



An Analysis of the Flood-Prone Areas in Birnin Kebbi, Using Remote Sensing and GIS

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Authors' contributions

This work was carried out in collaboration between both authors. Author AM designed the study, performed the geospatial analysis, wrote the protocol and wrote the first draft of the manuscript. Author SAY managed the literature review, and make corrections on the final draft. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: To identify settlements that are vulnerable to flooding within River Rima floodplain in Birnin Kebbi Local Government Area of Kebbi State, Nigeria.

Study Design: A flood vulnerability test was conducted by observing the relationship between the locations of settlements on the floodplain and elevation data, considering previous flooding events.

Place and Duration of Study: The study covers Birnin Kebbi Local Government Area of Kebbi State, Nigeria.

Methodology: This study uses Digital Elevation Model DEM obtained by The Shuttle Radar Topography Mission (SRTM). The Geographical Information System (GIS) technique (Map Overlay) was used where DEM was overlaid by settlement location (point data). Similarly, 3D view was used to confirm the result.

Conclusion: The result shows that 12 settlements in Birnin Kebbi LGA were located at the lower altitude (<207m) with close proximity from the river channel. Therefore, the settlements and the surrounding farmlands become vulnerable to flooding.

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Recommendations: It was recommended that the settlements should be relocated to higher ground for safety. Local farmers should use species of rice that can survive longer time when submerged by water. The Environmental Monitoring Agencies should include detailed images showing affected areas in their publications.

Keywords: Flooding; River Rima; Birnin Kebbi; Remote Sensing and GIS.

1. INTRODUCTION

Riverine flooding is a phenomenon where land surfaces around the river channel will be submerged by water either as a result of heavy rain within a short period of difficulties for water to follow its course that causes water to overflow its bank, as in [1]. Floods are part of the Earth's natural hydrologic cycle. Sometimes the hydrologic cycle got out of balance, sending more water to an area than it can normally handle. The result is a flood [2]. Cases of flooding in Nigeria have been frequently reported particularly in the wet season. This phenomenon mainly affects places within the floodplains of the major rivers and their tributaries as usually been predicted by the Nigeria Meteorological Agency (NiMet). For example, in the year 2020, NiMet predicted that heavy rainfall may result in flooding, which could disrupt traffic, delay construction activities, and weaken or wash out the soil and culverts that support roads, tunnels, and bridges. The riverine flooding mostly occurs at the lower altitude around waterways as described by [3].

The flood of 2012 is a major environmental event in Nigeria since its independence. The floods began in early July, killed 137 people and displaced over 120,000 people nationwide [4]. Similarly, the 2013 report of 2012 flooding stated that Floods are the most common and recurring disaster in Nigeria. The frequency, severity, and spread of these floods are increasing. Beginning in July 2012, heavy rains struck the entire country. The impact of the 2012 flooding was very high in terms of human, material, and production loss, with 363 people killed, 5,851 injured, 3,891,314 affected, and 3,871,53 displaced [5]. According to Nigeria's National Emergency Management Agency (NEMA), nearly half a million people have been affected by 2018 flooding in 8 states of the country. At least 108 people have died in the flooding, with a further 192 injured. The affected states include Anambra (64,331 people affected), Benue (2,201), Delta (37,017), Edo (31,113), Kebbi (94,991), Kogi (118,199), Kwara (41,680) and Niger (51,719) [6].

NIHSA in 2019 reported that 12 LGAs in the Kebbi state will be affected by floods which include Birnin Kebbi, Dandi, Kalgo, Koko/Bese, Suru, Aliero, Argungu, Augie, Bagudo, Bunza, Ngaski, and Shanga [7]. The contributing channels (tributaries) are Rivers Sokoto, Gagare, Bunsuru, Maradi, Zamfara, and Ka [8]. Similarly, the water released from the dams in the area (Bakolori and Goronyo) passed through River Rima that leads o flooding almost every wet season [9]. In 2018, The Kebbi State Emergency Management Agency has assessed damages caused by flood in 11 local government areas of the state. This includes communities in Argungu, Birnin Kebbi, Suru, Bunza, Aleiro, Kalgo, Jega, Bagudu, Gwandu, Dandi, and Shanga local government areas [10]. Upon the regular report of expected flooding by weather monitoring agency, most of the public remain ignorant until when the event occur before measures were taken. In the flood prediction report, only affected State and Local Government Areas were mentioned without identifying the individual settlements involved, that causes for the ignorance by the local populace.

