EVALUATION OF TREND IN FLOOD EVENTS ON RIPARIAN COMMUNITIES OF SHIRORO DAM, NIGERIA

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Abstract
With reference to global climate change which possibly causes heavy downpour, river erosion have led to upstream dam sedimentation, overflowing and large volume of water into Shiroro dam from the main river and its tributaries which may have been causing upstream spill over (back flow) water and also force the dam managers to release large volume of water to downstream sector in order to safe the dam from collapse. In the course of doing that, the downstream communities are exposed to river bank over flow into their houses, farmlands and displacement. Therefore the aim of this study was to evaluate the trend in flood events on riparian communities of Shiroro dam, Nigeria. The techniques used for data analysis were different statistical techniques such as Analysis of Variance (ANOVA), Regression analysis, percentage, frequency tables and graphs. The result shows monthly rainfall of August for 26 years (1990 to 2015) and the monthly rainfall tends to be increasing from 174.1mm in 2005 to 443.8mm in 1995. This has translated to more flooding activities in the study area due rise in inflow and outflow data. Recently, August for the years 2012, 2014 and 2015 has high monthly rainfall and the people in the study area confirmed that it resulted in more flooding activities with resultant effects on infrastructure, farm produce and lives of the inhabitant living in the area. The finding also shows that R^2 was 0.52 for annual rainfall, thus, rainfall account for 52.0% of the explained variance between annual rainfall and annual Inflow in the study area. This shows that other climatic variables like temperature and relative humidity also play important role in Inflow data since there is remaining 48%. It's therefore recommended that town planners as well as NSEMA specify habitable and non-habitable area in riparian communities of Shiroro dam so as to avoid the flood hazard from affecting the lives and properties of the people.

Keywords: Flood events, Riparian communities, Rainfall, Inflow, Outflow and Shiroro dam

Introduction

International Water Power and Dam Construction (IWPDC) (2011) offered definitions of dam as an enlarged natural or artificial lake, storage pond or impoundment created using a lock to store water. Dams can be created by controlling a stream that drains an existing body of water. They can also be constructed in river valleys and gorge as in the case of Shiroro dam on Kaduna River and Shiroro gorge. Alternatively, a dam can be built by excavating flat ground and/or constructing retaining walls and levees. IWPDC (2011) added that, dams can be used in a number of ways to control how water flows through downstream waterways: Downstream water supply (ii) Irrigation (iii) Flood control (iv) Canals (v) Recreation.

Etuonovbe (2011) defined flood as an overflowing of the great body of water over land not usually submerged. It is an extreme weather event naturally caused by rising global temperature which results in heavy downpour, thermal expansion of the ocean and glacial melt which in turn result in rise in sea level, thereby causing salt water to inundate coastal lands. Caribbean Disaster Emergency Management Agency (CDEMA) (2010) offered definition of flood as an abnormal progressive rise in the water level of streams or rivers which may result in the overflowing. Floods in the Caribbean can often be caused by heavy rainfall, dam or levee failures, tsunamis, storm surges or burst water mains. Mitigation on the other hand, is perceived as any structural or non-structural measure undertaken to limit the adverse impact of flood. UNESCO and WMO (1992) defined flood as relatively high flow as measured by stage height or discharge. According to Deyer (1988), all rivers are subject to flooding in the hydrological sense of inundation of riparian areas by stream flow that exceeds bankful capacity. In water resources engineering practice, flood is defined as unusually high stage. It is a flow of water in a river or stream channel beyond the capacity of that channel to carry, the excess overflowing the banks to form flood water hazards.

According to Ologunorisa and Abawua (2005), the obvious reason for flooding especially in municipalities and coastal areas in Nigeria lies in the wide distribution of low-lying coastal areas and river floodplains and because these areas have fast become a long standing attraction for human settlement, which Ojigi *et al,* (2013) concluded that this subsistence attraction has become a high risk factor in most part of Nigerian floodplain regions. On the causes and impacts of flood hazards, Ojigi *et al,* (2013) asserted that flood hazards are natural phenomenon, but the damages and losses from floods are the consequences of human actions because it has been known that floods can be caused by anthropogenic activities and human interventions in the natural processes such as increase in settlement areas, population growth and economic assets over low-lying plains prone to flooding which may lead to alterations in the natural drainage and river basin patterns, deforestation and climate change. Following the annual increase of flood disaster especially the devastating 2012 flood hazards in Nigeria coupled with improvement in the use of modern technologies for environmental monitoring such as remote sensing and GIS, the government of Nigeria and the relevant agencies such as National Emergency Management Agency (NEMA) and National Research Space and Development Agency (NARSDA) have recently put all efforts on environmental monitoring and management especially flood disaster (Ikusemoran *et al.,* 2013). Therefore this study evaluate trend in flood events on riparian communities of Shiroro dam, Nigeria.

