APPLICATION OF SPATIAL DATA SETS FOR MANAGING FLOODS IN CALABAR METROPOLIS, NIGERIA

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Abstract
This study explored the various remotely sensed-data sets and GIS techniques in managing flood disaster, analyzing its frequency and variation over a period of ten years spanning across 2013 to 2022. The study also examined the influence of rainfall and other factors on flooding events in the study area. The research was drawn across concepts of flooding with empirical studies in areas of rainfall variability, remote sensing and GIS application for flood management. The positivism methodology was adopted, which relied on the objective norms of scientific and quantitative approaches of geospatial analysis using remote sensing and GIS technicality with effective utilization of two Landsat scenes in the modes of 7/ETM+ and 5/TM as well as rainfall data, all of which were sourced secondarily covering a period of ten years. The analysis was quantitatively carried out using remotely sensed and rainfall data producing detailed flood maps, Tables and Charts. Result of the analysis showed that rainfall amount and intensity combined with uncontrolled urban development were major factors responsible for flooding. Others are narrow drains, over spilling of the Cross River, poor waste disposal habits, and topography. The study suggested controlled development, construction of drainage channels that would accommodate the run-off volume by structural measures among others as management techniques.

Keywords: Confusion Matrix, Flood Frequency, Flood Intelligence, Flood Management, Inundation,

1. Introduction

Global interest in flooding has intensified in recent times owing to increase in human population and urban expansion (urbanization), rise in sea level and notably climate change (especially frequent and severe rainfall events, melting of ice in Polar Regions and anthropogenic activities). The awareness of flood risk, the limited knowledge of flood disaster management in our settlements and the substantial number of human population that is vulnerable to flooding (Gill et al., 2004; Action Aid; 2006; Peduzzi et al., 2011). The impact of flooding recorded in the past three decades in some cities of the world have been enormous. For example, in the autumn of 2000 in the United Kingdom, 16,000 residential properties were flooded and about 1,200 properties were flooded in Central and Southern England in 2003 (UNDP, 2005, Ojikpong et al., 2016).These flood impacts have amounted to

tens of billion US dollars being spent on flood events (Guha-Sapir et al., 2013). The flood events have also affected many countries in Asia, notably China, Bangladesh and Thailand recording hundreds of thousands of deaths and rendering billions of people homeless, psychological depression, physical injuries, water borne diseases, anxiety and post-traumatic stress (Hunter, 2003; Few et al., 2004; Tapsell and Tunstall, 2008; Keith, 2013). The August 2016 flood disaster in Louisiana, USA recorded as one of the greatest destruction in the city in historic time. The flood occurred as a result of 72 hours down pour leading to inundations that claimed the lives of 13 people and 40,000 homes completely damaged (National Weather Service, 2016).

In Nigeria, flood impacts and their solutions have ever remained critical issues considering its history of destruction and damage to lives, property, and infrastructure amounting to billions of Naira (Obeta, 2014). For instance, the floods of 1980 at Ibadan 50,000 people were rendered homeless and property worth millions of naira were destroyed, the Kano 1988 rendered 40,000 people homeless and 2,000 people in Dekina, Kogi State, in May 1997 the flood ravage of Pategi, Kpada and Gbogdondogi Local Government Areas of Nasarawa State also rendered 1,500 people homeless (Ojikpong et al., 2016). In Calabar for example, flooding events are recorded on annual basis with enormous damage to lives, property and infrastructure as well as expending of public funds to managing flood emergencies. Many families have lost their settlements to flood, farmers also lost their farmlands, roads remained unpassable during flooding and drinking water rendered contaminated and unfit for drinking, relationships are destroyed as friends could no longer go out to see each other in the events of flooding thereby, increasing and creating psychological trauma on people. It is the realization of these cases that prompted this research to be carried out in Calabar Metropolis.

2. Literature Review

All over the world, Remote Sensing technology has been in use over the years by means of the early Landsat multi-spectral scanner with 80m resolution for pioneering some investigations in flood mitigation and management, for example, in flood prone areas of the USA. Such areas include Lowa (Hallberg et al., 2013; Rango and Anderson, 2014), Arizona (Morrison and Cooley, 2013), and Mississippi River basin (Deutsch et al., 2013; Deutsch and Ruggles, 2014; McGinnis and Rango, 2015; Morrison and White, 2016).In the early 1980s, Landsat TM+ imageries of 30 m resolution were the only data sets available for monitoring flood with

special attention given to solving the problems of flooding within the monsoon areas of the West African Coast (Berg and Gregiore, 2013), India (Bhavsar, 2013), and Thailand (Rauangsiri et al., 2014). Today, several imageries or data sets are made available by the US Geological Agency for mapping flood inundation and management such as Modis and AVHRR (Islam et al., 2010), Topex/Posseidon and ENVISAT (Cretaux et al., 2010), LiDAR, SAR, ALOS (Amarnath and Rajah, 2015; Phuong et al., 2015). The images are normally radio-metrically and geometrically corrected as standard products (Nsarr-u-minAllah et al., 2015).

