Earth Observation-based Damage Assessment of 2018 Flood in Parts of Hadejia-Jama' are River Basin, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author BAO performed the project work including field data collection and data analysis. Author AYY designed the first draft of the manuscript. Author SOI supervised the entire work while author GJ provided the technical assistance, reviewed the first draft manuscript and made the paper abstract. All authors read the final manuscript and approved for publication.

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ABSTRACT

Floods, Landslides, Forest fire, Volcanoes, Hurricanes and Tsunami among others are indeed considered as the most natural hazards that cause loosed of resources which includes human lives. Hadejia-Jama' are River Valley has a well-known seasonal occurrence of floodings with maximum interval of five years incidents historically. Among these disasters floods especially along the river basin particularly in developing nations like Nigeria became a regular disaster with state of frequent occurrences almost seasonally. This study assessed pre-flood and post-flood nature of floodplain along Hadejia-Jama' are from Jigawa to Tiga Dam in Kano State. Remotely sensed sentinel 2 satellite data and ALOS Digital Surface Model (DSM) was used for the study. The sentinel images were subjected to image pre-processing activities such as geometric correction

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and radiometric correction. To focus on the flood plain, a 5 km buffer of the area around Hadejia-Jama'are River Basin from Jigawa to Tiga dam were extracted from the data by using the extract/clip tools in ArcGIS 10.3 software. Findings of the study revealed that dominant land use along the floodplain prior to flood include bare surface, patches of agriculture/vegetation, settlement, water body. The study also revealed that patterns of flood damages vary irrespective of the risk with areas like Dawakin Kudu and Garun mallam were witnessing more flood damages than Miga LGA of Jigawa State. It is, therefore, concluded that Earth observation and its applications are useful tools/methods for flood damages assessment and evaluation as well as a basis for taking proactive steps in mitigating flood hazard along floodplains and another flood prone environment.

1. INTRODUCTION

Floods are the most frequent and threatening natural hazards in the world and often cause massive damage and destruction of property located near the water sources [1]. From developed to underdeveloped world, rivers and their floodplains resources have served for multiple human uses including as major axis of migration, settlement, agriculture, forestry, fishery, industrial development and trade [2]. This is not surprising since nonfunctional management of areas with such high potential for providing goods and services would be potentially inefficient [3,4]. Therefore, human beings have been attracted to settle on floodplain and river banks since time immemorial because of the rich alluvial soils, access to water supplies and cheap sites in urban centers especially for low-income families [5]. However, people living along floodplains of both major and minor river channels are constantly being ravaged by the menace of floods [6].

The floodplains of Hadejia-Jama'are River Basin (HJRB) is no exception to the risk of flood as it often witnesses episodic flash floods (a form of riverine flood) which occurs as a result of heavy rainfalls of long durations and dam failures upstream [7]. The catchment area of Hadejia-Jama'are River Basin Hydrological Area (HJRB-HA) is considered the largest floodplain in Northern Nigeria as it crosses so many towns and villages in Kano and Jigawa states as well as two-third of Bauchi state [8]. The floodplain of Hadejia-Jama'are River is associated with numerous economic activities. The floods often cause lots of damages to lives and properties with notable destruction of farmlands, crops, livestock, houses, schools, roads, markets and displacement of people amongst other things.

The estimation of economic flood damage is gaining greater importance as flood risk management is becoming the dominant approach of flood control policies [9,10]. Despite the fact that considerable research effort has been spent and progress has been made on damage data collection, data analysis and model development in recent years, there still seems to be a mismatch between the relevance of damage assessments and the quality of the available models and datasets [11,12]. Often, simple approaches are used, mainly due to limitations in available data and knowledge on damage mechanisms. With the advent of geospatial technology that aid remote sensing, researchers have been able to investigate flood thoroughly [13,14]. The first integration of remote sensing with flood monitoring mentioned in literature dates back to the 1970s, where data from Landsat 1 helped to analyze the Mississippi flood of 1973 [15]. Since then, scientists have continued to use satellite data as auxiliary sources for multiple reasons such as change detection, or observation of flood boundaries [16,17].

Iiyasu [8] after assessing the level of socio-economic and environmental risks associated with flood disaster in Hadejia-Jama'are River Basin (HJRB) for over five years (2011-2015) revealed that flood is the most common environmental disaster in the study area and the frequency of flood occurrence in the affected areas is almost every year. This implies that flood is a frequent occurrence in the area and the damage needs continuous assessment. Leaving a gap for this study to fill. Taking cognizance of the importance of Hadejia-Jama'are River Basin floodplain to the settlement around it, it has become very important to assess the damages caused by flood along with parts of Hadejia-Jama'are floodplain in recent years [8]. Thus, this study assessed the pre-flood and post-flood

nature of the study area as well as the extent of damage inflicted by flood in 2018.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

Hadejia-Jama'are flood plain is along Hadejia-Jama'are River Basin (HJRB) which falls within the geographical coordinates of 12º26'N and 10º04'E and has a total drainage area of 25,900 km^2 (Usman, et al. 2016). Hadejia-Jama'are River Basin (HJRB) is part of the Lake Chad Basin Hydrological Area identified as HA-VIII by the Nigeria Hydrological Services Agency (NIHSA), situated in the Sudano-Sahelian zone of Northern Nigeria. The area is bordered by Katsina state to the west, Kaduna and Plateau to the south, Yobe to the east and Niger Republic to the North (Fig. 1). The study area experiences four distinct seasons, *Rani* (warm and dry)*, Damina* (wet and warm), *Kaka* (cool and dry) and *Bazara* (hot and dry) closely associated with the movement of the Inter-Tropical Discontinuity (ITD) zone. The geology of the study area is predominantly characterized by chad formation which consists of marine and terrestrial sedimentary rocks of Precambrian ages which are highly unconsolidated and covered by dunes and sand in many areas. Some areas, however, like parts of Ringim, Kazaure, Dutse, Birnin Kudu, and Gwaram form part of Basement Complex in the state (Jigawa State Government (JG-SG), 2011 and Nigeria Hydrological Services Agency (NIHSA), 2014).

