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BIOPHYSICAL VULNERABILITY TO FLOOD IN THE DOWNSTREAM OF THE KUBANNI DAM, KADUNA STATE

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Abstract
Biophysical flood vulnerability analysis of downstream communities was conducted in the study area was classified into low, moderate and high flood vulnerable areas. The size of farmland declined from 6.222km2 in 1990 to 5.433km in 2020. The result also shows that the total area liable to flooding is about 5.477km2. The finding show that the floodable area increased in area extent from the dam breach outlet to the downstream outlet of Kubanni basin. Given percentage of the downstream area of the dam are highly vulnerable because of the flat terrain especially Tudun Wada, Sabon Gari and Gyallesu to the confluence with the Galma River.
Keywords: Vulnerability, Flood, Downstream and Kubanni

1. INTRODUCTION

Globally, a disaster related to a weather, climate, or water hazard has occurred every day on average over the past 50 years, killing 115 people and causing USD 202 million in losses daily (Yu and Jung, 2022). In the period between 1970 and 2019, there were more than 11,000 reported disasters attributed to climate and water hazards globally, with just over 2 million deaths and USD 3.64 trillion in losses, according to a comprehensive new report from the World Meteorological Organization (WMO) (WMO 2021). In the Sub-sahara Africa it has been reported that climate change impacts are becoming more intense and frequent than ever, as the observed impacts of climate extremes have increased and this is reinforcing poverty, affecting more than 40 % of the region's 360 million people (Trisos et al., 2022). One area of severe impact is agriculture as several studies have reported the consequences of climate extreme events on the agricultural sector, which is the main source of livelihood for many people in SSA (Ajetomobi, 2016, Ficchi et al., 2021, Fuller et al., 2018, Humphries et al., 2020, Wainwright et al., 2021). The observed impacts of climate change on yields of most widely produced crops in sub-Saharan Africa (millet, maize, sorghum, and rice) have been reported by many studies (Hadebe et al., 2017, FAO, 2018, Amouzou et al., 2019, , Atiah et al., 2022, Nyamekye et al., 2021, Oluwaranti et al., 2020). Climate change is not only affecting human activities but also the livelihoods of many people, with SSA being regarded as the region most vulnerable to climate change (Cuthbert et al., 2019). This is because key livelihoods depend on rainfall, as nearly 80 % of the agricultural land and crop production in this part of the world is rain-fed (Gérardeaux et al., 2018, Sarr et al., 2021). From 1970 up until recent years, nearly 14 % and 22 % of the East and West African populations respectively have been affected by extreme climate events such as windstorms, and multiple effects of drought including extreme temperatures (Diakite et al., 2020, Ekwezuo and Ezeh, 2020, Gebrechorkos et al., 2020). Other similar studies have established a warming trend through extreme heat events, with changes in patterns and amounts of rainfall (Ongoma et al., 2018, Rahimi et al., 2021, Marcotullio et al., 2021, Iyakaremye et al., 2022). Damage from flooding is also expected to increase in the future depending on adaptation efforts (Yu and Jung, 2022). Despite the improvements in flood mitigation measures and technological advancements, floods continue to endanger human lives (Cornwall, 2021). This is mainly due to the increasing human settlements and economic assets in floodplains, land-use change, and climate crisis (Sass et al., 2019, Faccini et al., 2021, Stefanidis et al., 2022). According to the sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC), projected increases in direct flood damages are higher by 1.4 to 2 times at 2 °C and 2.5 to 3.9 times at 3 °C compared to 1.5 °C global warming without adaptation. At global warming of 4 °C, approximately 10% of the global land area is projected to face an increase in both extreme high and low river flows in the same location, with implications for planning for all water use sectors (IPCC, 2022). According to the United Nations Environment Programme (UNEP) Adaptation Gap Report 2016, such increasing impacts will result in increases in global adaptation costs. It has been estimated that by 2030, these costs will amount to between USD 140 billion and USD 300 billion annually and by 2050 to between USD 280 billion and USD 500 billion (UNEP, 2016). Climate change impacts are not uniform in characteristics, frequency, and magnitude across the globe. This is because some areas are more vulnerable to certain impacts compared to others on the bases of geographic location, ecological conditions, and economic status (Malik et al., 2012, Malhi et al., 2020). Most developing countries are more vulnerable to climate change impacts because a large population of rural dwellers are economically deprived and depend mostly on rain-fed agriculture (O'Brien et al., 2004, Okon et al., 2021). Farmers and fishermen are most vulnerable because farming and activities are easily disrupted by climate change impacts such as changes in rainfall patterns, flooding, sea-level rise, and drought (Gizachew and Shimelis, 2014). Poverty further reduces the adaptive capacity of low-income people to adjust to climate change impact (Malakar and Mishra, 2016).