It can be recalled that The Nigeria Hydrological Services Agency (NIHSA) has warned that there is a high probability that a total of 74 Local Government Areas across the country will witness high flood risk when the rainy season begins in full this year (2020) including Birnin Kebbi. With the loss of six lives and still counting, thousands of hectares flooded and estimated economic losses of more than one billion naira by rice farmers [11].

In this research, Birnin Kebbi LGA was selected to conduct an in-depth study to identify settlements and their surroundings that are most vulnerable to frequent flooding using Remote Sensing and GIS. This technique reduces systematic bias in data gathering and large areas of land can be handled and monitored at a glance. The choice of this area for this research was due to the frequent riverine flood events that destroy farms, buildings, and causes harbor to social wellbeing. The aim will be achieved through the following objectives: to track record

of the previous flooding in the area; to obtain elevation data from remote sensing; identify geospatial locations of the settlements using GPS; and examine the relationship between the two data using Geographical Information Systems. Findings in this research will identify flood-prone areas in the Birnin Kebbi Local Government area with the view to sensitize the public to be at alert and local authorities to take measures to mitigate the harmful effects of flood hazard in the area.

2. MATERIALS AND METHODS

2.1 The Study Area

2.1.1 Geospatial characteristics

Birnin Kebbi is one of the local government areas of Kebbi State in Nigeria where the activities of River Rima are affected. The elevation of the area ranges between 150 and 300 meters Above Sea Level (ASL). About 90% of the area falls below the altitude of 250 meters (ASL) and relatively flat. These spatial characteristics of the land make it good for rice farming. Thus local populace in the area engages in both wet and dry season farming. The area is geographically located between Lat. 12° 17' 14" and 12° 39' 34"

N and between Long. 3° 59' 21" and 4° 36' 36" E (Fig. 1.).

2.1.2 Climate

According to Eberibe, et al. [12], the area falls within the class of semi-arid climate belt characterized by low mean annual rainfall ranging between 300-700mm from May to October (6 months of wet season) with the remaining months as the dry season. There is a marked seasonal variation in temperature and diurnal range of temperature. The daily maximum temperature of the area is between 36°C - 40°C. During the Hammatan season, the daily minimum temperature may fall below 18°C. Between February and April which is the peak of heat, the temperature reaches the highest of 44°C.

2.1.3 Soil

The area generally contains unconsolidated sediments conveyed by running water and wind. These are accumulations of organic matter, sand, gravel, loam, silt, and/or clay, and are often important aquifers. They are found in the floodplains of the Rima Basin. This type of soil provides a good ground for farming [13].

