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# EFFECT OF RESERVOIR UTILIZATION AND OTHER ANTHROPOGENIC ACTIVITIES ON THE HADEJIA RIVER VALLEY FLOODS: A REVIEW

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## ABSTRACT

The unceasing risk perception and socio-economic damages caused by flood disasters have been persistent in Hadejia River Valley (HRV). There is, however, a need to review upstream factors that could exacerbate downstream floods in the valley. The review tends to gain insight from the local and global flood occurrences due to the interplay between upstream reservoir management and other anthropogenic activities and downstream floods. The review underscores the impact of poor upstream reservoir operation, agriculture and other anthropogenic activities in exacerbating the occurrence of floods. These activities alter natural drainage patterns, reduce water absorption, and frequent spills from the major dams and hence, amplify runoff resulting in heightened flood risks. It was observed that reservoirs can serve as flood control facilities (if well-managed) and also exacerbate flooding by releasing large volumes of water too quickly or reaching capacity during intense rainfall events. It is, therefore, essential to consider the location, design, and operation of reservoirs, as well as their role within the HRV management context. In conclusion, the Hadejia-Jama'are River Basin Development Authority (HJRBDA) should adopt the Integrated Water Resource Management (IWRM) approach that combines reservoir management, land use, flood forecasting, and emergency response strategies for minimizing downstream flood risks and maximizing the utilization of the upstream reservoirs.

**Keywords**: Anthropogenic activities, Floods, Hadejia River Valley, Nigeria, Reservoir utilization

## INTRODUCTION

In history, flooding is one of the major natural disasters responsible for the loss of lives and properties, although human activities further exacerbate the fatalities. Flood-related losses (life and properties) in Africa, have been observed to increase over some few decades (Di Baldassarre *et al*., 2010). Climate variability as a result of climate change impact increases flood uncertainties, and this variation could be accurately predicted and quantified if the dynamic of climate-informed flood risk management tools were linked with human-induced problems. Human (anthropogenic) activities have been one of the major problems that result in flood downstream of major rivers across the globe because human tends to move close to the river course thereby, obstructing the smooth flow of water. Humans alter the drainage systems by way of erecting structures either directly or indirectly on the waterways and other domestic activities that could amount to damage to drainage systems.

Flooding is gradually becoming a serious problem in all 3 facets of sustainability (social, economic, and environmental) in Nigeria. The city of Hadejia and neighbouring communities lie in Hadejia-Nguru wetlands which is a wide expanse of floodplain situated in the north-west to the north-eastern part of the country which is located in lowland areas of the Hadejia River Valley (HRV). A larger proportion of this floodplain is affected by flooding events almost every year (Olalekan *et al.*, 2014). Based on this, flood has been one of the major problems faced by the people of Hadejia City and the neighbouring community and these problems have become persistent in recent years. There are several reports on the looming floods affecting this floodplain. A case in point is the red alert issued by the United Nations (UN) climate experts advising the relocation of Hadejia City over impending floods. The report further stresses the need to assess the flooding problem facing the HRV to provide adequate information resulting from this impending flood (Daily-Nigerian 2021), thereby informing the relevant authorities. In line with this wake-up call, a review of the effect of upstream reservoir utilization and anthropogenic activities on the downstream floods was conducted and reported herein,

Reservoirs or dams are constructed to intercept runoff and store the water for various uses. The reservoir can be utilized in any of the following two broad categories; a) *Conservation* - storage of surplus water at high flows for utilization during periods of deficient flows and b) *Flood control* - regulation of floods by storing some of the flows and releasing it gradually later. All over the world, water reservoirs or dams are used for many purposes including the provision of portable water supply, irrigation practices, hydropower, and flood mitigation (Shanono *et al.,* 2023). Sustainable utilization of water reservoirs requires dealing with the important issues related to reservoir sedimentation, inflows, operation rules, releases, spills, and anthropogenic activities among others (Obialor *et al.,* 2019). Generally, soil erosion is the major cause of reservoir sedimentation which is dependent upon some natural and anthropogenic factors. In addition, sedimentation continues to be one of the most shocking threats to not only the reservoirs but also river ecosystems around the world (Erena and Worku, 2018). This is undeniably correct because the flow of water from the catchment upstream of a reservoir is capable of eroding the catchment area and depositing material either in the rivers or reservoirs. The nature of the material in the catchment area, the slope of the catchment area, and the inlet streams are a factor, in addition to the nature of the ground cover and rainfall characteristics. The deposition of sediment will automatically reduce the storage capacity of the reservoir and the carrying capacity of the river. If the process of deposition continues, it is likely to reach a point when the whole reservoir and river may get silted up and the community can become vulnerable to floods (Garg, 2009). The occurrence of persistent drought in some parts of northern Nigeria particularly, the then Kano State which comprised

