulnerability status of irrigation water resources on rice and tomato production downstream of Tiga dam and the objectives are to examine the trends of rainfall, temperature, evaporation and reservoir water level in the study area and determine the Impact Vulnerability Status (IVS) of farmers to climate change on irrigation water based on rice and tomato water requirements in the study area.

THE STUDY AREA

The study area is Tiga dam located on Latitudes $11^0$17´30´´N to $11^0$28´00´´N and Longitudes $8^0$20´0´´E to $8^0$36´0´´E of Nigeria. The dam covers an area of 178 square kilometers with maximum capacity of nearly 2,000,000 cubic metres, with a potential irrigable area of about 45,300 hectares. The seasonal movement of the Inter tropical Convergence Zone (ITCZ), which resulted in wet and dry seasons, influences the climate of the region. The area is characterized by a mono-modal rainfall distribution averaging 600 to 1300 mm per annum. The length of the growing period is 90 to 165 days (for rain fed crops). Rainfall is strongly seasonal, and occurs between April and October (Abdullahi, 2015).

About 80% land mass of the study area is underlain by quartzite, undifferentiated meta sediments and basement complex rocks of the Precambrian upper Cambrian origin, while the soil is characterized into the Ferruginous Tropical Soils. The vegetation is categorized into Sudan and the Guinea savannah both haven been replaced by secondary vegetation while the major natural rivers include River Challawa and River Kano. The population of Tiga station downstream is about 544,170 according to 2006 population census, projected to 2018 at 2.7% growth rate resulting to 752,393. The economic activities of the people include farming, trading and fishing (Mustapha et al., 2014).