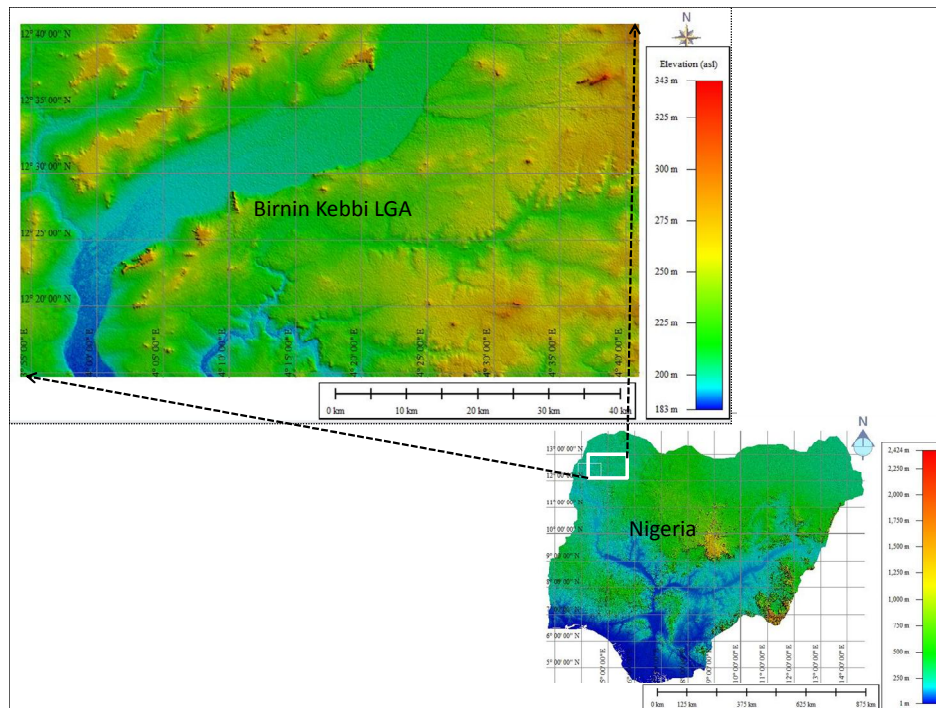


Fig. 1. The study area

2.1.4 Vegetation

The vegetation of the area is considered Sudano-Sahelian that is characterized by vast grassland with scattered woody vegetation found around the flood-plains. Small plants, usually grasses, shrubs, and small trees dominate the landscape of semi-arid regions. Certain plants in semi-arid regions may have some of the same adaptations as desert plants, such as thorny branches or waxy cuticles to reduce evaporation and water loss through their leaves [14].

2.2 Methodology

The Digital Elevation Model (DEM) data used in this research was an observation by environmental monitoring satellite called The Shuttle Radar Topography Mission (SRTM). The data have been enhanced to fill areas of missing data to provide more complete digital elevation

data with a resolution of 3 arc-seconds for global coverage. The entity ID is SRTM3N12E004V2I downloaded via GloVis (<https://glovis.usgs.gov/app>). The area of interest was windowed using IDRISI Taiga to focus on the study area. The Google Earth Pro was used to identify and create point data for each settlement within the study area (Table 1.).

The created point data and the downloaded Digital Elevation Model (DEM) were merged together to create a single image (map overlay) using Global Mapper software. This technique helps to visualize the interaction between settlement location and elevation. Visualization of the terrain characteristics (3D) was done using QGIS software. Field observation was used during the August 2020 flooding and photographed live flood incidents. The detailed process of this research is shown in Fig. 2.

Table 1. Geographical locations of the settlements

S/No	Settlement	Latitude	Longitude	Elevation in meters (asl)
1	Jawo	12.49750°	4.092222°	199.9
2	Unguwar Sani	12.50550°	4.104722°	197.8
3	Makera	12.51389°	4.119444°	201.7
4	Maurida	12.51972°	4.127500°	200.5
5	Unguwar Kayi	12.51472°	4.152222°	201.1
6	U. Mijin Nana	12.52722°	4.150000°	202.0
7	Unguwar Gero	12.53056°	4.179444°	200.5
8	Kola	12.44528°	4.116111°	204.5
9	Wuro Maliki	12.44083°	4.093056°	199.6
10	Bimin Kebbi	12.47389°	4.210000°	206.7
11	Ambursa	12.51028°	4.335000°	206.7
12	Dagere	12.56417°	4.414167°	205.7

