From Catchment to Reach: Predictive Modelling of Floods in Nigeria

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Key words: Floods, CAESAR, Predictive Modelling, Vulnerability Mapping, Flood Hazards

SUMMARY

Flood problems in Nigeria are investigated in this paper. Causes of the flooding are attributed to climate change, extraordinarily heavy rains, continued release of excess water from dams, poor channel maintenance and soil moisture saturation. Flooding is the most devastating natural hazards in the world claiming more lives and causing damage to property and infrastructure than any other natural phenomena.

Floods problem in Nigeria have tolled a new dimension in recent time. There is increasing vulnerability of populations and infrastructure to flooding and flood related hazards. More communities are now affected in the country. The impact is great on populations and infrastructure due to the encroachment of urban facilities on floodplain, poor enforcement of physical planning regulation with respect to floodplain management and waterway planning. Scenes of the flood show settlements and infrastructure such as road at risk during inundation.

Cellular Automaton Evolutionary Slope and River Model (CAESAR), a predictive model was applied to predict flood inundation extents in three different zones (Adamawa, Ibadan and Kogi State) in Nigeria. The results were validated with actual flood extent measurements. The study shows that the 2010-2012 floods in Nigeria exceeded the natural floodplains. From rainfall - runoff (catchment) to relative increase in water levels (reach), could floods have been prevented? The study recommends prevention and mapping of floods and sustainable management of floodplains in Nigeria.

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1. INTRODUCTION

Flood problems in Nigeria have toll a new dimension in recent time. There is increasing vulnerability of populations and infrastructure to flooding and flood related hazards. More communities are now been affected in the country. Flooding is among the most devastating natural hazards in the world claiming more lives and causing damage to property and infrastructure than any other natural phenomena (Nwilo et al., 2011, Ologunorisa, 2006; Alcira and Martha, 1991). The great floods have also reduced Nigeria's crude oil production drastically by 500,000 barrels per day (bpd) in the Niger Delta (Osun Defender, 2012). The rate of spread, number of internally displaced persons and magnitude of losses counted in the affected States have attracted the attention of the federal government of Nigeria. In an intervention speech presented by President Goodluck Jonathan on the flood situation, based on the impact assessment, the affected states were categorized into four federal government aid groups A to D.

Category A (Oyo, Kogi, Benue, Plateau, Adamawa, Delta, Bayelsa, Anambra); Category B (Jigawa, Kano, Bauchi, Kaduna, Niger, Nassarawa, Taraba, Cross-River, Edo, Lagos, Imo); Category C (Kwara, Katsina, Gombe, Ogun, Ondo, Ebonyi, Abia, Rivers) and Category D (Sokoto, Kebbi, Zamfara, Yobe, Enugu, Ekiti, Osun, Akwa-Ibom, Borno, FCT). The flood disasters which started as flash flooding in different parts of the country since the onset of the rainy season in April suddenly became intensive by late August, with unprecedented flooding in most states in Nigeria between 2010 and 2012. By mid-September, dams were overwhelmed giving way to flooding that sacked so many communities that hitherto lived peacefully in their domain in more than twenty states of the country.
The North Central states of Nigeria have been particularly vulnerable, especially, Kogi, Kwara, Niger, Benue and Nassarawa. Other states roiling under the siege of storm water include Anambra, Edo, Enugu, Akwa Ibom and Delta, among others. The flood overflow of the Lokoja-Abuja Road which rendered it impassable has made the issue of flooding a serious matter; given the fact that the road is a major road linking different parts of the country to the Federal Capital Territory. Figure 1 shows river and stream network in Nigeria.
Nigeria is not alone in this, in many parts of the world such as Sri Lanka, Brazil, Japan, India, Pakistan and Haiti; floods have sacked many communities and hundreds of billions of dollars lost to such disasters.