The two major rivers that traverse the study area are the Hadejia and Jama'are Rivers. The Hadejia River carries its source from the Kano Highlands, while the Jama'are River takes its source from the Jos plateau. Within the Hadejia-Jama'are River Basin (HJRB), the drainage system has been modified by the construction of Tiga and Challawa George dams on the Hadejia River, and Kafin Zaki dam on the Jama'are River (Usman et al. 2016). Apart from these dams, other large scale water resources management and irrigation projects like the Kano River Irrigation Project (KRIP) in the upper basin, Hadejia Valley Irrigation Project (HVIP) in middle basin and other artificial barrages are constructed on the river channels.

The water levels in these channels rises during the wet season and usually dries up during the dry season (i.e the water channels are seasonal). The channels drained through the Hadejia-Nguru wetlands and empties into the Lake Chad (Olofin et al. 2008).

Economically, over 15 million people are supported by the basin through agriculture, fishing, livestock keeping and water supply [18]. About 80% of the total land area of the study area is made up of arable land and as such, Agriculture is the major economic activity of the people in the study area. About 85% of the total population of the state engaged in Agricultural activities. Production in the state relies heavily on the rainy season in which the major Agricultural activities are practised [19]. Crops like Millet, Maize, Sorghum, Cowpea, Groundnut, etc. are usually cultivated during the rainy season [20,21]. Also, the Hadejia-Jama'are and Hadejia-Nguru Wetlands support extensive Fadama farming practices (Irrigation). Crops like Rice, Maize, Sorghum, Water Melon, and Vegetables (Onion, Tomato, Spices, Pepper and Potato) are usually cultivated. The wetlands also provide Fisheries resources as well as grazing land for livestock especially cattle (JG-SG, 2011).

This is the reason why whenever flood disaster occurs, it causes serious menace to the study area with several thousands of hectares of farmlands and crops worth millions of Naira being destroyed. Other economic activities in the study area include trade, mining, small scale manufacturing etc.

2.2 Data Used for the Study

Data required for the study are remotely sensed sentinel 2 satellite product and ALOS Digital Surface Model (DSM) that covers Hadejia-Jama'are floodplain from Jigawa to Tiga dam for the pre-flood period (March, 2018) and post-flood period (October, 2018). Sentinel-2 product was used because it offers optical imagery at high spatial resolution (10 m to 60 m) over land and coastal waters [22]. Sentinel imageries were accessed free of cost via https://landsatlook.usgs.gov/sentinel2/viewer.htm l website while ALOS DSM was sourced from https://www.eorc.jaxa.jp/ALOS/en/dataset/datase t_index.htm.

2.3 Data Processing

Environmental Systems Research Institute ArcGIS 10.3 Geographic Information System software was used for data processing. The sentinel images were subjected to geometric correction and radiometric correction after which a 5 km buffer analysis was carried out to subset

area around Hadejia-Jama'are River from Jigawa to Tiga dam from each large scene of the satellite imagery by using the extract/clip tools in ArcGIS 10.3 software.

2.4 Data Analysis

To understand the nature of the flood plain before the flood and after flood the preprocessed pre-flood and post-flood images undergo a supervised classification respectively. Using the supervised classification method, the location and identity of a number of land-use types (water body, agriculture/vegetation, settlement, baresurface) were recognized via a mixture of fieldwork, map analysis, individual experience, and digital image and aerial photograph interpretation. Specific sites were located on the remotely sensed data that characterize uniform samples of particular land-use types. These areas are known as "training sites," because the spectral attributes of these areas were utilized to sequence the classification algorithm to create a land-use map of the entire remotely sensed image.

