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Correlate Mapping of Impervious Surfaces as Flood Risk Assessment Strategy in Owerri, Southeastern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author JDN designed the study. Author KOEU performed the remote sensing and geostatistic analysis, wrote the protocol, wrote the first draft of the manuscript. Authors IEO and ADU reviewed and classified the level of flood risk of the study. Author MT managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Owerri is rapidly growing in population and built environment, with corresponding, high increase in pavements or paved surfaces. This study explores the integrated approach of Remote Sensing (RS) and Geographic Information systems (GIS) techniques in flood management with the goal of mapping areas vulnerable to flood hazard and, increase in paved surfaces. Digital elevation dataset from Shuttle Radar Topographical Mission (SRTM) were downloaded from USGS explorer. Also,

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Landsat 5 ETM of 1986, Landsat 7 ETM+ of 2000 and Landsat 8 ETM+ of 2016 imageries were obtained and subjected to supervised classification, using maximum likelihood classifier with ERDAS Imagine 2014. The derived map displayed the spatial and statistical variations of the classified Land Use and Land Cover (LULC) of 1986, 2000 and 2016. The result showed impervious surface rising from 1986 values of 31,625.93 Ha, to 47,979.09 Ha in 2000 and 50,297.33 Ha in 2016, implying approximately 31.2% in 1986, 47.31% in 2000 and 49.61 in 2016. The mean change in impervious surface from 1986 to 2000 was 16.1% compared with 2.3% between the periods. This implies the measure and spate of land conversion in Owerri between the periods showed upward swing. The mean percentage change from 1986 to 2016 revealed increases from 31.2% to 47.31% and to 49.61% for 1986, 2000 and 2016, respectively. Digital Elevation Model was developed with ArcGIS to identify flood prone areas within the study area. A flow accumulation model was created using the DEM before re-classification into high risk, moderate risk and low risk zones using contours and based on elevation. This was overlaid on the impervious layer of the area, to produce a vulnerability map showing locations at a particular level of risk, according to their proximity and extent of paved surface area. This confirms that changes in impervious surfaces, significantly, produce corresponding effect in flood vulnerability. This study recommended that adequate land use planning be enforced.

Keywords: Impervious surface; flood vulnerability; risk mapping; land use planning.

1. INTRODUCTION

Owerri is rapidly growing in human and animal population and built environment, with corresponding high increase in pavements or paved surfaces. Floods causing loss of lives and property are, increasingly becoming an annual phenomenon in Nigeria [1]. A combination of natural and anthropogenic causes - heavy rainfall, favourable relief, soils and topography, high and rising human population, waste management strategies, and deep and narrow river valleys - render the country susceptible to flood hazards and disasters [2]. According to [3], several lives and properties worth millions of Naira are lost, directly or indirectly, from flooding. In most urban centers of the country, especially, in eastern Nigeria, human population increase, landscaping, rising paved surfaces, streams and channel obstruction due to bad waste disposal habits and other human activities around flood plains are, according to [4,5] considered to be the major causes of the floods. Again, the encroachment of areas liable to floods by human settlements, and infrastructural development, has increased the exposure of these areas to flood hazards [3]. Impervious surface are surfaces that result from urban development which includes but not limited to roads, walkways all other paved surfaces including buildings and rooftops. Impervious surface are also referred to as build surfaces except for rock outcrops. Given that impervious surfaces encourages runoff, and reduces infiltration, it implies that increases in extent of impervious surfaces creates vulnerability and enlarges flood prone or floodable areas [6]. Similarly, the emergence, spatial growth and development of built environments – human settlements and infrastructural expansion – encourages flooding [7]. This study utilizes Remote Sensing (RS) and Geographic Information Systems (GIS) techniques, to map rising impervious surfaces around Owerri and environs, and assess the rate, trend and extent of impervious surfaces, since it is suspected that impervious surfaces may, significantly, contribute to exposure and vulnerability flooding in the area.

1.1 Aim and Objectives of the Study

The aim of this study is to map the rate and extent of impervious and floodable areas, so as evaluate the study area's susceptibility to flood incidence. This was achieved through the following ways

(i) To map the periodic land use and land cover of the area.
(ii) To determine the rate of change and trend of impervious areas for the period covered in the study.
(iii) To develop a 2D map of the area, overlaying it with the land use land cover map of the areas
(iv) To overlay the land use and land cover and DEM maps to generate the flood vulnerability map of the area.
(v) To assess the extent and classes of vulnerability of the study to flooding.