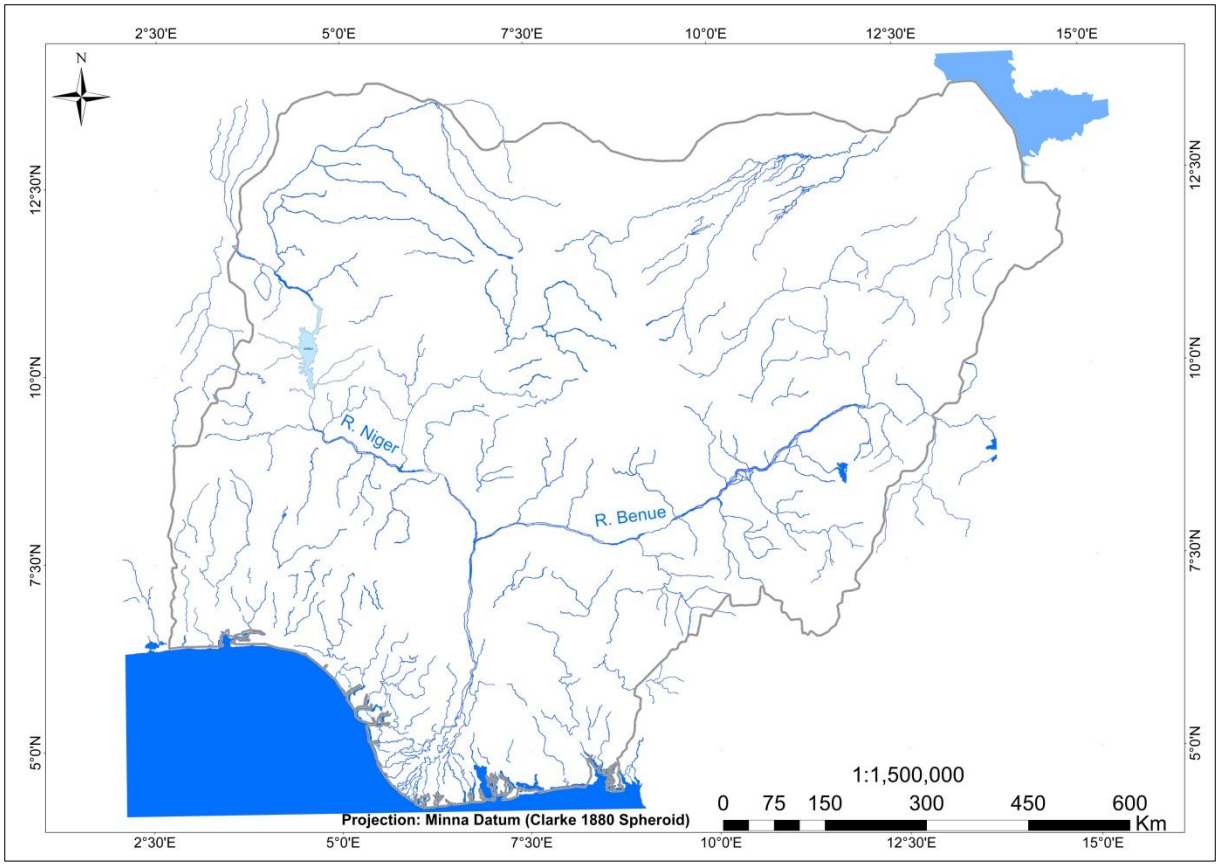

Figure 1: Nigerian Rivers and Streams Network (Map converted to digital by authors)

2. ASSESSMENT OF FLOODS IN SOME STATES IN NIGERIA

2.1 Kogi State

Ankpa, Idah, Edeke, Ugwoda, Iyieoba, and Adabatene Rivers were overflow their banks. Nine Local Government Areas (LGAs) and over ninety communities were affected in Kogi State. Listed below are information on the LGAs and communities assessed during the field visits.

- Lokoja: 10 Communities. The affected areas are: Old Poly Quarters by Meme bridge, Road to Ganaji village - buildings were submerged up to 6m water level mark, Kabawa road 600m stretch under water and 0.6m water level mark, Lokoja –Abuja expressway by Banaja Village- 300m stretch and 1.5m under under water.
- Idah: 21 Communities (some of the areas affected are Ugwoda, Adamu, Ogenegu, Ala, Ogegele, Opoju, Alashala, Alakabe, Ugbetulu, Shekene, Alokona).
- Ibaji: 75 Communities (Ota, Ojula Ojebe, Odeke, Ukponu, Odogu, Onale, Utodima, Oyedega, Ewele, Ike, Edeke, Omabo and others)
- Adavi Ajakuta: 15 Communities. The affected communities are: Gbaraga, Adagbo, Kporoku, Gadumo, Omi oye, Adogu North, Onyogaunu, Makoja, Opala, Ogwoja, Oguro/Niger bridge, Anumagbo/Ochonule, Agada, Manajo, Geregu, Ajakuta Native

town, ASCON camp, MIT camp, Meteorological Training Institute.

