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Comparative Analysis of Spatial Impact of 2012 and 2022 Flood Disaster along Lower Niger Basin in Nigeria

***AHUCHAOGU, UE; DURU, UU; IKWUEMESI, GO**

Department of Surveying and Geo-Informatics Federal University of Technology Owerri, Imo State, Nigeria

**Corresponding Author Email; ahuchaogujasper@gmail.com; udoemmy@yahoo.co.uk*
**ORCID: https://orcid.org/0000-0002-8063-1608*
**Tel: +2348035656394*

Co-Authors Email: ucheduru2000@yahoo.com; georgeikwu@gmail.com

ABSTRACT: In recent times there have been excess flooding due to climate change, which leads to disaster and destruction. Hence the aim of this paper is to investigate spatial impact of the two flood episodes that occurred in 2012 and 2022 along Lower Niger Basin in Nigeria using remote sensing data in GIS environment. Data used include administrative map of Nigeria, time series 30m resolution Landsat imageries captured before and during the peak of the flood episodes, SRTM DEM of 30m resolution and data generated from ground truthing. The pre- flood image was used as reference to determine the extent of flood in the disaster imageries. SRTM data was used for preparation of digital elevation model so as to investigate the influence of topography on spatial spread. This study revealed that 5622.13square kilometers of the study area (7.92%) was covered by flood in 2012 while 7428.771 square kilometers of land (10.47%) was inundated in 2022. This means that additional 1806.641 square kilometers (2.55%) of land surface has been exposed to flood in the study area within a time space of 10years. Upon field verification it was found that this was partly attributed to anthropogenic activities and urban expansion. It was therefore recommended that strict land use planning be enforced within the study area and public enlightenment programs should be initiated

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Heavy floods in Nigeria have shown increasing trend in recent years. Flood is usually disastrous overflow of water from a lake or other body of water due to excessive rainfall or other input of water (Anyanechi *et al.* 2020). As per Emmanuel *et al*. (2017), flooding results when inflow exceeds the caring capacity of a river channel. The term 'flood' is most notably used to describe the uncontrolled inundation of an area with water as a result of the overflow of water from a nearby stream or river over the natural or artificial banks (Christos *et al* 2022). The frequency and intensity of flood hazards are increasing globally. Averagely, 231 million people annually, are affected by one natural hazard or the other. Flooding has contributed majorly to loss of life and economic loss and it is expected that flooding will continue to increase in both intensity and frequency in the near future. Urbanization is among the major contributor to flooding in developing countries, by restricting flood waters movement. In the urban settlement, major part of the ground surfaces is covered by pavements, roofs and tarred roads. This obstruct the pervious part of the ground and drains are constructed that transmit flow faster than under natural condition (Jimoh 2020). The ability to measure vulnerability is increasingly being seen as a key step towards effective risk reduction and the promotion of a culture of disaster resilience (Birkmann, 2006). In the past decade in Nigeria,

**Corresponding Author Email; ahuchaogujasper@gmail.com; udoemmy@yahoo.co.uk*
**ORCID: https://orcid.org/0000-0002-8063-1608*
**Tel: +2348035656394*

thousands of lives and properties worth millions of Naira have been lost directly or indirectly from flooding every year. The impact of floods has been increased due to a number of factors including rising sea level and increased developments on flood plain etc. (Ologunorisa, 2004).

Re-occurring flood loses have handicapped the economic development of Nigeria and other developing and developed countries. The devastating flood occurrence and its multidimensional impact on the masses is currently a great concern to Nigeria and the world as a whole. In 2012 heavy flood event occurred in Nigeria. The event which was reported to be of 40 years return period was attributed to the release of water from Lagdo Dam in Cameroun and extreme rainfall. The resultant effect was devastation of low-lying areas along the Lower Niger-Benue basin.

The flood was very disastrous affecting a total of 14 States with 1.3 million people displaced and about 431 people lost their lives (Nkeki, 2013). The National disaster impact assessment rating (IAR) instituted by National Emergency Management Agency (NEMA) categorized the affected areas into group A, B, C and D in descending level of damage and part of the study area falls under group A and others in group B. In 2022 also, Nigeria experienced another high level of flooding resulting from the same sources and communities along lower Niger were also the worst affected. This was described as the worst flood disaster in the nation's history with over 30% of the entire country completely submerged resulting to the death of over 600 persons and displaced more than 2 million people from their homes while the actual costs are yet to be determined.