The band combinations utilized are 4, 3, 2 (Near-Infrared, Red, and Green) and 5, 4, 3 (Mid-Infrared, Near-Infrared, and Red). The 4, 3, 2 combination is very useful for identifying urban, residential, and forested areas. The 5, 4, 3 combination is very useful for identifying barren and areas of light vegetation and agriculture. Both combinations are equal in their ability to detect water. Once the image has been classified to the satisfaction of the user, the next step is to select the appropriate image classification logic.
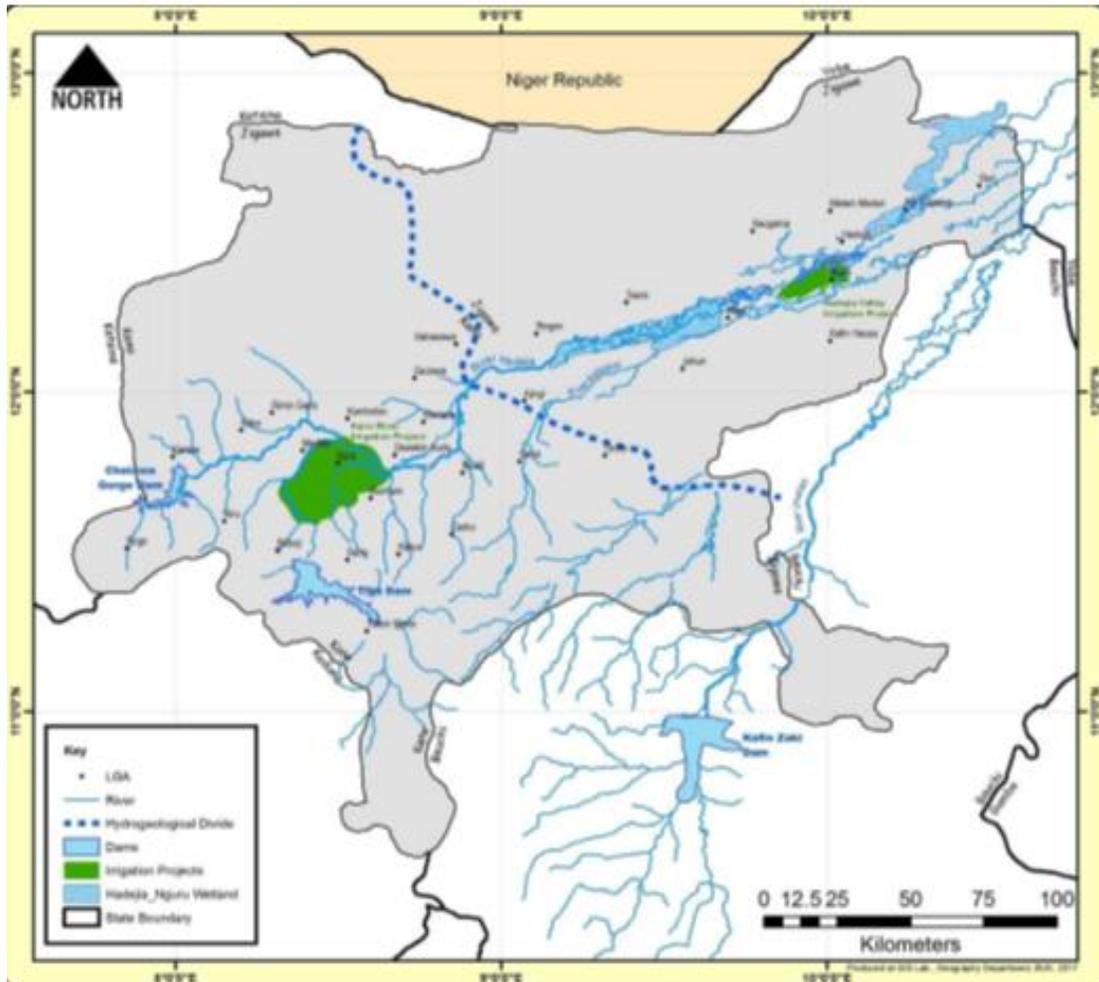

Fig. 1. Catchment of HJRB
Source: Google Earth, (2017), Produced at GIS Lab. BUK

For this research, the parametric rule maximum likelihood was used. Maximum likelihood and other parametric methods assume remote sensing data and knowledge of normally distributed data about the types of the fundamental class density functions. The nonparametric selected is parallelepiped. Parallelepiped and other nonparametric methods may be used with remotely sensed data that do not have a normal distribution and has no assumption that the types of fundamental densities are known (Jensen 2007). Once an image has undergone a supervised classification and the new supervised classification image has been created, the image was recorded. The recoding process eliminates all of the classes that do not have any value, thus leaving only the desired land-use classes once the supervised classification has been ran. The recording process also put all land-use classes in the same order, thus enabling a change detection.

Accuracy assessment is a vital element in testing the accuracy of resultant classes of the classification process i.e. comparing the classification to geographical data that are assumed to be true. Usually, the assumed-true data are derived from ground-truthing. Several methods are used for testing the accuracy such as overall accuracy (i.e. producer's and user's accuracy) and the Kappa coefficient [23]. The confusion (error) matrix is used to represent the accuracy assessment. Additionally, a coefficient of agreement between classified image data and ground reference data will also be calculated using Kappa statistics.