The application of these imageries to flood management could be individually or in combination of two different data sets such as Landsat and Modis.Though, Landsat 5 Thematic Mapper (MP) and Landsat 7 Enhance Thematic Mapper Plus (ETM+) imageries are used in this research through the positivism approach in which geospatial and quantitative image analysis are objectively and scientifically adopted (Blodget et al., 2015).GIS and Remote Sensing have played a significant role in the management of floods over the years as flood hazards are multidimensional with spatial components inherent in them (Coppock, 2015; Roser et al., 2017). The advantages of using GIS and Remote Sensing in flood management i s that i t generates a visualization of flooding and creates potentials for further analysis and estimation of probable damage caused by the hazard (Hausmann, and Weber, 2018; Clark, 2018; Malczewski, 2004). It is also important to integrate remotely sensed data with other spatial data such as google earth in carrying out appropriate analysis of land cover classes that relates to flooding (Quinn and Burns, 2015; Bhatta, 2009). The major problem of flood management with the use of space technology is the existence of clouds cover which is an impediment towards capturing the progress of floods during the peak periods (Rango and Solomon, 2017; Rashid and Pramanik, 2013; Lowry et al., 2011; Melack et al., 2014; Imhoff et al., 2017).

In the same vein, Khanna et al. (2000) asserts that the geostationary satellites such as Meteorological and Remote Sensing satellites are useful in forecasting heavy rainfall patterns, snowmelt run-off, and frontal systems. The use of high- resolution data from the US Geological Survey has greatly contributed to the understanding of various parameters relevant to rainfall run-off analysis, flood forecasting, and mapping with its hazard assessment that has been useful in planning and management. The combination of these two data sets (remotely sensed and

rainfall data) form the basis of analysis of this study.

Similarly, Khanna et al. (2000) added that space technology is an important mechanism for providing valuable information useful for flood assessment, mitigation and preparedness within the phases of flood. These space technology techniques include; weather monitoring, effective communication for early warning systems, monitoring and assessment, preparation of developmental plans for relief, rehabilitation and post-flood assessment with tele-medical services. However, Panzeri et al, (2012) argued that Remote Sensing as part of GIS technology play a vital role in flood mitigation through advancement in the sensor technologies such as image manipulation using GIS tool/technique in the design of hydrological and hydraulic models.

According to Hysenaj (2012) flood management is fundamental to the success and operations of flood emergencies and disaster managers who are ready for flood disasters, such that incidences of floods does not take them unawares. On the other hand, Keys (2019) emphasized that flood planning process must be led by specialist flood planners and emergency managers who are guided by past flood incidences and accomplished, not only by producing flood plans using GIS technology, but also by being involved in land use planning and decision-making processes. In a similar development, Alexander et al. (2011) asserts that GIS techniques would be applicable in identification of flood prone areas through mapping of the affected areas by showing early warning signs, thereafter rescue, and evacuation of the affected communities as part of flood management, prevention and mitigation.

In view of the modern technology, it would be appropriate to integrate Remote Sensing and Geographical Information Systems with other spatial data that provides tremendous potentials for monitoring and management of floods (Pradhan et al., 2009; Pradhan and Shafie, 2009) . Flo o d management would be successful by obtaining detail information or data about the expected frequency, character and magnitude of flooding events. The data needed for flood management have important spatial elements and are often referred to as “spatial data” with geographic components such as satellite imagery and rainfall data, (Bera et al., 2012; Veldkamp et al., 2016), these data were manipulated using Remote Sensing and GIS technicalities.The role of Remote Sensing application for flood management cannot be overemphasized, as it provides evidence of past flood, pattern taking, and the areas affected which would be useful in the analysis for prediction and

potential future mitigation and risk management from the observed changes of the past floods of 10, 20, and 30 years as in the case of this research.

In recent years, debates over causes of flooding in Nigeria have received significant attention in literature as mainly the aftermath of climate change which induced several patterns of rainfall such as long duration or low intensity of rains and short duration or high intensity of rains (Houston et al., 2011; Ayoade and Akintola, 2010; Adelekan, 2013; Soneye, 2014). Other factors responsible for flooding in Nigeria and Calabar precisely were also investigated as topography of the area, land use and land cover alterations, the influence of the Cross River and Qua River as well as the tidal/co-tidal activities and frequent incursion from Atlantic Ocean into the adjacent lowland areas also contribute to flooding (Gale, 2007; Aderogba, 2012; Odunuga, 2008).

