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Nature and Extent of Flood Risk Downstream of the Kubanni Dam, Kaduna State, Nigeria

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ABSTRACT

Several communities reside downstream of Kubanni Dam, thereby making them vulnerable to flood. However, the levels of vulnerability, areas, households, and buildings at risk of flooding downstream of Kubanni Dam remain unknown. This study employed Geographic Information System (GIS) techniques to identify areas and buildings at risk in the event of a breach of the Kubanni Dam. Areas liable to flood were delineated using ArcGIS software. Findings from the study revealed that in the event of any flooding due to the breach of the Kubanni Dam, the most affected areas would be Tudun Jukun, with about 2,699 buildings (25%), Gyallesu with about 2,180 (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 representing 7.2% of the total numbers likely to the affected. The results further showed that the Tudun Jukun area, with a population of 38,622, is located in a flood-risk area, followed by Tudun Wada, with a population of 26,487, which is also at risk. It was also found that the PZ area, with 4,997 households and 1,851 houses at risk of flooding, has the highest average number of persons per Hectare (68902.02) at risk of loss in the event of flooding. This study has demonstrated the effectiveness of GIS techniques in flood risk and vulnerability analysis as well as its potential in guiding physical planning and flood disaster risk reduction.

KEYWORDS

Disaster, security, extent, flood risk, downstream, Kubanni Dam, GIS.

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1. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) defined "climate change" as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods (2007). Climate change involves heightened temperatures, changes in precipitation trends, and other environmental components, such as pressure and humidity levels, across numerous regions (Weisheimer & Palmer, 2005; Battisti & Naylor, 2009; Yadav et al., 2015; Schuurmans, 2021). Apart from irregular weather patterns, the retreating of global ice sheets, and the corresponding elevation of sea levels, fluvial floods have also been reported as an important signature of climate change (Lipczynska-Kochany, 2018; Murshed and Dao, 2020; Michel et al., 2021). Floods have increased in frequency over the last few decades, resulting in severe events, with the average annual global cost estimated to be US$104 billion (Desai et al., 2015). Many studies have reported an increase in extreme rainfall and sea levels, which play a dominant role in the rise of severe floods (Aerts et al., 2018; Hudson et al., 2019). According to the IPCC (2018), projected increases in the frequency and severity of climate-related events, such as floods, are likely to increase the risk of disasters.

Floods are considered the most common and destructive natural disasters worldwide, accounting for approximately 20% of global natural disaster losses and posing a significant threat to human society's survival and development (Fang et al., 2015). Dilley (2005) estimated that more than one-third of the world's land area is vulnerable to floods, affecting approximately 82% of the world's population. According to statistics, in 2023, floods resulted in the deaths of approximately 7,600 people worldwide. However, this death toll is dwarfed in comparison to the peak recorded in 1999, when some 35,000 people died as a result of floods (Salas, 2024). According to UNHCR (2024), climate change exacerbates the risk of displacement. The past decade saw, on average, 24 million displacements caused by disasters every year: 92 per cent were triggered by weather-related hazards (with floods accounting for nearly half of these), and the rest by geophysical hazards, such as earthquakes. In 2023, floods caused 9.8 million displacements. Additionally, global economic exposure to flooding is expected to triple by 2050 due to the growth of populations and economies in flood-prone regions (Jongman et al., 2012).

In Africa and Nigeria, the pattern of flooding is similar to that observed globally. Floods are a major environmental problem that has been seriously affecting cities and villages in recent times, causing damage to property and loss of life in the country (Adegboyega et al., 2018; Nigeria Hydrological Services Agency, 2020; Okon et al., 2021; Echendu, 2021). Damage and losses to properties, including farmlands, and the economy have been identified as the two most devastating effects of floods (Adetunji & Oyeleye, 2013; Otomofa et al., 2015; Egbinola et al., 2017; Chinwendu et al., 2017; Eze et al., 2018). Poverty and increases in the prices of commodities are believed to result from flooding (Umar & Grey, 2022). The hazards tend to affect riparian communities in developing countries due to their increasing vulnerability and low adaptation capacity, as well as the fact that most occupations of the population living in West Africa are climate-sensitive. It is expected that changes in precipitation patterns (e.g., extreme rainfall) prompted by climate change will increase the intensity and frequency of weather-related disasters, including flash floods, riverine and coastal flooding, and pluvial floods, in many regions (Asadieh & Krakauer, 2017). Hence, there is a need for risk assessment, which will inform policies for sustainable water resource management and flood control, as well as ensure the safety of people's lives and properties.