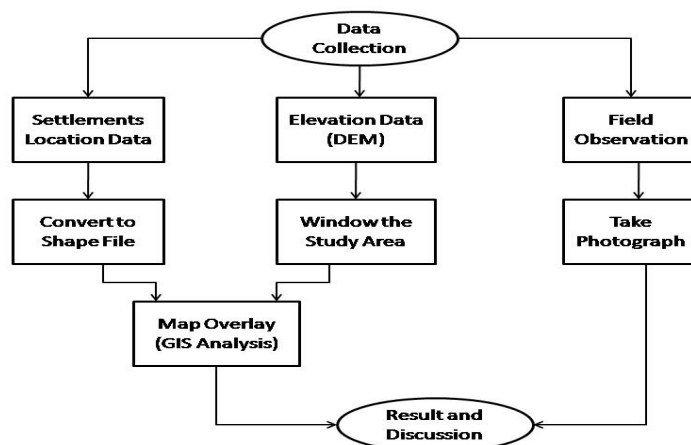


Fig. 2. Methodological flow diagram

3. RESULTS AND DISCUSSION

It were observed that the lower course of River Rima, which is a tributary to River Niger passed through Kebbi State, cutting across some Local Government Areas. These include Birnin Kebbi, Dandi, Kalgo, Koko/Bese, Suru, Aliero, Argungu, Augie, Bagudo, Bunza, Ngaski, and Shanga as mentioned in the introduction. it was observed that most waters from neighboring Sokoto and Zamfara States were channeled to the said River Rima. This means the lower course of Rima must have enough capacity to accommodate a large volume of runoff from vast lands (Fig. 3).

The water channel becomes silted due to high depositional activities that force water to overflow its banks. This process induces flooding in the area that claims farmlands and in some cases affecting neighboring settlements. The elevation data and field observation show that elevation below 207m in the area is considered to be a

flood plain. This statement was confirmed by [15]. Similarly, the result of the map overlay shows that the identified settlements in the area were located below 250 m (Fig. 4). This denotes that identified settlements (Table 1) are at risk of flooding.

It was observed that some settlements including Birnin Kebbi, Ambursa, and Dagere were found to be within the floodplain due to town expansion. Those settlements were found to be partly within the lower elevation and partly within the high elevation. The other settlements (Jawo, Unguwar Sani, Makera, Maurida, Unguwar Kayi, U. Mijin Nana, Unguwar Gero, Kola, and Wuro Maliki) were entirely found to be within the plain. To visualize and confirm the relationship between the identified settlements and the elevation, a 3D view was created using QGIS software. The created image (Fig. 5) confirmed that the settlements (white dots) were within the lower elevation (light blue background).