2. MATERIALS AND METHODS

2.1 Demarcation and Description of the Study Area

The study area is Owerri and environs, covering about 42 km^2. It is located between latitude 5º31' and 50 20' N and longitude 6º54'and 7º16'E. In this study, Owerri consists of three Local Government Areas (LGAs) including Owerri Municipal, Owerri North and Owerri West LGAs. The Rivers Otamiri and Nworie bisect the study area, creating major drainage landmarks.

The study area has the climate and vegetation of southern Nigeria [8], with apparent modifications by climate change. Owerri lies in the rainforest zone of Nigeria and records peak rainfall between May - July and September - November. Average annual rainfall is about 2,250 mm, and the average annual temperature is about 27ºC [9,10]. This area is underlain by the Benin formation of coastal plain sands. This formation, which is of late tertiary age, is rather deep, porous, and infertile and highly leached. In some parts of the study area, the soil consists of lateritic material under a superficial layer of fine grained sand, making the area susceptible to flooding and erosion. The soil would naturally be fertile but excessive leaching has removed much of the required plant food.

The estimated population of the area is 401,873 inhabitants, comprising about 32,000 households (FGN, 2006). The region is within the areas plagued by high human and animal population density, and intensive pressure on land, utilized for sedentary arable and poultry farming, mainly for food. The inhabitants are mainly traders; few are artisans, civil servants and native famers. The agricultural sector (crop production, livestock and fishery) is likely to retain its relative dominance in the long run [11], though the area is rapidly urbanizing.

2.2 Method

The Global Positioning System (GPS) points of some strategic flood prone locations were acquired during field work. Digital elevation dataset from Shuttle Radar Topographical Mission (SRTM) of 2010 were obtained from National Space Research and Development Agency (NASRDA). The satellite imageries analyzed for this study includes Landsat 5 Thematic Mapper (TM) of December 1986, Landsat 7 Enhanced Thematic Mapper Plus (ETM+) of December 2000 and Landsat 8 Enhanced Thematic Mapper Plus (ETM+) of 2016 all from path 188 and row 56. The imageries were acquired from the online archive of Global Land Cover Facility (GLCF), University of Maryland [12], USA and subjected to supervised classification, using maximum likelihood classifier in ERDAS IMAGINE 2014 edition.

2.3 Tools of Data Analyses, Processing and Procedure

The general analyses were done with ArcGIS 10.0, ArcMap and Arc Catalogue. These were used for the vectorization of shapefiles, and digitization of the various features from the imageries, to generate the map of the study area (see Fig. 1). Arc Catalogue was used in creating geo-database and shapefiles. The differently classified land use and land cover features were extracted using ArcMap. The Landsat imageries were imported into ERDAS Imagine 2014 and was used for the spatial, spectral and radiometric enhancement of the imageries. ERDAS Imagine 2014 edition was used to carry out colour composites. The image was submapped to concentrate on the area of interest using the shapefile for study area map digitized from the ArcMap. ERDAS Imagine 2014 was used to classify the imageries using the Maximum Likelihood Classifier (MLC) to generate the land use and cover map. The LULC map was classified into forest cover, farmland cover, bare surface cover, water bodies and impervious surface cover (built-up cover). The impervious surface covers of the study area was estimated for the 30 years covered by the study, using the land use and cover classified map. The impervious surface was overlaid on the DEM map of the area to generate the flood vulnerability map. The geographic coordinates of the flood prone areas were obtained during field work with hand held Etrex Garmin Version 16.0 GPS, and imported into the ArcGIS 10.0.

This study further demonstrated the use of SRTM data, Landsat satellite imagery and the integrated approach of RS and GIS techniques in flood risk management around Owerri. The map of the study area was delineated from the LGA vector data archive, from NASRDA. This data was then imported into ArcGIS as X, Y and Z. Interpolation process was carried out, using the spatial analyst tool to create a digital terrain model.