The significance of the both flood disasters in Nigeria lies in the fact that they were unprecedented (Ojigi 2012). For the fact that the magnitude of flood of return interval of 40 years re-occurred within a space of 10 years with similar effect to the people as the previous, call for a reliable approach to monitor the trend so as to reduce the impact on people and the environment.

The use of earth observation system (EOS) technology and GIS platform has been discovered to be an integrated, well developed and reliable approach in disaster monitoring and management. Therefore, the objective of this paper was to compare the spatial impact of the two flood episodes that occurred in 2012 and 2022 along Lower Niger basin in Nigeria.

MATERIAL AND METHODS

Study Area: The area under consideration in this study measures 70959.175 square kilometers and geographically located between latitudes 5°.00`N and 8°.45`N, then longitudes 5°.00`E and 7°.45`E. The area enjoys both wet and dry season with a total annual rainfall between 1000mm-1500mm. Mean annual temperature is about 27.7oc and a relative humidity of 30% in dry season and 70% in wet season. Average daily wind speed is 89.9km/hr. wind speed is usually at its peak in March and April. The basin is drained by two major rivers (River Niger and river Benue) which joined at Northern part of the basin before flowing towards south dividing the basin into nearly two equal wings and disaggregates into networks of rivulets that flow into Atlantic Ocean in Delta State, Nigeria

Fig1a 2012 flood at Lokoja in Kogi State, Nigeria
(Source; Google aerial photographs)

Fig1b. 2022 flood at Ndokwa East in Delta State, Nigeria
(Source; Google aerial photographs)

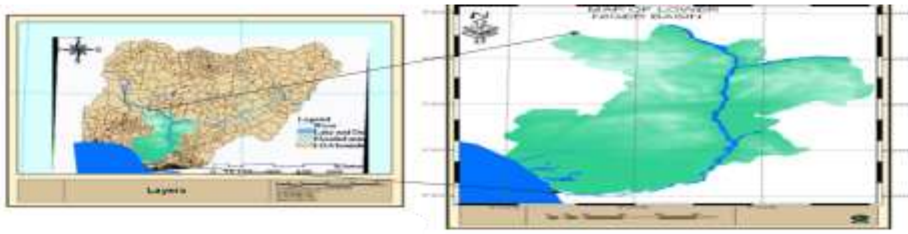

Fig 2 location map of the study area

Data Description and Procurement: Data used in this study includes 30m resolution shuttle radar topographic mission (SRTM) which was used for topographical analysis. This dataset is originally georeferenced into the horizontal datum of WGS84 and EGM96 geoids vertical datum. Other data sets include administrative map of the Nigeria from which the boundary shape file was extracted. Prior and during 2012 and 2022 flood Landsat image with resolution of 30m were downloaded from he internet. Landsat satellites use the Worldwide Reference System (WRS) of scenes divided up into paths and rows. According to NASA (2004), the Worldwide Reference System (WRS) is a global notation system for Landsat data. It enables a user to inquire about satellite imagery over any portion of the earth by specifying the PATH and ROW numbers. The WRS has proven valuable for the cataloguing, referencing, and day-to-day use of imagery transmitted from the Landsat sensors.

Methodology: This study was carried out as per the methodology shown in figure3. The time series Landsat imageries were pre-processed and enhanced to improve the visual distinction of features therein. The improved imageries were projected to WGS84 ZONE 32 in Arc-GIS 10.5 environment. The administrative map which was geo-referenced to the same coordinate system was digitized and used to clip the imageries to actual boundary limit. The reason for identifying in the same coordinate system is to ensure compatibility between the various environmental data-set. The creation of a personal geodatabase for each feature of interest was done in ArcCatalog extension of the ArcGIS 10.5. The digitizing process was done in the ArcMap environment for feature extraction. The true width of the river channel was extracted from pre-disaster imagery and in the same process, the flood layers along the river channel from the disaster imageries were digitized as polygon layers. The map generated from the pre-flood image was used as a reference to determine the extent of flooding in the disaster images. A comparison between the prior and during images of the flooded areas showed that, in 2012 and 2022, both Rivers Niger and Benue burst their banks, engulfing the small lakes, ponds, farmlands and settlements within the flood plain. Crops were ravaged and transportation routes blocked in the affected communities. Spatial erase was caried out to separate the actual width of the river from the flood within the disaster imageries. With the help of calculate geometry module of ArcGIS the flood extent in the disaster imageries were calculated.