- Omala: 18 Communities; Iglamela-Odolu: 39 Communities; Olamaboro; Ibasa: 61 Communities; and Ofu: 5 Communities.

The flood disaster in the state led to the establishment of internal displaced people's camp. Some of the camps set up include:

- Kabawa camp at located at Islamiya LGEA Nur/Pri. School, Lokoja- 558 people
- Adamkolo at Saint Louis Central camp, Lokoja- 975 people
- Gadima camp- 214 people (children 65, Female 78, and Male 71)

At Okume, a local re-settlement area was created by the community on a heap of sand dredged from the Niger (created sand Island). The FADAMA low land was submerged to 5.5m water level mark around Okume area. Infrastructures like Conference Hotel Lokoja completely were under water. Roads, bridges and buildings were inundated and hectares of farmlands were destroyed. There was also loss of lives, economic loss, breakdown in transportation as the major road linking the northern part of the country at some point was submerged as well as breakdown in educational activities as most school structures are used as relief camps for displaced persons in the State.

Interviewed conducted revealed that there was a major flood event in 1935 before the 2012 flood. The flood was as a result of water from Kanji Dam combined with inflow from the Benue channel from Cameroun.

Figure 2: Submerged Lokoja Conference Hotel. (Source: Authors' Field Work)

Figure 3: Ganaji express Road and Kabawa Road in Lokoja underwater. (Source: Authors' Field Work)

Figure 4: Submerged Buildings at Old Poly Quarters by Meme Bridge, Lokoja (Source: Authors' Field Work)

Figure 5: Hectares of Rice Farm Destroyed by Flood at Ajaokuta (Source: Authors' Field Work)

2.2 Oyo State

The Odo Ona flood in Ibadan, Oyo State was ushered in by a heavy rain rainfall that lasted not fewer than fourteen hours. The aftermath of flood that started at about 11.00pm on Friday,

August 26, 2011 (Figures 6-7) was alarming (Olayinka et al., 2012). Over one hundred lives were lost in a single day, property worth millions were destroyed, farmlands and products destroyed and the number of people displaced or sent to relief camps are in no small measure. It was indeed a flood hazard in recent time that left tears in the eyes of many. At least five bridges along the channel were affected or failed. Instrumental to flood problem in an area could be heavy down pour such that water cannot be controlled, blocked channel and drainages, and when engineering structures are not planned to curtail flooding.

Olayinka et al., (2012) reported that there is a fundamental question that a debate on the Odo Ona flood abatement measures must address**. Is the Ibadan flood a natural disaster, maintenance or structural failure?** The study revealed that water level at Oke-Ayo area was in the range of 7-10m, 6m at Oluyole Estate and Bakery area - off Gada Street and 4.5m at the New Garage area to mention a few. The average width of the Odo Ona channel is 20m. The study shows that the water outlet in the bridges mentioned earlier is about 8m. Considering the engineering structures in place before the flood, it is clear that there was no provision for excess in the outlets and water level information over time was not taken into consideration in determining bridge heights. This is believed to be the reason why the bridges were submerged in the area. Oyo State had recorded series of flood events in recent time with great impact on the people. According to Olayinka et al., 2012, some of the direct impacts of such flood events include loss of lives, physical damage caused include buildings, bridges, cars and structures, economic breakdown that led to hardship due to investment lost, rebuilding cost, emotional impact and impact on agriculture- fish and poultry farms, birds, farmland and products were destroyed.

Figure 6: Submerged Structure on Floodplain before and after Ibadan flood disaster at New Garage Bridge. (Olayinka et al., 2012).

Figure 7: Affected Bridge at Oluyole New Garage and structural failure at Eleiyele Dam Spill Way (Olayinka et al., 2012).

Result from mapping of the flood extent and determination of settlements and infrastructures shows that at least six (6) bridges were destroyed and over three thousand (3000) houses submerged in the area.

2.3 Benue State

In the Lower Benue catchment, Benue is one of the states hit by the great floods. Some of the towns affected in the State are Makurdi, Agatu, Logo and Adoka. Animals such as hippopotamus, crocodiles, and snakes were found around homes and communities. Figure 13 are flood scenes in Wadata area in Makurdi during the 2012 that resulted from massive water released from Cameroun Lagdo Dam.

Figure 8: Some Submerged houses in Wadata Area, Makurdi, Benue State

2.4 Kano State

The effect of flooding in Kano has been worse as no fewer than 19 persons were confirmed dead, many injured and more than 15, 000 people were displaced as a result of flooding in the state between August and September, 2012.