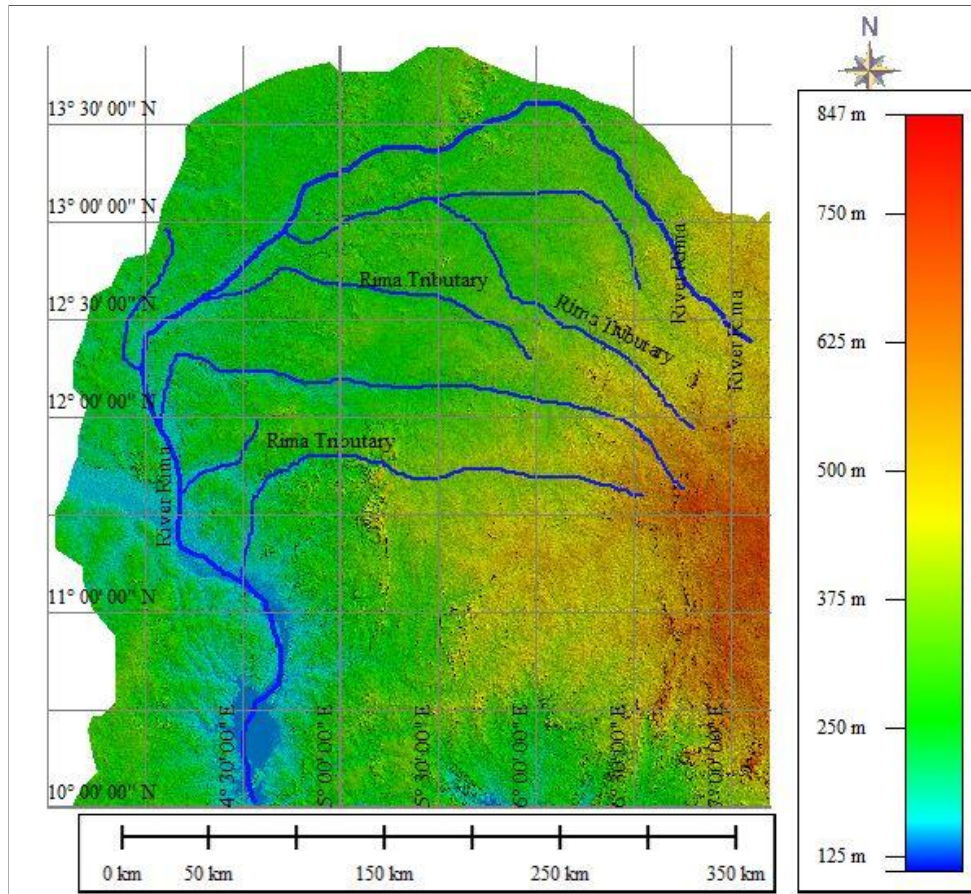


Fig. 3. River Rima and its tributaries

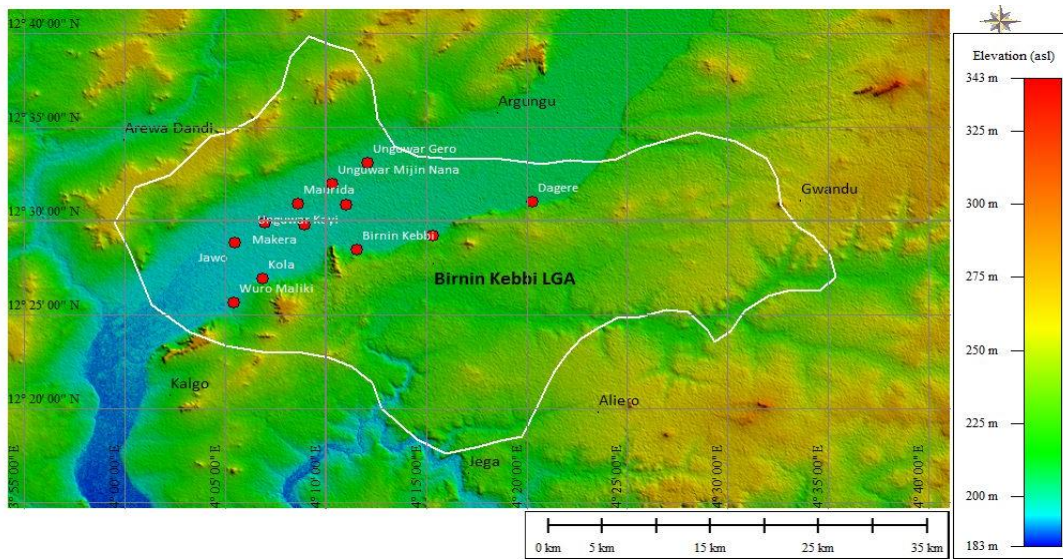


Fig. 4. Overlaid image showing flood-prone settlements

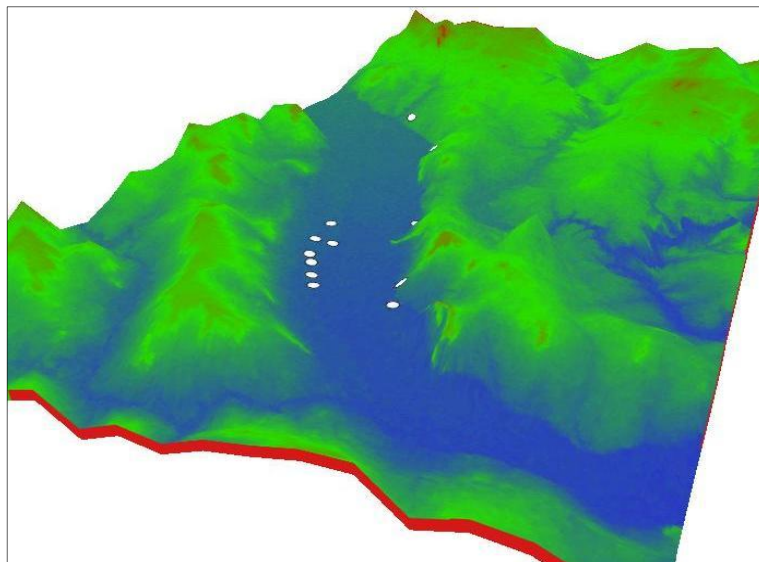


Fig. 5. 3D View of the affected settlements

Fig. 6 is a color composite image created to replace the land-use/land-cover (LULC) map due to the inability of the settlements to be visible on the LULC map. The composed image allows for the identification of the settlements shown using a black-dashed arrow on the image. The settlements, farmland, river channel, and floodplain are in purple, light-pink, blue, and gold-lime colors respectively. It appeared that the identified settlements are within the floodplain region, whereas, Birnin Kebbi, Ambursa, and Dagere are partially within the floodplain region

(Fig. 6). The floodplain cut-across the area from the northeast to the southwest angles.