Several communities in Nigeria are vulnerable to flood, though their levels of vulnerability vary spatially. Hence, studies have been conducted to determine the flood risk and vulnerability levels of different communities across Nigeria using various methods, including statistical modelling and Geographic Information System (GIS) techniques. Iftikhar and Iqbal (2023) asserted that flood risk can be mitigated through flood forecasting and mapping of flood-prone areas. Identifying flood-prone areas is crucial for effectively managing flood risks (Rebouh et al., 2024). Therefore, Isma'il and Saanyol (2013) developed a GIS-based flood vulnerability map to identify areas vulnerable to flood disasters around River Kaduna in Nigeria. Similarly, Shuaibu et al. (2022) developed a GIS-based flood risk and vulnerability mapping assessment to outline scenarios that reduce risk and vulnerability associated with floods in the Hadejia River basin, Nigeria. GIS is the use of computer tools (software, hardware) and appropriate geospatial techniques for the analysis of geographic (geospatial) data. Ndanusa et al. (2022) attempted to quantify vulnerability indicators and develop a multidimensional approach for flood vulnerability assessment in Mokwa, an area inhabited by downstream communities of the Kainji Dam in Niger State, Nigeria, using a participatory approach and Geographic Information Systems (GIS). The study concludes that the multidimensional approach to flood vulnerability provides information on both the vulnerable population and the factors driving vulnerability in the area. Gabriel et al. (2022) presented an approach for assessing the relative impact of such land use changes on economic flood damages and associated risk. The results of the comparative flood risk assessment using the proposed framework indicate the potential for identifying optimal locations in catchments for reducing off-site flood damage and minimising flood risk increment (Gabriel et al., 2022). Aladejana and Ebijuoworih (2024) presented a multifaceted approach and methodology to generate a statewide flood risk map by analysing both flood vulnerability and flood hazard factors. This study delineated flood risk by integrating flood hazard and flood vulnerability within Kogi State, Nigeria. They discovered that out of 295 villages, 65 are located in the high flood risk zone.

Umar and Gary (2023) asserted that flooding in Nigeria is an annual problem, but the adverse impacts can be mitigated through effective management. Therefore, studies on flood risk management are extremely valuable for effective flood disaster risk management. The downstream of Kubanni Dam falls within northern Nigeria, a region that has been identified as the most affected by flooding, where flood risk management should be focused (Umar & Gary, 2023). Additionally, several communities reside downstream of the Kubanni Dam, thereby making them vulnerable to flooding. However, the levels of vulnerability, areas, and households and buildings at risk of flooding downstream of Kubanni Dam are still unknown. It is on this premise that the present study is designed to assess the nature and extent of flood risk at locations downstream of the Kubanni Dam in Kaduna State, Nigeria, to provide information on the areal extent and the number of buildings at risk of flooding in the study area. The study will also provide relevant information that will aid in physical planning, guide disaster management agencies towards targeted interventions, and inform disaster risk reduction policies for effective disaster risk management in Nigeria.

2. Materials and Methods

2.1. 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 (Figure 1). The study area is located within two Local Government Areas (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 the Kubanni basin is typical of the climate in Zaria and Its Environs. It is described as an Aw climate with distinct wet and dry seasons (Hore, 1970). Oscillations of two contrasting air masses determine the characteristics of the climate: tropical maritime and tropical continental air masses. The tropical maritime originates from the Gulf of Guinea and ushers in the rainy season. The tropical continental climate originates from the Sahara Desert and ushers in the dry, cold, and dusty season called the harmattan, which 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.