2.5 Bayelsa State

Over 90 per cent of Bayelsa State was been submerged by flood (Thisday, 2012). Six of the eight local government council areas in the state were under water. Only Nembe and Brass were not affected. The Niger Delta University (NDU) situated at Amassoma was submerged by the flood.

2.6 Adamawa State

In Adamawa State, Rivers Benue and Gongola overflowed their banks coupled with released water from the Lagdo Dam in Cameroun and the Dadin- Kowa and Kiri Dams. Over 89 schools were destroyed by the floods. Other schools in the area were taken over as camps by communities displaced by the flood disaster. The flood also claimed lives in the State.

3. CAUSES OF THE GREAT FLOODS IN NIGERIA

Before any sustainable prevention and control measure can be suggested for the recent floods in Nigeria, knowledge of the cause(s) is necessary. Flooding in Nigeria occurs in the floodplains of rivers when the capacity of water courses is exceeded and where there are blockages of water courses and flood channels. River defences may then be overtopped due to increased water levels, or breached by large objects of debris carried at high water velocities. This is what happens when we have fluvial flooding. Another kind of flood common in Nigeria is flash flood. Flash floods are floods from sudden downpour. Increased impervious surfaces could also contribute to flooding in cities like Lagos.

3.1 Climate Change

Climate change is primarily responsible for the flooding. If a place like Jigawa which is very close to Republic of Niger, an arid land is experiencing flooding, then there is Climate change. Bariweni et al., (2012) documented that climate Change is an attributed cause of flooding because when the climate is warmer it results to: heavy rains, relative sea level will continue to rise around most shoreline and extreme sea levels will be experienced more frequently.

3.2 Incessant Heavy Rainfall

The floods are believed to be due to extraordinarily heavy rains. Nigeria has two rainy seasons, the first lasting from March to the end of July and the second commencing in early-September and ending around mid-October. The country often experiences flash floods in these periods. Heavy rains caused River Niger to overflow right from its roots. These heavy rains are believed to be due to Global warming.

Lagos experienced over eight hours of rain which almost submerged areas such as Okota, Isolo, Jakande Estate, Ijora, Lekki, Victoria Island and some parts of Ikeja. The long hours of heavy flooding did not only shut many residents of the state in, it also shut many out as it resulted in long traffic snarl since many roads such as the Apapa-Oshodi Expressway were

almost completely cut off by the flood. However, although the waters swept away some vehicles and other valuables, the flooding did not record any loss of life, the experience in June when excessive downpour caused the bridge linking Lagos and Ogun States at Ayobo, in Ayobo/Ipaja Local Council Development Area to submerge with six adults and a child reportedly carried away while attempting to cross from Ogun to Lagos State.

3.3 Release of Water from Dams

The continuous release of excess water from dams is another reason for flooding. With the dams filled, it would be dangerous to leave them like that, so the authorities came up with a systematic way of discharging the water so as to avoid dam breaks. Water from both Shiroro and Kainji dams had to be discharged and that was partly responsible for the flooding in Kogi State and other states downstream. Sudden release of water in Oyan Dam (figure 9) led to the flooded Ogun River Catchment in 2011 (Olayinka et al., 2012). The opening of Cameroonian dam (Lagdo dam) caused flooding in Adamawa State.

Figure 9: Oyan Dam in Ogun State and the Ibadan free fall (gravity) Dam in Oyo State (Source: Authors Field Work).

3.4 Saturated Soil Moisture

Soil moisture saturation could lead to serious flooding. The wetlands which are floodplains are saturated. Water is therefore forced to move landward leading to inundation.

3.5 Poor River Channel Maintenance: Blocked and Narrow Channel

The channels are too narrow and blocked with sediments, sand dune, bamboo trees and debris, and could not contain excess water. In such a situation, the river overflows its bank. This is believed to be partly the reason for the Ona River flood in Ibadan. Looking at the channels from maintenance point of view, one could say that there was no maintenance plan in place (Olayinka et al., 2012).

The study conducted by Nwilo et al., (2012) in Adamawa State, revealed a constriction along the Benue River. Result of flood simulation at different flow regime reveals the presence of boulders in part of the channel and the river starts to overflow its bank at the part depicting

the highest number of boulders. The presence of boulders along the channel hinders smooth flow of water thereby resulting in settlements being inundated.