There is also the influence of urbanization caused by population growth, poor urban planning, poor environmental management and indiscriminate solid waste disposal (Okeke, 2003; Lamond et al, 2012; Adeleye and Rustum, 2011). These factors seems to be responsible for flooding in Calabar in relation to vulnerabilities of social systems and the elements vulnerable to flooding in the area, the development of slum and shanty settlements and lack of knowledge of flooding among urban residents in urban areas and local communities as well as the public are also known to be critical propellers of flooding (Agbolar and Agunbiade, 2007; Nwankwo, 2013; Ayoade and Akintola, 2010; Odunuga et al., 2012; Oloke et al., 2013; BNRCC, 2008).

The impact of flooding in Calabar is intensified by population density and urban expansion, depth of floods, flood duration and extent as well as water flow velocity (Aderogba, 2012). These have resulted to displacement of people from their homes, mortality, destruction of urban infrastructure, submergence of settlements, physical injuries, and disruption of economic activities which directly relate to social systems (Ugwu and Ugwu, 2013; Olajuyigbe et al., 2012; Ajibola et al., 2012; Aderogba, 2012). Other impacts include loss of social values, air and water pollution, and the spread of vector borne diseases (Adelekan, 2010; Bashire et al, 2012). There is also city-wide poverty caused by flooding due to destruction of farmlands and interruption of social and essential services (Olajiyugbe et al., 2012).

These impacts are also categorized into three significant scales – individual, household and community scales of impacts. At the individual scale, the inability of friends and relatives to visit one another while in flooded

homes affects social relationships and thus, leads to depression. There is also food insecurity as food items stored in these flooded homes are often lost in the process with numerous health impacts such as chronic skin infection from exposure to continental environmental systems (Adelekan, 2010). Household scale of impact considers deterioration of buildings quality, intrusion of contaminated water into residential apartments, damage to household properties, sanitation facilities and lack of excellent quality drinking water. The community scale of impacts includes disruption of movement, uncle an environment, damage to public utilities and facilities such as schools, libraries (Obongha, 2018). Several researches have been conducted on flooding in Nigeria and Calabar without giving appropriate attention to using Remote Sensing data sets in determining the spatial extent, variation and frequencies of flood for formulation of some management techniques, which form the basis of this research.

3. Materials and Method

In order to effectively carry out this research, two (2) Landsat Satellite imageries for a period of ten years spanning from 2013 to 2022 have been utilized. Satellite remotely sensed data, including aerial photographs, offers accurate, reliable, and consistent information for urban flood analysis and historical land cover changes (Veldkampet al., 2016). Satellite remotely sensed data has been known for effective and efficient flood analysis because it is easily accessible and available at the USGS website (https://landsatlook.usgs.gov/viewer.html). The images were radio-metrically and geometrically corrected as standard products (Nsarr-u-minAllah et al., 2015).

In accomplishing the objectives of the study, remotely sensed data sets of Landsat scenes in 5/TM and 7/ETM+ modes were acquired within the period of high rainfall in the study area, since flooding is primarily a product of rainfall amount and intensity (Nouaceur and Murarescu, 2016). The months of high rainfall in the study area are May, June, July, August, September, and October. Landsat scenes used in this study were acquired within these months of high rainfall. Google Earth images were also utilized for a better visualization and interpretation of the training data. Table 1 shows the spectral and technical details of the Landsat scenes used in this study. However, it is worth mentioning here that the thermal bands of the images were not considered in the analysis.

Table 1: Technical Specification of Imageries

Year	Sensor	Bands	Spatial resolution	Path/row	% cloud cover	Date of acquisition
2013	TM	1-5 & 7	30 m	188/56	00%	19-10-2013
		Pan (8)	15 m			
	TIR	6	-			
2022	ETM+	1-5 & 7	30 m	188/56	00%	18-10-2022
		Pan (8)	15 m			
	TIR	6	-			

Source: Data Analysis, 2023

The climate of Calabar is that of subequatorial type, characterized by high rainfall and temperatures giving rise to two seasons namely, wet (rainy) and dry seasons. The wet season takes place from March to November while dry season takes a brief period from December to February every year. However, flooding in Calabar is intensified by high rainfall amount, duration and intensity (Nouaceur and Murarescu, 2016). To measure this requires a rainfall data for the duration of the study. Therefore, rainfall data were sourced from the Nigeria Meteorological Station (NIMET), Calabar, containing rainfall data for 2013 and 2022 as shown in Table 2. Another important source of data used in this study is the map library of Nigeria (maplibrary.org/library/stacks/africa/nigeria/crossriver/index.htm) where the shape files of the study area were sourced from.

Table 2: Rainfall Data

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	AMOUNT
2013	23.6	63.5	76.1	216.4	303.6	524.4	207.7	363	367.2	393	77.6	63.7	2679.8
2022	0	7.4	131.5	157.7	383.7	402.5	538.7	422.8	234.3	236.5	9.4	0	2524.5

Source: NIMET Station, Calabar, 2023

Table 2 shows rainfall data sourced from NIMET for the analysis of rainfall amount and intensity as required by this research.