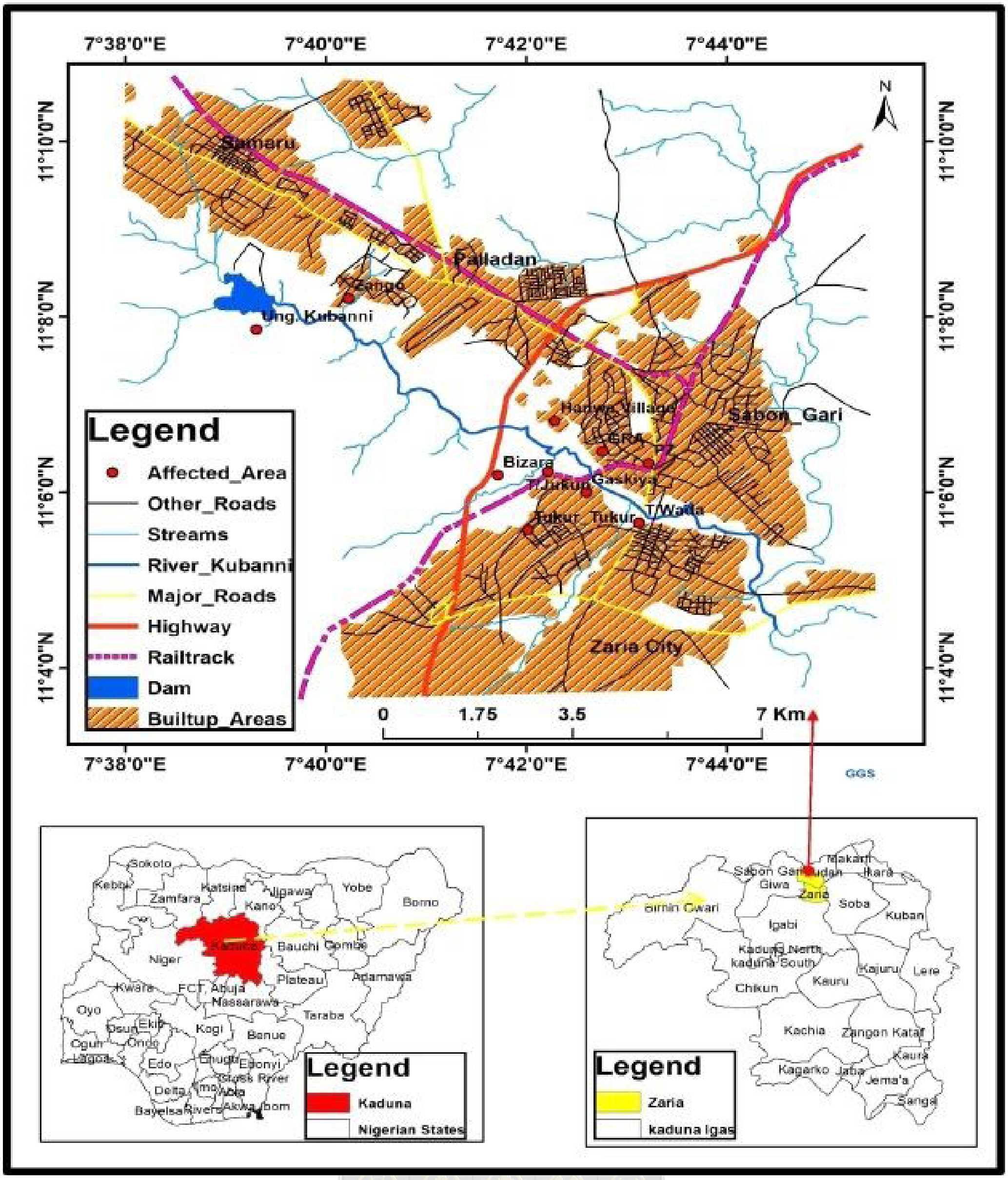

Figure 1. The Study Area is shown downstream of Kubanni Dam
source: Modified from Google Maps, 2022.

These Pre-Cambrian rocks consist of migmatites, gneisses and north-south trending meta-sedimentary rocks, intruded by a series of granitic and mafic-ultramafic rocks of late Pre-Cambrian to early Palaeozoic age as McCurry (1973) reported evidence of complex structural patterns such as joints and faults, formed mainly by invading granitic plutons in the Basement belonging to the widely distributed Pan-African magmatic suite present. The Kubanni River has its source on the Kampagi hill in Biye, near Zaria. It flows in the southeast direction through Ahmadu Bello University and joins river Galma at the confluence northwest of ABU's Main campus in Sabon Gari. The Kubanni basin system is ephemeral, intermittent, and exhibits a dendritic pattern, which is deeply incised by numerous gully systems (Ologe, 1971; Bello, 1973). The most prominent land use practice in the study area is agricultural land use (Ezenwa et al., 2022a), which is cultivation and animal husbandry. This is because the economic base of virtually all rural and semi-urban settlements in northern Nigeria is subsistence agriculture. The use of land for agricultural activities is influenced by several factors, including the land-to-resident ratio and the location of the soil. As the land-to-resident ratio increases (population density increases), the percentage of land in fallow decreases due to an increase in farming activities. The increase in land use intensity as population density rises creates problems in maintaining soil fertility.

2.2. 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 Land Use Land Cover (LULC) change in a GIS environment and determine the land use that is vulnerable to flood disasters. A sufficient number of GPS coordinates using the NGS 84/UTM Zone 32N spatial reference system were collected in the field to train the maximum likelihood algorithm for proper supervised classification of Landsat images from 1990, 2000, 2010, and 2020. Some of the collected GPS coordinates were also used for the ground truthing during accuracy assessment. High-resolution satellite imagery, QuickBird data (60cm resolution) from 2017, was used to extract relevant features for risk and vulnerability analysis. Google Earth, including its "show historical imagery" function, was also used to assist in the classification and accuracy assessment of Landsat images of the study area and to extract different features on the ground. Direct field observation was conducted during the reconnaissance survey to gather information about the possible land use/land cover (LULC) classes into which the study area can be classified. It was used to verify the data obtained through change detection. The topographic map Zaria sheet 102, 1969, was used to delineate the floodplain (downstream).