Figure 10: Bamboos and debris in the middle of Ona River along Alaafin Avenue Source (Olayinka et al., 2012)

4. SUSTAINABLE FLOOD COMBAT MEASURES

Having known the specific causes of the floods, the question now is what are the sustainable combat measures? How do we prevent and control it? Knowledge of the following will be useful at this point:

- Has the natural floodplain been exceeded?
- What is the floodline like (spread)?
- What are the physical planning regulations for floodplains and water ways and to what extent are they implemented?

In the face of the natural disaster that has submerged about half of the country; many Nigerians are of the opinion that the deluge of flood that may not abate soon would have been mitigated had the state governments heeded the strong warning from the Nigerian Meteorological Agency (NIMET) for more rain forecast. Based on findings of this study, therefore, some combat measures are suggested.

- Demolishing of structures along the water ways (floodplain or drainage line). Town Planners to war against erection of illegal structures by river side in the entire country. Illegal structures are instrumental to constant flooding during the rainy season Reasonable setback must therefore be enforced.
- Information or early notice is therefore necessary for Nigerian government from the Cameroonian authorities before releasing water from the lake. This has to be enforced to mitigate the impact of flooding from the Benue channel.
- All affected bridges to be reconstructed, high and with outlets wide enough (wide outlet width) to contain excess water in case of a 25 hour rain that could rise to 15m water level mark.

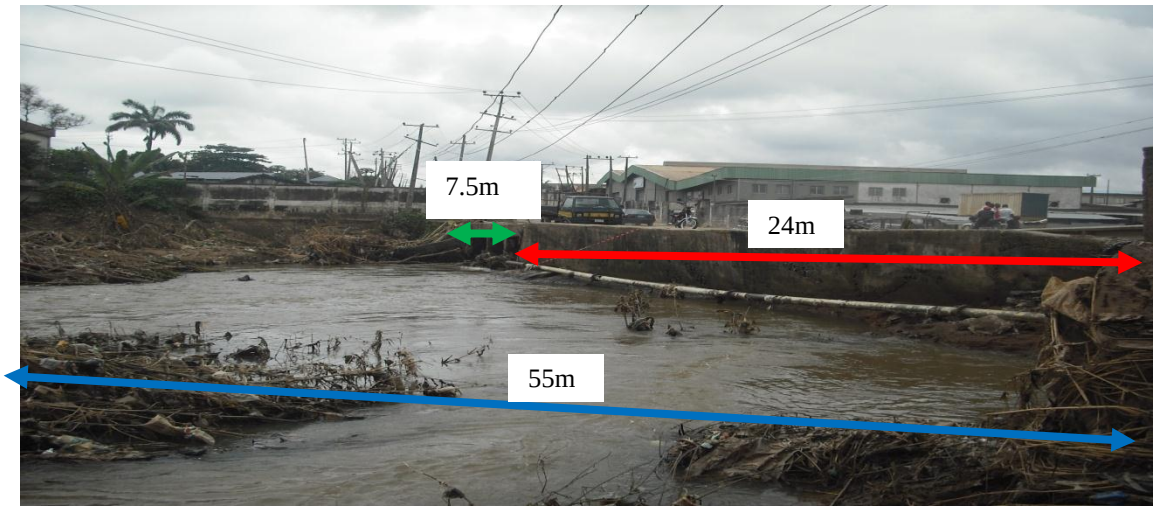

Figure 11: The Bridge at Oluyole structurally designed without consideration for width of the floodplain, channel size and maximum water level. The widths of the outlet (Green), Retainer Wall (Red) and Floodplain (blue) (Source: Olayinka et al., 2012).

- Modelling and spatial analysis information (scientific approach) of low, medium and high flow regimes. This will show the settlements at risk and exact extent to relocate people and sediment deposit in the channel.
- Dredging is recommended along the river channels in some area widen it up and give the channel the ability to contain excess water. Example areas with sand dune in the channel, presence of boulders and narrow width, etc.
- Construction of more dams in the country to curtail excess water.
- An overhead bridge or fly over will be useful at the flood site along Abuja-Lokoja, a major route linking the north and southern part of the country.
- There is a strong need to develop a culture of maintenance for all the channels in Nigeria.

In the case of Ibadan, Oyo State, from maintenance point of view, one could say that there is no channel maintenance plan in place, particularly for the Ona River (figure 11). Flood event in Ibadan shows that flood disasters have happened over and over in the area and possibilities of reoccurrence exist.