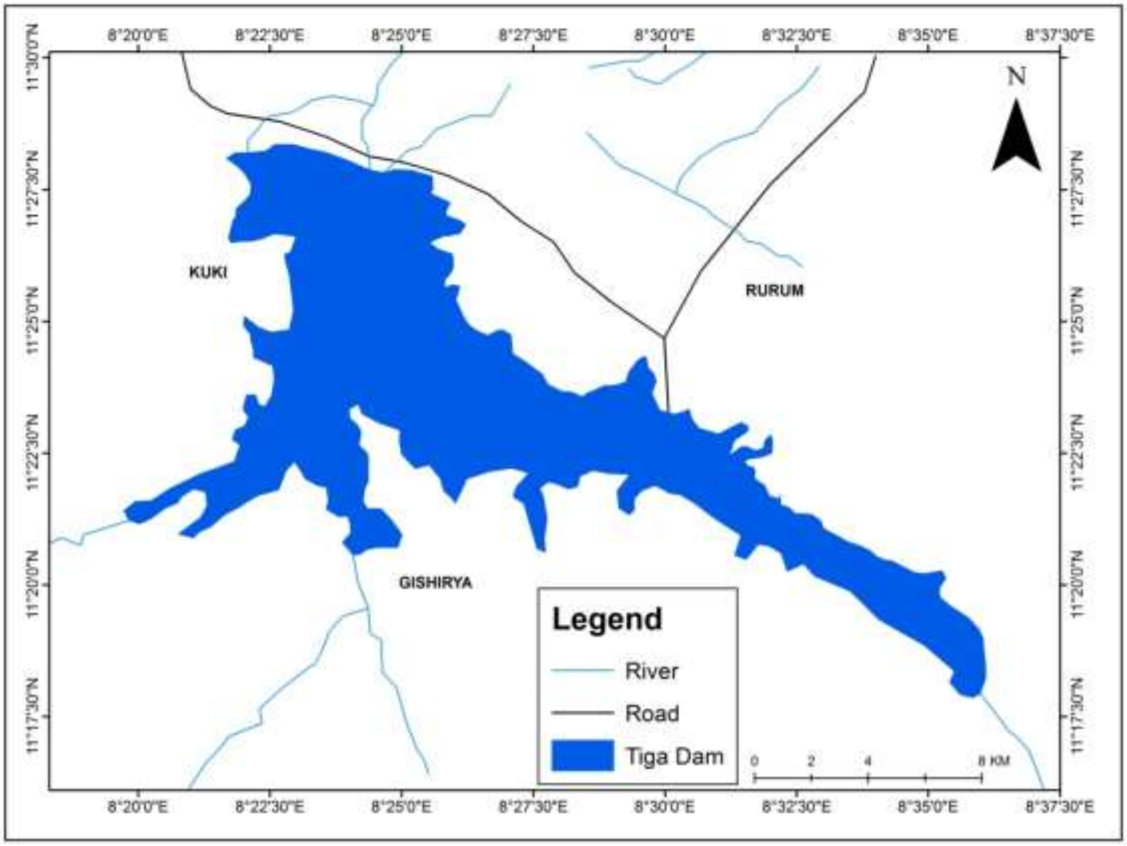


Fig 1: Tiga Station

Source: Adapted from Google Imagery

METHODOLOGY

Purposive sample method was used to select Tiga station based on its downstream population and its irrigation farming activities, while also considering the technology and industrial status of states in the study area. A survey of the study area was carried out, in order to get the researcher acquainted with the study area and the data required for the study. The researcher visited the dam station and downstream at different days. The researcher was introduced to the facilities by the project managers, who gave detail accounts of how the station was been maintained especially with regards to readings of hydro metrological data, while at another time, the researcher visited the study area (downstream) in order to derived strategic modalities in carrying out the field investigations. A Focus Group Discussion was carried out with the help of some local field assistants and some farmers to know the exact effects of climate variability and irrigation water resources on these crops production. The types of data required for the study include Tiga station rainfall data from 1989-2018, Tiga station temperature data from 1989-2018, Tiga station evaporation data from 1989-2018 and Tiga station reservoir water level data from 1989-2018. All data were obtained from Tiga station.

Trend analysis was used to show the trends of the hydro climatic variables for rainfall, temperature, evaporation and reservoir water level in which a linear trend line equation was displayed on the graph. A five years moving average was also used to show upward and downward peaks in trends while the Impact Vulnerability Status (IVS) of farmers to climate change on irrigation water resources on crop production was carried out using the rainfall data in the study area while adopting Turkes (1996) Normalized Rainfall Index (NRI) which uses annual or seasonal rainfall totals and the standard deviation to indicate the water level of any given season. The NRI for a given station as defined by Turkes (1996) is computed thus;

$$NRI=\frac{Rsy-LM}{SD}$$

Where Rsy = the rainfall total for the station during a year (or season)

LM = the long term mean (of the period specified for the station) and

SD = Standard deviation of the annual (or seasonal) rainfall total for that station. Table 1 shows the classification of the index as defined by Turkes (1996).