The present study applied GIS techniques to determine the nature and extent of flood risk downstream. Isma'il and Ndanusa (2022) proposed a geospatial data mining approach for effective flood risk management, as geospatial techniques can determine elements at risk and the spatial extent of vulnerability. The maximum likelihood supervised classification method was adopted by Ezenwa et al. (2022a), where it was used to process satellite images and determine the Land Use and Land Cover (LULC) classes for the Kubanni drainage basin landscape.

2.3. Data Analysis

The processing and analysis of Landsat Images and all other GIS data were done using ERDAS Imagine and ArcGIS software, while all numerical data were analysed using MS Excel. To achieve the nature and extent of flood risk in the study area, a water surface Triangulated Irregular Network (TIN) was generated to delineate the floodplain. The floodplain delineation was created using a polyline theme to identify the floodplain and a depth grid. The water depth grid was created by subtracting the rasterised water surface TIN from the Terrain TIN. Then, the flood risk was divided into the hazard component and the vulnerability component. The vulnerability assessment was facilitated by the use of a binary model based on the presence or absence of a flood of a particular intensity in a specific land use type. Initially, the Kriging interpolation method was used to estimate the bathymetry. However, because Kriging provides a smooth representation of reality and has implications for subsequent computations (volume, area), the simulation method (turning bands) was subsequently employed. For a better understanding of the potential impacts of a dam break in the study area, it is essential to understand the general land use and land cover of the area. To achieve this, the following datasets were created:

a. Land use and Landover of the Kubanni Dam Area:

The land use and land cover of the area were created by extracting information from a high-resolution satellite image of the area. The primary land use and land cover types identified in the image were built-up areas, bare land, farmland, shrubland, forest, and wetlands. This land use/land cover represents the significant elements that could be at risk of flooding within the Kubanni basin in the event of a dam breach.

b. Proximity Analysis of Buildings to River Kubanni.

Proximity analysis is a neighbourhood operation in GIS that creates buffers around features within specified distances. In this study, a proximity analysis was carried out using the distance operation in ArcGIS Spatial Analyst. The operation created buffer zones at 100m intervals for the 600m study extent (i.e., 600m downstream of the Kubanni River at 100m, 200m, 300m, 400m, 500m, and 600m, respectively). The buffer zones were then overlaid on the flooded area dataset to extract the extent of flood vulnerability within a given distance of 100m to 600m from the Kubanni River. In addition, the study area was based on the settlements in the area, as follows: Zango, Aviation, Graceland, Hanwa, Tukur-Tukur, GRA, Sabon Gari, Tudun Wada, Gyellesu, and Angwan Kaya. This was done to show which of these areas was more at risk and likely to be more affected by a dam breach.

c. Overlay of the Flood Inundation over the Buildings/Houses

The results obtained from the flood inundation were overlaid on the land use and land cover in ArcGIS. The purpose of this overlay analysis was to identify which land use and land cover, as well as buildings/houses, would be most affected in the event of water inundating the floodplain within the Kubanni basin due to a probable breach of the dam. Rebouh et al. (2024) demonstrated how GIS techniques, including overlay analysis, buffering, and interpolation, played a critical role in analysing flood susceptibility.

d. Flood Risk Analysis

Digital contour surfaces of reservoir bathymetry were performed by two interpolation methods: Kriging and simulation (turning bands) techniques. The spatial coexistence model was used for risk assessment, which involved reclassifying the floodwater depth into values ranging from 1 to 10. Thereafter, the results of these two analyses were combined for the flood risk assessment. This risk assessment process was automated using a customised graphical user interface in ArcGIS to classify flood risk into three major risk classes: low risk, moderate risk, and high risk, as done by Isma'il and Saanyol (2013) in flood vulnerability mapping and risk analysis of the River Kaduna. The risk analysis was conducted to assess the impact of risk on people's land use and land cover in the area. To assess the effects on the people, baseline data were collected, as outlined below.

i. The average number of households per building was 2.7, as documented in NPC (2009)

ii. The average household size in Kaduna State is 5.3, as contained in the document from the National Bureau of Statistics (NBS, 2019)

iii. The average amount of land occupied per person is 0.22 hectares, as reported by FAO (2006).

The application of Remote Sensing data with GIS techniques is the most common approach to flood modelling in Nigeria (Umar & Gary, 2023). Several studies have demonstrated the effectiveness of GIS in flood risk and vulnerability analysis. Shuaibu et al. (2022) developed a spatial flood risk assessment map of the Hadejia River basin. The spatial distribution of flood-risk zones in the Hadejia River basin was mapped using the Analytic Hierarchy Process (AHP) method, integrated with a Geographic Information System (GIS), to reduce the risk and vulnerability associated with floods. Ndanusa et al. (2022) recommended that a multidimensional approach to flood risk assessment is required to provide a holistic view of residents' degree of vulnerability to flooding, which can be achieved by integrating a field survey with a GIS approach.