A flow accumulation model was created using the DEM and the impervious areas within 500 meters buffer from the river channels were overlaid to re-classify the built surfaces into classes of vulnerability such as high risk, moderate risk and low risk areas, using contours of equal intervals, based on elevation. This was overlaid on the map of the area to produce a vulnerability index map of the area.

3. RESULTS AND DISCUSSION

Results of the LULC analyses, extent and variations in impervious surfaces with temperature in the study area are presented in this section. These results show changes in bare surface, water body, impervious surfaces and vegetation classes, pointing to copious changes likely to impact adversely on to increase in flood in the years ahead. The explanatory maps are presented in Figs. 2–8, while the tables are shown on Tables 1–4.

The derived maps displayed the spatial, areal and statistical variations of the classified LULC of 1986, 2000 and 2016. The result shows impervious surface increasing from 1986 values of 31,625.93 Ha to 47,979.09 Ha in 2000 and 50,297.33 Ha in 2016, implying approximate percentage change of 31.2% in 1986, 47.31% in 2000 and 49.61 in 2016. The change in impervious surface from 1986 – 2000 was 16.1% compared with 2.3% between the periods favour increase in impermeability and expected runoff. This implies that the measure and spate of land conversion in the city between the periods. Similarly, the areal extent of flood prone and floodable areas also increased. This indicates that the study area is vulnerable to flooding in the years ahead, especially, if the impervious surfaces continue to rise with corresponding rainfall values.

The digitized topographic map (Fig. 6) was interpolated to generate DEM of the area. The DEM clearly shows that the lowest elevation is found around Rivers Otamiri and Nworie, with an elevation of between 33 to 57 m above sea level. The elevation of other areas increase towards the north, with the highest being 141 m above sea level.

Fig. 7 presents the vulnerability and variation risk map of the study area, as well as the impervious areas at the different periods. The high flood risk zone was modeled with a distance of 500 m from the river lowland areas. The total areal coverage of the high risk zone was estimated as 3,915.72ha, within the total area. The elevation of the surrounding area relative to the river was considered in the buffered distance.

Vulnerability classes of impervious surface are presented in Fig. 8. It shows the total percentage area coverage of impervious surface. The classes are, high risk (8%), moderate risk (27%) and low risk (65%) of the study area. The total area of high vulnerability is 3,915.72 ha or about 39.16 sq.km.

The vulnerability map obtained from the overlay of vulnerability map on the impervious layers presents the extent of flood risk. From the underlying digital elevation model, residential buildings and other paved surfaces within the high risk zone of which is located within 500 m are observable in the map. During fieldwork, it was observed that certain population high density and low density areas, area within the zones. In the event of any flood, the yellow class be may overcrowded, due to spilled local or neighbourhood migrants from the high risk zones, as a result of flood-risk rescue operation.

Table 1. LULC classification and coverage in 1986 (from Landsat 5 TM)

Class names	Count	Area (M^2)	Area (Ha)	Area (%)
Unclassified	0	0	0.00	0.000
Water body	19235	15623628.75	1562.36	1.542
Primary forest	541303	439673361.8	43967.34	43.385
Farm land	244109	198277535.3	19827.75	19.565
Impervious surface	389362	316259284.5	31625.93	31.207
Bare surface	53655	43581273.75	4358.13	4.300
Total	1247664	1013415084	101341.51	100.000