Statement of the Problem

With reference to global climate change which possibly causes heavy downpour, river erosion have led to upstream dam sedimentation, overflowing and large volume of water into Shiroro dam from the main river and its tributaries which may have been causing upstream spill over (back flow) water and also force the dam managers to release large volume of water to downstream sector in order to safe the dam from collapse. In the course of doing that, the downstream communities are exposed to river bank over flow into their houses, farmlands, displacement etc. Similarly, with increasing population in the study area, human activities through deforestation due to farming, fuel wood demand, grazing and local mining at the upstream sector may lose the soil for easy runoff and erosion causing upstream sedimentation thus, back flow flood (Lawal & Nagya, 2009).

Several researches have been carried out on trend in flood events across the world and in Nigeria; notable among them are the works of Adger (2008) on Disaster risk reduction, Climate change adaptation and human security in Norway; International Strategy for Disaster Reduction (ISDR) (2009) on United Nation International Strategy for Disaster Reduction (UNISDR); European Union (EU) (2011) on Environmental Impact Assessment and its Amendments in Europe; World Commission on Dams Report (WCDR) (2013) on Dam Structure for Water Impoundment; Mohan (2008) on National Disaster Management Guidelines, Management of Floods in India; Abubakar (1997) on Environmental Impact Assessment of Shiroro Dam some hydrometeorological variables in the Kaduna River Basin; Salami and Sule (2010) on overview on Reservoir Operational Impact of Kainji, Jebba and Shiroro Dams on the environment; Usman and Ifabiyi (2012) on Socio economic Analysis of the Operational Impacts of Shiroro Hydropower Generation in the lowland Areas of Middle River Niger; National Emergency Management Agency (NEMA) (2012) on Nigeria Lost N2.6 trillion to 2012 Floods Disaster. Studies have also been carried out by Zago (1999), Tyabo (2005), etc. on the hydrological, ecological and climatological impact of Shiroro dam to the immediate environment. None has been carried out on trend in flood events on riparian communities of Shiroro dam, Nigeria which is part of the missing gap that this paper was intended to fill. Therefore the aim of this study was to evaluate the trend in flood events on riparian communities of Shiroro dam, Nigeria.

Study Area

Shiroro Hydroelectric Dam is situated in confluence between Rivers Kaduna and Dinya within Shiroro Local Government Area of Niger State. The lake is located on River Kaduna at the Confluence of Kaduna River and Dinya River. The lake is located on Latitude 8°51′01″N to 10°20′04″N and Longitude 5°50′01″E to 07°10′41″E (See Figure 1) Kaduna River is the major River feeding the lake. The River takes its source from the west and Northwest of Jos Plateau. The river flows westward from the plateau at an elevation of 1,500 metres to 1,800 metres through Kaduna town at an elevation of 633metres, the major left hand tributaries of the Kaduna River at the upstream of Shiroro reservoir are the River Sarkin/Pawa and River Dinya. They rise from hilly areas within the basement complex plains near Kaduna (Garba and Mohammed, 2011).