Terrain and Overlay Analysis: The tiles of the elevation raster (DEM) were mosaicked using data management module of ArcGIS 10.5 and the generated data was transformed from geographic coordinate system to projected coordinate system (i.e. from GCS-WGS1984 to WGS1984 World Mercator). The elevation raster was clipped to actual boundary limit and used for surface analysis of the study area. The flood layers were overlay on the administrative map of the study area disaggregated to local government level and the spatial extents of the floods at various locations were digitized and calculated. In the same process the flood layers were overplayed on the elevation map so as to investigate the influence of landscape pattern to flood spread at various locations.

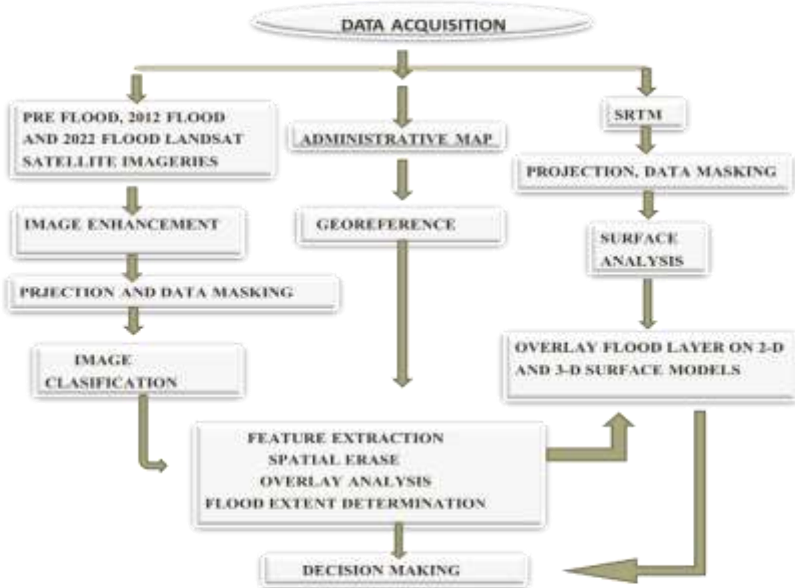

Fig. 3 Methodological flow chart

RESULTS AND DISCUSSION

In this study, the spatial impact was evaluated based on the proportion of the landed area submerged. Figures 4 and 5 shows the comparison of the spatial coverages during 2012 and 2022 flood disasters respectively in the study area. In both maps blue signifies the actual river limit before flood. This study revealed that the actual area affected by the floods were 5622.13 square kilometers and 7428.771 square kilometers beyond the natural limits of the river and this constitute 8.0% and 10.47% of the study area respectively (see figure6 and 7). This means that the spatial spread of 2022 flood was 2.47% in excess compared to 2012 spread.