3. Results and discussion

To determine the extent of buildings at risk of flooding, the study area was divided into twelve different settlement zones, namely Tudun Jukun, Tukur Tukur, Sabon Gari, PZ Area, Hanwa, Angwan Kaya, Aviation, GRA, Graceland, Gyellesu, Zango, and Tudun Wada. The flood extent was overlaid on these zones, and the number of buildings at risk was counted, as shown in Table 1.

Table 1: Number of Houses at Flood Risk

Zone	Number of Building	%
Tudun Jukun	2699	25.0
Tukur Tukur	46	0.4
Sabon Gari	918	8.5
PZ Area	185	1.7
Hanwa	984	9.1
Aguwan Kaya	162	1.5
Aviation	-	-
G.R.A	772	7.2
Grace Land	149	1.4
Gyellesu	2180	20.2
Zango	845	7.8
Tudun Wada	1851	17.2
Total	12,750	100.

Table 1 shows that in the event of flooding due to the breach of the Kubanni Dam, the most affected areas will be Tudun Jukun (25%), Gyellesu (20.2%), and Tudun Wada (17.2%). Tukur Tukur (0.4%) and Graceland (1.4%) have the lowest number of buildings on the floodplain. This could be because these areas are the least affected and are located on the undulating uplands of the study area. This result also supports the findings of Hosseinzadah-Tarbrizi (2022), who noted that some population centres downstream of the Sattarkhan dam in Iran face a notable risk. The arrival times of the flood, recession times, and maximum velocities in the targeted areas have been calculated to inform emergency action plans. These areas have many buildings within the floodplain, and observations during the fieldwork reveal evidence of increasing encroachment of residential buildings along the floodplain. As most of the floodplain is occupied by buildings, it would increase the rate at which the river experiences siltation, which in turn would increase the rate of flooding, thereby expanding areas that are likely to be flooded. The findings of this study corroborate those of Isma'il and Saanyol, who reported that areas falling within the flood-prone zone of River Kaduna are the most vulnerable to the flood risk of the river. The result is also in agreement with the finding of Jibrin and Opatoyinbo (2015), which showed that 76% of the land used for dry season farming along the floodplain of River Kaduna was overtaken by built-up structures. Mangaji (2019) conducted a study on the effects of seasonal flooding on unplanned settlements along the River Kubanni in urban Zaria. The results revealed that settlements such as Gaskiya, Tudun Wada, Rinji, Gangaren Mallam Hamza, Hanwa village, and Zango were the primary areas at risk in the Kubanni catchment. Gaskiya and Tudun Wada are reported to be among the high-vulnerable settlements, and Hanwa village, Zango, and its environs are among the moderately vulnerable settlements. The level of flood risk and vulnerability of the settlements in the study area is presented in Figure 2.