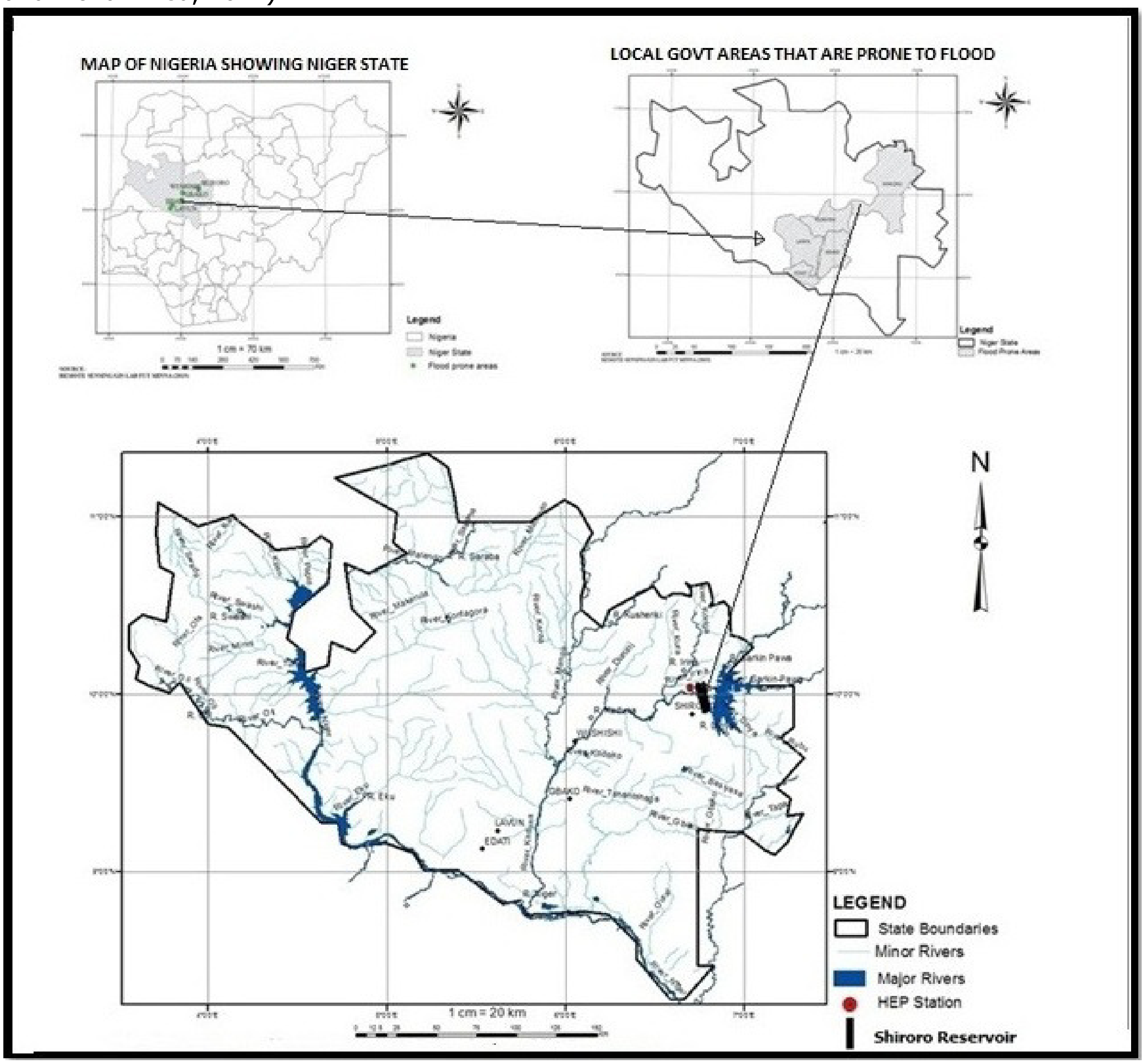

Figure 1: Location of Shiroro dam on River Kaduna and its tributaries

Materials and Methods

The techniques used for data collection and analysis of flood disaster management study of upstream and downstream communities of Shiroro Dam in Niger State include reconnaissance survey and used annual rainfall, in-flow and outflow data. To achieve the aim of this study which was to examine the trend in flood events in the study area; annual rainfall data from 1990 to 2015 as well as in-flow and out-flow data for the same period were sourced from Shiroro Hydroelectric Power Station (SHPS) in Hydrology Department and Nigeria Meteorological Agency NIMET (Abuja airport or Minna airport). The study used tables to show the rainfall amount, in-flow and out-flow data from the dam and the mean total annual rainfall occurrence in millimeters to identify the most wet and drought seasons which could have possibly caused flood or not in the study area. Also a trend in flood events was determined from the above secondary data. Different statistical techniques such as Analysis of Variance (ANOVA), Regression analysis, percentage, frequency tables and graphs were used for flood trend and analysis of effects.

Results and Discussion

As shown in Figure 2, mean monthly rainfall for the period under study (1990 - 2015) tend to be increasing, higher in the months of August to September and the least in the months of January to February.