3. RESULTS AND DISCUSSION

3.1 Floodplain of Hadejia River Prior to Flood

The pre-flood image of Hadejia River floodplain, specifically a 5 km buffer of Hadejia River is shown in Fig. 2. The image was subjected to interactive supervised classification to determine the land and land cover characteristic of the floodplain prior to the occurrence of flood.
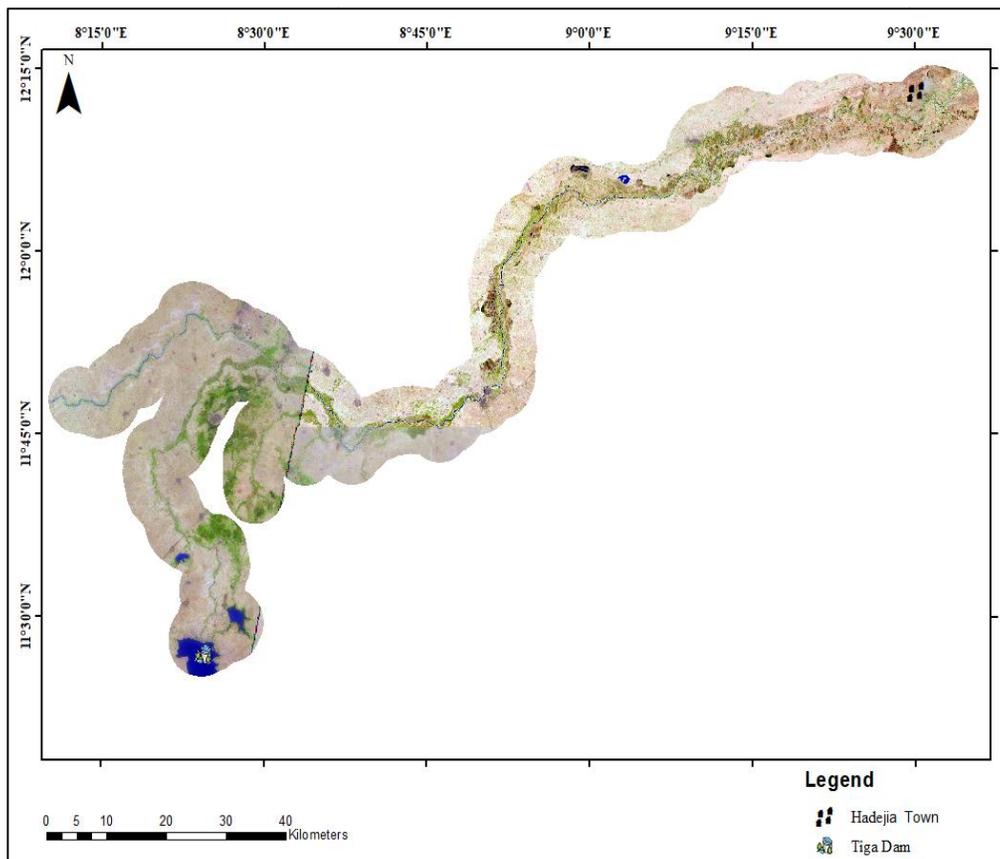

Fig. 2. Floodplain of Hadejia River (5 km of Hadejia Jamaare river)

3.2 Preflood Classification of Hadejia Jamaare Floodplain Land Cover

The classification carried out on the floodplain image identified five (5) different land-use classes along the flood plain, settlement, bare surface, Agriculture/vegetation, water body and unclassified (Fig. 3). The settlement occupies about 71.51 Km^2, Bare surface occupies 2295.43, Agriculture/vegetation, water body and unclassified areas occupied about 481.54 Km^2, 42.67 Km^2 and 43.43 Km^2 respectively (Table 1). Odunuga et al. (2011) identified flood plain complex (wetland), water body 4.19 km^2, riparian forest, agricultural land, shrub savanna and Grass savanna/bare surfaces as major land use cover along the floodplain of Hadejia River.

3.3 Floodplain of Hadejia River after Flood

The post-flood nature of Hadejia River floodplain which covers a 5 km buffer from Hadejia River is shown in Fig. 4. The image was subjected to interactive supervised classification so as to determine the land and land cover characteristic of the flood plain after the occurrence of flood.

Table 1. Pre-flood classification of Hadejia river floodplain land cover

Land cover	Area (Km^2)
Settlement	71.51
Bare Surface	2295.43
Agriculture/Vegetation	481.54
Water Body	42.67
Unclassified	43.42
Total change	**2934.6**

Table 2. Post-flood classification of Hadejia river floodplain land cover

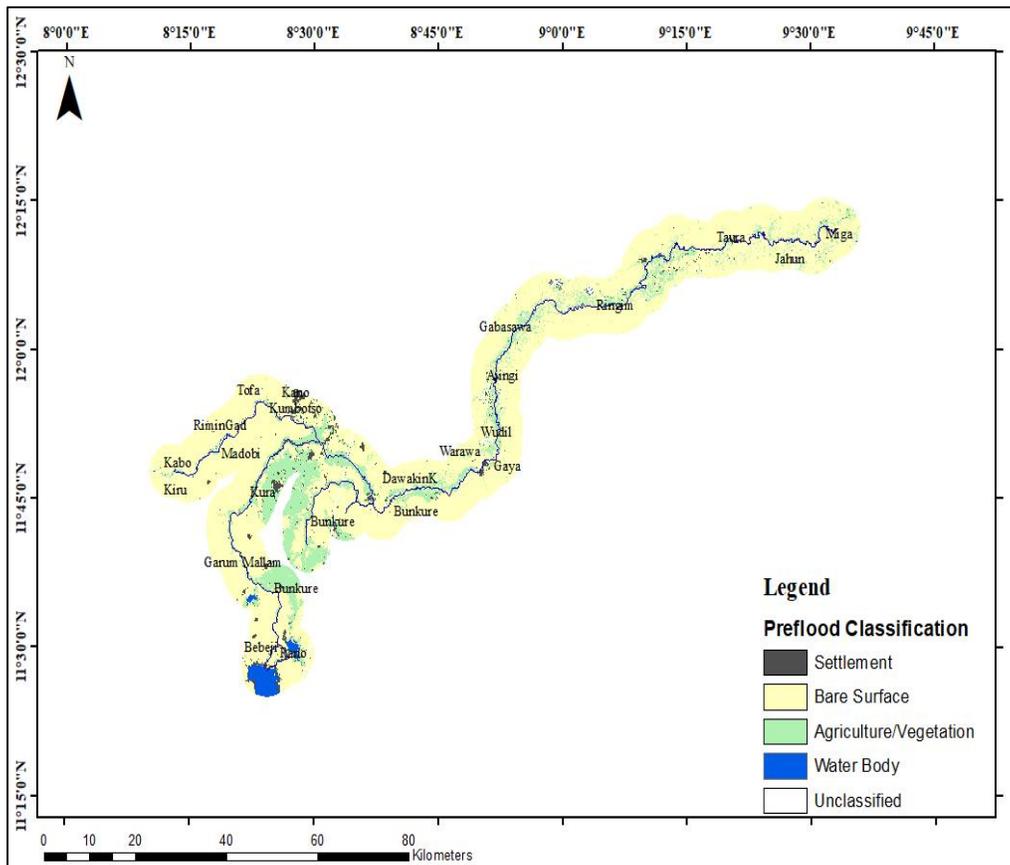| Land cover	Post-flood area (Km^2)
Settlement	62.58
Water Body	129.13
Agriculture/Vegetation	1418.39
Bare Surface	574.35
Flooded	538.49
Unclassified	211.03
Total change	**2933.97**

