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SPATIO-TEMPORAL HYDRO-METEOROLOGICAL VARIABILITY CHALLENGES ON FLOODPLAIN WETLAND ECOSYSTEM SUSTAINABILITY DOWNSTREAM OF HYDROELECTRIC DAMS, NIGER STATE, NIGERIA

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Sustainability.

ABSTRACT

Hydro-meteorological trend and recurring seasonal flood are fundamental obstacles in the country's task towards the attainment of food security, diversification of economy, sustainability of the physical environment and socio-economic livelihood. This study utilized rainfall records (1980-2015) and hydrological record (1990-2015). A simple flood monitoring and early warning methodology hinged on an Intra-seasonal Rainfall Monitoring Index (IRMI) to identify and monitor flood condition adopted. The computed Hydro-meteorological variables (IRMI, Gauge Height, Inflow and Discharge) were summarized and classified at pentad level to determine peak flow, its variability and flood risk from low to extremely high. The result revealed spatio-temporal variability in IRMI peak values and consistency peak values across the study area. This triggered high, very high and extremely high inflow values that led to sustained moderate and high discharge in recent times; thus, leading to loss of floodplain wetland that aggravated downstream flood as evident in the study area in the years 2010, 2011, 2012, 2013 and 2014 due to steady increase and consistency in IRMI, inflow and discharge peak values. Consequently, there is need to adequately understand the hydro-climatic parameters that trigger flood risk and its impact on sustainability of wetland ecosystems to enhance the knowledge base for effective disaster risk reduction.

Contribution/Originality: This revealed Spatio-temporal variability in IRMI values across the study area, the steady increase in IRMI value beyond 10 indicating higher runoff potentials. Thus, exacerbating inflow into rivers and reservoirs and the resultant high discharge. Basically, these pattern and trend are vital for floods monitoring and forecasting.

1. BACK GROUND OF THE STUDY

Climate variability and change have been aggravating flood risk and community vulnerability across Nigeria particularly in the fertile floodplain wetland ecosystems. Climate variability and change are therefore perhaps the most serious environmental threats to the fight against hunger, malnutrition, disease and poverty in Africa, mainly through impacts on agricultural productivity [1, 2]. In addition, Masipa [3] acknowledged that Africa's ability to adapt and protect its food security will depend on the understanding of risks and the vulnerability of various food items to changes in climate. Floodplains globally are natural assets but here in Africa, these rich and fertile ecosystems that support the livelihoods of large populations are highly vulnerable to seasonal rainfall related hazards with damages to crops, property and infrastructure. Global increases in the magnitude and frequency of flood events have raised concerns that traditional flood management approaches may not be sufficient to deal with future uncertainties [4]. Similarly, Masih, et al. [5] concluded that available evidence from the past clearly shows that the African continent is likely to face extreme and widespread weather events in future. Hence, there is an urgent need to develop adequate understanding of the extreme events based on accurate and up-to-date information on seasonal, intra-seasonal and inter-seasonal rainfall related hazards.

Fundamentally, the recurring flood events point to the need to develop timely, reliable and up-to-date hydro-meteorological information to enhance the understanding, monitoring, and forecasting of floods for disaster risk reduction across the floodplain. Understanding impacts of regional-global change on wetland functions, associated ecosystem services and evaluating suitable management practices for mitigating them, is a major challenge for scientists [6]. This will enable reliable national flood management planning (through development of proper flood management strategy based on spatio-temporal flood intensity and trend), such that flood will constitute a resource rather than a disaster. Equally, this will boost implementation of national agricultural intensification, economic diversification, growth and poverty eradication programmes.

2. RESEARCH METHOD

2.1. The Study Area

The Study areas are part of the Lower Niger River Basin within Niger State, North Central Nigeria, accommodating the three major hydropower generating stations namely; Kainji, Jebba and Shiroro dams. Kainji hydroelectric dam is located on the river Niger at the downstream tip of Kainji Island (longitude $4^{0}25.82^{1}$- $4^{0}38.42^{1}$E and latitude $4^{0}25.82^{1}$ - $4^{0}38.42^{1}$ N) in Borgu Local Government Area of Niger State, Nigeria. Its construction was initiated in 1964 and completed in 1968. The Jebba reservoir was built strategically downstream of the Kainji dam on the River Niger and located on Gungu (longitude $4^{0}39.81^{1}$- $4^{0}46.95^{1}$ E and lat. $9^{0}13.86^{1}$ - $9^{0}18.49$' N) Jebba North in Niger State. However, the case of Shiroro hydropower dam is different, as it is built on River Kaduna (longitude $6^{0}47.99^{1}$ –$6^{0}54.36^{1}$ E and latitude $9^{0}57.04^{1}$- $10^{0}4.53^{1}$ N) about 40 km Northeast of Minna, the Capital of Niger State (Figure 1). However, because Kaduna River and its tributaries take their origin from the North central highlands, there is ample 'inflow' into the Shiroro dam which unfortunately could become too much when rainfall is unusually too heavy.

The Niger River from its source to the Coastal Niger delta is joined by eighteen major and several minor tributaries this include Sokoto and Kaduna Rivers. The floodplain of these rivers and tributaries attracted most rural settlements due to availability of flood plain wetlands, and its vital resources (hydromorphic soil and moisture) which usually enhance year-round cultivation and fishing. It is the continent's third longest river (4,200 kilometers), traversing nine countries [7]. The river Niger is thus an important resource for all the countries it traverses.

Niger State is characterized by Tropical Savanna (Aw) climate with distinct wet and dry seasons, the wet season occurring in the northern summer period. The heavy rainfall during this period ordinarily induces flood water as well as sustain inflow into Kainji, Jebba and Shiroro reservoirs. The weather depends to a large extent on the air mass which covers the area and its depth. The hottest months of the year are February, March and April with temperatures ranging from 38^{o}C in the north to about 27^{o}C in the South.

2.2. Methodology

Daily rainfall of upstream (Sokoto and Kaduna) and downstream (Minna) locations records (1980- 2015) and hydrological records (1991 - 2015) of Kanji and Shiroro were sourced from the Department of Geography, Federal University of Technology, Minna, Nigeria. These were analysed at pentad level to determine and visualize the spatio-temporal hydro-meteorological (rainfall, inflow and discharge peaks) variability in addition, infer flood challenges in the floodplain wetland ecosystem downstream of the hydropower dams in Niger State.