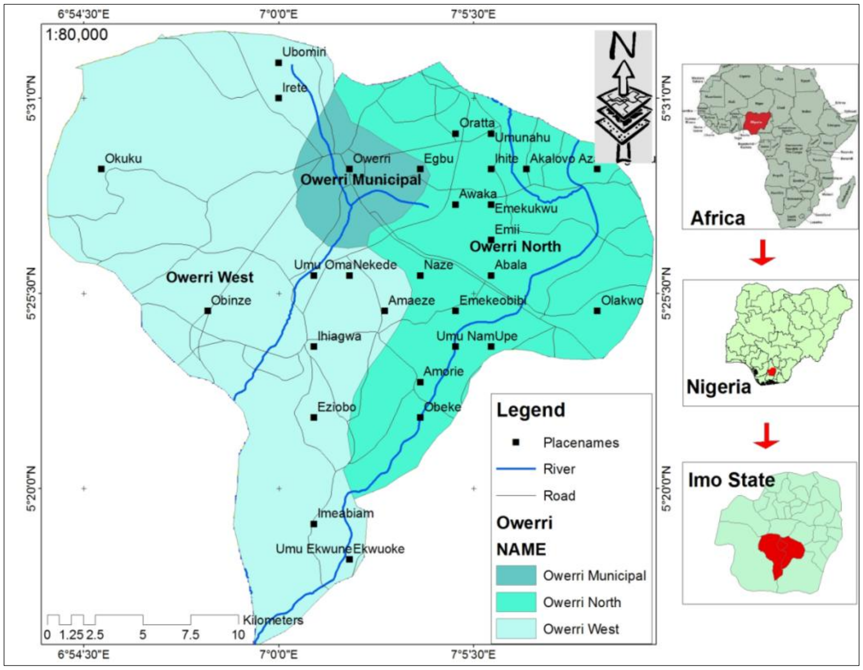

Fig. 1. Map of the study area, Owerri and environs

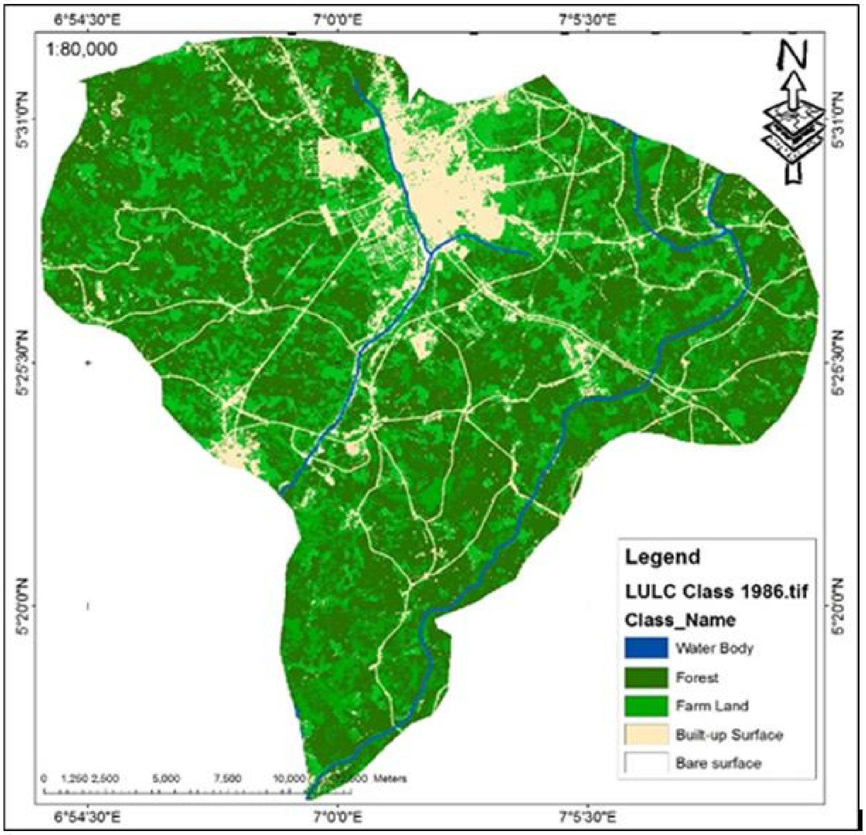

Fig. 2. LULC distribution of Owerri in 1986

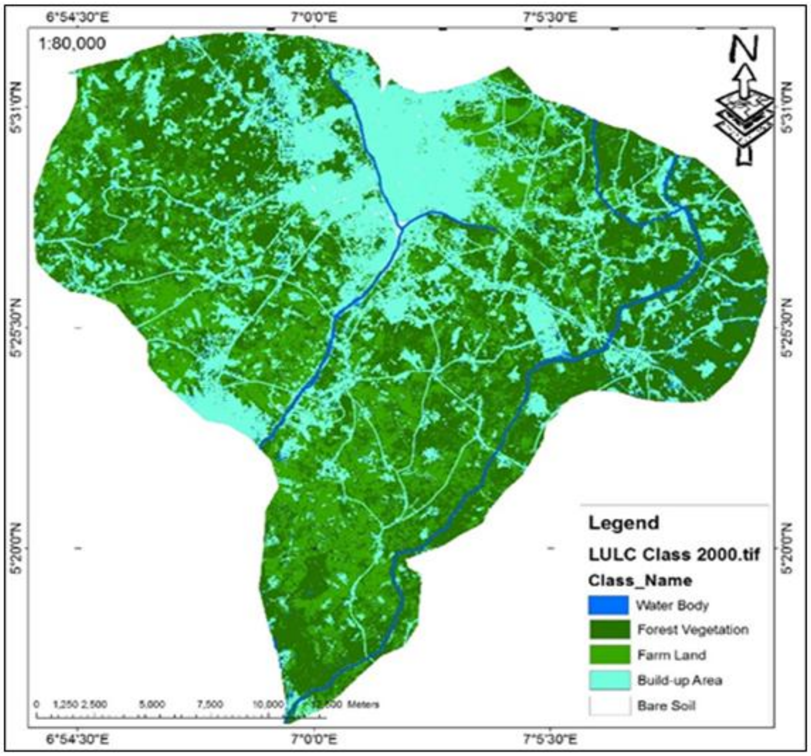

Fig. 3. LULC distribution of Owerri in 2000

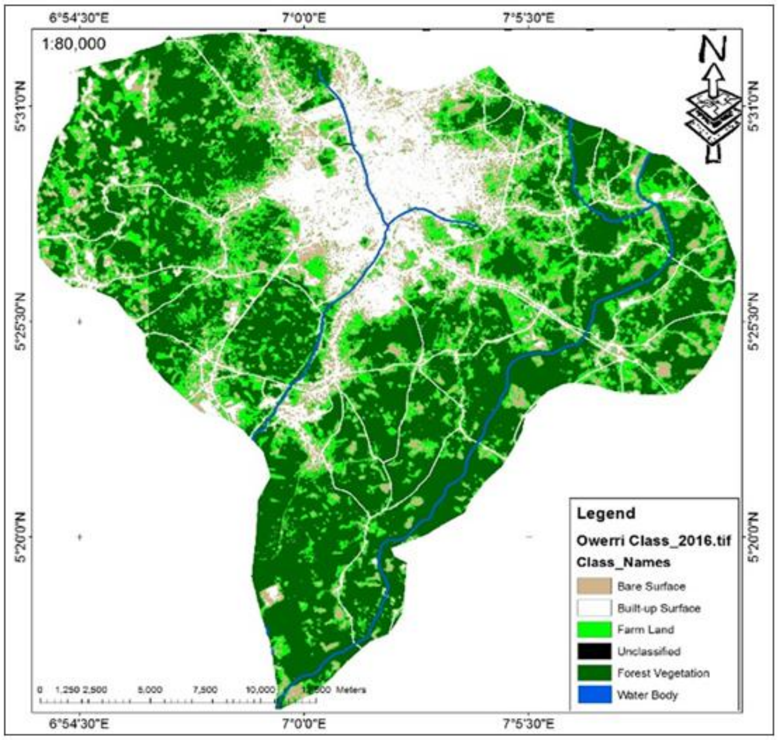

Fig. 4. LULC distribution of Owerri for 2016

Table 2. LULC classification and coverage in 2000 (Landsat 7 ETM+)

Class names	Count	Area	Area (Ha)	Area (%)
Unclassified	0	0	0	0.00
Water body	11107	9996300	999.63	0.99
Primary forest	260785	234706500	23470.65	23.14
Farm land	241967	217770300	21777.03	21.47
Built-up surface	533101	479790900	47979.09	47.31
Bare surface	79802	71821800	7182.18	7.08
Total	1126762	1014085800	101408.6	100.00

Table 3. LULC classification and coverage in 2016 (Landsat 8 ETM+)

Class names	Count	Area (M^2)	Area (Ha)	Area (%)
Unclassified	0	0	0.00	0.00
Water body	12100	10033925	1003.39	0.99
Primary forest	403762	334819638.5	33481.96	33.02
Farm land	144185	119565411.3	11956.54	11.79
Built-up surface	606540	502973295	50297.33	49.61
Bare surface	56043	46473657.75	4647.37	4.58
Total	1222630	1013865928	101386.59	100.00