Table 1 Classification of Normalized Rainfall Index

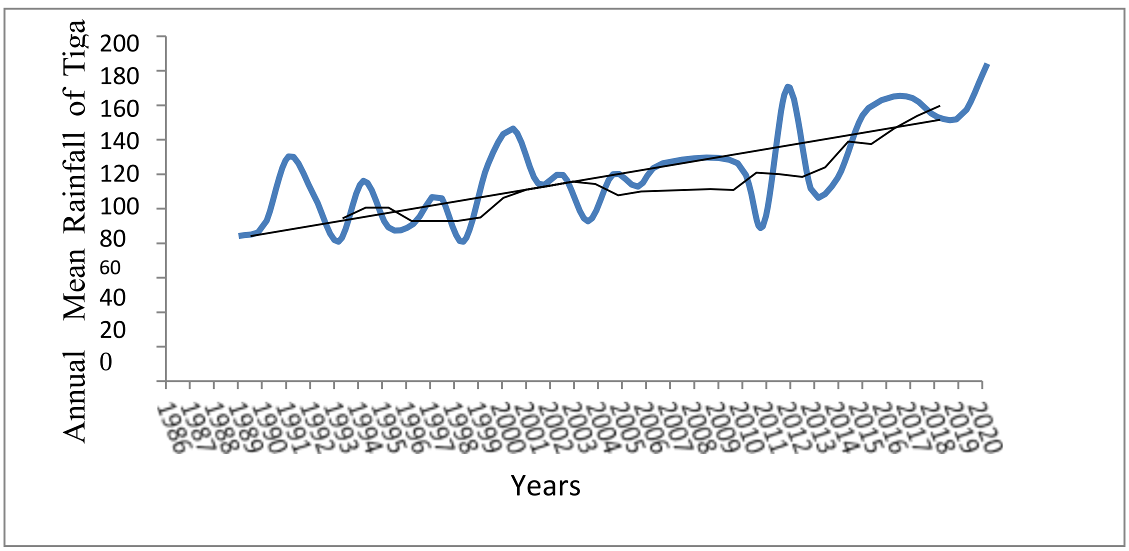
$NRI=\frac{Rsy-LM}{SD}$	Character of Rainfall	Farmers'Impact vulnerability status
1.31 or more	Very wet	Highly vulnerable
0.86 to 1.30	Moderately wet	Vulnerable
0.51 to 0.85	Mildly wet	Slightly vulnerable
0.50 to -0.50	Near normal	Not vulnerable
-0.51 to -0.85	Mild drought	Slightly vulnerable
-0.86 to -1.30	Moderate drought	Vulnerable
-1.31 or less	Severe drought	Highly vulnerable

Source :Turkes, 1996

The table was used to interpret the intensity of rainfall and its impact vulnerability status on rice and tomato production on mean annual rainfall basis considering the optimal water requirement according to Aryal (2013) who noted 711.45mm for rice and 786mm for tomato in a total growing period.

RESULTS AND DISCUSSION

The rainfall data collected from Tiga dam station was subjected to time series analysis, in order to show the trend of rainfall for the time frame of study (1989-2018).Fig. 2 shows the trend of rainfall in the Tiga dam for the period of thirty years (1989-2018).



Legend

$y = 2.2494x - 4387.7R^2 = 0.5141$

Trend line of Annual Mean Rainfall for Tiga Station

Linear Annual Mean Rainfall of Tiga Station

5 per. Mov.Avg. Rainfall of Tiga Station

Fig. 2: The trend of mean annual rainfall in Tiga dam for the period of thirty years (1989-2018)

Source: Author's Analysis

Fig. 2 shows that rainfall in the study area has been fluctuating and the pattern showed significant increase over the years, although there were major decrease in the amount of rainfall received in 1993, 1995, 1998, 2004, 2006, 2011 and 2014 while the 5-year running-means showed a slight increase in annual rainfall above the linear annual mean at the beginning of the data up to the 1996. From the late 1996 to the late 2017, rainfall was below the linear annual mean. The rainfall started increasing from that point to the end of the data. The result contradicts the findings of Atedhor (2015) who worked on agricultural vulnerability to climate change in Sokoto state, Nigeria which reported downward trends of annual rainfall and raindays in Sokoto. However, findings from research work of Adegbehin, Yusuf, Iguisi and Zubairu (2016) on the effects of some weather parameters and reservoir inflow pattern on hydroelectric power generation in Kainji dam Niger state, Nigeria shows an increase in precipitation.

The temperature data collected from the study area was subjected to time series analysis, in order to show trend of change for the time frame of study (1989-2018). Fig 3 shows the trend of mean annual temperature in Tiga dam for the period of thirty years (1989- 2018).