An Intra-Seasonal Rainfall Monitoring Index (IRMI) was used to estimate and monitor peak of rains at pentad level during the growing season then to assess its impact on reservoir inflow and discharge. IRMI was computed on a pentad-by-pentad basis from the beginning of May using the expression, (Cpt)2 /(hpt×Nb×100), where Cpt = cumulative pentad rainfall since May 1, hpt = highest pentad total rainfall since May 1, Nb = number of breaks in rainfall and 100 is a factor. The index rises gradually as the rains become steady indicating varying moisture condition; onset, break, dry spell, drought, flood and cessation [8, 9].

The temporal pattern exhibited by IRMI peak value in each pentad was used to monitor flood level from 1st July (37 pentad) when there is potential for abundant rainfall that trigger IRMI values. Usman and Abdulkadir [8] identified pentad that has IRMI>10 as an indicator of abundant moisture and was used to deduce peak runoff and river flow that which will certainly trigger higher inflow necessitating discharge. Several studies recommended the use of peaks-over-threshold (POT) data (derived by selecting values over a certain threshold) instead of annual maxima as extreme rainfall data input to frequency analysis [10]. Moreover, Zhongmin and Xiaofan [11] indicated that total rainfall of a 10-day period during the rainy season plays an important role in flood prevention and drought reduction with economic benefits for water resource management. IRMI peak values at pentad levels were used to identify, visualize and deduce the effects of meteorological variability on floodplain wetland ecosystems using descriptive and inferential statistics.

Furthermore, the reservoir hydrological records; inflow and discharge were summarized at pentad level and used to classify flood risk levels in addition to its potential impact on wetland ecosystems. Increased frequency and magnitude of extreme rainfall events questions the stationary climate assumption which is an underlying assumption of frequency analysis of extreme rainfalls [10].

The computed hydrological variables (Inflow and Discharge) were classified at pentad level from low to extremely high risk. These was used to determine peak inflow, discharge, their variability and associated flood risk (Table 1 and Table 2). In addition, the values were plotted graphically to depict and infer flood risk across the wetland ecosystem. Mann-Kendall trend test was used to measure the strength of the relationship between the variables, along the lines of the assertion by Donald, et al. [12] that trend analysis can be applied to all the water quality variables. The p-value and the alpha values measure the significance of the trend while the tau-value estimates the magnitude of the trend.

Table 1. Peak inflow, flood risk level and interpretation scheme.

Discharge Classification (M3/SEC)	Risk Level	Interpretation Scheme
< 250	1	Low
> 250 < 500	2	Moderate
> 500 < 750	3	High
> 750 < 1000	4	Very High
> 1000	5	Extremely High

Table 2. Peak discharge, flood risk level and interpretation scheme.

Inflow Classification (M3/SEC)	Risk Class	Interpretation Scheme
< 500	1	Low
> 500< 1000	2	Moderate
> 1000 < 1500	3	High
> 1500 < 2000	4	Very High
> 2000	5	Extremely High

3. RESULTS AND DISCUSSION

3.1. Climate Variability and its Effects on Wetland Ecosystems

The results depict spatio-temporal variability typical of rainfall across the three locations as indicated in IRMI values (Figure 2-3). Sokoto has lowest IRMI values mostly less <10 implying low runoff, less flood potential upstream and low inflow to Kainji (Figure 4). While Kaduna for most years' record IRMI values greater than ten (>10) an indication of higher runoff, inflow into streams, rivers and reservoir. Hence, these higher peak values could be a prime factor responsible the recurring flood upstream of River Kaduna with devastating impact on Kaduna and Environs in recent times. Minna values depicts the contribution of downstream rainfall values in increasing runoff and aggravating flood potentials across the floodplain wetland ecosystem. Since extended period of peak values will lead to accumulation of water and at extreme cases the mashes and ponds are washed away thereby intensifying floodplain flood downstream. Generally, it's only one year each 1987 and 2007 for Minna and Kaduna respectively that had IRMI <10 (Figures 2 and 3). This is in agreement with Frederic and Mesmin [13] that concludes that, rainfall reinforces the risk of flooding by increasing flood water and increasing the vulnerability of populations.