Kano and Jigawa States necessitated the creation of dams during the late 1960s and early 1970s. These dams are meant to supply water for domestic uses, irrigation, livestock farming, and flood control (Umma *et al.,* 2014). Most of the dammed rivers in Kano State are tributaries to the Hadejia River which is located within the catchment of the Hadejia-Jama'are River Basin (HJRB). The catchment of the Hadejia-Jama'are River Basin Hydrological Area (HJRB-HA) is considered the largest floodplain in northern Nigeria because it crosses many towns and villages in Kano and Jigawa States and two-thirds of Bauchi State (Iliyasu, 2017). The floodplains of HRV are also located within the HJRB and are not exceptional at the risk of a flood as it often witnesses episodic flash floods. Such frequent floods occur not only as a result of heavy rainfalls of long durations but also poor upstream reservoir operation and other anthropogenic activities (ICOLD, 2018). The estimation of economic flood damage is gaining greater importance because flood risk management is becoming the dominant approach to flood control policies (Chioma *et al.,* 2019; Leibrand *et al.,* 2019).

Kano state has the largest concentration of dams in Nigeria with about 26 reservoirs in the state. Over the past four decades, climatic variability, sedimentation, and increased human activities such as farming (rainfed and irrigation) within the catchment have resulted in the degradation of the rivers and dams. Some of the problems that have been affecting dams include gradual silting up, eutrophication (nutrient building), escalated gulley erosion and invasion of exotic aquatic weeds such as typhagrass, and use of agrochemicals (Umma *et al.,* 2014). This change in flow patterns has created conditions that have caused a massive invasion of the exotic Typha weeds and massive siltation into the rivers. This situation has greatly reduced the carrying capacity of the rivers and resulted in poor drainage as well as flash floods (Fortnam & Oguntola, 2004).

The major dams along the Hadejia-Jama'are River Basin are the Tiga and Challawa dams both located in Kano State. In 1974, the then Kano State Government constructed a 6 km long embankment Tiga Dam across the Kano River. The original designed capacity was 1,974 x $10^6$ $m^3$. At the time of construction, the Tiga dam received an average annual runoff of 1.3 x $10^6$ $m^3$ and an average annual rainfall of 1000 mm from a catchment area of 6,553 $km^2$. The main purpose was to provide a substantial amount of water for the Kano River Irrigation Project (phase I and II), the Kano city water supply, regulate the flow to the Hadejia River Valley, and a possible hydroelectric power generation (Haskoning Consultants, 1978). Moreover, the dam operation seemed evidently below utilization capacity, as Kano City water supply expansion was still on course and the major irrigation projects such as the Kano River Irrigation Project Phase I & II and the Hadejia Valley Irrigation Project are still not completed. Evidently, this is an indication of underutilization with performance far below the initially intended use. The Challawa Gorge Dam is situated at Karaye Local Government, about 90 km southeast of Kano, Nigeria. The main purposes of the dam include controlling floods downstream of Hadejia River Valley, irrigation practices, improvement of water supply to Kano city and other towns as well as fisheries and livestock development and recreation (Olatunji, 2005). Figure 1 shows the Hadejia River Valley (HRV) showing the 2 major dams and the Hadejia River Valley wetland (Olalekan et al., 2014).