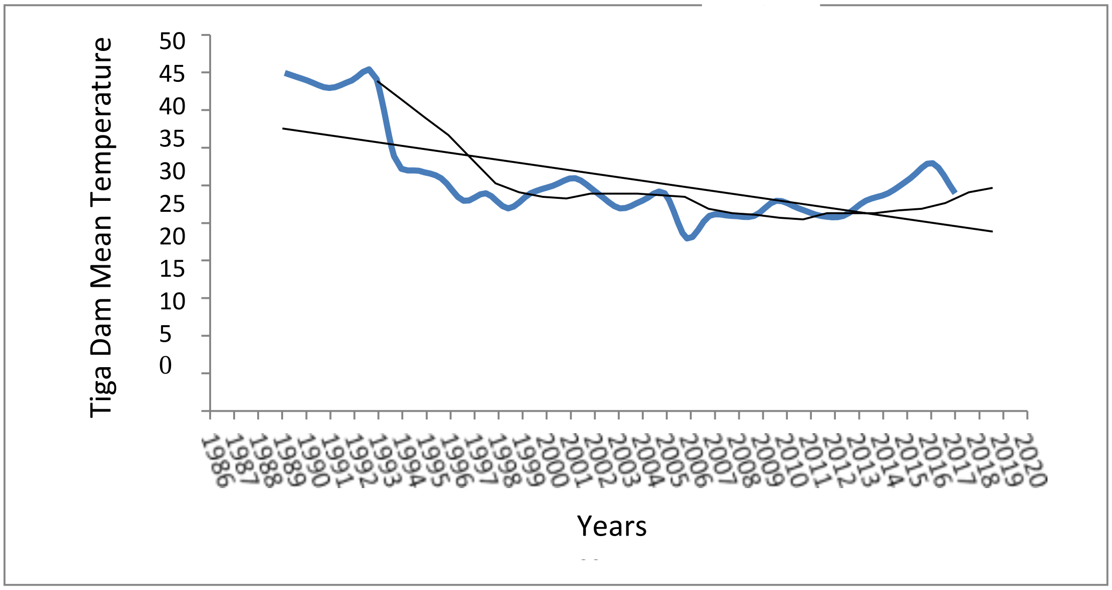


Fig 3: The trend of mean annual temperature in Tiga dam for the period of thirty years (1989- 2018).

Legend

y = -0.4573x + 946.92R² = 0.4391

Trend line of Mean Annual Temperature in Tiga Station

Linear Annual Mean Temperature of Tiga Station

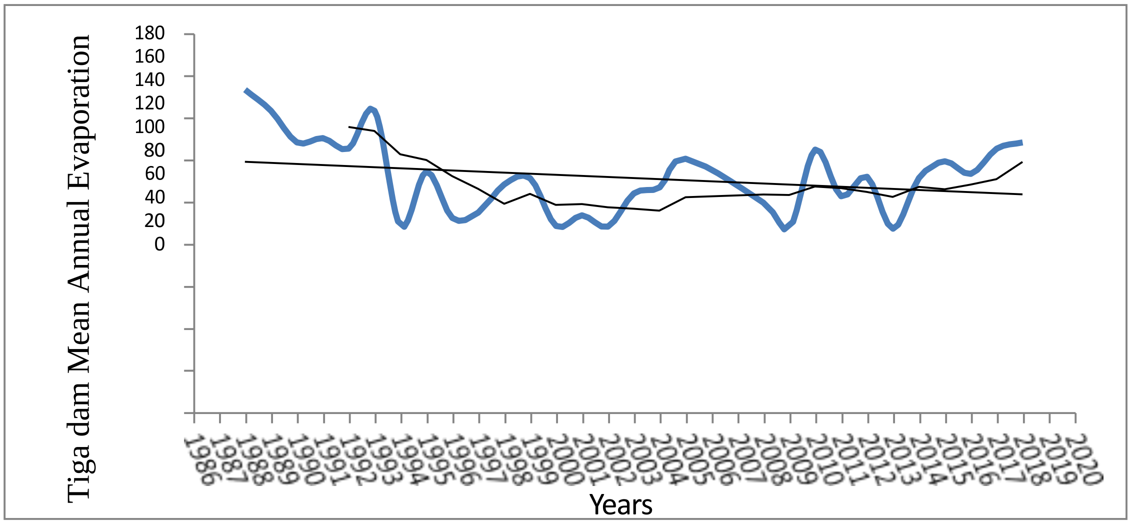
5 per. Mov. Avg.Temperature of Tiga Station

Source: Authors analysis

Fig. 3 shows that the temperature trend of the study area was on the increase from 1989 to 1993. However, a decrease below the linear annual mean started in 1996 to 2013 with various levels of fluctuations while a steady increase was noticed from 2014 to 2018. Similarly, the 5-year running-means showed a major increase in annual temperature above the linear annual mean from 1992 to 1996 and a slight increase from 2014 to 2018 while for most time of the study period the annual temperature was below the linear annual mean.