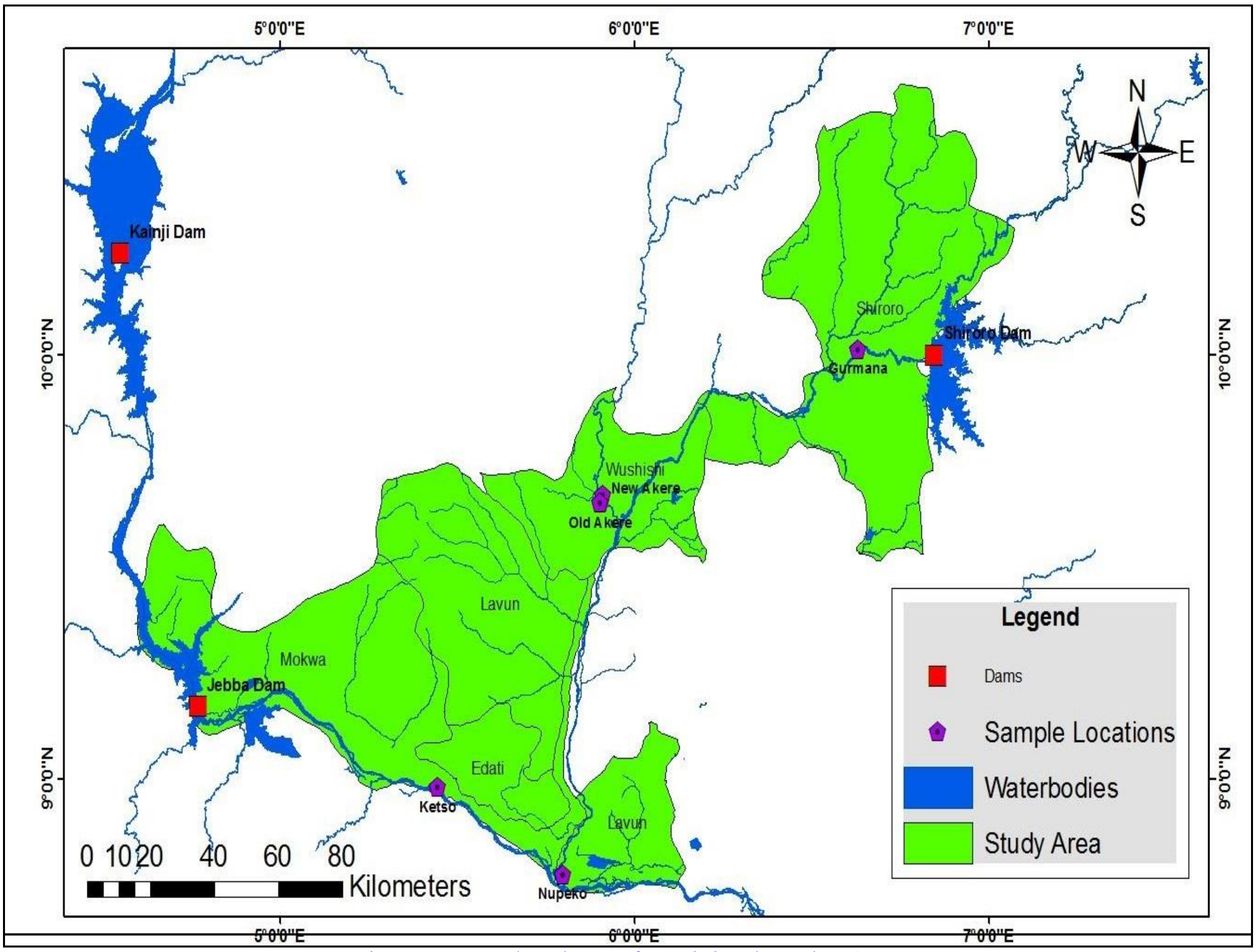
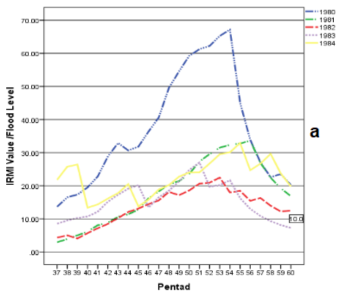
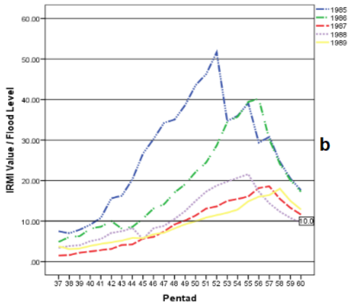


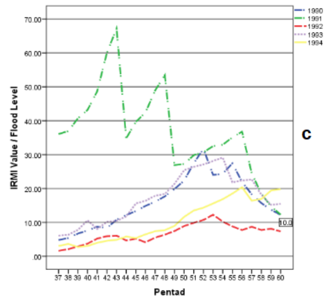
Figure 1. Reservoirs, Rivers and sample locations Niger State.



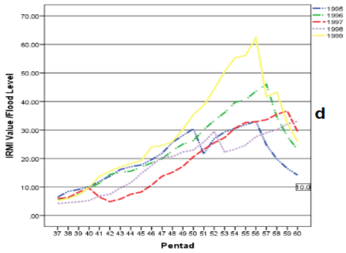
IRMI Flood Risk (1980-1984)



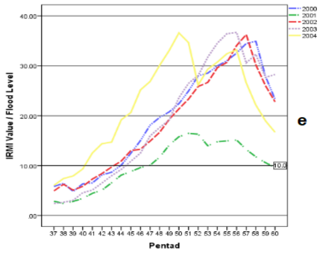
IRMI Flood Risk (1985-1989)



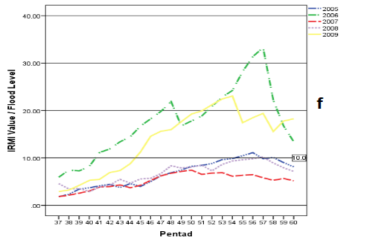
IRMI Flood Risk (1990-1994)



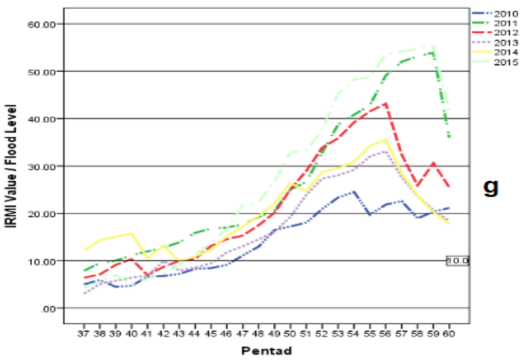
IRMI Flood Risk (1995-1999)



IRMI Flood Risk (2000 -2004)

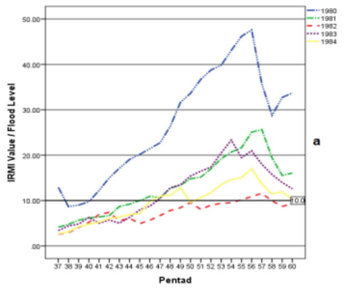


IRMI Flood Risk (2005- 2009)

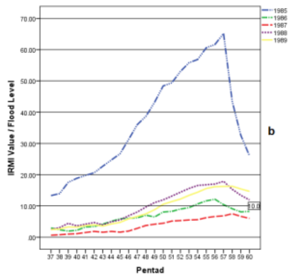


IRMI Flood Risk (2010-2015)

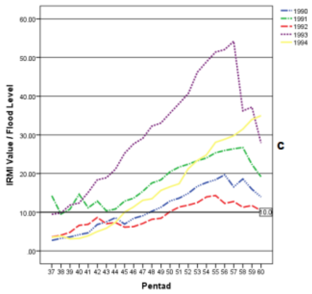
Figure 2a-g. Kaduna IRMI flood risk level 1980- 2015.