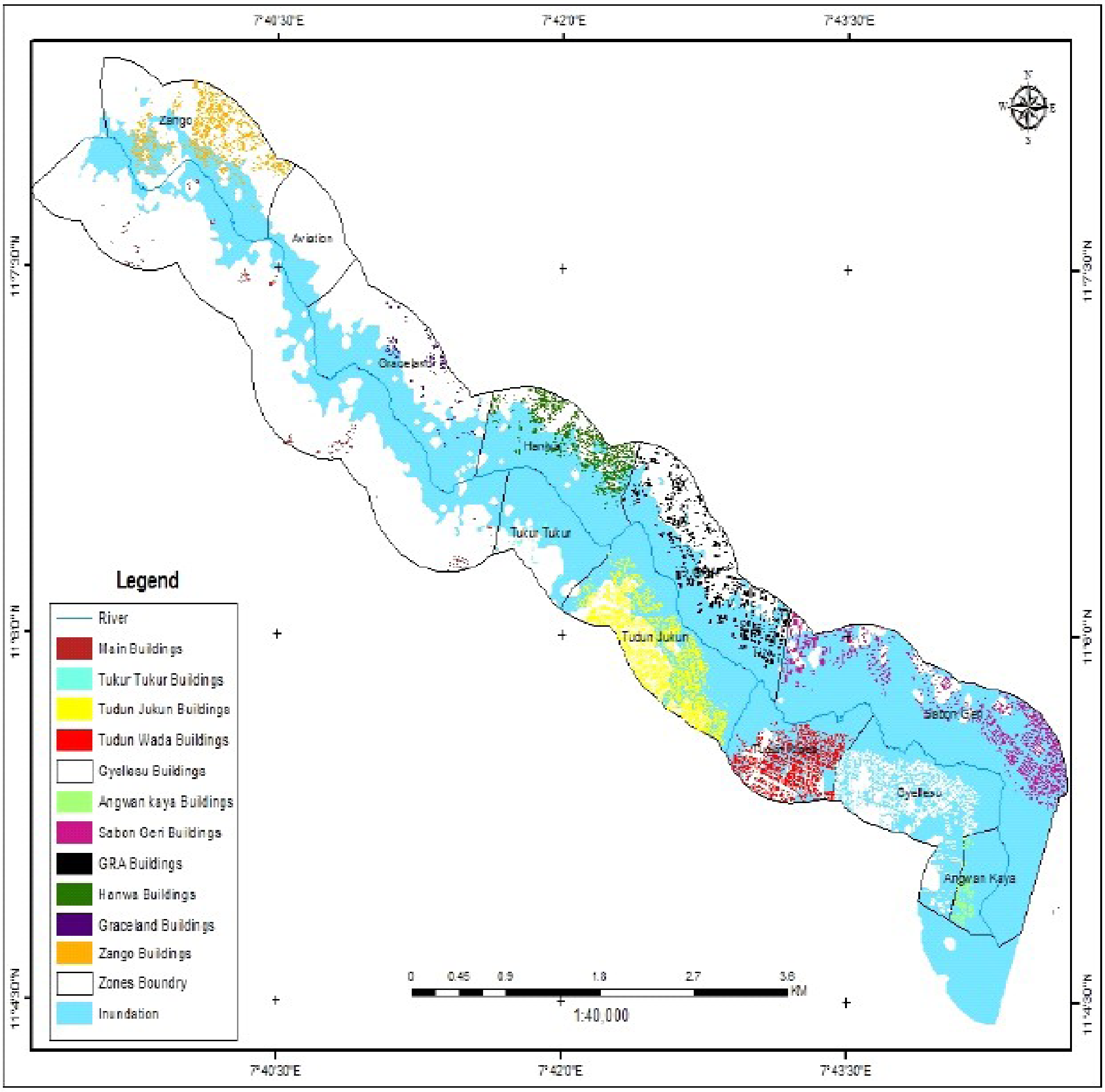

Figure 2. Levels of Flood Risk in the Study Area

Ezenwa et al. (2022a) identified five land use and land cover classes around the Kubanni drainage basin, which are built-up area, water, vegetation, farmland, and bare land. However, Ezenwa et al. (2022b) established that farming is the dominant land use in the study area. Farming has the potential to exacerbate flooding in the Kubanni region because it leads to deforestation and the gradual siltation of the Kubanni dam resulting from agricultural and other anthropogenic activities. Another influential factor is encroachment and building on the floodplain. Iftikhar and Iqbal (2023) reported that Dha City in Pakistan is built on a floodplain area, which is why it is often flooded with monsoon rainwater. Conversely, sustainable flood risk management involves implementing natural solutions, such as afforestation or developing land surfaces with water retention and infiltration capacity at strategic locations within the catchment (Gabriel et al., 2022).

Table 2 shows that a total population of 154,419 is at risk of floods, based on an estimated total of 29,135 households. It can be seen that the Tudun Jukun area has the highest population at risk of flooding, with a total of 38,623 individuals and a corresponding number of 7,287 households. This is followed by Gyellesu, with 31,195 people at risk of flooding, which comprises a household population of 5,886 and 2,180 houses. Tudun Wada is the third most vulnerable to flood risk, with a population of 26,487, a household population of 4,997, and 1,851 houses. The fourth most vulnerable area is Hanwa, with 14,081 people at risk of flooding, a household population of 2,656, and 984 houses. The fifth most vulnerable area is Sabon Gari, with a population of 13,136 at risk, comprising a household population of 2,478 and 918 houses. The sixth most vulnerable area is Zango, with a population of

12,091 at risk of floods, comprising a household population of 2,281 and 845 houses. The seventh most vulnerable area is G.R.A., with a population of 11,047 at risk, comprising 2,084 individuals and 772 houses. The eight most vulnerable areas are Tukur-Tukur, with a population of 658, at risk of flooding, comprising 124 households and 46 houses. The ninth most vulnerable area is PZ, with a population of 2,647 at risk, comprising 499 households and 185 houses. The tenth most vulnerable area is Anguwan Kaya, with a population of 3,318 at risk, comprising a household population of 437 and 162 houses. The eleventh most vulnerable area is Grace Land, with a household population of 402.3 and 149 houses. The Aviation Sector has no estimated population and household at risk and is therefore not considered vulnerable to flood risk in the study area. This is because the area remains unbuilt. The Household/Population at risk of flood is presented in Table 2.