Fig. 4: flood extent map of lower Niger basin in 2012

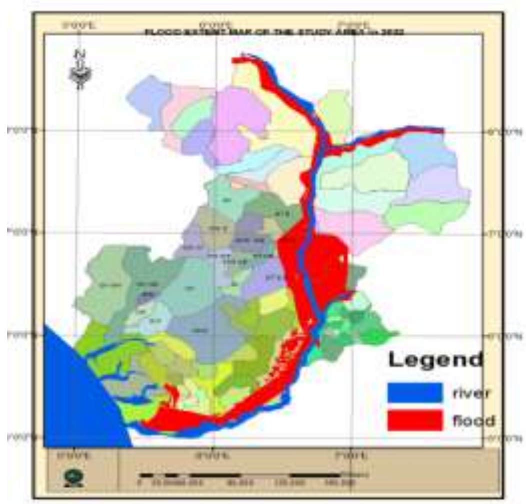

Fig. 5: flood extent map of lower Niger basin in 2022

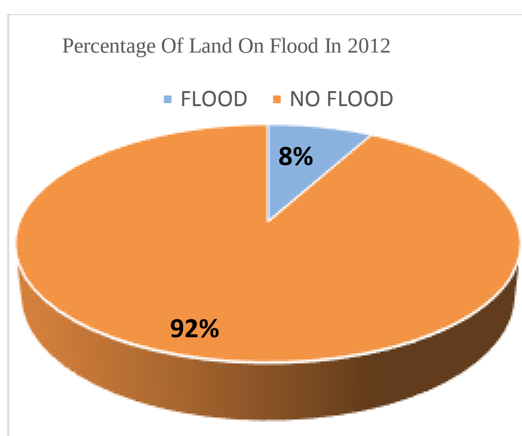

Fig. 6: percentage of land under flood in 2012

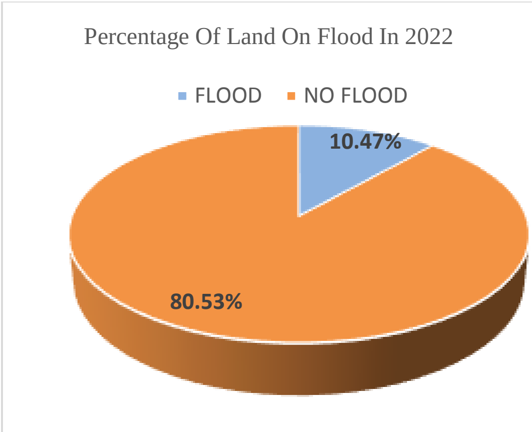

Fig. 7: percentage of land under flood in 2022

Figure 8 shows the extent of spread across the states within the study area. Kogi state recorded the highest spread in both episodes with spatial coverages of apprroximately 2960 square kilometers and 3717 square kilometers respectively. This is followed by Anambra which recorded 1078 square kilometers and 1868 square kilometers, next is a Delta with spread of approximately 976 square kilometers and 1110 square kilometers. Edo was the the least in terms of spatial inpact with spatial coverage of 608 square kilometers and 733square kilometers in both events. The difference in spatial impact was greatest in Anambra state which recorded a difference of approximately 790 square kilometers followed by Kogi state which recorded a difference of approximately 751 square kilometers. The high variations within these areas may be attributed to athropogenic activities which alters the land use and flow regime within these locations by creating more impervious surfaces through urban expansion etc. This resulted to more overland flow within these areas when compared to other locations. It was also observed that the spatial inpacts were higher across the study area in 2022 when compared to 2012 (see figure figure 9 and table1.

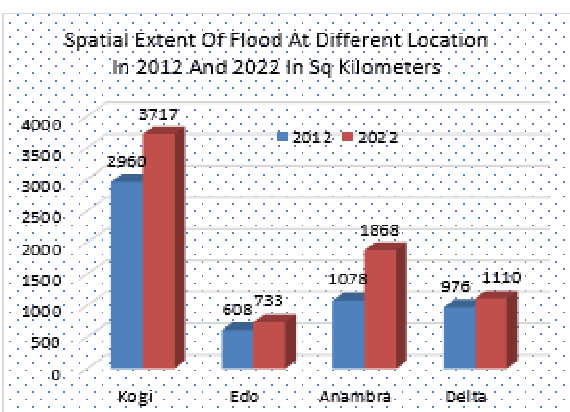

Fig 8 comparison of flood spread between 2012 and 2022 within the maior catchments within the basin

Fig 9 Hydrograph of spatial extent of 2012 and 2022 flood along lower Niger basin

Table1 spatial extent of 2012 and 2022 flood along lower Niger Basin

STATES	2012	2020
Kogi	2960.177km^2	3717.202 km^2
Edo	607.972 km^2	733.097 km^2
Anambra	1077.973 km^2	1868.098 km^2
Delta	976.007 km^2	1110.374 km^2

Figure 10, figure 11 and table2 are the spatal extents on local government level during 2012 and 2022 respectively. This study revealed that 26 L.G.A's were affected in 2012 as against 28 L.G.A's that were affected in 2022.

It is also seen that Ibaji, Lokoja, Anambra west, Basa, and Ndokwa West that ranked 1st, 2nd, 3rd, 4th, and 5th in terms of spatial spread in 2012 also maintain the same order in 2022. However there are some exceptions for example, Idah LGA recorded a higher spread in 2012 when compared to Igalamalu LGA while in 2022 the reverse was the case. In 2012, Ogbaru LGA recorded a lower spread than Oshimili North LGA while in 2022 the reverse was also the case etc. These variations were the result of alteration in land use pattern which affected the landscape within these regions thereby changing the flow regime. The differences in spatial extent of spread between the two episode at local government level can be seen in table 3.