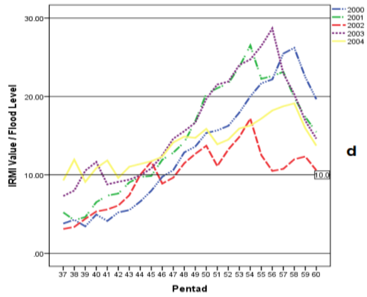
IRMI Flood Risk (1980-1984)



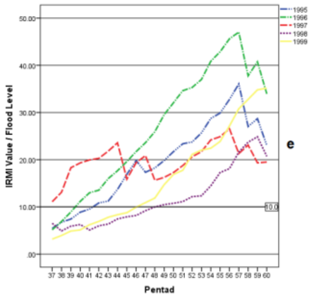
IRMI Flood Risk (1985-1989)



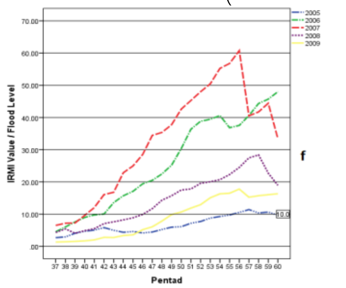
IRMI Flood Risk (1990-1994)



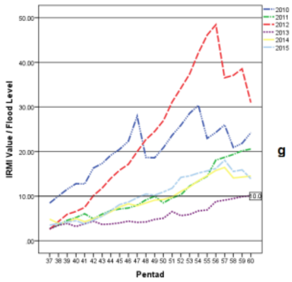
IRMI Flood Risk (1995-1999)



IRMI Flood Risk (2000 -2004)

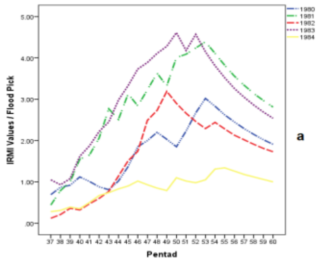


IRMI Flood Risk (2005- 2009)

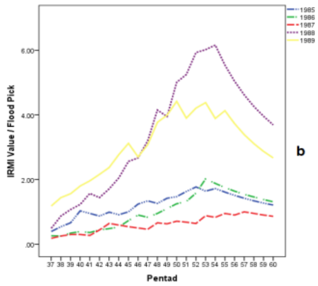


IRMI Flood Risk (2010-2015)

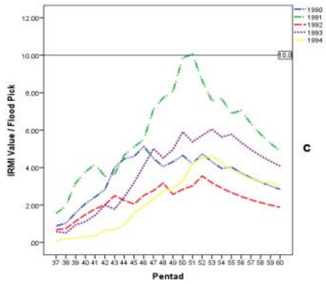
Figure 3a-g. Minna IRMI flood risk level 1980- 2015.



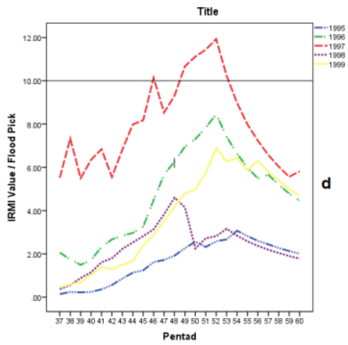
IRMI Flood Risk (1980-1984)



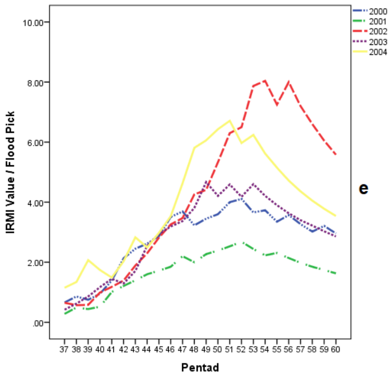
IRMI Flood Risk (1985-1989)



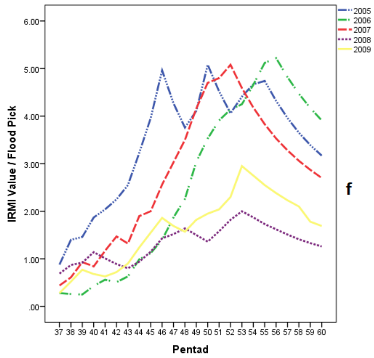
IRMI Flood Risk (1990-1994)



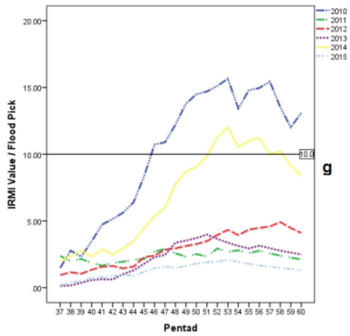
IRMI Flood Risk (1995-1999)



IRMI Flood Risk (2000 -2004)



IRMI Flood Risk (2005- 2009)



IRMI Flood Risk (2010-2015)

Figure 4a-g. Sokoto IRMI flood risk level 1980- 2015.

3.1.1. Rainfall Variability in Kaduna, its Potential Impact on Shiroro and Kaduna Floodplain Wetlands

Figures 2a and b indicate that Kaduna IRMI values increased gradually between 1981-1989 with IRMI values slightly above 30 while 1980 and 1985 values rose steadily to 47 and 65 which is an indication of higher runoff that could aggravate flood. However, the drastic decline at about pentad 52nd and 50th signaled early cessation, reduce flood potential and moisture stress typical of the 1980s.

The 1991-1999 IRMI values expect 1999 rose gradually between pentad 37 and 54th as 1991was characterized with fluctuations due to breaks in rainfall thereby minimizing runoff and subsequently inflow (Figure 2c-d). By implication, 1990s value doesn't constitute threat to floodplain wetland ecosystem.

The 2000-2009 IRMI peak values were generally characterized by gradual rise and oscillatory pattern that will certainly limit runoff and inflow into the water bodies (Figure 2e-f). Fundamentally, the IRMI values of 2011, 2012 and 2015 rose steadily across the rainy seasons (Figure 2g). These three years are distinguished as years of severe flood across the entire floodplain wetland ecosystem in the country. This pattern of steady rise is a prime contributing factor aggravating severe and devastating flood across the ecosystem and riverine communities. Flooding which arguably has been more damaging for Nigeria has worsened recently due to a number of possible factors including rapid population growth, urbanization, poor urban planning and climate change especially in increased frequency and intensity of rainfall [14].