Fig. 3. Pre-flood classification of Hadejia river floodplain land cover
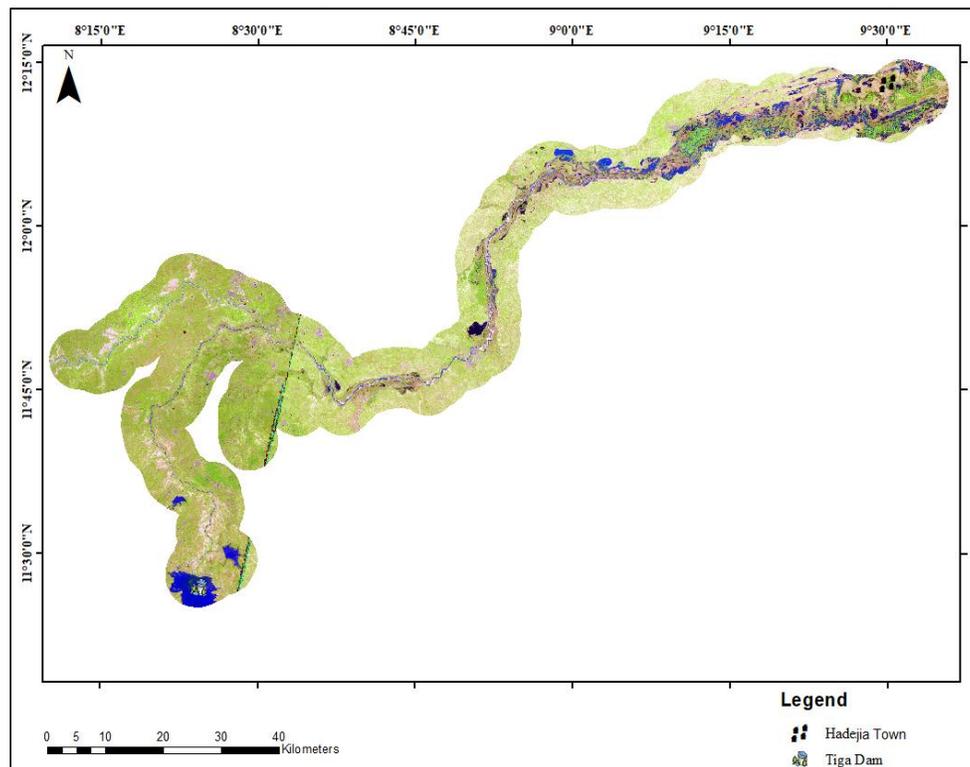
Fig. 4. Post flood nature of Hadejia river floodplain

3.4 Post-flood Classification of Hadejia Jamaare Floodplain Land Cover

The classification carried out on the floodplain post-flood image identified six (6) different land-use classes which include settlement, water body, Agriculture/vegetation, bare surface, flooded (areas damaged by flood) and unclassified (Fig. 5). Settlement occupies about 62.58 Km^2, water body occupies 129.13 Km^2 Agriculture/vegetation occupies 1418.39 Km^2 while bare surface, flooded and unclassified areas occupies 574.35 Km^2, 538.49 Km^2, 211.03 Km^2 respectively (Table 2). Increase in Agriculture/vegetation affirms that Hadejia-Jama'are River System (H-JRS) ecosystems is highly utilized for food production systems and livelihoods support (Odunuga, et al. 2011).

3.5 Difference in Post-flood and Pre-flood Land Cover Classification

The difference in post-flood and pre-flood land cover classification of the floodplain presented in Table 3. It shows that settlement reduces with 8.93 Km^2, bare surface decreases with about 1721.08 Km^2, Agriculture/Vegetation increases with about 936.85 Km^2. Area occupied by water

body also increases by 86.46 Km^2, unclassified areas increases by 167.61 while flooded area occupies 538.49 Km^2. Nhamo, Magidi and Dickens (2017) also confirmed that distinct landcover types, seasonal variations and differing sizes, in wetlands can be observed in mapped from satellite image classification.