3.1 Methods of Data Analysis

The remotely sensed-data sets were stacked by layer stacking method in order to get false composite image (Jensen, 2005; Jensen, 2006). Bands R=5, B=4, G=3 were loaded for 5/TM and 7/ETM+. Each Landsat scene was rectified to a common coordinate system of UTM zone 32 and WGS 84. The images were resized through spatial subset for the analysis. While the training data for supervised image classification were defined through ground trothing and known land cover classes by manual interpretation of the imagery as supported by Google earth for appropriate identification of the existing land cover classes (Quinn and Burns, 2015).

Classification of Satellite images is a process in which every pixel in the satellite imagery is characterized into a different land cover

class (Lillesand et al., 2004). With the instrumentation of Google earth and known land cover types, information and visual interpretation of satellite images and classification criteria are recognized based on spectral and land cover analysis (Fan et al., 2009). This process was followed by execution of supervised image classification with algorithm of maximum likelihood for the two imageries that span across ten years of the study, and six land cover classes of Settlements/Urban, Vegetation/Forests, Floods/River Water, Marshy Area, Barren Land, and Farming Area were identified.

A change detection statistical analysis was also applied in identifying the various changes that occurred between each land cover class within the years under study with emphasis on the degree and frequency of floods and its changes. This study however, considers flood management using Remote Sensing and GIS as such, the study is concerned only with floods, and therefore, becomes imperative to consider the variability of the land cover area of floods/river water and other land cover classes that are affected by floods but may not necessarily dwell on detailed land use study, while a simple binary classification of satellite remotely sensed data is appropriate (Bhatta, 2009).

The analysis also adopted the post classification of Confusion Matrix using the ground truth ROIS to determine the overall accuracy assessment and kappa coefficient. The standard overall classification for land use maps is set between 85% and 90% (Anderson et al., 2016; Lins and Kleckner, 2016). However, the overall accuracy and values of kappa statistics are shown in Table 3. The analyses of rainfall data were also carried out using quantitative statistics and graphical representation to determine the values of monthly and annual rainfall of the selected years as shown in the Table 2. The rainfall data is vital to this study because all the cases of floods in Calabar Metropolis were caused by rainfall amount, intensity, and duration. The regimes of rainfall have been represented in graphs.

Table 3: Satellite Images Classification Statistics

S/No.	Year	Overall accuracy (%)	Kappa coefficient
1	2013	91.74	0.89
2	2022	92.39	0.90

Source: Data Analysis, 2023

3.2 The Study Area

Calabar is the capital of Cross River State of Nigeria located in the South-Eastern part of the country. It is between latitudes 040N 5611N and 050N 411N and longitudes 080E 1811E and 0802411E. It is bounded at both sides by Great Kwa River and the Cross River, about 60,000 meters away from the Atlantic Ocean and is made up of several Creeks and Rivers that drains the lithology of the city into the Atlantic Ocean. The city is a lowland area with the highest point being 200 meters above sea level, while other areas are zero meters above sea level (Udo, 2011).

Notable among these Rivers is the Cross River which takes it source from the highlands of Western Cameroon and flows westerly into Nigeria and follows a South Westerly direction from it confluence with the Aya River in Nigeria and then flows towards the south receiving the Aboine River from the Udi Hills and passing through the tropical rainforest and mangrove swamps. The Cross River takes about 489,000 meters' course to the Bight of Biafra through its estuary shared with the Calabar River and finally drops into the Atlantic Ocean (Gale, 2007).

Calabar can be accessed by sea, land and air. It is bounded by the mangrove swamp in the South which limit its growth southward. The soil profile of Calabar has been seen to contain grey colour, porous unconsolidated non cohesive alluvial layer of fine sand, overlying an impermeable much consolidated firm and plastic alluvial dark coloured silty clay with organic matter. The study area under this condition is capable of supporting thick humid forest, but due to urbanization process, most of the virgin forests have been altered (Udo, 2011). The soils are very fertile but mostly affected by leaching and inferred by activities that lead to erosion. All these are the product of high rainfall amount and duration.

Calabar has subequatorial type of climate with high temperature that does not fluctuate greatly. The rainfall distribution shows double maxima with two peaks. The rains start in March to November reaching its climax in the months of June to September. The annual average rainfall is about 2000mm to 3000mm which is convectional in nature predicated by the maritime air mass (Offiong, 2004). Over 90% of the annual rainfall occurs within the

perio d of nine months (March to November) with three months' dry season (December to February). Calabar is a humid tropical city with high rainfall intensity and duration which tends to accelerate run-off volume and rate thereby, resulting to flooding and

environmental degradation due to extensive area of concrete surfaces (Okeke, 2003).