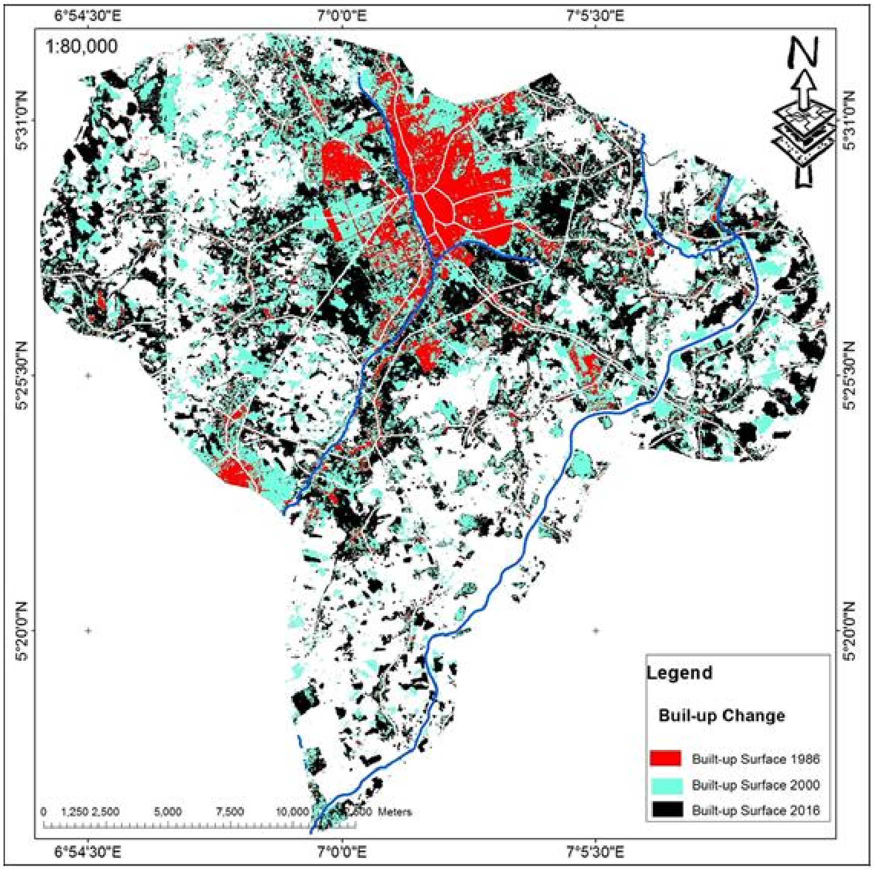

Fig. 5. Change detection map of built-up surfaces

Table 4. LULC Change distribution (1986, 2000 and 2016)

	1986		**2000**		**Change 1986 - 2000**		**2016**		**Change 2000 - 2016**	
	AREA (Ha.)	**AREA (%)**	**AREA (Ha.)**	**AREA (%)**			**AREA (Ha.)**	**AREA (%)**		
Farm land	19827.75	19.565	21777.03	21.47	1949.28	1.905	11956.54	11.79	-9820.49	-9.68
Bare surface	4358.13	4.3	7182.18	7.08	2824.05	2.78	4647.37	4.58	-2534.81	-2.5
Impervious surface	31625.93	31.207	47979.09	47.31	16353.16	16.103	50297.33	49.61	2318.24	2.3
Forest land	43967.34	43.4	23470.65	23.14	-20496.7	-20.26	33481.96	33.03	10011.31	9.89
Water body	1562.36	1.54	999.63	0.99	-562.73	-0.55	1003.39	0.99	3.76	0