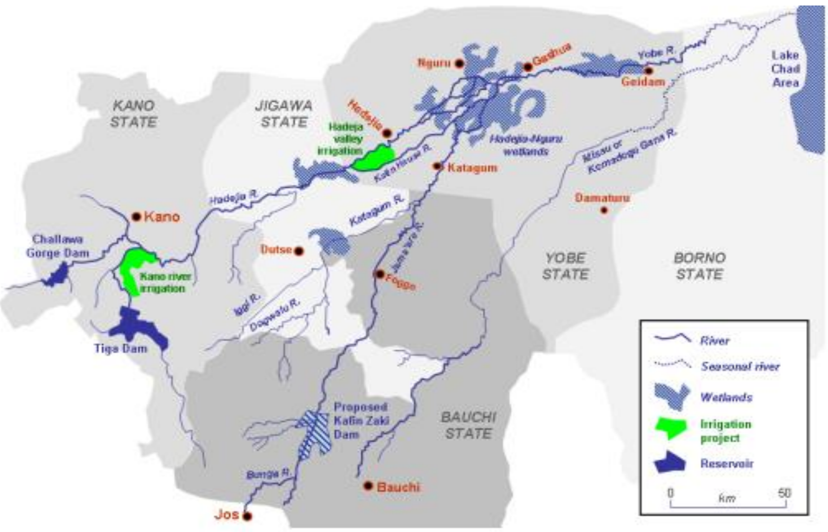


Figure 1: Hadejia River Valley Area showing the 2 major dams and Hadejia Valley wetland (Olalekan et al., 2014).

**The Interplay Between Upstream Anthropogenic Activities and Downstream Floods**

Human beings are the primary agents for altering the state of the ecosystem (Shanono and Ndiritu, 2020). Human developmental activities such as farming, buildings, channelization, and dam construction among others pose serious effects on the balance of our fragile river basin systems and environment at large (Mertzanis *et al.,* 2011; Shanono, 2019). For example, the unceasing accumulation of sediments, eutrophication, phytoplanktons in water bodies, and the widespread of invasive and non-native plant species (e.g. Typhagrass) are the results of several upstream human activities that greatly influence and continue to threaten the functionality of dams and rivers of HJRB (Umma *et al.,* 2014).

Many Nigerian communities increasingly suffer local recurrent flooding during the rainy season. The local nature of this flooding makes them receive little or no attention. However, the cumulative effects of such smaller flooding incidents are no less important than major events and require more attention (Echendu, 2022). Figure 2 below is a map of Nigeria that showcases areas prone to flooding and the

Hadejia-Jama'are River Basin (HJRB) is included which comprises Kano and Jigawa State, particularly the Hadejia River Valley (HRV). Today, we face a situation whereby disasters are occurring back-to-back. The unpreparedness of the world to sufficiently respond to concurrent environmental and public health due to flood catastrophes highlights an urgent need to improve human resilience to flood shocks (Béné, 2020). This necessitates establishing the connections among different global problems and seeking synergistic ways to resolve them. More capacity building is especially important in susceptible developing countries if global sustainability is to be attained (Adhikari *et al.,* 2020). In Nigeria, the impact of flooding on food security and enabling development is an area that requires adequate attention from various stakeholders (Akukwe *et al.,* 2020).

Nigeria is a food-insecure nation and it is among the most vulnerable and at risk of food insecurity due to climate change, economic crises, and conflict (WFP, 2020; Maina *et al.,* 2023). It experiences annual flooding in many of its states and the impact on its food security is widely acknowledged (Durodola 2019). In July 2021, the country's president blamed flooding for the rising food insecurity. Other factors that impact food security, range from insecurity (which prevents farmers from accessing their lands) to communal conflicts among farmers and herdsmen (Echendu, 2022). However, flooding remains the highest factor (Wizor and Week 2012). Agriculture, fisheries, and aquaculture which are the primary sources of food in Nigeria, are all adversely affected by flooding. Thus, food insecurity is a persistent and ever-increasing problem in Nigeria and the government has been working to address it (Osabohien *et al.,* 2018). The problem has worsened since 2020, when Nigeria faced extreme food shortages and record-breaking flooding disasters (Echendu, 2022). In a study on food security by Week and Wizor (2020) in a Nigerian community, 75.6% of the respondents reported experiencing acute food insecurity. Following major floods, a significant surge in malnutrition levels is experienced due to the impacts of flooding (Douglas 2017). The World Food Programme, in their 2020 global report on food crises, reported that, in 2019, flooding affected 32 out of the 36 states in Nigeria. In October of the same year, Adamawa, one of Nigeria's states was hit by its worst flooding event in 17 years, affecting more than 100,000 people (WFP, 2020).