Difference in spatial impact of the two flood episodes by local government level is shown in table3 below. It can be seen that there was extensive spatial spread during 2022 flood when compared to that of 2012. A total of 22 L.G.As suffered from higher inundation extent in 2022 excluding Kotonkafi, Ajeokuta, Oshimili South and Isoko South LGAs which recorded decrease in spread

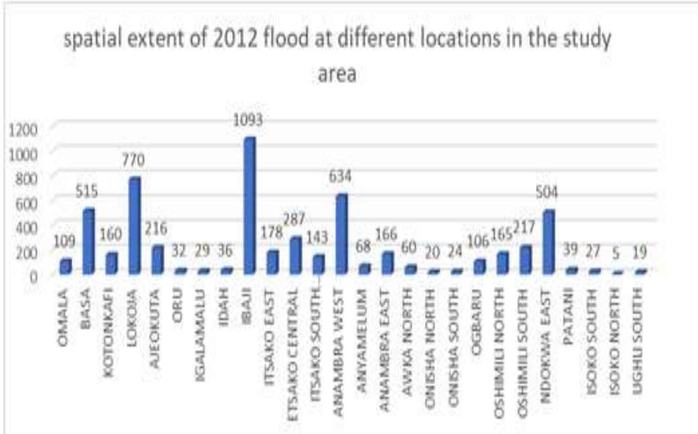

Fig 10 spatial spread of flood in the study area disagregated to local government level in 2012

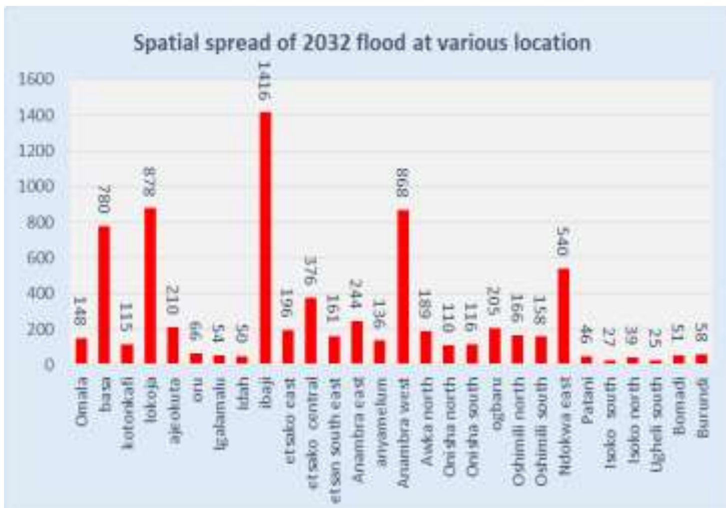

Fig 11 spatial spread of flood in the study area disaggregated to local government level government level

Table2 Spatial spread of 2012 and 2022 flood at various locations within the study area

Affected LGA'S	Flood in 2012 (Km²)	Flood in 2022 (Km²)	Affected LGA'S	Flood in 2012 (Km²)	Flood in 2022 (Km²)
OMALA	109.01	147.989	ANYAMELUM	68.001	135.978
BASA	514.998	780.001	ANAMBRA EAST	165.977	244.01
KOTONKAFI	159.989	114.988	AWKA NORTH	60.074	188.889
LOKOJA	770.121	878.021	ONISHA NORTH	20.024	110.19
AJEOKUTA	215.996	210.013	ONISHA SOUTH	23.989	115.985
ORU	31.997	66.178	OGBARU	105.896	205.022
IGALAMALU	28.981	54.142	OSHIMILI NORTH	165.083	166.004
IDAH	36.102	49.998	OSHIMILI SOUTH	216.899	157.889
IBAJI	1093.021	1415.872	NDOKWA EAST	503.999	540.133
ITSAKO EAST	177.805	195.882	PATANI	39.012	45.975
ETSAKO CENTRAL	287.004	376.112	ISOKO SOUTH	26.988	28.012
ITSAKO SOUTH EAST	143.163	161.103	ISOKO NORTH	5.012	38.776
ANAMBRA WEST	634.012	868.024	UGHLI SOUTH	19.014	24.799
BURUNDI	X	58.011	BOMADI	X	5150.775

Terrain analysis: Elevation is one of the most significant factors of flood hazard identification in a given area. Studies have shown that exposure to flood increases with decrease in terrain elevation. Figure12 and figure13 show the overlay analysis of flood layer on the elevation map of the study area. The elevation model revealed terrain elevation range of 20m to 540m above mean sea level. The Northern part of the Basin is upland while the southern part is low lying area. This study revealed that the affected areas during the two flood events are within elevation range of 20m to 120m above mean sea level.