This contradicts the work of Atedhor (2015) where the researcher reported an upward trend in the annual mean temperatures when working on agricultural vulnerability to climate change in Sokoto state. Dammo, Yakeen, Deborah, Yadima and Sangodoyin (2017) who carried out research on seasonal trend analysis of climatic indices on gauge Rivers in North East Nigeria also reported an increase in temperature trend. However, year 2013 to 2018 of this finding showed an increase in trend. This late increase could be as a result of changes caused by anthropogenic factors and other climatic variables. An increase in temperature is capable of increasing evaporation rate and this will affect crop yield negatively. It is also capable of increasing precipitation which might lead to flooding thereby causing total destruction of crops resulting to poor yields.

The Evaporation data collected from the study area was subjected to time series analysis in order to show trend of change for the time frame of study (1989-2018). Fig. 4 shows the trend of mean annual evaporation in Tiga station for the period of thirty years (1989- 2018).



Legend

$y = -0.5158x + 1156.6R^2 = 0.0692$

Trends of MeanAnnunal Evaporation for Tiga Station

Linear Mean Evaporation of Tiga Station

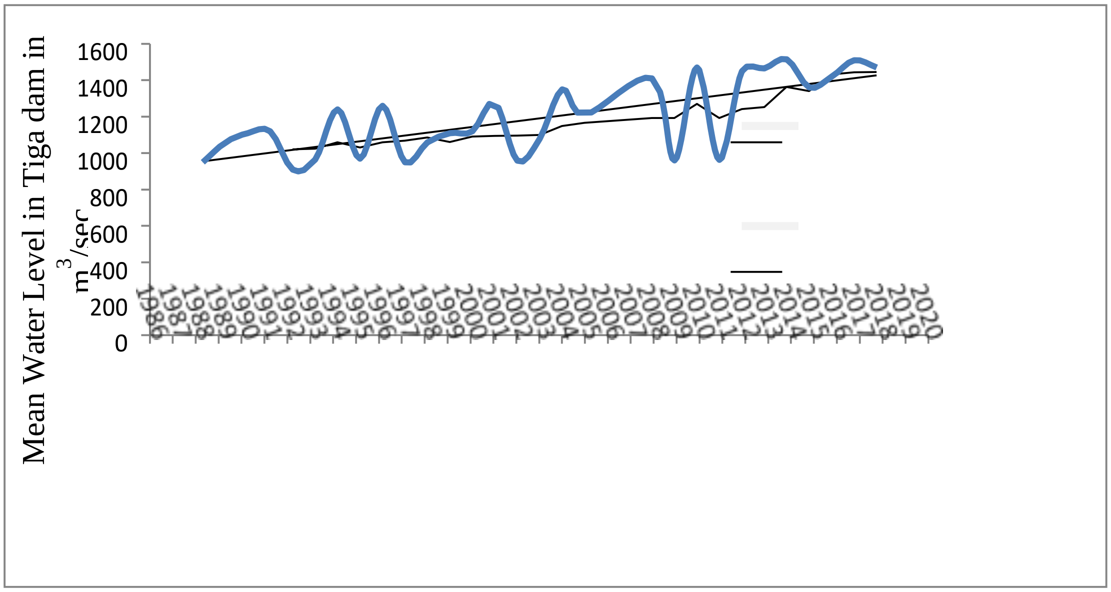
5 per. Mov. Avg. Annunal Evaporation of Tiga Station

Fig. 4 The trend of mean annual evaporation in Tiga dam for the period of thirty years (1989- 2018).