Flooding is predominant in the low- lying plains of Calabar. Most of these areas have narrow street drains that cannot accommodate the volume of the run-offs which eventually result to flash floods owing to long duration of rainfall of about five or more hours giving rise to inundation and ponding of the city. The example of August 5 and 6, 2017 flood incidence in Calabar (Obongha and Yaro, 2020). Calabar was selected as the site for this study because of its frequent flood cases recorded annually without appropriate attention to address it but this research has made some attempts toward addressing repeated flood cases in the study area. Figure 1 is the map of the study area.

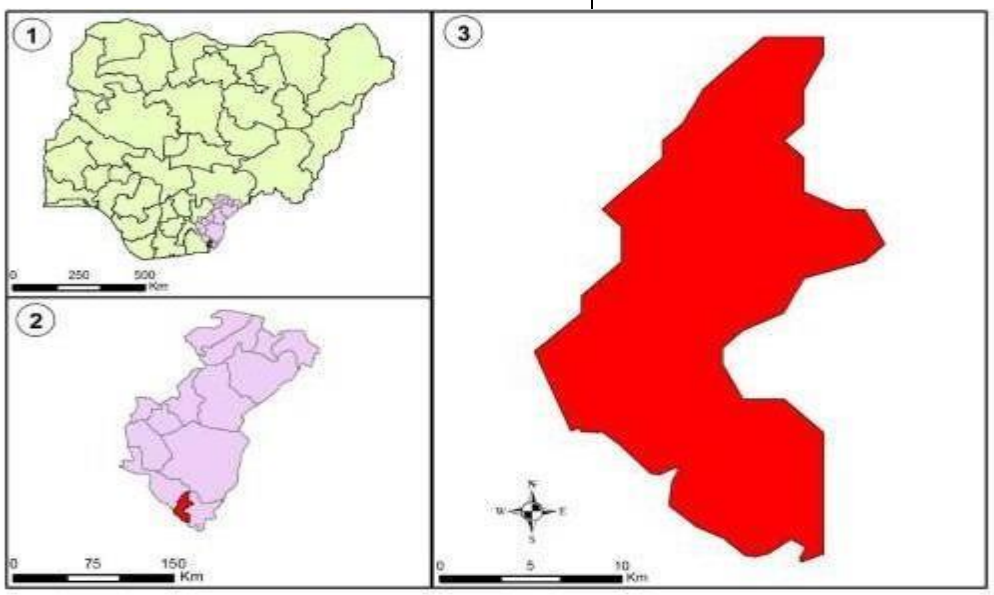


Figure 1: Map of the Study Area
(1)Country: Nigeria (2) State: Cross River State (3) City: Calabar.

4. Analysis and Results

The analysis was carried out with combined rainfall and spatial data (remotely sensed). Since flooding in the study area is predominantly caused by rainfall amount, intensity and duration. It is practicably important to consider the annual and monthly rainfall (mm) of the study area for the years under investigation. Figure 2 is derived from Table 2 showing the annual rainfall of the years under investigation.

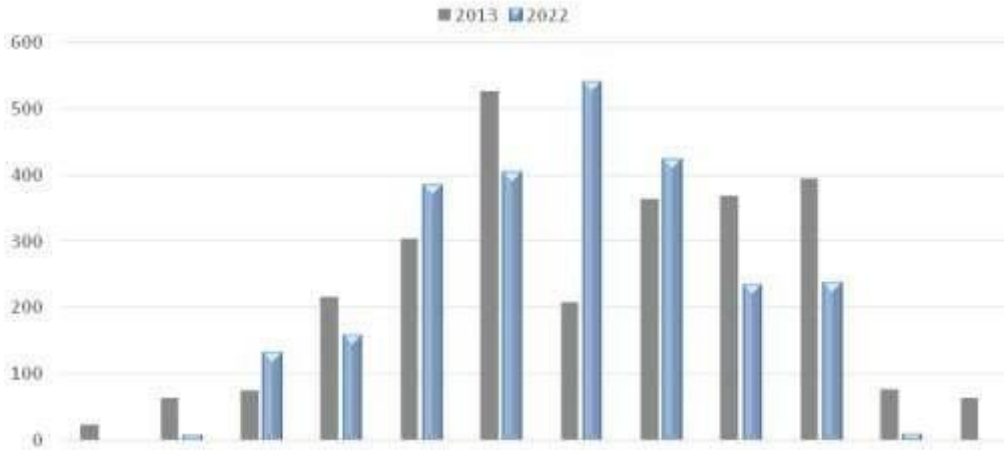


Figure 2: Annual Monthly Rainfall (mm) For 2013 and 2022
Source: Data Analysis, 2023

Figure 2 shows that rainfall in 2013 was higher in the months of June, October, September, August, and May. While, in 2022 it was higher in the months of July, August, June, and May. Rainfall of these months brought about the hazardous and malicious flooding of the years under comparison.