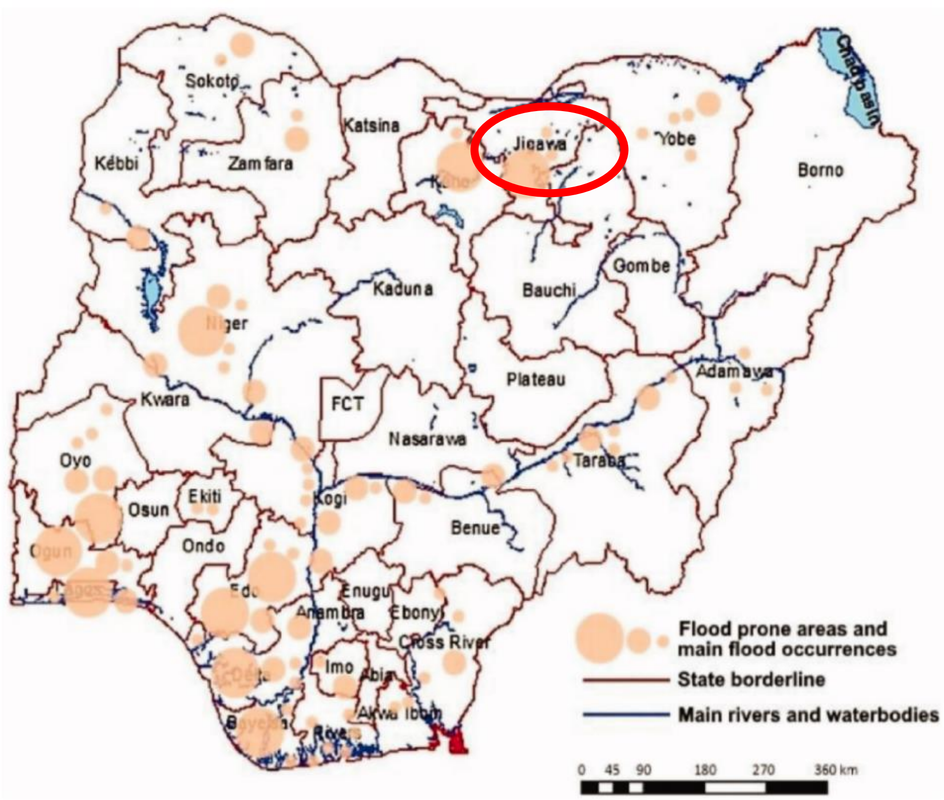


Figure 2: Map of Nigeria showing flood-prone areas of HJRB and HRV included (Echendu, 2022)

## Lessons Learned from Local and Global Flood Occurrences

### *Local occurrences*

Flooding arises from structural failures, heavy rainfalls, and a host of human-induced factors. Floods depend on rainfall amounts and rates, topography, land use, soil type, and antecedent moisture conditions. Flooding is regarded as one of the most destructive natural disasters and causes serious loss of life and economic damage worldwide (Mertzanis *et al.,* 2011). Thus, the risks and damages caused by flood disasters in terms of loss of life and property, displacement of people, and disruption of socio-economic activities as well as the loss of valuable agricultural land can never be overemphasized.

The causes of flooding in Nigeria were assessed by Magami *et al.,* (2014) which include dam failure, overflowing of major rivers, ignoring warnings from Nigeria's meteorological agency, delays in the evaluation of flood victims, and settlement of people in flood-prone areas. Other causes of flooding include climate change impact (e.g. extraordinarily heavy rains) and the continued release of excess water from artificial reservoirs. The study further pointed out that poor maintenance of drainage channels coupled with indiscriminate waste disposal results in flooding in Nigeria.

The city of Hadejia and neighbouring communities are known to be located in lowland areas of HRV. The Hadejia lies in

Hadejia-Nguru Wetlands which is a wide expanse of floodplain wetlands situated in the northwest to northeastern Nigeria. Flood has been one of the major problems faced by the people of Hadejia town and the neighbouring community and this problem is becoming persistent in recent years. There are several reports on the looming floods affecting this area. In 2019, NAN (2019) reported that Jigawa State Government has spent N2.7 million on clearing 15 km of typhagrass along the stretch of the Hadejia River, in Guri Local Government Area. The major aim was to mitigate the impact of the flood and despite this, the problem is still lingering.