Source: Authors analysis

Fig 4 shows slight decrease on the evaporation trend for the time frame of study (1989 to 2018) with an obvious lower evaporation rate in 1994, 1996, 2000, 2002, 2009 and 2013 while the 5-year running-mean showed a major increase in annual evaporation above the linear annual mean from 1993 to 1996 while other years were below the linear annual mean. A steady rise above the linear annual mean picked up from year 2016 to 2018. A decrease in trend as revealed from this study is not in line with the findings of Ogolo (2011) on regional trend analysis of pan evaporation and temperature in Nigeria where the researcher observed an increasing evaporation rate in the northwest and north central region of the country of about 80%. The researcher also attributed increased evaporation rate to climate change. The researcher noted that high evaporation rate as observed in the study area creates more arid environment while downward trend of evaporation results in a more humid environment. The decrease in evaporation in this study trend might be as a result of long term decrease in temperature as revealed from temperature trend in Fig. 3.

The reservoir water level data of the study area was subjected to time series analysis in order to show trend of change for the time frame of study (1989-2018). Fig 5 shows the trend of mean annual water level in Tiga dam for the period of thirty years (1989-2018).



Legend

$y = 15.743x – 30394$ $R^2 = 0.5076$

Trends of Mean Annual water level in Tiga Station

Linear Mean water level in Tiga Station

5 per. Mov. Avg. Annual water level in Tiga Station

Fig. 5 shows the trend of mean annual water level in Tiga dam for the period of thirty years (1989- 2018).

Source: Authors analysis

Fig.5 shows a significant increase in the water level trend for the period of thirty years (1989- 2018) with various fluctuations at various years although there were some few drop in water level in 1992, 1993, 1995, 1997, 2002, 2009 and 2011 while the 5-year running means showed a slight decrease in the annual water level below the linear annual mean almost throughout the time frame of study although a slight increase above the linear annual mean occurred in year 2016 to 2018. This result contradicts the findings of Sabo, Karaye, Garba and Ja'afar (2016) who carried out a research on typha grass impacts on agricultural productivity along Hadejia River, Jigawa State whose research reported a decrease in flow of water. However, it was attributed to blockages by typha grass and silt deposits within the river channel. Similarly, the works of Adegbehin et al., (2016) on the effects of some weather parameters and reservoir inflow pattern on hydroelectric power generation in Kainji dam Niger state, Nigeria using 30years rainfall, evaporation, temperature and reservoir inflow data to investigate the trends and variability of these parameters, showed a decrease in the trend of reservoir inflow pattern.

The classification Table 1 was used to clearly interpret the Normalized Rainfall Index (NRI) in order to determine the Impact Vulnerability Status (IVS) of farmers to climate change on irrigation water resources and crop production considering the optimal water requirement according to Aryal (2013) who noted 711.45mm for rice and 786mm for tomato in a total growing period. The formula defined by Turkes (1996) is computed as;

$$NRI=\frac{Rsy-LM}{SD}$$

Where Rsy = the rainfall total for the station during a year (or season)

LM = the long term mean (of the period specified for the station) and

SD = Standard deviation of the annual (or seasonal) rainfall total for that station. This was use to derive Table 2

Table 2 Classification of Mean Annual Normalized Rainfall Index in Tiga Station Downstream as against General Water Requirement for Rice and Tomato production