3.1.2. Rainfall Variability in Minna and its Potential Impact on Rivers Kaduna and Niger Floodplain Wetlands

Generally, the IRMI pattern of Minna is similar to that of Kaduna (Figure 3a-g). The1980 - 1989 IRMI value rose gradually above 10 apart from 1980 and 1985 that were characterized by steady rise and downward trend at about 54th pentad which is an indication of early cessation (Figure 3a and b). This affirmed the dryness that was typical of 1980s.

Likewise, the 1991 -1999 affirmed that except 1993 and 1996 the peak values rose gradually and some characterized with fluctuations that certainly minimized runoff and inflow with the potentially to reduce flood risk (Figure 3c and d). Apparently, 1993 and 1996 constitute threat and by implication resulted to severe flood recorded in two the years downstream.

The 2000-2009 IRMI peak values except 2007 are generally characterized by gradual rise and oscillatory pattern that will limit runoff and inflow into the water bodies (Figure 3e and f). The 2007 values rise above 10 in 40th pentad and rose progressively 62, this trend are always of paramount concern while 2008 and 2009 values rise gradually as the 2005 was below 10 an indication of low runoff and inflow. The 2010 value rises above 10 in 38th pentad but the values are characterized with variability and lower peak which will certainly moderate runoff and subsequent inflow into the rivers (Figure 3g). The steady rise of the IRMI values from pentad 40 – 56th without remarkable fluctuations is an indication of high rainfall which is devoid of break and is major factor that aggravates 2012 flooding events across the country. Similarly, Frederic and Mesmin [13] concluded that gradual increase in annual rainfall amounts especially in the last two decades is the cause of increased flood water heights. The 2011, 2014 and 2015 values rises gradually while 2013 value is generally below 10 an indication of no flood condition throughout the growing season.

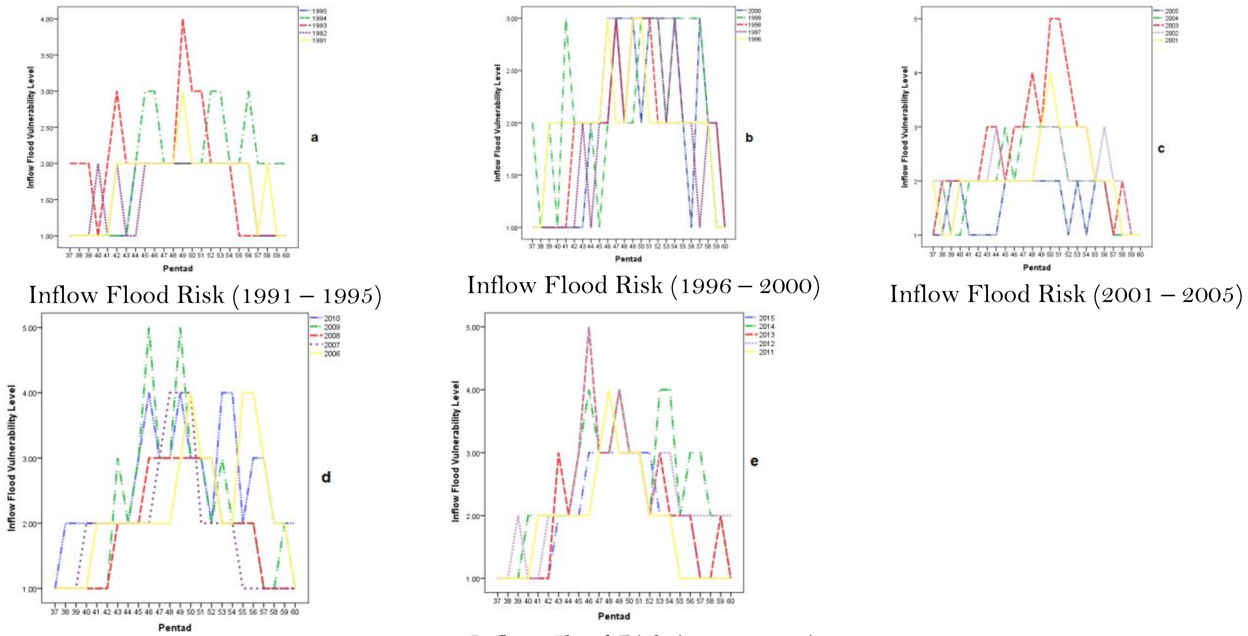
3.1.3. Rainfall Variability in Sokoto and its Potential Impact on Kainji reservoir and Sokoto-Rima Floodplain Wetland

Generally, IRMI value in Sokoto and environs are lower than 10, an indication of low inflow Figure 4a-g. In 1980s the peak IRMI value was 6, in the 1990s the value rose above 10 in 1991 and 1997 in the 59th and 52nd pentads respectively and the peak value between 2000 and 2009 was 8. Similarly, between 2010 and 2015, the IRMI values rose above 10 only in 2010 and 2014; these are indications of increased IRMI values and more frequency peak values between 1980-2015. Hence, by implication there is increase in runoff and subsequent inflow into rivers and reservoirs.

3.1.4. Spatio-Temporal Variability in IRMI Values

An analysis of the IRMI values from the 37th to 60th pentads over the study period, revealed higher IRMI peak values recent times, confirming [15] report that heavy precipitation events are on the increase. Higher peak values were recorded across Kaduna in 1980, 1985, 1986, 1991, 1996, 1999, 2011, 2012 and 2015. Rainfall intensity –

heights, spread, frequency and associated havocs should be increasing by the years [16]. Similarly, Minna and its environs were characterized by high values in 1980, 1985, 1993, 1996, 2006, 2007 and 2012. In Sokoto and environs, values have also shown tendency to rise above 10 in recent times. This indicates that there is spatio-temporal variability in IRMI peak values and their potential contribution to river and reservoir inflow, in agreement with Douinot, et al. [17] which concludes that information on number of raindays, the occurrence and severity of the wettest day of each month and the total rainfall received may also prove valuable in better understanding the climatology and identifying changes in the weather regimes. The higher peaks values with less variability across the pentads have continued to trigger high and very high inflow and the resultant discharge into the floodplain wetland ecosystem thereby, aggravating recurring flood in the downstream communities.