IPCC, (2007) defines vulnerability to climate change as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes". Patwardhan et al, (2007) similarly defined vulnerability to climate change as "the degree to which geophysical, biological and socio-economic systems are susceptible to and unable to cope with, adverse impacts of climate change". Vulnerability is seen as a function of "exposure", "sensitivity" and "adaptive capacity" (IPCC, 2007). Exposure is seen as the extent to which a system experiences internal and external system perturbation, pressures, or changes (Menezes et al, 2018). Sensitivity is defined as the degree to which a system is affected or will respond to system perturbations or changes (such as a change in climate) either positively or negatively (IPCC, 2001). Such changes could be either long-term changes in climate conditions, or changes in climate variability, which includes the magnitude and frequency of occurrence of extreme climatic events (O'Brien et al, 2004). Adaptive capacity is defined as the ability of a system to adjust its behavior and characteristics to enhance its ability to cope with external stress (Brooks, 2003). It is considered "a function of wealth, technology, education, information, skills infrastructure, access to resources, and stability and management capabilities" (IPCC, 2001).Flood prone area such as areas downstream of Kubanni Dam in Kaduna State are particularly vulnerable to climate change given its extensive river network, rapid landuse and land cover modification, and the high population of people dependent on agriculture and fishing. Beside the climate drivers, the geological, hydrological and social (e.g., growing population rate in urban areas) and structural (e.g., urbanization rate, sewage system) factors which are expected to be on the increase will directly contribute to increase the vulnerability of populations in flood prone areas and limit the soil absorption capability, exposing local communities to pluvial flood events (Bacciu et al., 2020).For any meaningful water resources development project in the basin leading to climate change adaption, it important to understand levels biophysical vulnerabilities to determine appropriate policies and interventions for different ecological regions characterized by different socio-economic levels.

2. MATERIALS AND METHODS

Study Area

The study area is located within the Kubanni drainage basin between Latitudes 11º06' to 11º07'N of the Equator and Longitudes 7º40'-7º40'E of Greenwich Meridian (1). The study area is located within two LGAs, namely; Zaria and Sabon Gari. It is situated in the northwest of Zaria in Kaduna State. However, the specific area under study lies downstream of the Kubanni Dam to the confluence with the Galma River, Zaria. The climate of Kubanni basin is typical of climate in Zaria and Environs. It is described as Aw climate with distinct wet and dry seasons (Hore, 1970).The Characteristics of the climate are determined by oscillations of two contrasting air masses; tropical maritime and tropical continental air masses. The tropical maritime originates from Gulf of Guinea and ushers in rainy season. The tropical continental originates from Sahara deserts and ushers in the dry cold and dusty season called the harmattan that occasionally limits visibility and reduces solar radiation (Hore, 1970). The area is underlain by Pre-Cambrian rocks which lie in the mobile zone between the West African and Congo Cratons. These Pre-Cambrian rocks consist of migmatites, gneisses and northsouth trending meta-sedimentary rocks, intruded by a series of granitic and mafic-ultra- mafic rocks of late Pre-Cambrian to early Palaeozoic age as McCurry (1973) report evidence of complex structural patterns such as joints and faults, form largely by invading granitic plutons in the Basement belonging to the widely distributed Pan-African magmatic suite present. Kubanni River has its source from the Kampagi hill, in Biye, near Zaria. It flows in southeast direction through Ahmadu Bello University and joins river Galma at the confluence north-west of ABU Main campus in Sabon Gari. Kubanni basin system is ephemeral, intermittent and assumes a dendritic pattern which is deeply incised by numerous systems of gullies (Ologe, 1971; Bello, 1973). The most prominent land use practice in the study area is agricultural land use which are cultivation and animal husbandry. This is because the economic base of virtually all rural and semi urban settlement in northern Nigeria is agriculture and it is subsistent. The use of land for agricultural activities is influenced by several factors such as land per resident ratio and location of soil quality. As the land per resident ratio increases (population density increases) the percentage of land in fallow decreases due to increase in farming activities. The increase in intensity in land use as population density increases creates problem in maintenance of soil fertility.