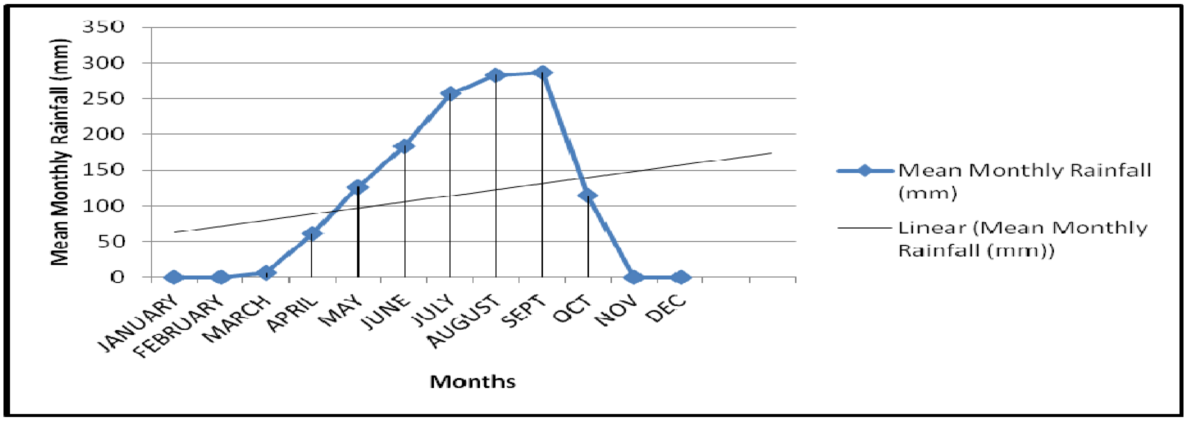

Figure 2: Mean Monthly Rainfall of the Study Area

Source: Authors Data Analysis, 2016

The highest monthly rainfall was in the month of August with a value of 282.58mm and the least were in the months of November to February with a value of 0.0mm. The highest monthly rainfall has lead to flooding in both up and downstream of the study area and this was as a result of more rainfall which have lead to more inflow and outflow within the operational area of Shiroro dam, thus, this process have been leading to frequent flooding in the months of July to September. This implies that its only in wet season that flood events occurred in the study area.

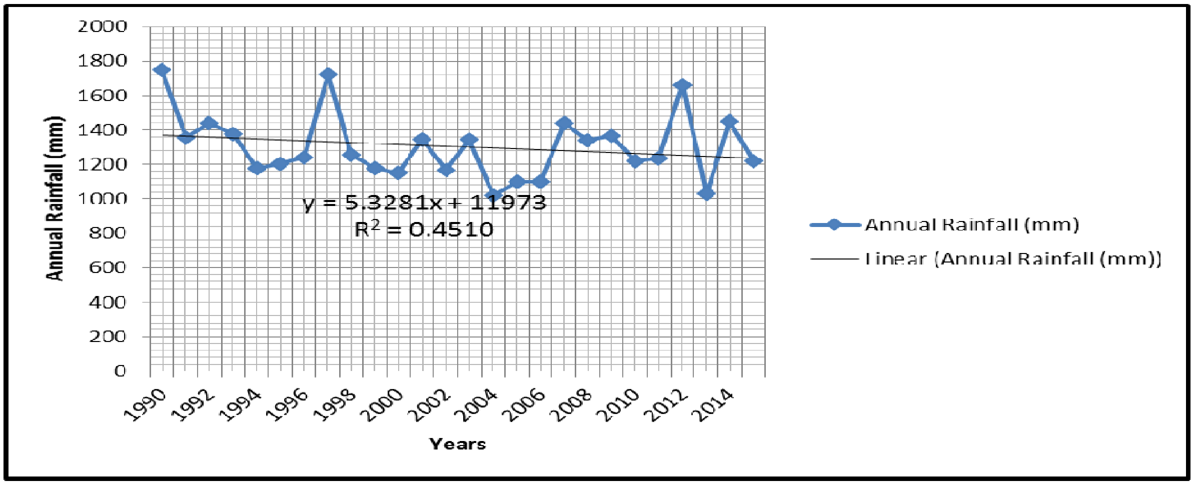

Figure 3: Annual Rainfall in the Study Area
Source: Authors Data Analysis, 2016

Considering the mean annual rainfall of about 1303.6mm in 26years (1990 to 2015), from 1990 to 1993, 1997, 2001, 2003, 2007 to 2009, 2012 and 2014 has annual rainfall data above the mean; while the remaining 14 years revealed annual rainfall below the average which indicate that annual rainfall is decreasing despite some fluctuation. This shows that annual rainfall is decreasing which has affected Shiroro dam through its inflow and outflow negatively.