Year	Annual Rainfall Amount	NRI=RSY-LM / SD	Character of Rainfall	Farmers' Impact Vulnerability Status
1989	510.24	-0.87	Moderate Drought	Vulnerable
1990	756.96	0.50	Near Normal	Not Vulnerable
1991	724.36	0.49	Near Normal	Not Vulnerable
1992	459.84	- 0.91	Moderate Drought	Vulnerable
1993	1047	+2.02	Very Wet	Vulnerable
1994	510.24	- 0.87	Moderate Drought	Vulnerable
1995	756.96	0.48	Near Normal	Not Vulnerable
1996	724.36	0.50	Near Normal	Not Vulnerable
1997	724	0.49	Near Normal	Not Vulnerable
1998	731.58	0.50	Near Normal	Not Vulnerable
1999	853.98	0.83	Mildly wet	Slightly Vulnerable
2000	761.92	0.48	Near Normal	Not Vulnerable
2001	752.34	0.46	Near Normal	Not Vulnerable
2002	530.88	-0.67	Mild Drought	Slightly Vulnerable
2003	764.86	0.45	Near Normal	Not Vulnerable
2004	751.84	0.43	Near Normal	Not Vulnerable
2005	733.2	0.48	Near Normal	Not Vulnerable
2006	733	0.47	Near Normal	Not Vulnerable
2007	651.84	-0.88	Moderate Drought	Slightly Vulnerable
2008	651	-0.87	Moderate Drought	Slightly Vulnerable
2009	513	-0.86	Moderate Drought	Slightly Vulnerable
2010	999.36	+1.98	Mildly wet	Slightly Vulnerable
2011	726.58	0.50	Moderate Drought	Slightly Vulnerable
2012	781.96	0.44	Near Normal	Not Vulnerable
2013	720	0.48	Near Normal	Not Vulnerable
2014	728.12	0.49	Near Normal	Not Vulnerable
2015	731.58	0.50	Near Normal	Not Vulnerable
2016	570.66	-0.84	Mild Drought	Slightly Vulnerable
2017	653.96	0.45	Near Normal	Not Vulnerable
2018	769.88	0.49	Near Normal	Not Vulnerable

Source: Authors analysis

Table 2, revealed that 1993 was very wet and vulnerable to excessive flooding while 1999 and 2010 were mildly wet. Year 1989, 1992, 1994, 2007, 2008 and 2011 all had a moderate drought while 2002, 2016 had mild drought scenario. Rice and Tomato cultivated in these years were slightly vulnerable to water shortage, while in all other years, water availability was within required limit of 711.45mm for rice and 786mm for tomato in a total growing period. This implies that any excess or deficit from this, will likely affect the yields of these crops.

In details, for 18 years which accounted for 60% of the time frame of study for rice and tomatoes were near normal and not vulnerable, 7years (23.33%) experienced moderate drought and were slightly vulnerable while 2years (6.67%) experienced a mildly wet scenario and were still slightly vulnerable. Another

2years (6.67%) also experienced mild drought and were slightly vulnerable. Only a year which accounted for (3.33%) experienced a very wet season and was very vulnerable.

Findings from this study appears to have similar outcome with that of Chinda, Saraya and Uduma (2016) on analysis of Normalized Rainfall Index (NRI) and Impact Vulnerability Status (IVS) of sorghum farmers to climate change in Gusau station, Zamfara State, Nigeria whose study reported more periods (53%), when rainfall was near normal most especially between 1975 and 1983. The study also revealed that about 28% was influenced by drought occurrences. Severe drought was only recorded once in 1987 while moderate drought was recorded in the early 70s and middle and late 80s. About 19% was influenced by increases in the rainfall amounts which majorly occurred in the millennial periods with the highest peak recorded in 2008. Although, there was no incidence of severe drought in the study, findings from focus group discussions revealed that 80% of the farmers reported flooding during rainy season and deficit of water in the later days of the dry period (mostly between January and March of each year), this might be as a result of operational failures (poor storage facilities) in the reservoir.

CONCLUSION

In conclusion, the trends of the parameters for the time frame of study were shown using trend line, while the moving average showed every five year pattern of change above, within and below the linear mean. Rainfall and reservoir water level showed increasing trend while all other parameters showed decreasing trends. Also the impact vulnerability status (IVS) of farmers to climate change revealed periods of deficit, optimal and excess water availability to rice and tomato cultivation vulnerability downstream. It was recommended that special project and strategies should be adopted to address the issue of water deficit during dry season and over flowing of the reservoir stations during raining seasons as this will help control surplus and deficit water inflow and outflow in all seasons as well as limits flooding, destruction of cultivated crops, arable lands and properties, while maintaining consistency in water flow.

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