Inflow Flood Risk (1991 – 1995)

Inflow Flood Risk (1996 – 2000)

Inflow Flood Risk (2001 – 2005)

Inflow Flood Risk (2006 – 2010)

Inflow Flood Risk (2011– 2015)

Figure 5a-e. Kainji inflow flood risk 1980- 2015.

3.2. Reservoirs Inflow and Flood Risk

The inflow into the reservoirs during the rainy season particularly after the 37th pentad reveals high variability Figure 5 &6. It's also unveiled the increase of high, very and extremely high inflow into the reservoirs in recent times.

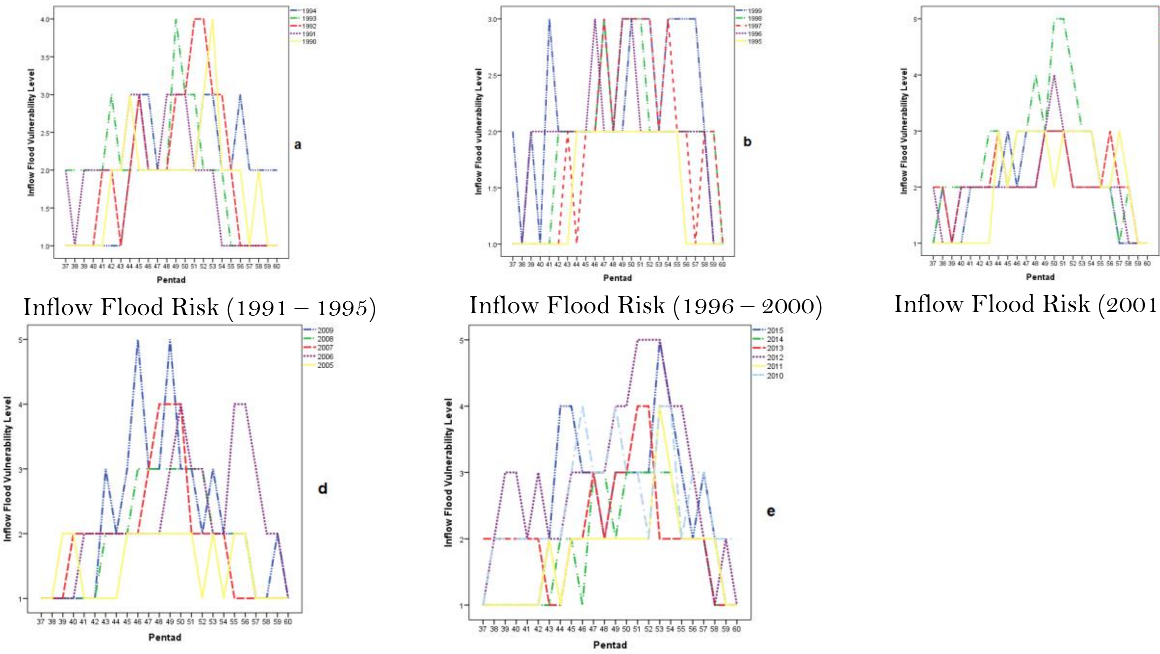
3.2.1. Kainji Inflow and Flood Risk

Specifically, Inflow into Kainji reservoir between 1991-2000 were characterized with low, moderate high inflow except in 1993 that very high inflow was recorded once. Similarly, 2001-2015 were characterized with variability coupled with higher peaks (very and extremely high inflow) indicating higher flood potentials (Figures 5a-e). The years 2001, 2003, 2006, 2007, 2009, 2010-2015 recorded very high inflows while in 2003, 2009, 2012 and 2013, extremely high recorded.

Moreover, in 2004, 2008 and 2015, high inflows were recorded for five and six consecutive pentads (46-51) and (46-52) respectively. A similar pattern was recorded in 2003, 2010 and 2014 when extremely high and very high inflows were sustained for two pentads each. Ashcroft, et al. [18] indicated that basins experienced significant increases in peak discharge values, especially in the upstream areas. These consecutive occurrences coupled with higher inflow peaks will lead to increased reservoir volumes which will certainly aggravate higher discharge and higher water level across the wetland ecosystem.

3.2.2. Shiroro Inflow and Flood Risk

The inflow values of Shiroro reservoir are characterized by variability and are generally higher than that of Kainji dams as such; this shows the significance of the tributary contributions to the recurring flooding events. The 1990s inflow were characterized variability I low, moderate, high and very high inflow peaks were recorded in 1990, 1992 and 1993 (Figure 6a).



Inflow Flood Risk (1991 – 1995) Inflow Flood Risk (1996 – 2000) Inflow Flood Risk (2001 – 2005)

Inflow Flood Risk (2006 – 2010) Inflow Flood Risk (2011– 2015)

Figure 6a-e. Shiroro flood inflow risk level (1990-2015).

Figures 6a-e depict higher inflow values recorded from 2000 - 2015 which have continued to intensified flood in recent times. Exclusively, very high inflow was recorded in1990, 1992, 1993, 2001, 2003, 2006, 2007, 2010, 2011, 2012, 2013, & 2015 while extremely high inflow was recorded in 2003, 2009,2012 & 2015. Also, consecutive occurrences of the high, very and extremely high increased; Figure 5e unveils the competition between high, very and extremely high inflow values from 2010 – 2015. Tabari [19] showed intensification of extreme precipitation and flood events over all climate regions which increases. Thereby, there is need to develop adequate understanding of the variables intensifying flood for enhance preparedness and disaster risk reduction.