Table 2. Household/Population at Flood Risk

Locality Neighbourhood	Estimated Number of Households	Estimated Population at Risk
Tudun Jukun	7,287	38,622
Tukur-Tukur	124	658
Sabon Gari	2,478	13,136
PZ Area	499	2,647
Hanwa	2,656	14,081
Aguwan Kaya	437	2,318
Aviation	-	-
G.R.A	2,084	11,047
Grace Land	402	2,132
Gyellesu	5,886	31,195
Zango	2,281	12,091
Tudun Wada	4,997	26,487
Total	29,135	154,419

The area of farmlands at risk of flood is presented in Table 3. A total of 899.831 Hectares of farmland are at risk of flooding. The analysis by locality showed that 5.3% of the farmland is at risk of flooding, located in Tudun Jukun, and 4.4% of the farmland is located in Tukur-Tukur. At Sabon Gari, 16.5% of the farmlands are at risk; 34.8% in the Main PZ area, Hanwa is 5.2%; Aguwan Kaya is 2.0%, Aviation is 2.4%; GRA is 4.1%; Graceland is 12.0%, Gyellesu is 2.9%; Zango is 7.7% and Tudun Wada is 2.7% of the farmlands are at risk of flooding.

Table 3. Area of Farmlands at Flood Risk

Locality	Area of Farmland at Risk (Ha)	%
Tudun Jukun	47.355	5.3
Tukur Tukur	39.969	4.4
Sabon Gari	148.551	16.5
PZ area	313.191	34.8
Hanwa	46.858	5.2
Angwan Kaya	17.936	2.0
Aviation	21.365	2.4
GRA	37.089	4.1
Graceland	107.665	12.0
Gyellesu	26.51	2.9
Zango	69.212	7.7
Tudun Wada	24.13	2.7
Total	899.831	100.

Based on the findings above, it is evident that the PZ area has the largest farmland area, at 34.8%, that is at risk of flooding. This could be because the PZ area is essentially a commercial land use and has nutrient-rich soils, allowing for dry-season farming. This result is in agreement with the findings of Kissi (2014), which revealed that the closeness of households and farmlands to the river body, the type of construction, and the position of settlements are among the main determinants increasing the community's vulnerability to flood disasters. Table 3 further illustrates the flood risk to food security in the study area. Out of the total area of farmland at risk (899,255 Ha) and 197,876Ha which represents the total average hectare/person 0.22(Ha), Tudun-Jukun has 47,355 Ha area of farmland at risk with 10418.1 average hectare/ person 0.22 Ha under risk of food scarcity due to flooding. Tukur-Tukur has a 39,969 Ha area of farmland at risk, with 8,793.18 hectares per person and 0.22 Ha at risk of food scarcity. Sabon Gari has 148,551Ha area of farmland at risk with 32,681.22 average hectare/ person 0.22(Ha) under risk of food scarcity due to flooding. PZ area has 313,191 Ha area of farmland at risk with 68902.02 average hectare/ person 0.22(Ha) under risk of food scarcity.

The flood risk and farmland areas are presented in Table 4. Among the land use types, cropland exhibited the highest vulnerability, with at least 10,234.8 Hectares susceptible to a flooding event of a 100-year return period (YRP). Hanwa has a 46,858 Ha area of farmland at risk, with an average of 10,308.76 ha per person (Ha) at risk of food scarcity. Aguwan Kaya has 17936 hectares of farmland at risk (Ha), with an average of 3945.92 hectares per person (Ha) at risk of food scarcity.

Table 4. Flood Risk and Farmlands Area.

Locality/neighbourhood	Area of farmland at risk (Ha)	Average Hectre/ person 0.22(Ha)
Tudu Jukun	47355	10418.1
Tukur-Tukur	39969	8793.18
Sabon-Gari	148551	32681.22
PZ area	313191	68902.02
Hanwa	46858	10308.76
Anguwan kaya	17936	3945.92
Aviation	21365	4700.03
GRA	37089	8159.58
Graceland	107665	23686.03
Gyellesu	26051	5731.22
Zango	69212	15266.64
Tudun-Wada	24013	5282.86
Total	899,255	197,876

In addition, it can be observed from Table 4 that Aviation has 21,365 hectares of farmland at risk (Ha), with an average of 4,700.03 hectares per person (Ha) at risk of food scarcity. GRA has a 37089 Ha area of farmland at risk, with an average of 8,159.58 ha per person (Ha) at risk of food scarcity. Graceland has an area of 107,665 hectares of farmland at risk, with an average of 23,686.03 hectares per person (Ha) at risk of food scarcity. Gyellesu has 26051 areas of farmland at risk (Ha) with 5,731.22 average hectare/person 0.22(Ha) at risk of food scarcity. Zango has a 69,212 area of farmland at risk (Ha) with 15,266.64 average hectares/person 0.22(Ha) at risk of food scarcity. Tudun Wada has a 24013 Ha area of farmland at risk, with 5282.86 average hectare/person 0.22 (Ha) at risk of food scarcity.