R-square (R^2), or the square of the correlation coefficient, is a fraction between 0.0 and 1.0. A R^2 value of 0.0 means that there is no any correlation between X and Y and no linear relationship exist between X and Y. On the other hand, when R^2 approaches 1.0, the correlation becomes strong and with a value of 1.0 all points lie on a straight line. R^2 of 0.4510 shows that there is linear relationship between the annual rainfall and the years.

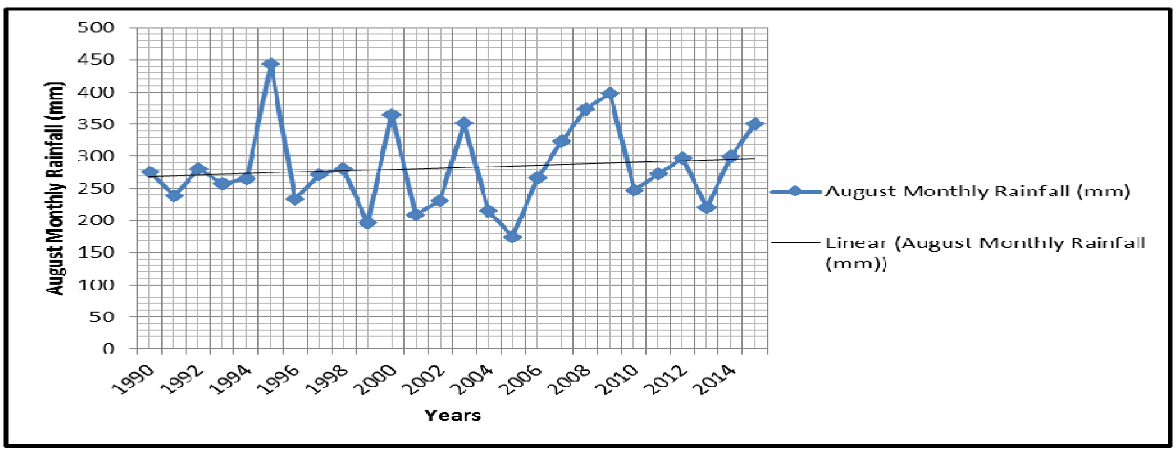

Figure 4: August Monthly Rainfall of the Study Area
Source: Authors Data Analysis, 2016

Figure 4 shows monthly rainfall of August for 26 years (1990 to 2015) and the monthly rainfall tends to be increasing from 174.1mm in 2005 to 443.8mm in 1995. This has translated to more flooding activities in the study area due rise in inflow and outflow data. Recently, month of August for the years 2012, 2014 and 2015 has high monthly rainfall and the people in the study area confirmed that it resulted in more flooding activities which has effected both infrastructure, farm produce and lives of the inhabitant living in the area.

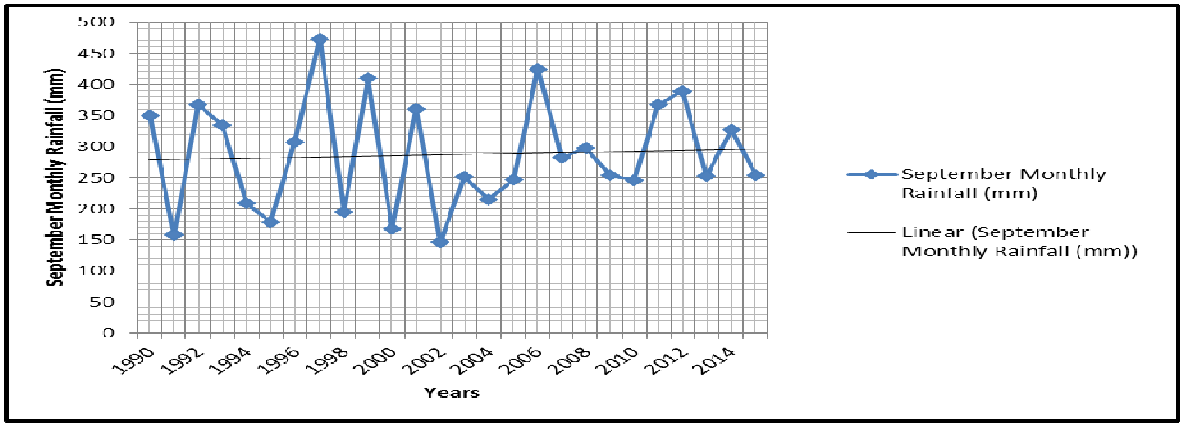

Figure 5: September Rainfall in the Study Area
Source: Authors Data Analysis, 2016