4.1 Predictive Modelling of Floods in Nigeria

Given the extent of spread and level of impact on the people, and the need to protect and manage the environment effectively, a holistic approach is required. This entails carrying out complex flood modelling and spatial analysis, risk and vulnerability assessment in the area. Inundation levels was simulated at different flow regime in the Adamawa State floodplain (figure 14) using CAESAR. Flood analysis and overlay operation revealed a large number of settlements at risk on the floodplain (Nwilo et al., 2012).

4.1.1 Cellular Automaton Evolutionary Slope And River (CAESAR) Model-Numerical

CAESAR is a two dimensional flow and sediment transport model. The basic components of the CAESAR model are Digital Elevation Model, flow data and sediment information. It can simulate morphological changes in river catchments or reaches, on a flood by flood basis, over periods up to several thousands of years (Coulthard et al. 2002). CAESAR occupies a unique space in fluvial modelling. It has the capability to simulate timescales that are useful to engineers, researchers of fluvial systems (1-100 years) and to simulate flooding and morphological change of pertinent spatial scales (from 2 km reaches to 400+ km catchments). The cellular framework uses a regular mesh of grid cells to represent the river catchment studied. It is based upon the cellular automaton concept, whereby the repeated iteration of a series of rules on each of these cells determines the behaviour of the whole system. (See: Chapter 4 of Coulthard, 1999 for details). CAESAR model was used to simulate flood at different flow regimes and flood inundation extent determined. Settlements vulnerable to floods (at risk) were then assessed.

(a) (b)

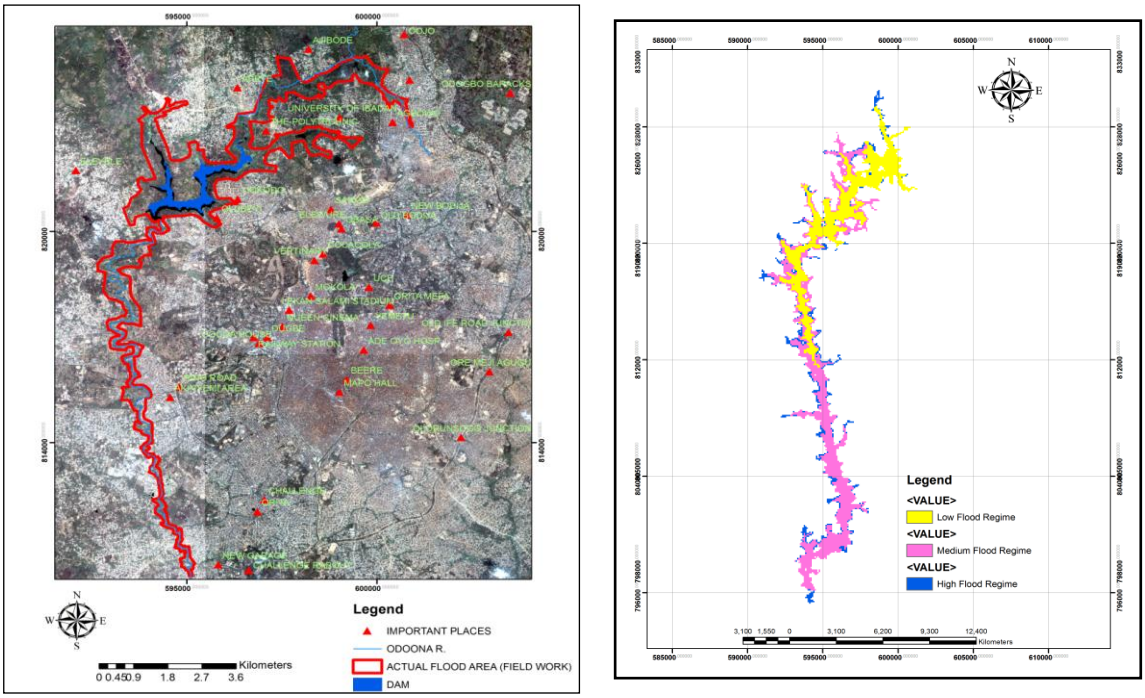

Figure 12: (a) Flood Extent Map from Satellite image and Field Observation showing settlements and infrastructure at risk and (b) Simulated Flow Regimes and Inundation Extents for Ibadan.