Results in Table 4 indicate that the PZ area has the highest average number of persons per Ha (68902.02) at risk of food scarcity in the event of flood risk. This result corroborates the findings of Oluoko-Odingo and Krhoda (2020), which showed that flooding negatively affects food security by increasing the number of food-insecure households to 92.8%. The regression coefficient of ◎0.798 indicates a powerful adverse effect of flooding on household food security. The findings suggest that flooding can increase the vulnerability of communities to food insecurity, necessitating long-term support to cope; it can also hinder the achievement of Sustainable Development Goal 2. Week and Wizor (2020) examined the effects of flood risk levels on food security, livelihood and socio-economic characteristics in the flood-prone areas of the core Niger Delta, Nigeria.

The study's findings showed that 75.3% of respondents believed that basic food was scarce following the floods. Meanwhile, 69.9% admitted that flood events negatively influence crop growth and development by washing away farmlands. Additionally, 69.9% agreed that farmland erosion has caused chronic, enduring food insecurity within the communities. Further evidence suggests that 75.6% of respondents agreed that flood incidents contribute to acute food insecurity, which in turn affects residents' livelihoods. Week and Wizor (2020) concluded that floods have reduced farmland efficiency in food production, resulting in food insecurity, lower incomes, and poorer living conditions for residents in the core Niger Delta States. Idoko (2016) examined the impact of floods on food security among rural farmers in the Dagiri Community, Gwagwalada Area Council, Abuja, Nigeria. The findings indicated that areas in Dagiri, particularly along the banks of River Usuma, with significant farming activities, are highly susceptible to flood disasters. Ongoing land use planning violations, population growth, and use of substandard construction materials heighten the towns' vulnerability to flood hazards. To mitigate the risk of flooding in residential areas, it is essential to implement an integrated national flood disaster risk reduction plan. Tout (2023) emphasises the need for a national policy targeting effective flood risk management, which should include prevention, management, and rehabilitation strategies for flood hazards. This study makes a significant contribution to developing an integrated national flood disaster risk reduction plan for effective flood disaster risk management in Nigeria.

Because the houses and farmlands that provide settlement and means of livelihood for the communities in the study area are at risk of flooding, the vulnerability of the communities to flooding is generally high, as it is multidimensional, encompassing both physical and economic aspects, with the potential to expose the communities to social and environmental vulnerabilities. Ndanusa et al. (2022) revealed that the downstream communities of Kainji Dam in Niger State, Nigeria, experienced high flood vulnerability due to multidimensional vulnerability, encompassing economic, physical, social, and environmental aspects. Shuaibu et al. (2022) reported how combining the flood hazard and socioeconomic vulnerability indices of the Hadejia River basin revealed high to very high flood risk in the downstream and central upstream parts of the basin. Similarly, Cvetković et al. (2018) reported how gender influenced flood risk perceptions and preparedness of individuals. Perić and Cvetković (2019) established a correlation between risk perception and demographic, psychological, and socio-economic factors, which have implications for communities' disaster preparedness.

The present study has established that the flood risk downstream of Kubanni Dam is multi-dimensional. In contrast, previous studies have shown a relationship between flood risk perception among communities and flood preparedness. It is therefore recommended that future studies in the downstream region of Kubanni Dam should focus on this relationship.

4. Conclusion and recommendations

This study employed a GIS technique to assess the nature and extent of flood vulnerability in areas downstream of the Kubanni Dam. It was concluded that in the event of any flooding due to the breach of the Kubanni Dam, the most affected areas would be Tudun Jukun, with about 2,699 buildings (25%), Gyallesu, with about 20.2%; Tudun Wada with about 1,8551 building (8.5%), Zango with about 845 building (7.8%) and Government Reserved Area (GRA) with about 772 buildings or 7.2% of the total number of affected buildings. Evidence was found of increasing encroachment of housing development along the floodplain in these areas. The study also concludes that the Tudun Jukun area has the highest population at risk of flooding. In contrast, the PZ area has the highest average number of persons per Hectare (68902.02) at risk of food scarcity in the event of flooding. This study recommends the application of GIS techniques to guide physical planning and reduce the flood disaster risk and vulnerability of communities. This study utilised low-resolution satellite images for land use and Land Cover classification. A higher-resolution satellite image will provide more accurate input and better results for flood risk and vulnerability analysis in the study area.

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