Considering the monthly average of 287.2mm from Figure 5 which was derived from linear trendline, 12 years have monthly rainfall above average and the years include 1990, 1993 to 1994, 1997 to 1998, 2000, 2002, 2007 to 2008, 2011 to 2012 and 2014. This shows that more flooding were likely to be recorded in those months of the years with higher magnitude due to the magnitude of inflow in to Shiroro dam. The remaining years like 1991, 1994 to 1995 have less magnitude considering both the total volume of rainfall in September and the daily rainfall record. This finding was in line with the finding of Inflow analysis of the study.

The hydrologic variables considered in this study include Inflow and Outflow. As indicated in Figure 6, the mean monthly Inflow has the highest value in the month of September with 1045m^3/sec and the lowest was in the month of April with the value of 29.03m^3/sec.

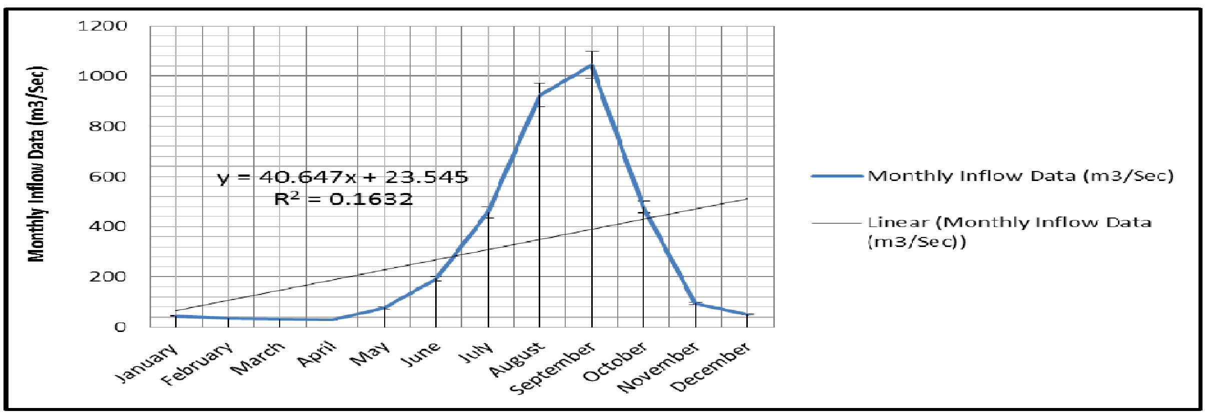

Figure 6: Monthly Inflow of Shiroro Dam
Source: Authors Data Analysis, 2016

The monthly Inflow started increasing from May with 78.72m^3 and got to its peak in the month of September with 1123.48m^3, then started decreasing as rainfall decreased from 506.4m^3 in November to 26.68m^3 in April. R^2 of 0.1632 shows that there is linear relationship between the monthly Inflow and the monthly rainfall and this relationship comes to play as monthly Inflow increases. As indicated in Figure 6, the Linear Forecast Trendline shows that mean monthly inflow will continue to increase as long as rainfall increases along River Kaduna and evaporation decreases.