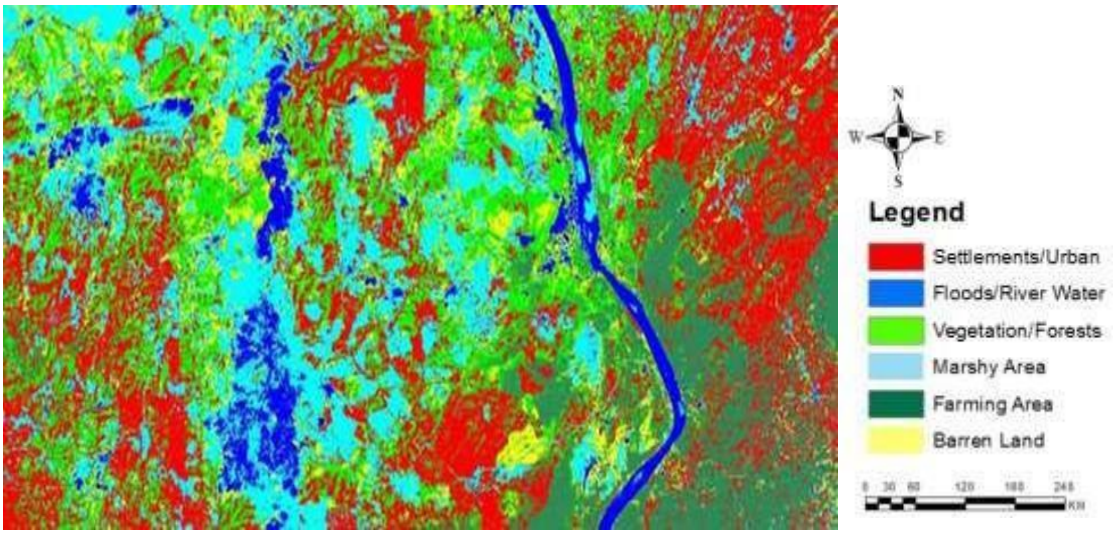


Figure 3: TM 2013 (bands 1-5 & 7)
Source: Data Analysis, 2023

Figure 3 shows the image analysis of the 2013 Landsat Scene with six land cover classes as shown in the Legend. The analysis shows that flooding was actually intensive in 2013 but the image was captured during the flood recession which made most of the flooded areas to be occupied by the Marshy Areas.

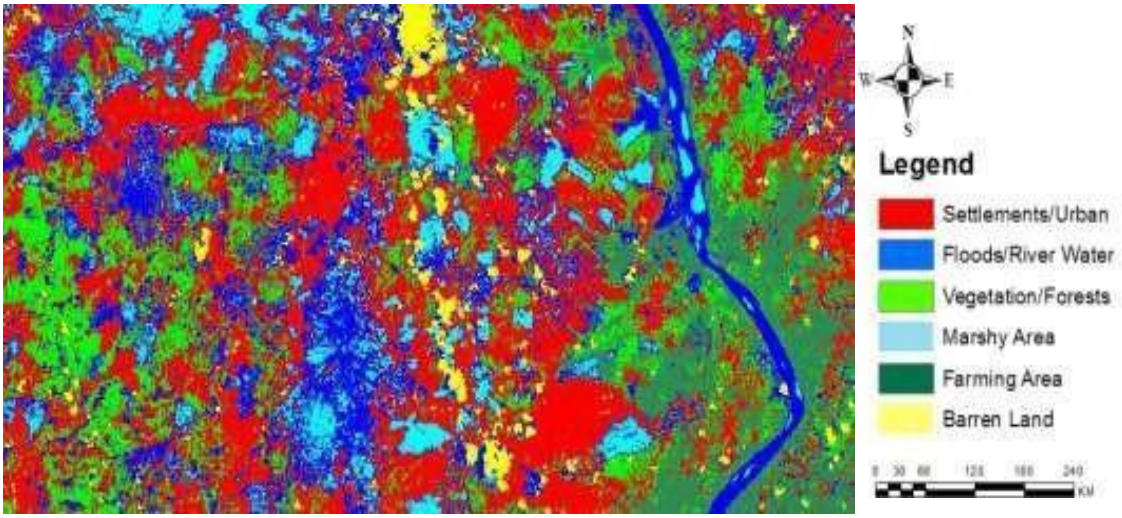


Figure 4: ETM+ 2022 (bands 1-5 & 7)
Source: Data Analysis, 2023

Figure 4 shows the image analysis of the 2022 Landsat Scene with six land cover classes as shown in the Legend. The analysis shows the difference in flooding over a period of ten years. However, it represents an increase in urbanization which brought about a reduction in vegetation cover, barren areas, thereby paving way for intensive flooding. Flooding was higher in built-up areas which made it possible for this competition between settlements and flooding.