3.6 Flood Prone Area and Flood Damages

The level of flood risk along the floodplain in terms of magnitude and severity was simulated using the Digital Elevation Model (DEM), drainage patterns, and other remotely sensed datasets. The result which was classified into three risk zones, low flood risk, high flood risk was overlaid with areas damaged by flood as presented in Fig. 6. The high-risk zones are areas that are likely to be inundated in a flooding event while the low-risk areas are the least liable to flood [24]. From the map Miga, Jahun, Taura, falls in the high flood risk zone, Ringim, Babasawa, Ajingi, Warawa, Gaya, Dawakin Kudu, Bunkure, Kumbotso, Kano, Tofa, Kura, Rimingado falls in the moderate flood risk zone and Kabo, Kiru, Garrum Mallam, Bebeji and Rano falls in the low risk Zone [25].
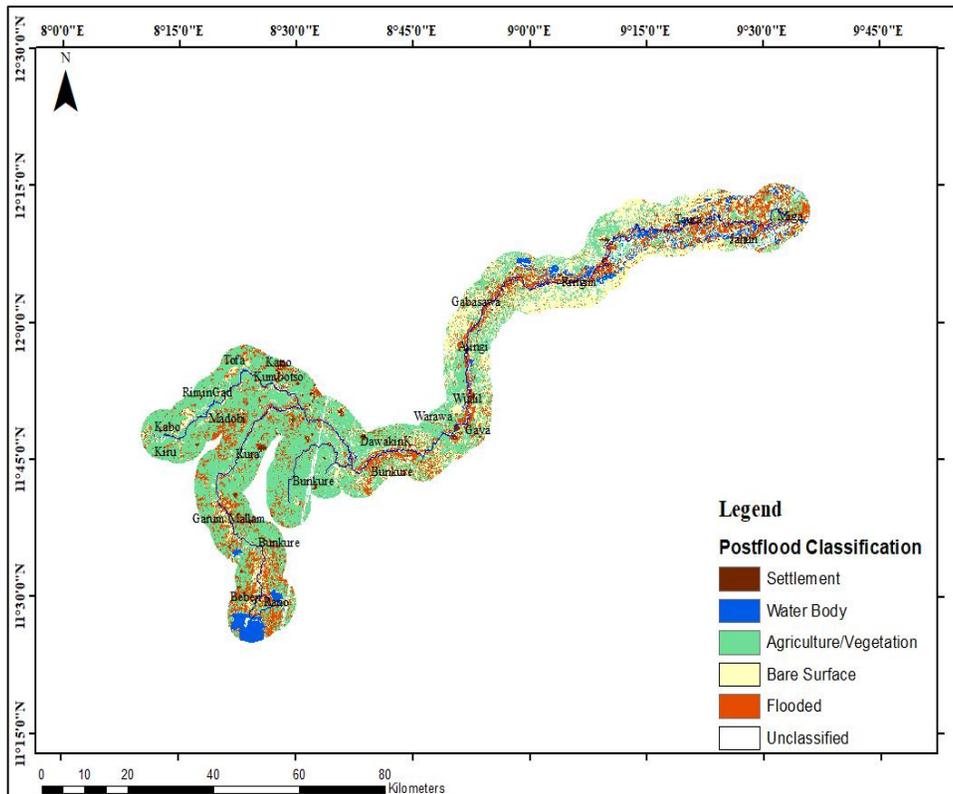
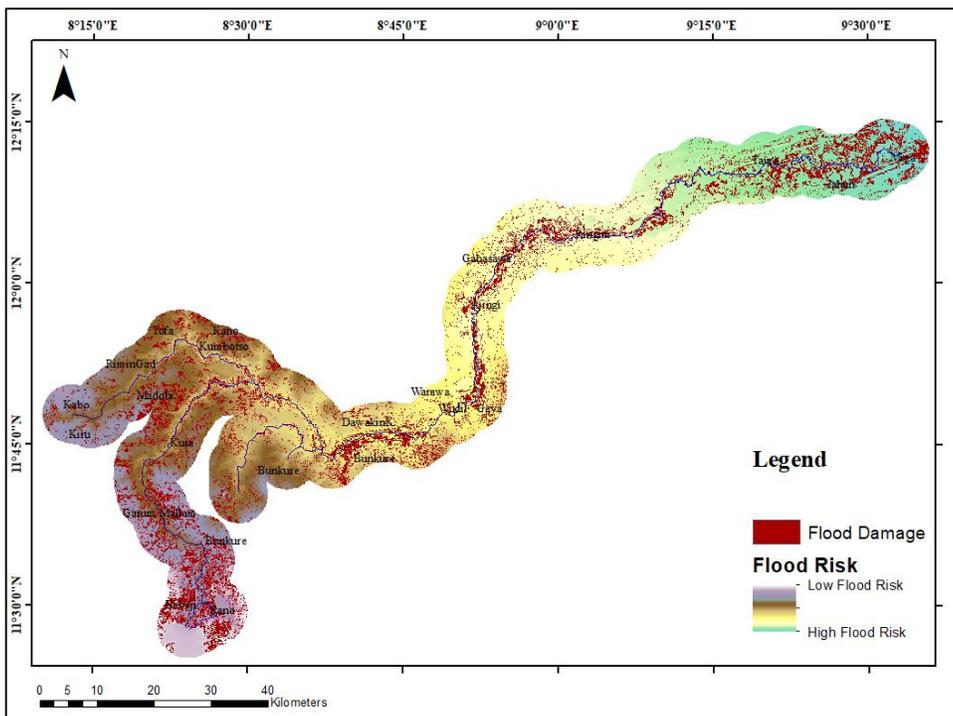**Fig. 5. Post-flood classification of Hadejia river floodplain land cover**