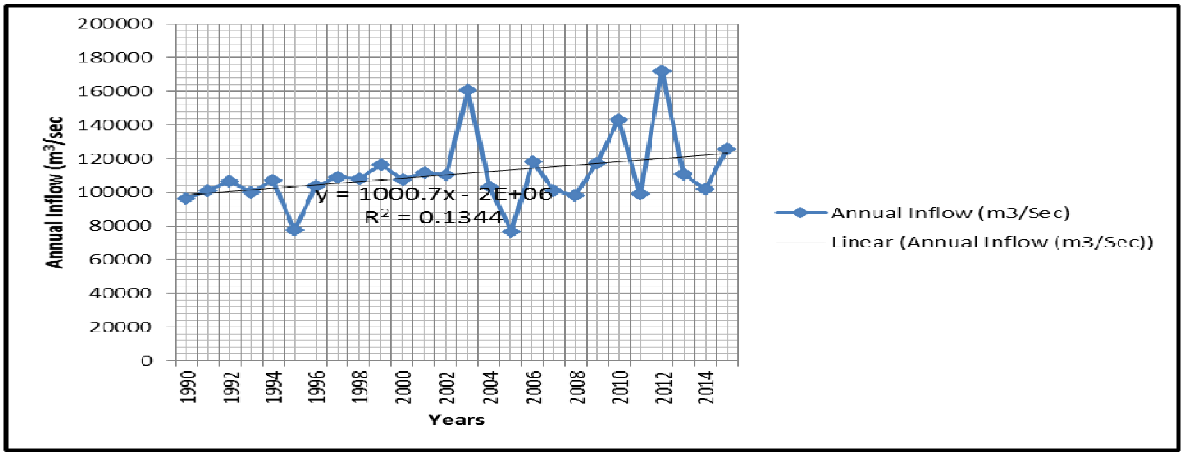

Figure 7: Annual Inflow of the Study Area
Source: Authors Data Analysis, 2016

Figure 7 shows that annual inflow has been increasing despite some fluctuation in some years. Year 2012 has the highest annual inflow with 171839m^3/sec while 2005 has the lowest annual inflow (76897m^3/sec). From Figure 7, mean annual Inflow was 110931m^3/sec and this shows that 8 years which include 1991 to 1992, 1994, 1998, 2000, 2003, 2007, 2010 and 2012. R^2 of 0.1344 shows that there is linear relationship between the annual Inflow and the years and this relationship come to play as years Inflow increases.

Dam operations play an important role in the quantity of Inflow and outflow production on Shiroro dam. This is because the performances of hydrology depend on the rules guiding water intake and release. Where there is an inefficient reservoir rules water intake will be affected, and this will consequently affect outflow in the study area. Efficient operation rules for a reservoir would be difficult to design without knowing the relative importance or the contribution of individual hydrology elements like inflow and outflow; especially on monthly basis.

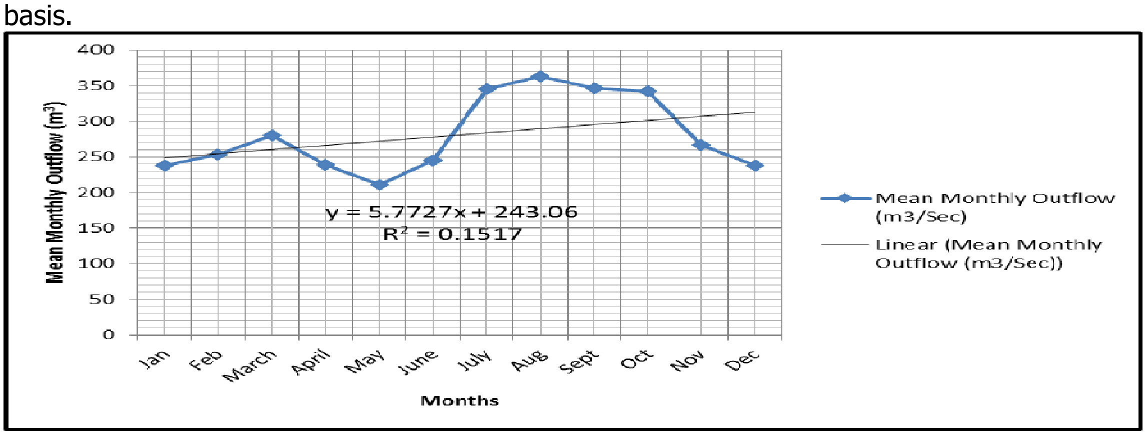

Figure 8: Monthly Outflow of Shiroro Dam
Source: Authors Data Analysis, 2016

The mean monthly outflow of Shiroro dam has its peak in the month of August with a value of 351m^3/sec and the lowest was in the month of May with 211m^3/sec. This shows that mean monthly Outflow follows the pattern of monthly rainfall and monthly Inflow of Shiroro dam. This also shows that flooding phenomena was more active in the months of July to September from the findings.