Table 4: Land Cover Statistics of 2013 and 2022

Land cover class	Area (km²)		Changed area
	2013	2022	
Settlements/ Urban	2399	2855	456
Vegetation/ Forests	1704	1615	-89
Floods/ River Water	2007	2759	752
Marshy Area	1334	1150	-184
Barren Land	789	747	-42
Farming Area	1220	1464	243
Total	10021	10021	

Source: Data Analysis, 2023

Table 4 shows the various increases and decreases in the identified land cover classes between 2013 and 2022. These ten years shows tremendous increase in land cover classes of settlements, floods/river water and farming area. While there was a decrease in vegetation/forests and barren land from 2013 to 2022, however, the degree of flood was higher in 2022.Figure 5 shows the graphical representation.

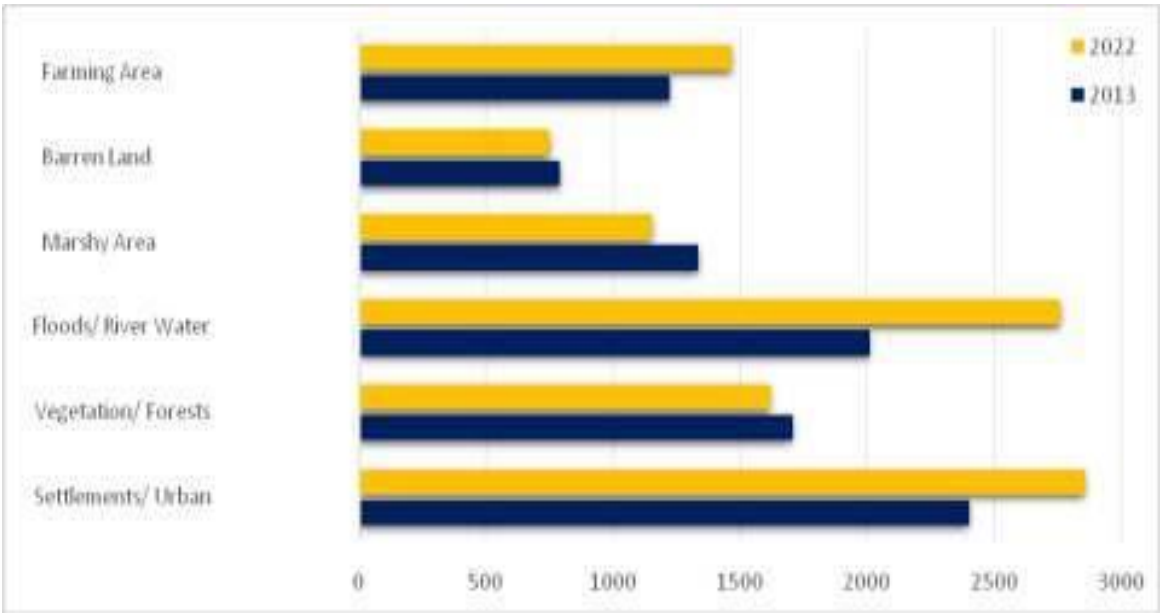


Figure 5: Land Cover Variation for 2013 and 2022
Source: Data Analysis, 2023

Table 5: Confusion Matrix Statistics of 1991 and 2001

Land cover class	2013		2022	
	Producer	user	Producer	user
	acucracy (%)	accu (%)	accu (%)	accuracy (%)
Settlements/ Urban	88.26	99.00	94.42	92.63
Vegetation/ Forests	92.26	66.39	83.09	68.67
Floods/ River water	91.83	96.85	93.00	95.09
Marshy Area	97.64	97.04	88.75	95.20
Barren Land	100.00	99.24	93.40	67.35
Farming Area	87.00	86.72	95.77	97.40
	(Overall Accuracy = 91.74, Kappa = 0.89)		**(Overall Accuracy = 92.39, Kappa = 0.90)**	

Source: Data Analysis, 2023

Table 5 shows the confusion matrix statistics of 2013 and 2022. It represents the producer accuracy in percentages as the ratio of the classified pixels of each land cover type in relation to the total number of ground troth pixels as well as the user accuracy which expresses the ratio of the probability of classified pixels of each land cover type in relation the actual pixels in percentages. The overall accuracy and the kappa coefficient of the 2013 and 2022 were also shown in Table 5.

5. Discussion

In this study, the concept of flood management was employed with the utilization of two Landsat scenes and rainfall data. Ten years' duration was used to compare floods of 2013 and 2022 in attempting to arrive at some appropriate

techniques of flood management in the study area. Figure 2 shows the annual monthly rainfall of 2013 and 2022 which was derived from Table 2 and the analysis shows that rainfall was higher from the months of May to October. 2013 has higher rainfall in May, June, August, September, and October while in 2022, rainfall started in May to October forming a peak in July with higher rains which eventually were flooded months.