(a) (b)

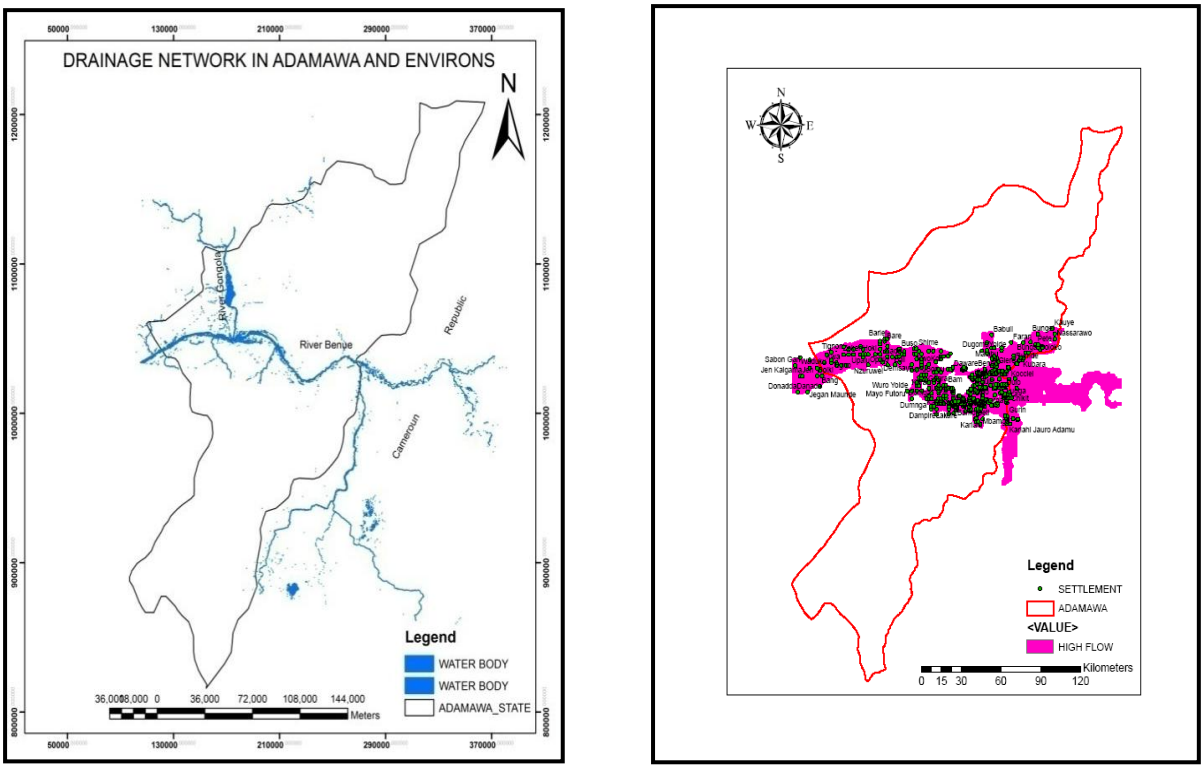

Figure 13: (a) Drainage Network in Adamawa and (b) Inundation levels Simulate in Adamawa State Floodplain.

4.1.2 Floodplain Modelling and Vulnerability Mapping from Terrain Data

Flood inundation extents and vulnerability maps of Rivers Niger and Benue through Kogi State and environs were derived from SRTM and Radar Data as shown in figures 14 and 15 respectively. Using terrain data, areas were classified into five according to vulnerability to floods and compared with the actual flood extents from RadarSat data from UN-SPIDER. This study shows that most settlements are on the natural floodplain. The RadarSat data also shows that the flood extent in 2012 exceeded the natural floodplains. It is therefore possible to model and predict the flood inundation extent with buffer zones before the flood events.