Another recent report by Daily-Nigerian (2021) that a United Nations climate expert has issued a red alert, advising relocation of Hadejia town over impending floods. The report further stressed the need to assess the lingering flooding problem to provide adequate information resulting from this impending flood. In addition, the report claimed that climate change coupled with anthropogenic activities are the major cause of the looming floods ravaging Hadejia city and its neighbouring communities. However, it is based on this background that motivated this review to come up with responsive mitigation and/or adaptation strategies that may be implemented to lessen the impact of the looming flood and hence, strengthen the resilience of the affected communities along the valley. Figure 3 shows some affected Hadejia residents during the 2020 flood.

Figure 3: Some affected Hadejia communities during the 2020 flood

The heaviest rain on record that caused the flood in the city of Ibadan occurred in 1980 and 2011 when the city recorded 274 mm and 188 mm of rainfall during a single flood episode. An accurate assessment of the havoc created by floods in the city of Ibadan over the years is difficult to obtain because of the paucity of official data. Some official estimates have been made and the losses from the flood disaster of August 1980 were estimated at over N300 million (Nigerian naira, or USD 1.92 million), while over 500 lives were lost (Akintola 1994). The estimated amount to fix the culverts and bridges damaged by the 2011 flood is N2.1 billion. This indicated that although the rainfall of 2011 incidence was not the highest in the recorded history of Ibadan city, the monetary value of damages to property that resulted from the event was by far the highest.

***Global occurrences***

Flood risk is predicted using several scenarios of climate variabilities and socio-economic changes and damages (Wing *et al.,* 2018). Dams have significantly changed hydrological processes all over the world, and this needs to be considered in flood hazard mapping, forecasting, and mitigation. A case in point is that from 1972 to 2006, there were 531 flood events in the USA designated as catastrophes, and losses were estimated to exceed $176 million per event (Changnon, 2008). Thus, flooding has remained one of the deadliest fatalities and the most costly damages to properties and human lives of all weather-related hazards not only in the United States but also in many other countries of the world (Ashley and Ashley 2008). To mitigate such flood hazards, various types of structural measures, such as dykes and dams, have been built along rivers coupled with effective management strategies and operation rules. According to the World Register of Dams, more than 58,000 large dams with a height of >15 m have been constructed globally (ICOLD, 2018). The number of dams is still increasing each year, especially in developing countries (Gleick, 2012; Linnerooth-Bayer & Mechler, 2015). It is important to note that in floodplain catchments, the basic functions of dams are to suppress downstream flooding followed by supplying water for irrigation, human consumption, and electricity generation. Dams' structural obsolescence, lack of proper maintenance, and ageing were considered to be high-level risk factors that could lead to dam breakage and flooding downstream. In line with this, another case is that out of about 85,000 dams in China, approximately 30,000 (36%) pose significant risks (Sheng *et al.,* 2006).

Flooding already constitutes the most serious natural hazard facing the United Kingdom (Thorne, 2014). Over 6 million properties along with significant parts of the national infrastructure essential for power supply and transport are at risk from coastal flooding (Prime *et al.,*2015). In the United Kingdom alone, the financial consequences are significant and formed the basis of a key economic assessment of the natural hazard risk and coastal defence strategy. This led to a planned UK investment of £2.5 billion in flood defences over 6 years to protect housing (Penning-Rowsell *et al.*, 2005). However, the economic impact of coastal flooding on agricultural land has received little attention, understandably as most impact assessments have tended to focus on urban rather than rural locations. Nevertheless, large proportions of the most productive agricultural land occupy low-lying, reclaimed coastal regions. These areas are not only susceptible to coastal flooding climate scenarios (Spencer *et al.*, 2015), but the risk has manifested in widespread farmland inundation and crop losses along the east coast of England and low-lying coastal regions including the Netherlands (Spencer *et al.*, 2015). To reduce the incidence of coastal flooding in the United Kingdom, shoreline management plans have been implemented, and analogous approaches have been undertaken globally. Such approaches review the economic viability of any protection measure because the construction and maintenance of a defence system come at a significant cost. In the United Kingdom, a modelling and decision support framework was employed to assess potential losses based on residential and commercial property values. The value of farmland used in assessments, following the UK Treasury guidance, is based on land values, without considering contrasts in high-value crop outputs and localized supply chain economic and strategic impacts (UK Cabinet Office, 2017).