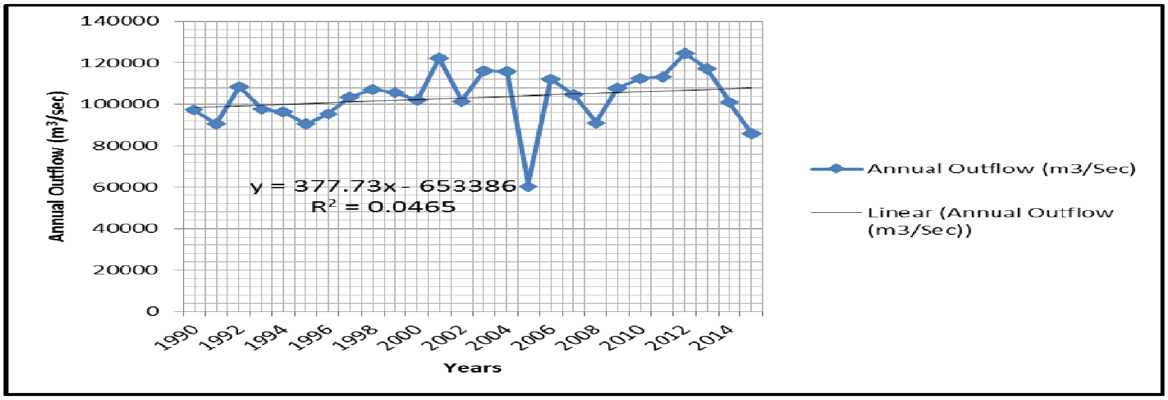

Figure 9: Annual Outflow of Shiroro Dam
Source: Authors Data Analysis, 2016

Annual outflow of Shiroro dam have been increasing since 1990 despite some fluctuation and the peak outflow was in year 2012 with a value of 124472m^3/sec; while the lowest value was in the year 2005 with a value of 60135m^3/sec. This highest outflow which was in 2012 correspond to one of the worst flood in the history of the study area. Shiroro reservoir inflow which is being closely monitored has recorded a few surges since May in response to the prevailing hydrological trends and events on the basin as confirmed by instrumental records. For instance an unusually high average daily inflow magnitude of 1389m^3/sec was recorded on the 31st May 2012. Similarly, another high inflow value of 2004m^3/sec was recorded on the 18th of August. All other records up to the 9th September were generally around 1000m^3/sec. Furthermore, inflow from 9th September have been high but quite normal and generally above 2000m^3/sec with a peak of 2406m^3/sec on the 13th.

However, this trend suddenly changed on the 16th September as a flash flood induced by prolonged heavy downpour lasting more than 48hours from within the immediate vicinity of the reservoir and adjacent basins pushed inflow to unprecedented levels. As a result of the long duration and high-intense rainfall which measured up to 120mm at Shiroro, inflow sharply increased from the 2026m^3/sec of 15th to an extraordinary and unprecedented magnitude of 4000m^3/sec *(average)* on the 16th leading to extra rapid reservoir filling. Reservoir operation for flood management and reservoir control which was embarked upon immediately thus became very hectic and unavoidable. The need to keep the reservoir at safe and steady state therefore necessitated the release of large volumes of water through the spillway gates.

Table 2: ANOVA for Annual Rainfall and Annual Outflow

Model		Sum of Squares	Df	Mean Square	F	Sig.
	Regression	454652620.301	1	454652620.301	1.045	.317^b
1	Residual	10440527592.315	24	435021983.013		
	Total	10895180212.615	25			

a. Dependent Variable: Annual Inflow (m^3/Sec)
b. Predictors: (Constant), Annual Rainfall (mm)
Source: Authors Data Analysis, 2016

From the table of the F-distribution, critical value of F at 0.05 = 4.26 since the calculated F of 1.04 < 4.26, thus, there is a significant linear relationship between annual rainfall and annual Inflow of Shiroro dam.

Table 3: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change
1	.204[a]	.052	.002	20857.181	.052

Source: Authors Data Analysis, 2016

As indicated in Table 3, R^2 was 0.52 for annual rainfall, thus, rainfall account for 52.0% of the explained variance between annual rainfall and annual Inflow in the study area. This shows that other climatic variables like temperature and relative humidity also play important role in Inflow data since there is remaining 48%.

Conclusion

As indicated in the findings of this study, it shows that rainfall, inflow and outflow are the major players in trend of flood events in the study area. The results shows that August and September monthly rainfall couple with inflow and outflow of the stated months are the controller of flood events in the study area which in turn has affected the environment and socio-economic activities of the riparian communities negatively. This study confirmed that any significant increase in monthly rainfall will lead to inflow, outflow and subsequently flood events across the riparian communities of Shiroro dam, Niger State. It's therefore recommended that town planners as well as NSEMA specify habitable and non-habitable area in riparian communities of Shiroro dam so as to avoid the flood hazard from affecting the lives and properties of the people.

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