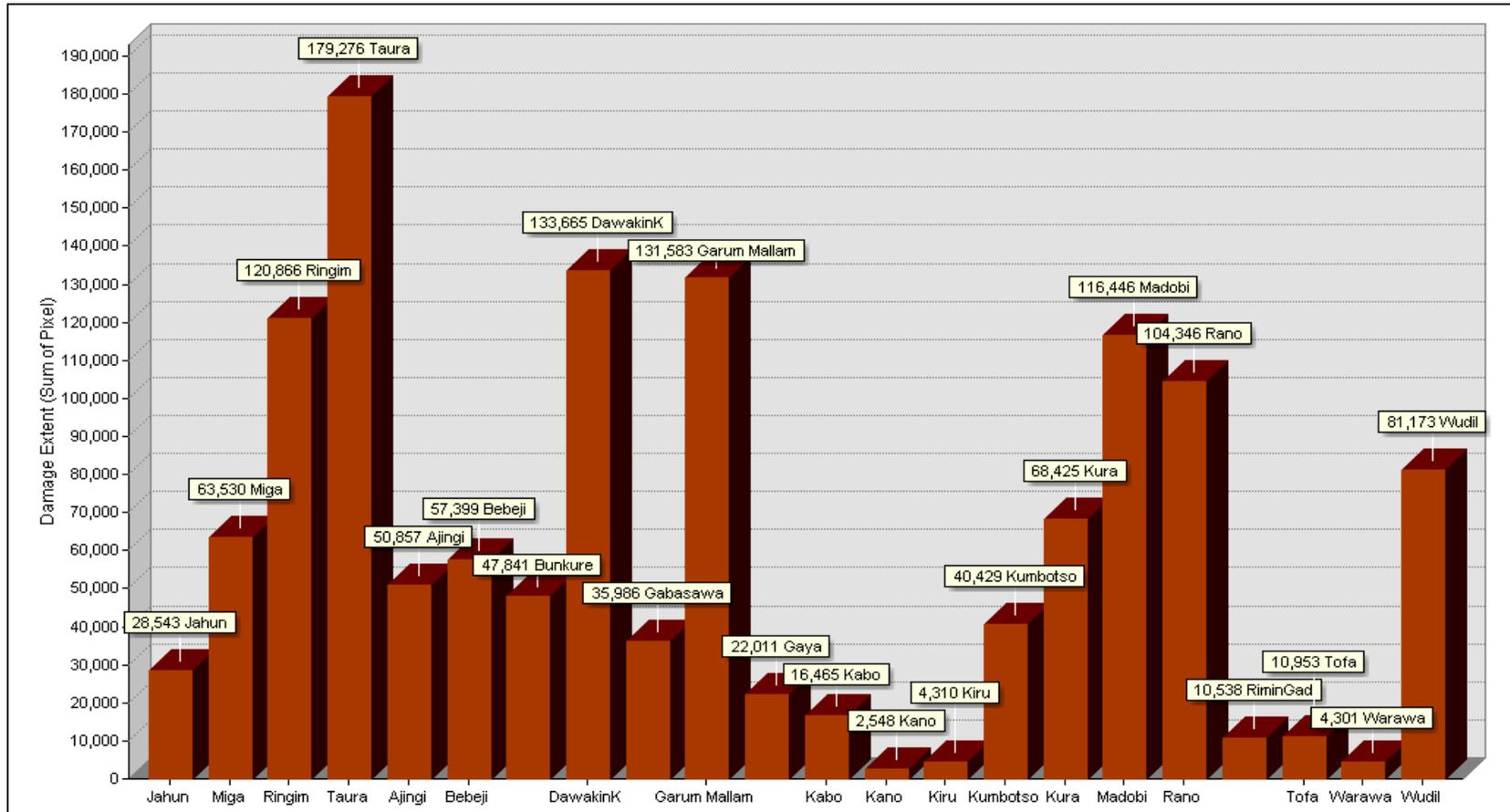**Fig. 6. Flood prone area and flood damages along the floodplain**

Fig. 7. Extent of damages across local governments along the floodplain

Table 3. Difference in post-flood and preflood classification

Land cover	Preflood (area in Km^2)	Post-flood (Area in Km^2)	Difference (Area in Km^2)
Settlement	71.51	62.58	8.93
Bare Surface	2295.43	574.35	1721.08
Agriculture/Vegetation	481.54	1418.39	936.85
Water Body	42.67	129.13	86.46
Unclassified	43.42	211.03	167.61
Flooded	-	538.48	538.48

However, the incidence of flood damages could be observed in various degree across the flood plain irrespective of their flood risk level. Obviously, this could be explained by the geomorphology, slope, and steepness of the area. Umar (2015) also classified that areas like Miga, Jahun and Taura are prone to high flood risk due based on digital elevation model.

3.7 Extent of Damages across Local Governments along the Floodplain

The extent of damages across local governments along the floodplain shown in Fig. 7 indicate that Taura has the highest damages by flood, followed by Dawakin Kudu, Garum Mallam, Ringim, Madobi and Rano among others while Kano Municipal recorded the least damage by flood. This could be because of several local factors such as precipitation, slope angles of some areas that could make them closer to water levels. Odunuga and colleagues (2011) also reported that there is a decrease in rainfall amount from the Hadejia upstream (the south of the basin) to the downstream northern part of the basin.