In Kenya, for example, flooding was reportedly exacerbated by the effects of the pandemic and severely impacted food security and livelihoods (Aura *et al.,* 2020). The number of people facing food insecurity globally was projected to double by the end of 2020 in a world that was already off-track to achieve the SDGs by 2030. The growing problem of food insecurity thus portends a significant setback. Food insecurity is, therefore, linked to a mix of factors, one of which is recurrent flooding disasters (Banik, 2019). Usually, during the peak flood season, dam operators face conflict regarding the objectives of the reservoir like flood control, irrigation and domestic supplies, power generation, and saving the water for later use when the rain ceases (Bai and Tamjis 2007). At the same time, dam water levels are often lowered to avoid dam flooding or overtopping and maintain the dams' safety. The key difference between dams and all other flood protection measures lies in the fact that although dams serve as flood control structures they also introduce a new risk of dam flooding which is one of the major factors of dam failure and of course downstream floods. Globally, the chance of flooding occurring due to a dam breakage or poor utilization is estimated to be about 35% (Chinnarasri, *et al.,* 2004). The risk of dam flooding during extreme floods has become a primary concern for hydraulic engineers, emergency planners, and responders. During intense rainfall, it is known to cause massive flooding causing socio-economic and environmental damages (Adeoye and Babatimehin, 2009). Thus, dams should be closely monitored during periods of heavy rainfall, especially dams with large numbers of people immediately downstream such as HRV.

**Implications for Change**

***Reservoir operation and flood hazard***

Although dams are good flood control structures, can also pose a huge risk because dams store millions or billions of litres of water so if they were to fail, they would cause widespread death and damage downstream. Magami *et al.*, (2014) assessed the causes and consequences of flooding in Nigeria and dam failure is one of the major causes. On September 14, 2012, the Warawa dam in Kano State collapsed which led to the submergence of numerous communities (Ezugwu, 2013). Dam flooding or spill occurs when the reservoir elevation reaches its maximum (Hossaini., *et al.*, 2009). It also exacerbates the flood conditions which leads to increasingly destructive effects downstream of the dam. It is also worth noticing that dam flooding occurs due to not only heavy rainfall but also poor dam operating rules, lack of adherence to the operating rules, and underutilization of the dam. Thus, effective operation of dams is a major issue of concern not only during the period of high rainfall. In addition, the performance of water dams in Nigeria is still largely below expectation and this can be seen in the frequent dam breakages in the northern part of the country, which is partly due to underutilization of the water resources. Reservoir operation influences temporal flow patterns, which have implications on water resources management and also affect healthy riverine ecosystems. There is evidence that the water resources in Nigeria's dams are largely under-utilized and have not been properly managed which immensely contributed toward the intensified flood problems. An example of poor dam operation is the sudden, rapid, and uncontrolled release of water which commonly leads to severe floods and significantly impacts the downstream inhabitants (Sun *et al.,* 2012). Another example is that the rainy season in Kano begins from May to June, and it is expected that by May, the major dams (such as Tiga and Challawa) will be drawn down ready to store more water when the rain begins. However, this is not always the case in major dams of HJRB because Phase II of KRIP is still not developed, a larger proportion of Kano city is not connected with pipe water and the irrigation project at Challawa dam is still not developed.