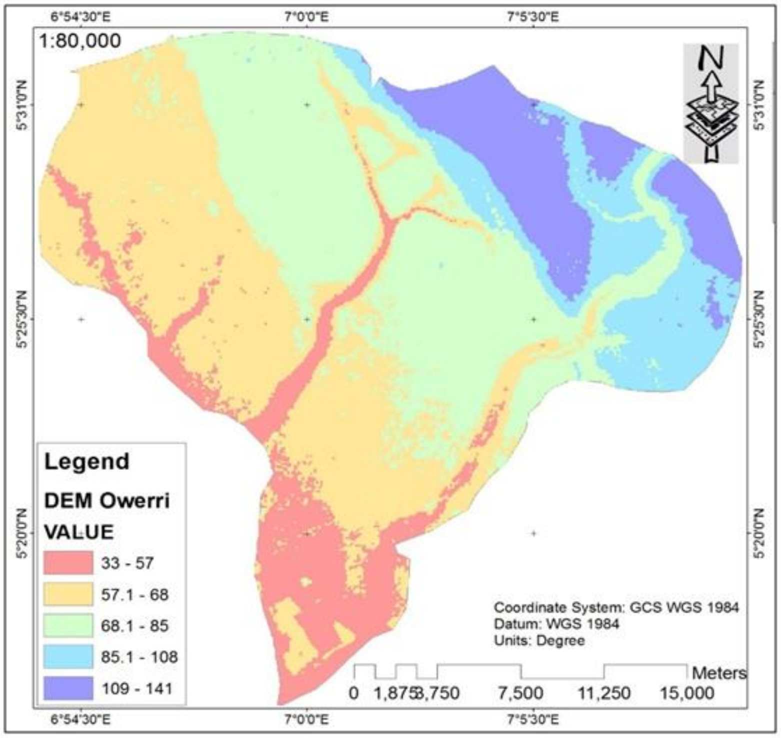

Fig. 6. DEM map of the study area

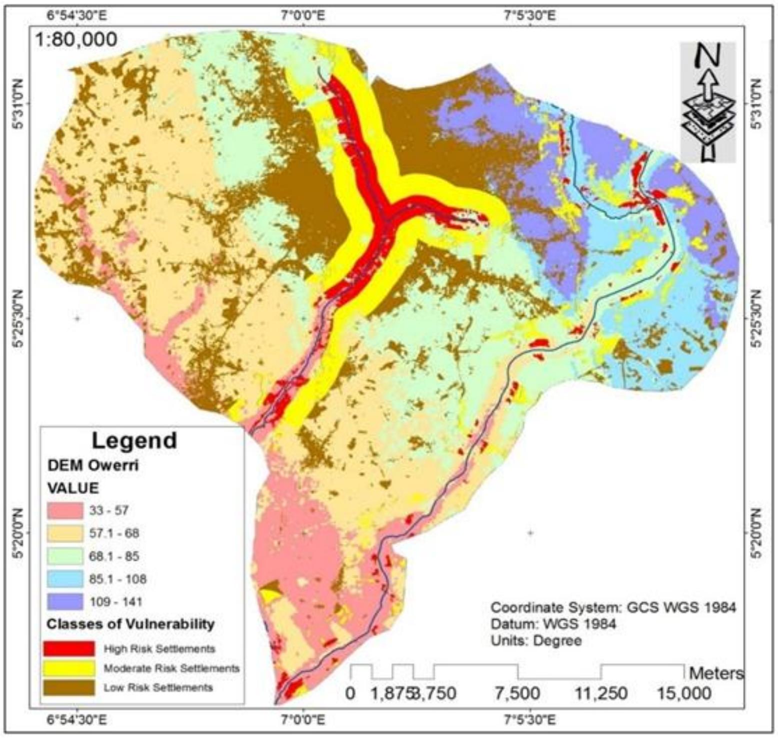

Fig. 7. Flood vulnerability map of the study area

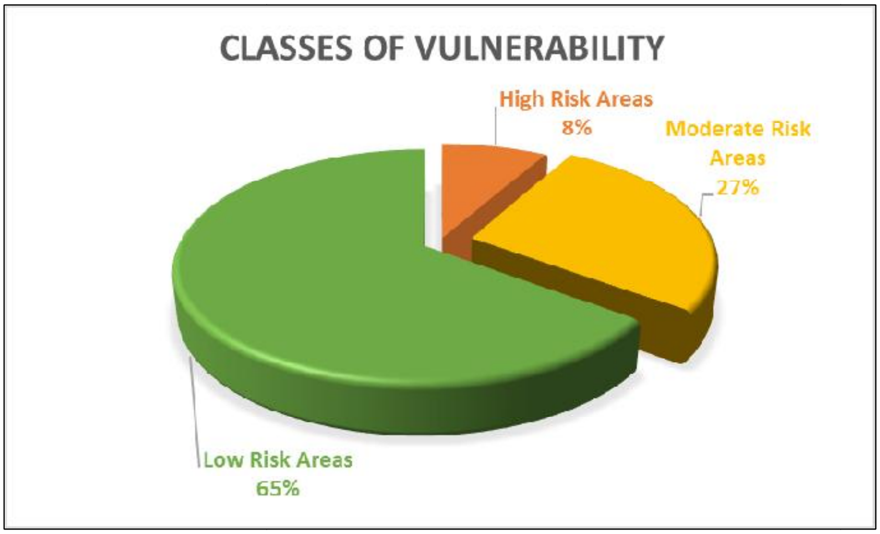

Fig. 8. Classes of impervious surfaces vulnerable to flood

4. CONCLUSIONS AND RECOMMENDATIONS

The study area is, presently, remotely prone to massive flooding, though small scale or local flooding may occur in isolated places. Though studies have shown rapid increases in impervious surface amidst built environment, urban expansion and increase in the provision of infrastructural facilities. These bear implications and imperativeness for other environmental changes especially weather modifications, settlement pattern and residents' reactions, and amenability to planning codes, statutes or regulations. There should be proactive, enforceable regulation on setbacks from the low lands. Permeable pavements o surfaces should be a better, qualitative change in the direction the water moves and the environmental processes it undergoes. It is known, that if properly designed, constructed and maintained permeable surfaces absorb natural rainfall, and inexpensive vacuuming maintains or restores surface infiltration [13]. Therefore, to create livable and sustainable environment in the study area, greening the area and enforceable regulation on permeable surface are ideal promulgation. This may re-configure contemporary biodiversity and recreate a livable environment in the area which, believably, will further reduce vulnerability to flooding.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ologunorisa ET, Flood risk assessment and management in Nigeria: Perspective from the Niger Delta. Selfers Educational Books; 2006.
2. Oyinloye MA, Kufoniyi O. Analysis of landuse, landcover change and urban expansion in Akure, Nigeria. Journal of Innovative Research in Engineering and Sciences. 2011;2(4):234-248.
3. Muhammad I, Iyortim OS. Application of remote sensing and geographic information systems in flood vulnerability mapping: Case study of River Kaduna. International Journal of Geomatics and Geosciences. 2013;3(3). ISSN 0976– 4380