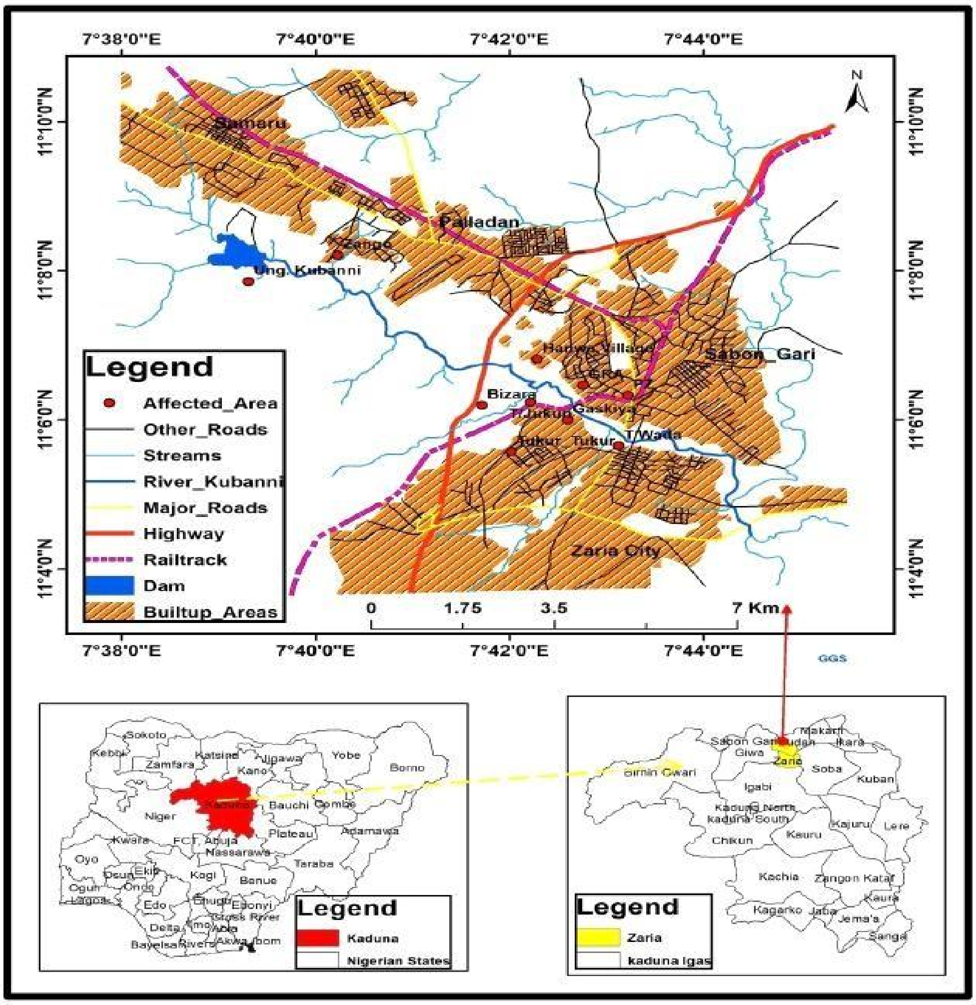

Figure 1: The Study Area showing downstream of Kubanni Dam.
Source: Modified from Google, 2022**.**