A devastating flood problem is prolonged flooding also known as stagnant water or water standing or submergence (Cuc., *et al.,* 2012). Prolonged and frequent flooding event is associated with serious environmental hazards as well as public health threats due to the accumulation of municipal sewage, foul odours, mosquitoes, and the growth of water hyacinth. The economic impact of the floods was also widespread as it negatively affected the agricultural production of the country. Dam failure studies have always emphasized the effect of flood downstream either due to dam break, poor operation, or flooding. Dam flooding and prolonged flooding have directly relocated millions of people and pose a public health threat. Operators of reservoirs frequently control downstream floods using a set of operational guidelines that specify discharges before, during, and after a storm. To trap the storm's peak flow and postpone its release until a less destructive moment, operators strive to store the surge of inflows during a storm in available reservoir storage space. Operators of reservoirs face the issue of determining when to start holding water for a flood, how long to hold it, and whether to release water in advance of a storm to free up additional storage space. Reservoir operation guidelines aid in system optimization and flood control (Hanaski et al., 2006).

Flood inundation modelling has become a possible and reliable tool for gaining insight into flood risk assessment and subsequent mitigation action over the past decades (Sampson *et al.,* 2015). The flood hazard maps produced by these models fill significant gaps in ungauged areas and can provide valuable information for flood risk managers. Large-scale flood inundation models split the catchment into several reaches and the flood hazard of each reach is simulated by computing the inundation that results from particular design floods. Thus, the impact of dams on flood hazard can be reflected by the change in the magnitude of design floods downstream of reservoirs. However, dam characteristics are complex, and the operation process of each dam tries to balance multiple objectives such as flood control, water supply, hydroelectric power generation, or other environmental objectives. Therefore, the impact of dams on flood hazard will alter depending on different reservoir operating purposes. However, to ensure the safety of the dam structure and downstream areas, the water level of dams is usually not allowed to exceed the flood control pool level before flood events. It is reasonable to assume that dam operating rules simplify considerably during extreme flood return periods.

***Other anthropogenic activities and flood hazard***

Climate change impacts are revealed in Nigeria as increased occurrences of dry spells and off-season rains which have caused variations in planting seasons in a country that depends mainly on rain-fed agriculture (Ologeh *et al.,* 2018). Climate projections indicate changing conditions in Nigeria, with the dryer regions experiencing more aridity with longer dry spells while the humid regions will experience much more intense precipitation during the rainy season leading to more flooding events (Olaniyi *et al.,* 2013). Nigeria experienced its worst flooding in recent history, wherein around 363 people died, more than 2.3 million people were displaced, and 16 million people were impacted (Echendu, 2022). This flooding received national and international attention due to its magnitude, as 32 out of Nigeria's 36 states were affected.

Human activities that contribute toward the frequent occurrences of floods include industrialization, technology development, urbanization, deforestation, burning fossil and agricultural activities. Other human-caused factors include poor waste management systems, poor or non-existent drainage systems, weak implementation of planning laws, and corruption (Nnaemeka-Okeke, 2016). Climate change is making weather less predictable, especially in developing countries like Nigeria where facilities to predict and manage weather conditions are not adequate. Nkwunonwo *et al.,* (2015) assessed flooding and flood risk reduction in Nigeria intending to determine the cardinal gaps. The study observed that flooding has become a frequent hazard in Nigeria due to some human-induced factors such as rapid population growth, urbanization, and poor urban planning. Similarly, Nwigwe and Embergo (2014) assessed the causes and effects of floods in Nigeria and revealed that building of illegal structures on or across drainage channels, land reclamation or encroachment, poor physical planning, inadequate drainage channels, blockage of canals and drains, and collapsed dams were the primary causes of flooding in major cities and towns in Nigeria. Figure 4 below shows a typical example of city inundation in Kogi State.

Figure 4: Flood in Kogi State, Nigeria

**Suggestions for Flood Mitigation Actions at HRV**

i. **Adoption of improved flood forecasting and warning system:**
   - An improved flood warning system and strategy need to be installed.
   - The aim was to give people more time to take action during flooding, potentially saving lives.
   - Advance warning and pre-planning can significantly reduce the impact of flooding.

ii. **Increase spending on flood defences:**
   - Construction of wing dykes are slats that are placed on either side of the channel. This helps reduce the risk of flooding by getting water away from an area at risk of flooding as quickly as possible, preventing a buildup of water.
   - Rehabilitation should first be considered in resolving poorly maintained dams in Nigeria and this can be planned to be achieved over a specified period.