4. Olusegun EO. Towards comprehensive, long – term approaches to disaster management in Nigeria. ISDR INFORMS. 2004;4.
5. Olusegun EO. Disaster and sustainable development: Some reflections and African perspective. In the Proceedings of the 2004 Directors and Heads of Disasters Management Organization in Nigeria National Conference. 2004:159–170.
6. Barroca L. Indicators for identification of urban flooding vulnerability. National Hazards Earth System, Science. 2006;6:553–561.
7. Njoku JD, Ebe TE, Pat-Mbano EC. Detection and mapping of land use and land cover classes of a developing city in southeastern region of Nigeria, using multi-

band digital remotely- sensed data. African Research Review: An International Multi-disciplinary Journal. 2010;4(3):315-330.

8. Njoku JD. Analysis of the effect of global warming on forests of southeastern Nigeria using remotely - sensed data. Unpublished PhD dissertation submitted to the department of geography and environmental management, Imo State University, Owerri, Nigeria; 2006.
9. Ibe K, Sowa A. Hydrology of part of the Oramiriukwa river basin, southeast of Owerri, Imo State, Nigeria. Hydrogeology Journal. 2002;10(4):509-521.
10. Idah PA, Mustapha HI, Musa JJ, Dike J. Determination of erodibility indices of soils in Owerri west local government area of Imo State, Nigeria. Assumption University Journal of Technology. 2008;12(2):130-133.
11. Njoku JD, Ukaegbu KOE, Amangabara, GT, Iwuji MC, Anyanwu JC. Correlation of impervious surfaces and ambient temperature variation in Owerri, southeastern Nigeria. Journal of Renewable and Alternative Energy Technologies. 2015;1:115–123.
12. Global Land Cover Facility (GLCF), 1986, 2000 and 2016 web-based data archive University of Maryland, USA.
13. Ifatimehin OO, Musa SD, Adeyemi JO. An analysis of the changing land use and its impact on the environment Anyigba Town, Nigeria. Journal of Sustainable Development in Africa. 2009;10(4):357-364.

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