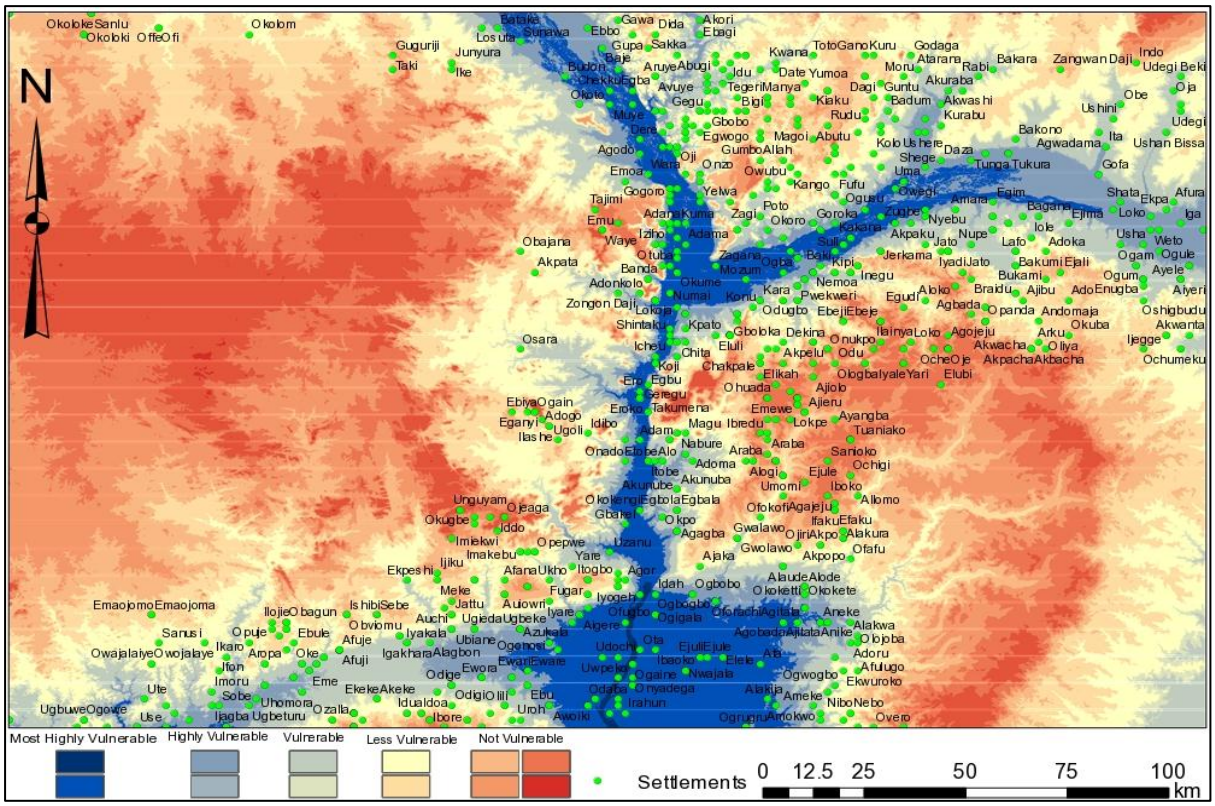

Figure 14: Flood Vulnerability Map of Rivers Niger and Benue Confluence from SRTM data.

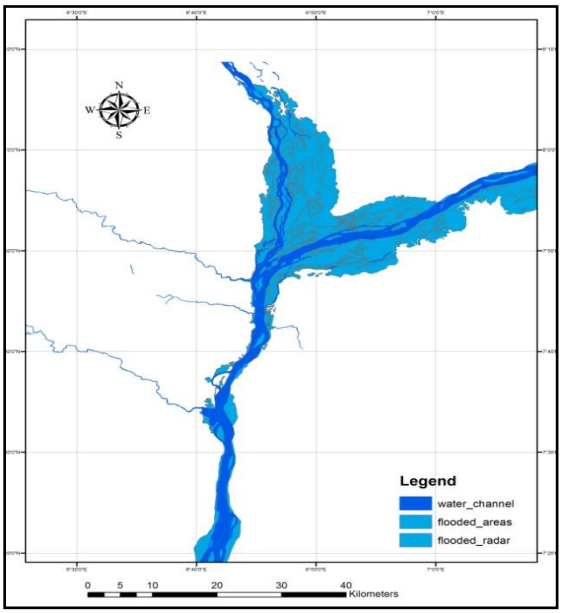

Figure 15: Flood Extent around the Rivers Niger and Benue Confluence and environs from RadarSat data.

5. SUMMARY AND CONCLUSION

Flood problems in Nigeria have been investigated in this paper. Causes of the flooding are attributed to climate change, extraordinarily heavy rains and continued release of excess water from dams. The 2012 flood events in Nigeria exceeded the natural floodplains. Other reasons from findings in this study are poor channel maintenance and soil moisture saturation. Scenes of the flood show settlements and infrastructure such as road at risk during inundation. The impact is great on populations and infrastructure due to the encroachment of urban facilities on floodplain, poor enforcement of physical planning regulation with respect to floodplain management and waterway planning. Prevention and sustainable management options have been emphasized. The floodplains and their extents have to be mapped and well demarcated. This will create more awareness to the rural dwellers and urban improper settlers as well make it easy for enforcement agencies to enforce planning order across the country.

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