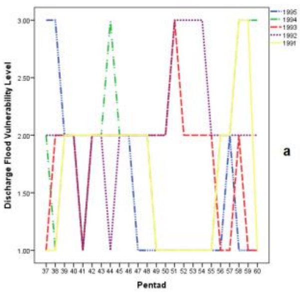
Specifically, 2012 was the year of most devastating flood across the floodplain wetland ecosystem in Nigeria. The year recorded high inflow from the 37th pentad for two consecutive pentads then followed by oscillation between high and moderate inflow for four pentads after which high inflow was sustained for five consecutive pentads (45-49) where it rose steadily through very high between pentads 49-50 to extremely high for another five consecutive (50-54th) pentads. This pattern is a prime contributing factor to the 2012 flooding event in Nigeria. The years 2010, 2013 and 2014 exhibit similar pattern with lower consistency of higher inflow. Jahn [20] rightly concludes that extreme weather events have always had and will continue to have significant consequences for the society and the economy. By implication, this pattern signals the need for future flood preparedness through identification and development of mitigation and adaptation strategies for enhance sustainability of wetland ecosystem and the resultant livelihood.

3.3. Reservoirs Discharge and Flood Risk

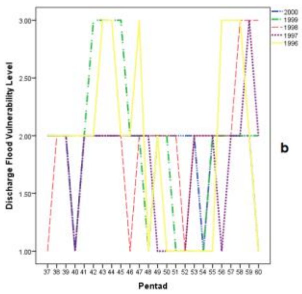
The discharge from the reservoirs exhibited spatio-temporal variability, as Kainji values were characterized with fluctuations between low, moderate, and high discharge. While Shiroro discharge varies from low to extremely high discharge.

3.3.1. Kainji Discharge and Flood Risk

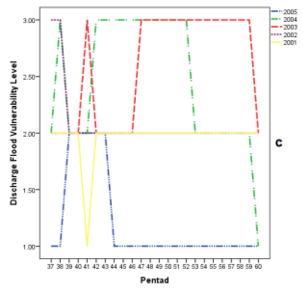
The discharges from the reservoir exhibited temporal variability, with the 1990s' discharge characterized with fluctuations between low, moderate, and high discharge with dominance and consistency in low and moderate discharge (Figures 7a and b). However, the consistency of moderate and high discharge persisted couple with decline in low discharge between 2001 to 2017. Specifically, 2005, 2006, 2008 and 2015 recorded consistency of low discharge, moderate discharge was consistent for about 22 pentads in 2001 and 2002 (38 - 60th pentad) and about 20 pentads in 2009 (Figures 7c and d). Similarly, high discharge was sustained for 12 and 10 consecutive pentads in 2003 and 2004 as apparent in Figure 7c.



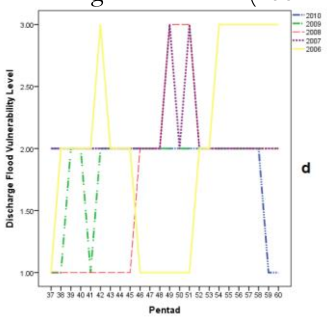
Discharge Flood Risk (1991-1995)



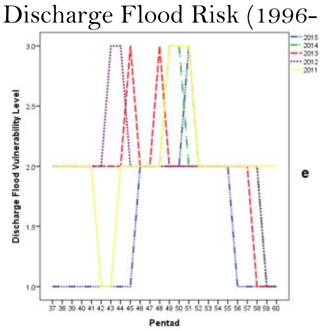
Discharge Flood Risk (1996- 2000)



Discharge Flood Risk (2001- 2005)



Discharge Flood Risk (2006- 2010)



Discharge Flood Risk (2011- 2015)

Figure 7a-e. Kainji discharge flood risk (1911- 2015).

The consistency in moderate and high discharge is fundamental factor in recent flood events that threatens livelihood across the ecosystem downstream of the hydroelectricity dams. Past experience with climate extremes contributes to understanding of effective disaster risk management and adaptation approaches to manage risks [21]. Hence there is need for adequate understanding of the variables for the development of proactive sustainability measures to enhance economic diversification, growth, human livelihood and socio-economic development as pathway towards disaster risk reduction.

3.3.2. Shiroro Discharge and Flood Risk

The 1990s discharge levels show dominance of low and moderate discharge with less consistency of higher discharge (Figures 8a and b) as high discharge were consistent for three and four pentads in 1992 and1999 respectively. The consistency of moderate and high discharge was intensified between 2000 and 2004; high discharge persisted between 46 – 59th pentads in 2003 and 42 – 52nd in 2004 (Figure 8c). The peak flood risk for

2005-2009 was characterized by variability across the pentads which will definitely minimize downstream flood (Figure 8d).

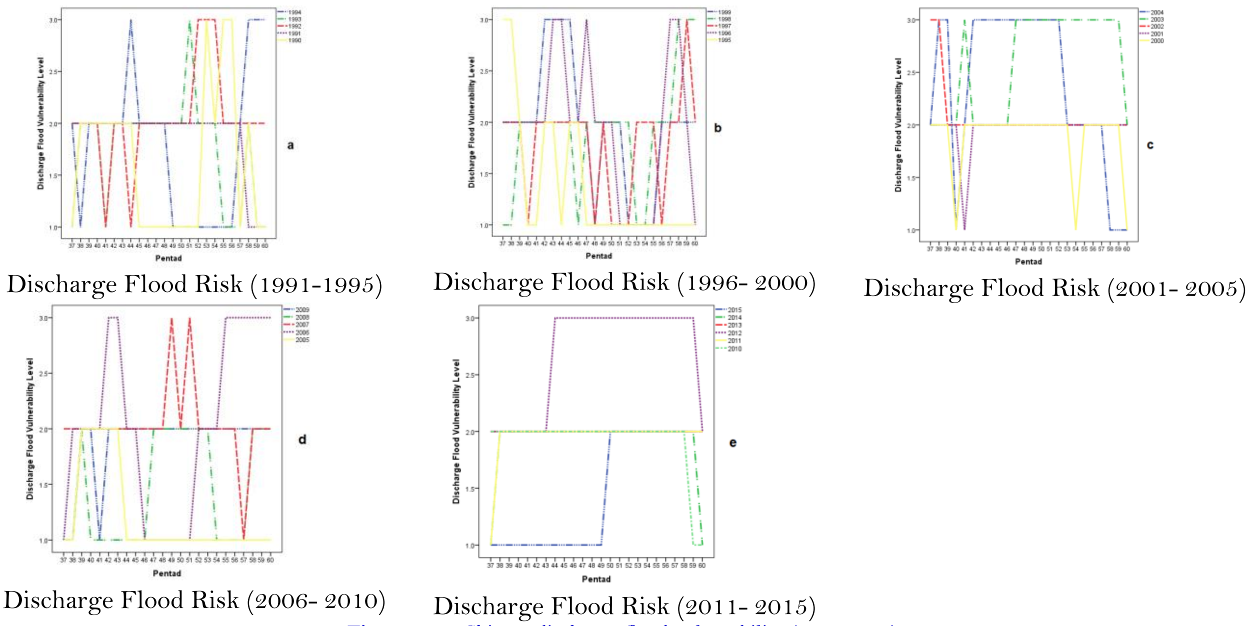


Figure 8a-e. Shiroro discharge flood vulnerability (2010-2015).