Datasets and Sources

The study used both primary and secondary data. Landsat OLI TIRS image and Landsat ETM+ images spanning from 1990, 2000, 2010 and 2020 were obtained from USGS GloVis (http://www.glovisusgs.gov) free of cost.This set of data was used to assess LU/LC change in a GIS environment and determine the land use that is vulnerable to flood disaster. Sufficient numbers of GPS coordinates using spatial reference system of NGS 84/UTM Zone 32N were collected in the field to train the maximum likelihood algorithm for proper supervised classification of 1990, 2000, 2010 and 2020 Landsat Imageries. Some of the collected GPS coordinates were also used for the ground trothing during accuracy assessment. A high Resolution Satellite imagery Quick bird data (60cm resolution) 2017 was to extract relevant features for risk and vulnerability analysis. Google Earth including its "show historical imagery" function was also used in assisting classification and accuracy assessment of Landsat images of the study area and extract different features on the ground. Direct field observation was carried out during the reconnaissance survey to get information about possible LULC classes in which the study area can be classified into. It was used to verify the data obtained through change detection. Topographic map Zaria sheet 102 1969 was used to delineate the flood plain (downstream).

Data analysis

The processing and analysis of Landsat Images and all the other GIS data was done using ERDAS imagine 2015, Arc GIS 10.3, while all the numerical data was analyzed using MS Excel. Determination of the Level of Vulnerability of the Settlement and the People downstream of the Kubanni Dam after the unsteady 2D flow analysis was completed, the area inundated by the 2D flow was exported into ArcGIS for further flood hazard and risk analysis. The various land uses affected by the inundation were determined in ArcGIS, by overlaying the inundation map over the land use map and then clipping off the areas affected by the flooding. The results were then exported and computed in excel with their area and percentage coverage. Dam breaks are modeled using the inline structure editor. Inline structure editor allows the user to input an embankment, define overflow spillways and weirs, and gated openings. Gate openings can be controlled with time series of gate openings or using the elevation control gate operation features. The vulnerability of individuals and communities to flood can be assessed by adopting either or both of biophysical and socio-economic flood vulnerability concepts (Cutter, 2000). The emphasis of this study is on biophysical flood vulnerability on exposure factor, which Balica (2012) defined as the predisposition of individuals and communities to be disrupted by a flood event due to its location in the same area of influence. This study adopts the work of Obafemi and Nwankwoala (2019) that considered the proximity of building to active river channels as a factor that determine flood vulnerability to examine the number and percentages of building located 100m, 200m, 300m, 400m, 500m and 600m away from the Kubanni river. Subsequently, building located 100-499m from river Kubanni were classifies as moderately vulnerable to flood and 500m-600m as less vulnerable to flood.

3. RESULTS AND DISCUSSION

The flood vulnerability of buildings/farmlands based on their proximity to River Kubanni is presented in Table 1. and Figure 2. The result showed that a total of 2,467 buildings (19.4% of houses)/ 4.5ha (50.56%) of farmland are found within 200m proximity to River Kubanni and are classified as highly vulnerable Another 5,476 (42.9%)/2.4ha (26.96%) buildings/farmland have moderate vulnerability to flood and are located within 200m to 400m from River Kubanni. A total of 4,807 (37.7% of house)/2.0ha (22.48) buildings /farmlands have low flood vulnerability and are found within 400m to 600m from River Kubanni. This corroborates the finding of Ahmed (2019) that assessed Ajiwa dam flood vulnerability where the dam was buffered with 500m while the river was 300m buffered. The result shows that five (5) settlements were located within the flood vulnerable areas. This is also similar to the finding of Ikusemoran and Adegoke, (2014) who identified flood risk and vulnerability of communities in the Benue floodplains, Adamawa which was caused from the Lagdo dam in Cameroon, over 120 communities were identified as vulnerable communities.