It is clearly evident that the settlements identified to be within the floodplain are liable to experience flooding as predicted by weather monitoring agencies of Nigeria as stated in the introduction section of this research. On September 1st, 2020, some locations in the area where the flooding event occurs were photographed (Plate 1). Image a, b, and c on plate 1 are Makera, Maurida, and Unguwar Kayi

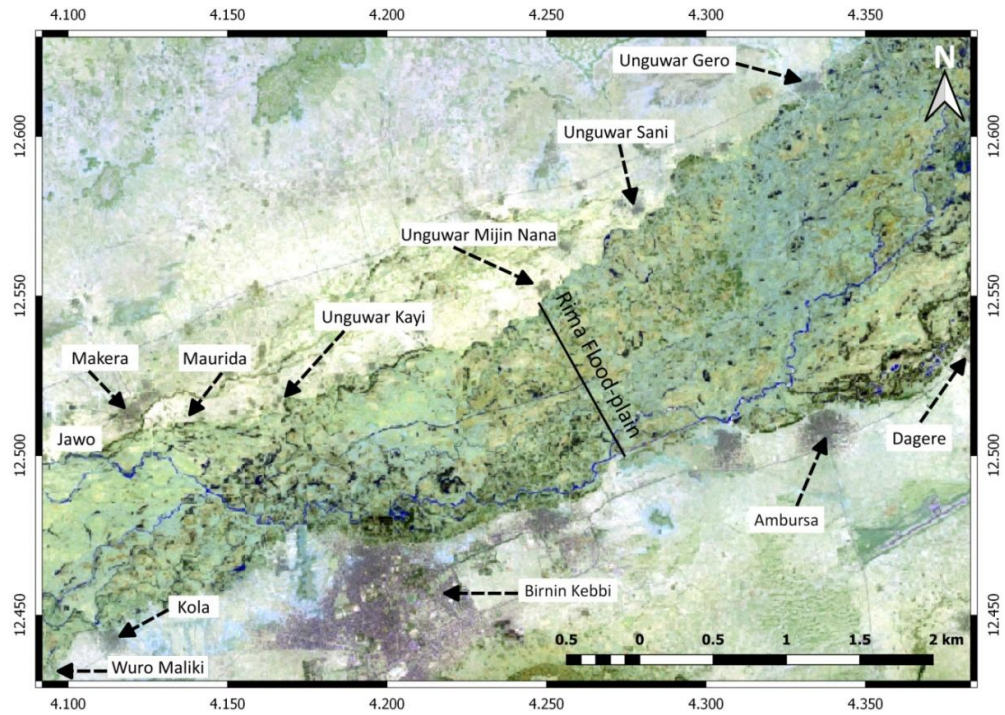


Fig. 6. Color-infrared map of the study area (543-Composite)



Plate 1. Flooding of River Rima, August/September 2020 (Photo by Author)

respectively. The water has reached the settlements and even overflows their houses that are located near the river channel. Similarly, image d is a location near Dukku Hill in Birnin Kebbi, while image e and f are submerged farmlands where Rice and Millet crops were destroyed located between Birnin Kebbi and Makera settlements.

4. CONCLUSIONS AND RECOMMENDATIONS

It was concluded that 12 settlements in Birnin Kebbi LGA were located at the lower altitude (<207 m) with proximity from the river channel. Therefore, the settlements and the surrounding farmlands become vulnerable to flooding. It was recommended that the settlements should be relocated to higher ground for safety. Local farmers should use a species of rice that can survive a longer time when submerged by water. The Environmental Monitoring Agencies should include detailed images showing affected areas in their publications. The local populace, local authorities, and the general public should take weather predictions serious with precautionary measures as in most cases, the predictions become reality.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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