Figures 3 and 4 are the Landsat scenes which shows the rate of floods and other land cover classes within the years under study. The analysis in Figure 3 shows that the image was acquired during flood recession and as such most of the flooded areas were then seen as marshy areas made up of mud whereas, Figure 4 shows the level of flood which implies that the image was acquired during the peak of flood. Figure 5 has again, shown the land cover variation within a period of 10 years. The analysis as derived from Table 4 shows that Land cover classes of vegetation and barren lands lost much of its spatial area to settlements which pave way for flooding. It also shows the competition between settlements and floods within the years under investigation which shows that as settlements continues to grow without appropriate control measures, flood events took advantage of that and inundated the study area.

In applying flood intelligence and management techniques considering circumstances surrounding flooding and competition within the identified land cover classes that also influence flooding in the study area, the use of structural and non-structural measures could be necessary. Structural measures involve the various engineering technicalities of construction of drainage channels that are capable of containing the run-offs volume during downpours. The non-structural measures involve certain strategies such as flood plain zoning, flood plain regulations and flood plain building codes.

6. Conclusion

This study is aimed at exploring the various remote sensing techniques by producing detailed hazard assessment maps as well as hydrological and inundation charts that are useful for flood management in the study area. The findings of the study however, revealed that the frequency of floods over the years depended on the amount, intensity, and duration of rainfall. It was demonstrated with the aid of rainfall data showing that months of high rainfall amount were associated with substantial proportion of flooding, affecting all the land cover classes in the study area. Again, the rate of flooding was also found to vary according to the amount of rainfall, land configuration, and the prevailing land cover type (for example, settlements).

It was also found that the rate of flooding was continuously increasing directly proportional to accelerated urban development. This implies that as development of settlements continuous to grow, flooding also paved it ways through these channels and expand to areas which were originally not flooded. However, this is evidenced in the work of Adeleye and Rustum (2011), who found out that most of the flooding in Nigerian cities are caused by inadequate or poor urban planning. Figure 4 also confirmed the fact that development pattern in the city of Calabar is carried out haphazardly without control, many of these settlements were erected without planning permission and some of which were not properly sited as they were built on flood prone areas and as such becoming vulnerable to floods during the wet season. Settlement areas are associated with hard core

pavements and landscapes capable of holding water infiltration and percolation capacity. This makes it possible for sudden and occasional heavy downpours to settle on the surfaces for a long period causing flooding and ponding of water. Uncontrolled development also lacks accessibility and accessibility brings about development of drainage channels. It was also revealed that most of the drainage channels constructed are narrow and could not accommodate the water volume especially when it rains heavily. In some cases, these narrow drainage channels are also congested with waste which stem from the habit of throwing them in the channels. All these are compounded to aggravate extensive flooding whenever it rains.

Another factor that contributed to the rate and frequency of flooding in the study area is the topography. Most of these areas that are constantly flooded as shown in Figures 3 and 4 are found in low lying areas (flood prone areas). These areas are below 100 meters above sea level and it becomes difficult for rain water to flow freely in the midst of congested buildings and congested narrow drainage channels. The mouth of the Cross River also over flow annually and inundate the adjacent land cover areas impacting negatively on them.

In view of these findings, it is advisable to adhere to the flood intelligence technicalities of inundation management. It is also necessary to introduce the various adaptation options of autonomous and planned – autonomous adaption rely on individual responsibility on managing floods without the support from any government institution while, planned adaptation deals with institutions of government being responsible in managing floods for the affected citizens through legislative and institutional framework such as NIMET, National Emergency Management Agency, Department of Climate Change, and Ministries of Environment and many more.

It is also important to strengthen the development control department of the Town Planning Unit with the backing of the governmental instrument to ensure that all developments are scrutinized and passed the test before giving permission to carry out. The area of development should also be stated in line with best practice and in conformity with the master plan of the city. There is need to invoke the zoning power as a strategy to eliminate impact of flooding on livelihoods of communities. This can be done by zoning most of these flood prone areas with floods frequency of 10 to 50 in ten to thirty years to growing urban landscape trees, recreational park areas and urban agriculture especially for the cultivation of crops that needs water such as rice, maize, vegetables, and water yam. This would also help to enhance food productivity.

There must be efficiency in town planning ensuring that activities of the city are planned appropriately, regulated and guided by the law. There should be construction of adequate drainage channels with appropriate capacity to accommodate the water volume and proper awareness in form of education and campaign be institutionalized to prevent inappropriate disposal of waste on the drainage channels. Noncompliance to these regulations should be subjected to prosecution without fear or favour.

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