Table 1: Flood Vulnerability due to Proximity of Buildings to Kubanni River

Proximity to River Kubanni (m)	Number of Buildings (Built up)	%	Farmland (ha)	%	Vulnerability level
100-200	2,467	19.4	4.5	50.56	High
200-400	5,476	42.9	2.4	26.96	Moderate
400-600	4,807	37.7	2.0	22.48	Low
Total	**12750**	**100**		**100**	

Source: Author's Analysis, 2021.

Although the number of buildings tends to decrease with increasing proximity to the river, however, several houses were found to be within the flood plain and this shows that most of the flood plain has been taken over by urbanization. Most of the buildings with close proximity to the Kubanni River are around Tudun Wada, Sabon Gari, Gyellesu and Hanwa where there is stiff competition for the scarce land. The attraction the floodplain offers for human development is due to the presence of rich soil for agricultural purposes. Hence, people tend to move to settle right on the plain to engage in farming activities, particularly around Tudun Wada and Gyellesu where the floodplain is very extensive. This result is in line with the finding of Indrawan & Siregar (2018) which revealed that the flooded areas due to the overflowing of Deli River consisted of seven subdistricts. This result also corresponds with the finding of Kissi (2014) on flood vulnerability assessment of the downstream part in the Mono River basin in the Yoto district South – eastern Togo. Result revealed the closeness of households' farmlands to the river body, the type of construction and the position of settlements, the household size, the low level education of household head, the lack of diversification of livelihood strategies, the lack of adequate flood warning system and lack of willingness and ability to take responsive actions coupled with inadequate emergency services, are identified as main determinants increasing communities vulnerability to flood disaster. The result further corresponds with findings of Romaneseu, et al., (2018) that the vulnerability of the population and building of a village situated in the eastern part of the eastern Carpathians. The results revealed that 58 dwellings with high vulnerability will be affected in the case of a flood with an exceeding probability of 5%. Regarding farmland, at 100m a total of 28.09% of farmland was inundated, 22.47% at 200m, 1.3 at 300m, 14.6% at 400m, 11.24% at 500m and 11.24% at 600m respectively. This is mainly because the flood plain has also been taken over by extensive cultivation. This result further corresponds with Membele et al.,

(2021) which revealed that exposure to flood hazard was the most common (99%) used in mapping flood vulnerability in developing countries. Most of the studies revealed (78%), however, combined more than one element. Flood vulnerability was considered in this study as the extent of exposure of houses, farmland and wetland cultivation to a potential flood inundation from the dam breaks analysis with regard to the proximity of buildings farmlands to the Kubanni River. The vulnerability is shown in Table 4.4, Figure 4.7 and 4.8. The results showed that a total of 12,750 buildings are within 600m distance to the Kubanni River and are vulnerable to flood hazard due to dam break. Results revealed the work of Ingle and Chattopadhyay, (2022) that application of spatial mapping of physical infrastructure ascertains visualization of highly vulnerable zones in diverse setting requiring exploration. This is because all of these buildings are located downstream of the dam and in close proximity (in some cases within) to the floodplain. The built up area was estimated at 100m to be 0.2 km^2,at 200m 0.6km^2, at 300m 1.1 km^2, at 400m 1.3 km^2, at 500m 1.3 km^2 and at 600m 1.4 km^2 respectively. This showed that the settlement is expanding away from the river channel due to competition for farmland with rich soil. Other land uses such as shrub land and bare land were not significant in terms of area coverage hence they were ignored in this analysis. This is because as observed from the fieldwork and data analysis, they are mostly situated in the low-lying floodplain. Most of the farming activities, shrub land and bare land are mostly in the upland area of the basin which account for the low area of coverage by the potential flood inundation from a dam break.