iii. **Developing flood management plans and strategies:**
   - There is a need to develop a formal framework or guidelines for analyzing the changes in flood risks that can occur due to ageing to avoid a potential increase in flood risk after a structure is decommissioned.
   - Adopting flood inundation modelling tools thereby gaining insight and subsequent mitigation

action. The flood hazard maps produced by these models can provide valuable information for flood risk managers.
   - Need for a flood risk awareness campaign to educate and raise the consciousness of the communities vulnerable to potential flood risk.
   - Specific early warnings from mass media were another contributing factor that can reduce flood disaster fatalities.
   - Adopt integrated water resources management (IWRM) approach that combines reservoir management with land use planning, flood forecasting, and emergency response strategies is crucial for minimizing flood risks and maximizing the benefits of existing reservoirs of HRV.

iv. **Restore rivers to their natural courses:**
   - Dredging/clearing of typhagrass and sand along the stretch of minor and major rivers
   - In a situation where a dam becomes undesirable and hazardous to an economic, environmental, and social public, there is a need to decommission it.

v. **Conduct a vulnerability analysis:**
   - Hydrologic and hydraulic modelling can help estimate current flood risk and potential future risk with climate-induced changes while presenting the data in an easy-to-understand graphical format.
   - These flood modelling toolboxes include many resources to choose from, helping to identify the appropriate level of detail for each request.
   - The modelling produces maps that indicate where flood-prone areas are located, which can then be confirmed with past observations and used to evaluate alternatives to minimize flooding.

vi. **Implement mitigation projects**:
   - Projects that focus on improving stormwater management or reducing flood risk from a major river can be effective ways to mitigate flooding.
   - These projects include traditional and innovative practices and can consist of levees, floodwalls, impoundments, improved conveyances, wetland restoration, acquisition of flood-prone properties, and even stormwater harvest and reuse.
   - Water resources engineers can combine their experience with new data and tools to identify the best flood mitigation practices for every community.

vii. **Provide public outreach and education:**
   - More work has to be done to enlighten people living in flood-prone areas on the flood-related dangers.
   - Need to develop accessible and easy-to-use tools for estimating and understanding flood risk.

**viii. Preparedness activities:**
   - These are intended to achieve a sense of readiness for the flooding emergency which includes the following:
   - emergency preparedness plans should be tailored to address the specific needs of the community.
   - Communities are required to develop a hazard mitigation plan and update it every five years, but that does not mean these communities are covered.
   - Engage neighbouring communities and all parties expected to contribute to the response process so they can provide useful feedback and understand their role.
   - Ensure flooding-related issues and projects are identified in the plan to ensure eligibility for funding programs.
   - Conduct an emergency exercise to identify deficiencies in your plan and update it accordingly.
   - Like the planning process, engage neighbouring communities who can provide mutual benefits by sharing and/or swapping critical resources.
   - Using the developed games to make this activity more enjoyable and effective.

## CONCLUSIONS

This review has illuminated the intricate interplay between anthropogenic activities and flooding events from local and global experiences although with more emphasis on local incidences. The evidence presented underscores the undeniable impact of human actions, such as urbanization, deforestation, and improper land use, in exacerbating the frequency and intensity of floods. These activities alter natural drainage patterns, reduce water absorption, and amplify runoff, resulting in heightened flood risks. Additionally, the study demonstrates the significance of effective mitigation measures, such as sustainable urban planning, afforestation, and improved infrastructure, in mitigating the adverse effects of anthropogenic influences on flooding. The complex and multifaceted interplay between reservoir utilization and floods was also reviewed and critically analyzed. It was observed that reservoirs can serve as flood control facilities and also exacerbate flooding events. This depends largely on various factors such as capacity, operation strategies, and the characteristics of the upstream watershed. Research indicates that well-managed reservoirs can help control flooding by capturing excess water during heavy rainfall and gradually releasing it, thereby reducing the downstream flood peak. However, if reservoirs are not managed properly, they can contribute to flooding by releasing water too quickly or by reaching capacity during intense rainfall events. It is, therefore, essential to consider the location, design, and operation of reservoirs, as well as their role within the larger watershed management context. An integrated approach that combines reservoir management with land use planning, flood forecasting, and emergency response strategies is crucial for minimizing flood risks and maximizing the benefits of existing reservoirs of HRV.

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