Fundamentally, Figure 8e unveils the insecurity of the ecosystem to recurring flood as result of the smoothening that characterized discharge in recent times. Consistency in moderate discharge was recorded in 2010, 2011 and 2014 as 2012 recorded high discharge from 42nd – 58th pentad. This affirmed that smoothing of variability that typical of reservoir discharge and consistency in moderate and high discharge are fundamental factors threatening the floodplain wetland ecosystem downstream as evident in the study area in the years 2010, 2011, 2012, 2013 and 2014. It's also apparent that dams to a great extent that reservoirs minimize flood since despite the high, very high and extremely high inflow that were recorded, discharge from the reservoirs oscillates between moderate and high discharge signifying their role in moderating flood.

3.4. Trend Analysis

The IRMI inter-annual pentad Mann Kendall's trend test affirmed the spatio-temporal variability typical of rainfall across the study area. This is apparent from the results as from 37th - 60th pentads with (p-values greater than alpha=0.05) suggesting an increase in IRMI trend over Minna while Kaduna revealed a decreasing trend in IRMI trend from 37th - 42nd & 45th pentads while 46th-60th pentads showed an increasing trend. Furthermore, the trend over Sokoto revealed generally an increasing trend that was statistically significant from 52nd-60th pentad.

Similarly, the inter-annual pentad Mann Kendall's trend test for Intra-inflow and discharge over Shiroro and Kainji from 1990 to 2015 revels positive trend across the pentads. Generally, the inflow and discharge over Kainji and Shiroro revealed an increasing trend but most of the changes across the pentads were not statistically significant while few were statistically significant. This positive trend is a prime contributing factor aggravating the recurring flood threat across the wetland ecosystem in the country. Zia and Saeed [22] conclude that the diverse and pervasive threats to wetlands point the need for comprehensive monitoring efforts. Thus, its crucial to monitor the variable and integrate them for the development flood risk management strategies.

3.5. Hydro-meteorological Variability and its Potential Impact on the Floodplain Wetland

The apparent steady rise in IRMI peak values after 37th pentad signals increase runoff across the study that has been escalating the recorded reservoir inflow. Projected changes from both global and regional studies indicate that it is likely that the frequency of heavy precipitation, or the proportion of total rainfall from heavy falls, will increase in the 21st century over many areas of the globe [23]. The resultant Inflow responded positively as more pentads record higher inflow peak values in recent times, consecutive occurrence of high inflow into Kainji and the competition between high, very and extremely high inflow into Shiroro as well as decline in low inflow unveils the effect of climate variability on floodplain wetland ecosystem across the downstream communities.

These have continued to necessitate increase discharge and subsequent over flow of river banks and accumulation of excess water in the ecosystem which most can lead to degradation and loss of the vital resources. Thus, by implication, climate variability is prime factor aggravating flood events and threatening sustainability of floodplain wetland ecosystem across the country. The current investments in DRR are not at par with the increasing physical and social vulnerability of the regions [24].

Consequently, the dominancy and consistency in the moderate and high discharge levels are indicator for increase flooding events across downstream community as low-level discharge have continued to give way for moderate and high discharge in recent times. This affirmed by Frederic and Mesmin [13] and Haider [25] that there is no doubt that climate risks in recent years have experienced significant strengthening. In addition, the positive trend of the variables reveals increase flood potential which are threat to food, socio-economic, national and regional security as large proportion of populace depends on this ecosystem for livelihood.

The debate on whether climate change will impact on peoples' livelihoods and, hence, the need to act is essentially over and has instead shifted to the development of strategies needed by different regions and countries to adapt to climate change effects [26]. It is crucial to note that, this pattern signal need for future flood preparedness that should in-cooperate proactive environment friendly and structural approaches as tool for disaster risk reduction, enhance sustainability of wetland ecosystem and the resultant livelihood other than reactive that always dominate disaster management across the country. ICSU-ISSC [27] highlighted that disaster risk reduction should be based on firm scientific knowledge, vast information/data, and the systematic development and application of policies, strategies and practices to minimize vulnerabilities and disaster risks throughout a society.

4. CONCLUSION

The results revealed Spatio-temporal variability in IRMI values across the study area, steady increase in the IRMI value beyond 10, indicates higher runoff potentials which have been exacerbating inflow into rivers and reservoirs. Thereby, affirming the uniformity of moderate and high discharge beyond 37th pentad as well as the consequential downstream flood across the wetland ecosystem. The high concentration of rainfall, the resultant consistency in high, very and extremely high inflow are intensifying moderate and high discharge which are fundamental factors in recent flood events that threatens livelihood across the downstream communities. In addition, the positive trend of the variables is fundamental hydro-meteorological factors aggravating the recurring flood threat in the country.

Outwardly, the research shows the linkage between high IRMI values (consistent rainfall concentration) and high reservoir inflows and consequent outflows. This is affirmed by very strong positive correlation between IRMI, inflow and outflow. Invariably, the higher the IRMI values, the higher the inflow into reservoirs and the higher the chance of reservoir discharge and consequently, the higher the risk of flood occurrence downstream. Thus, this necessitates the need for the development of environment friendly proactive strategies that will enhance communities' capacity to live with risk. Moreover, it's crucial to defining an indicator of Flood Risk Potential (FRP) that could be used to forecast flood possibility using the research variables for the downstream communities.

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