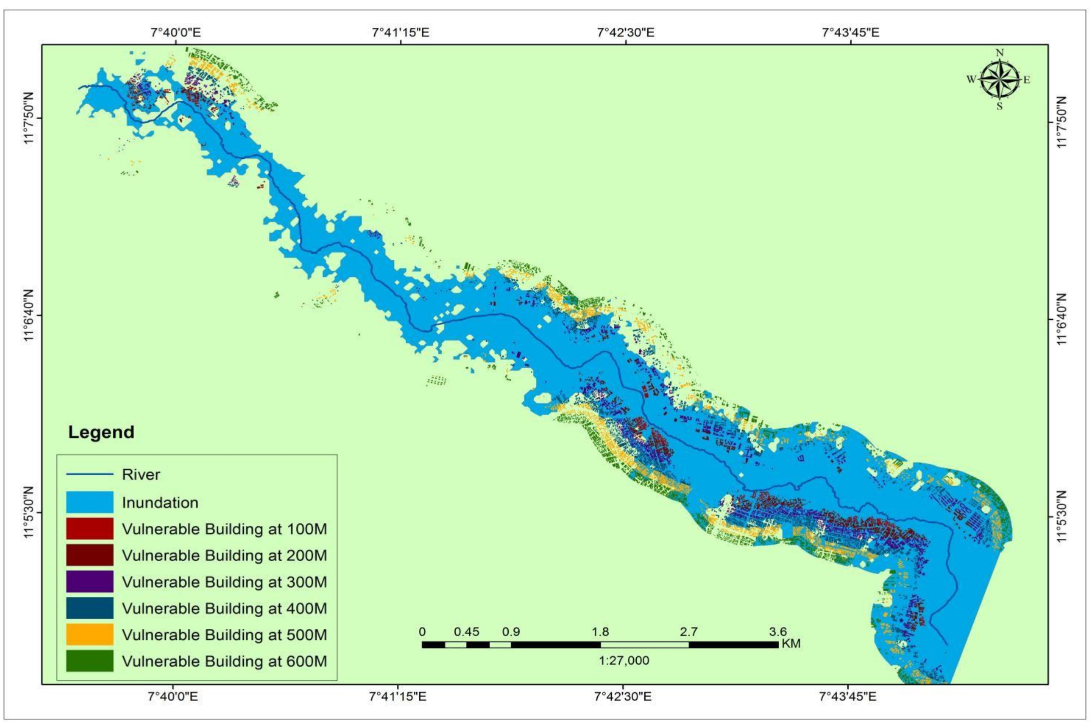

Figure: 2 Vulnerability of Buildings and Farmlands
Source: Author's Analysis, 2021

4. CONCLUSION AND RECOMMENDATIONS

Most of the area downstream of the Dam is highly vulnerable because of the flat terrain especially between Tudun Wada, Sabon Gari, down Gyallesu to the confluence of the Galma River. The study concludes that a total of 12,750 buildings are within 600m distance to the Kubanni River and are vulnerable to flood hazard should here be a break. The study also concludes that built up is increasing away from the river channel due to the competition for land. The study also conclude that the most affected areas will be Tudun Jukun with about 2,699 buildings (25%), Gyallesu with about (20.2%), Tudun Wada with about 1.851 buildings (17.2%), Hanwa with 984 buildings (9.1%), parts of Sabon Gari with about 918 buildings (8.5%), Zango with about 845 buildings (7.8%) and the Government Reserved Area (GRA) with about 772 buildings or 7.2% of the total number of affected buildings in the event of any flooding due to the breach of the Kubanni Dam. The study recommends there is the need to prevent and mitigate the likely effects of flooding due to dam break by frequently releasing water from the dam through the spill way by the dam authorities.

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