Table3 Difference in spatial spread between 2012 and 2022 flood within LGAs along Lowe Niger Basin

S/ N	L.G.A'S	2022 Spread (Km^2)	2012 Spread (Km^2)	Diff. (Km^2)	RMK	S/N	L.G.A'S	2022 Spread (Km^2)	2012 Spread (Km^2)	Diff. (Km^2)	RMK
1	Omala	148	109	39	Increased	15	Anambra W	868	634	234	Increased
2	Basa	780	515	265	Increased	16	Awka N.	189	60	129	Increased
3	Kotonkafi	115	160	-45	reduced	17	Onisha N.	110	20	90	Increased
4	Lokoja	878	770	108	Increased	18	Onisha S.	116	24	92	Increased
5	Ajeokuta	210	216	-6	reduced	19	Ogbaru	205	106	99	Increased
6	Oru	66	32	34	Increased	20	Oshimili N.	166	165	1	Increased
7	Igalamalu	54	29	25	Increased	21	Oshimili .S	158	212	-54	reduced
8	Idah	50	36	14	Increased	22	Ndokwa E.	540	504	36	Increased
9	Ibaji	1416	1093	323	Increased	23	Patani	46	39	7	Increased
10	Etsako East	196	178	18	Increased	24	Isoko S.	27	28	-1	reduced
11	Etsako C.	376	287	89	Increased	25	Isoko N.	39	5	34	Increased
12	Etsan S.E	161	143	18	Increased	26	Ugheli S.	25	19	6	Increased
13	Anambra E.	244	166	78	Increased	27	Bomadi	51	-	51	Increased
14	Anyamelum	136	68	68	Increased	28	Burundi	58	-	58	Increased

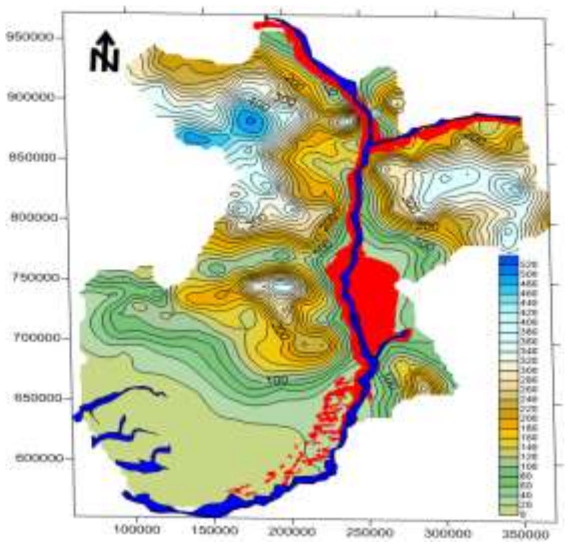

Fig 12 overlay analysis of 2012 flood layer on elevation map of the study area

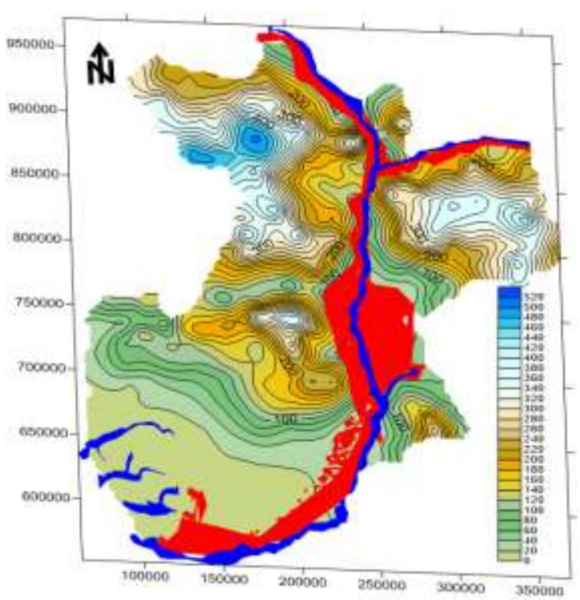

Fig13 overlay analysis of 2022 flood layer on elevation map of the study area

Conclusion: In contemporary times, the pace of climatic changes is increasing at an alarming rate. As a result of this, the intensity of rainfall appears to be gradually showing increasing trend thereby causing floods in many areas and countries worldwide. In this study, attempt has been made to compare the spatial impact of 2012 and 2022 flood along Lower Niger with the view of gaining practical understanding of the trend. Result shows that the spatial spread of 2022 flood event across the study area was 2.47% in excess when compared to 2022 flood episode. The higher impact was attributed to anthropogenic activities and other human induced activities contributing to increasing trend in climatic change. Base in this there is need for improvement in land use planning, intensification of environmental education, building of artificial retention pond and relocation of communities at low lying areas to upland.

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