4. CONCLUSION

People living along floodplains of both major and minor river channels are constantly being ravaged by the menace of floods. Timely assessment of this impact has been near to impossible due to the tedious nature of the conventional flood damage assessment techniques. This study was able to showcase the severity of flood damage across floodplain of Hadejia Jamaare with the aid of remote sensing and geographic information system. It is, therefore, concluded that remote sensing and geographic information system are useful tools for assessment and evaluation of flood damages as well as a basis for taking proactive steps in mitigating flood hazard along floodplains and another flood prone environment. It was therefore recommended that there is need for continuous assessment of preflood nature of

flood plain so as to be able to have a basis for comparing the incidence of flood damage with. Also, there is a need for timely post-flood evaluation so that time intervention can be provided to victims of flood damage. Most importantly, there is a need to provide damage extent report based on remote sensing and geographic information system to aid planning and allocation of relief materials for affected regions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Aladejana O, Salami AT, Adetoro OO. Potential flood hazard zone mapping based on geomorphologic considerations and fuzzy analytical hierarchy model in a data scarce West African basin. Geocarto Int.; 2019.
2. The Federal Government of Nigeria, Nigeria Post-Disaster Needs Assessment (PDNA) 2012 Floods. 2013;1–188.
3. Jeyaseelan AT. Droughts & floods assessment and monitoring using remote sensing and GIS Satell. Remote Sens. GIS Appl. Agric. Meteorol; 2003.
4. Kundu S, Aggarwal SP, Kingma N, Mondal A, Khare D. Flood monitoring using microwave remote sensing in a part of Nuna river basin, Odisha, India. Nat. Hazards; 2015.
5. Oluwasegun AH. GIS Analysis of flood vulnerable area in Benin-owena river basin Nigeria. Indones. J. Geogr. 2017;49(1): 27–33.

6. Udo EA, OOC, BCN, GUA. Flood hazard analysis and damage assessment of 2012 flood in Anambra State using GIS and remote sensing approach. Am. J. Geogr. Inf. Syst. 2015;4(1):38–51.

7. Commission E. Update on floods in Nigeria; 2018.

8. Iliyasu U. Flood risk assessment in parts of Hadejia- Jama' are River Basin (HJRB) of Jigawa State, Nigeria By Umar Iliyasu An M.Sc. Thesis submitted to the Department of Geography, Faculty of Earth and Environmental Sciences, Bayero University, Kano in pa; 2017.

9. Chioma OC, Chitakira M, Olanrewaju OO, Louw E. Impacts of flood disasters in Nigeria: A critical evaluation of health implications and management. Jàmbá J. Disaster Risk Stud. 2019; 11(1):1–9.

10. Leibrand A, Sadoff N, Maslak T, Thomas A. Using Earth observations to help developing countries improve access to reliable, sustainable and modern energy. Front. Environ. Sci. 2019;7:1–14.

11. Klemas V. Remote sensing of floods and flood-prone areas: An overview. J. Coast. Res. 2015;314:1005–1013.

12. Ekeu-wei Iguniwari Thomas B. Application of open-access and 3rd party geospatial technology for integrated flood risk management in data sparse regions of developing countries. Preparedness, Response and Recovery; 2017.

13. Ugonna C. A review of flooding and flood risk reduction in Nigeria. Glob. J. Human-Social Sci. 2016;16(2).

14. Irimescu A, Craciunescu V, Stancalie G. Remote sensing and GIS techniques for flood monitoring and damage assessment. Study Case in Romania. 2010;1–10.

15. Mariappan S, Roslee R, Sharir K. Flood Susceptibility Analysis (FSAn) using Multi-Criteria Evaluation (MCE) technique for landuse planning: A CASE from penampang, Sabah, Malaysia. J. Phys. Conf. Ser. 2019;1358(1).

16. Vishnu CL, et al. Satellite-based assessment of the august 2018 flood in parts of Kerala, India. Geomatics, Nat. Hazards Risk. 2019;10(1):758–767.

17. World Bank. Assessment of the state of hydrological services in developing countries. 2018;55.

18. Edoka I, Akinyemi A, Akinlolu T. Flood disaster: An empirical survey of causative factors and preventive measures in Kaduna, Nigeria. Int. J. Environ. Pollut. Res. 2015;3(53):53–66.

19. Kefi M, Mishra BK, Kumar P, Masago Y, Fukushi K. Assessment of tangible direct flood damage using a spatial analysis approach under the effects of climate change: Case study in an urban watershed in Hanoi, Vietnam. ISPRS Int. J. Geo-Information. 2018;7(1).

20. Aladejana O, Salami AT, Adetoro OO. Potential flood hazard zone mapping based on geomorphologic considerations and fuzzy analytical hierarchy model in a data scarce West African basin. Geocarto International. 2019;1-26.

21. Dano, Umar Lawal, Abdul-Lateef Balogun, Abdul-Nasir Matori, Khmaruzzaman Wan Yusouf, Ismaila Rimi Abubakar, Said Mohamed, Mohamed Ahmed, Yusuf Adedoyin Aina, Biswajeet Pradhan. Flood susceptibility mapping using GIS-based analytic network process: A case study of Perlis, Malaysia. Water. 2019;11(3):615.

22. County ICS, Cu NIDȘ, Student PD, Asachi G. Floods damage estimation using sentinel-1 Satellite, no. June 1970. 2017; 115–122.

23. Tiepolo M, Rosso M, Massazza G, Belcore E, Issa S, Braccio S. Flood assessment for risk-informed planning along the Sirba River, Niger. Sustain. 2019;11(15).

24. Idowu D, Zhou W. Performance evaluation of a potential component of an early flood warning system-a case study of the 2012 flood, lower Niger River Basin, Nigeria. Remote Sens. 2019;11(17).

25. Government L, State K. Spatial multi-criteria analysis for mapping of flood vulnerable areas in Fagge Local Government Area of Kano State, Nigeria. Futy J. Environ. 2019;13(1):23–35.