Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.4, No.13, 2014

Analysis of Patterns of Encroachment on Flood Vulnerable Areas by Settlements around River Kaduna, Kaduna South LGA, Nigeria

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Abstract
This study assessed the patterns of encroachment of settlements on flood vulnerable areas of river Kaduna. The ENVI version 4.7 software aided the import of images one after the other in a Geo-tiff format. Proximity analysis was then applied to discover relationships. The river Kaduna was buffered using the multi-ring method and various settlements were overlaid on the buffer ring to determine settlements at risk. Change computation was made between 1990 and 2010 with the ENVI.4.7 version basic tools. Since image is classified, the detection statistic was used where the equivalent classes were defined and the needed pair was added. This provided the change detection statisticoutput. Results show the rate of change of the flood vulnerability and other land use/land cover classes of the study area. Also, since settlements can be observed within the very high risk zones to the left or right of the river, this suggests that the area has a very high risk of flood as corroborated by the GIS results. In events of flooding, the blue zone may be used as a staging area for rescue operations within the area.
Keywords: Flooding, floodplains, remote sensing, GIS, river Kaduna.

Introduction

Historically, flood plains have been attractive to human settlements for the availability of fertile land, freshwater supply and transportation. These perceived advantages led to the beginning of modern settlement areas (Bue, 1967). After decades and even centuries of development, anthropogenic influences have introduced new contaminants to these flood plains. Particularly at the margins of such settlements, rural activities are juxtaposed and landscape features are subject to rapid modifications (Floyd, 1978). A recent report in Saturday Tribune (2012) on flooding in Nigeria showed that flood sacked communities, some were totally wiped out, buildings submerged, properties destroyed, farmlands wiped out, and incalculable and irreversible damage was done to food and cash crops, rendered hundreds of thousands of citizens homeless and caused death to many citizens. This is not strange in communities situated at the bank of major rivers and coastal communities in Nigeria, more importantly when the Nigeria Emergency Management Agency (NEMA) predictions and warnings about the flood in many parts of the country early 2012 were ignored. NEMA traced the cause of the devastating flooding in the country to the release of large volume of water from the Goroyo dam in Sokoto State and warned that so far, other rivers and streams on the routes may be affected especially communities in Niger and Kwara States that host the Kainji dam. The hinterland cities cannot be totally excluded from flood disasters because most of them are vulnerable hence at risks. Nigeria has been slow to realise the potentials of remote sensing and GIS in flood disaster management. This is confirmed by the response to the recent flood disasters that affected more than 23 States in the country claiming many lives and properties, and threatening the ecological biodiversity. Remotely sensed imagery and GIS may prove very effective in identifying the spatial component of flood management offering a synoptic view of the spatial distribution and dynamics of hydrological phenomena such as flood and erosion. They are used to measure and monitor the areal extent of flooded areas, provide a quantifiable estimate of the land area and infrastructure affected by flooding and erosion (Izinyon and Ehiorobo, 2011). Goel et al, (2005) presented the technique for preparation of flood hazard maps which included the development of digital elevation model and simulation of flood flows of different return periods. Bhadra et al, (2011) proved that GIS technique is effective in extracting the flood inundation extent in time and cost effective manner for the remotely located hilly basin of Dikrong, where conducting conventional surveys is very difficult. Also Orok (2011) states that a flood risk map should be able to identify the areas most vulnerable to flooding and estimate the number of people that will be affected by floods in a particular area. Jeb and Aggarwal (2008) carried out a study aimed at analyzing flood risk and modeling plans for flood abatement in Kaduna metropolis. Given the recurrent nature of the problem in Kaduna metropolis, they recommended further research for efficient

risk management which could estimate the lives at risk due to the hazard. This paper hence presents the patterns of settlement encroachment in the flood vulnerable areas of river Kaduna.

Study Area

With an area of 59km^2 and a population of 402,390 at the 2006 census, Kaduna South lies within latitudes 10^{0}26`N and 10$^0$32`N of the equator and on longitudes 7^{0}24`E and 7$^0$28`E of the Greenwich meridian. It falls into the tropical continental (Sudan) climate according Koppen's classification with seasonal rainfall pattern of high intensities. Mean annual temperature is about 24.5^{0}C and mean annual rainfall is about 1,185mm. Annual evapotranspiration almost equates annual rainfall. It has distinct wet and dry seasons. The area is inhabited by the Hausas who are mainly dry season vegetable farmers in the floodplains of river Kaduna. The incidence of flooding is yearly however, the damage to crops and houses is relative to the intensity of the flood. Flood disasters that have in inundated large areas along river Kaduna flood plain from the river claimed several lives and properties. Therefore, a need for efficient flood hazard assessment of patterns of settlement encroachment will mitigate the damage incurred next time there is massive overflow and also curb the current rapid expansion of settlements into the low-lying flood plains by establishing appropriate land-use legislations.

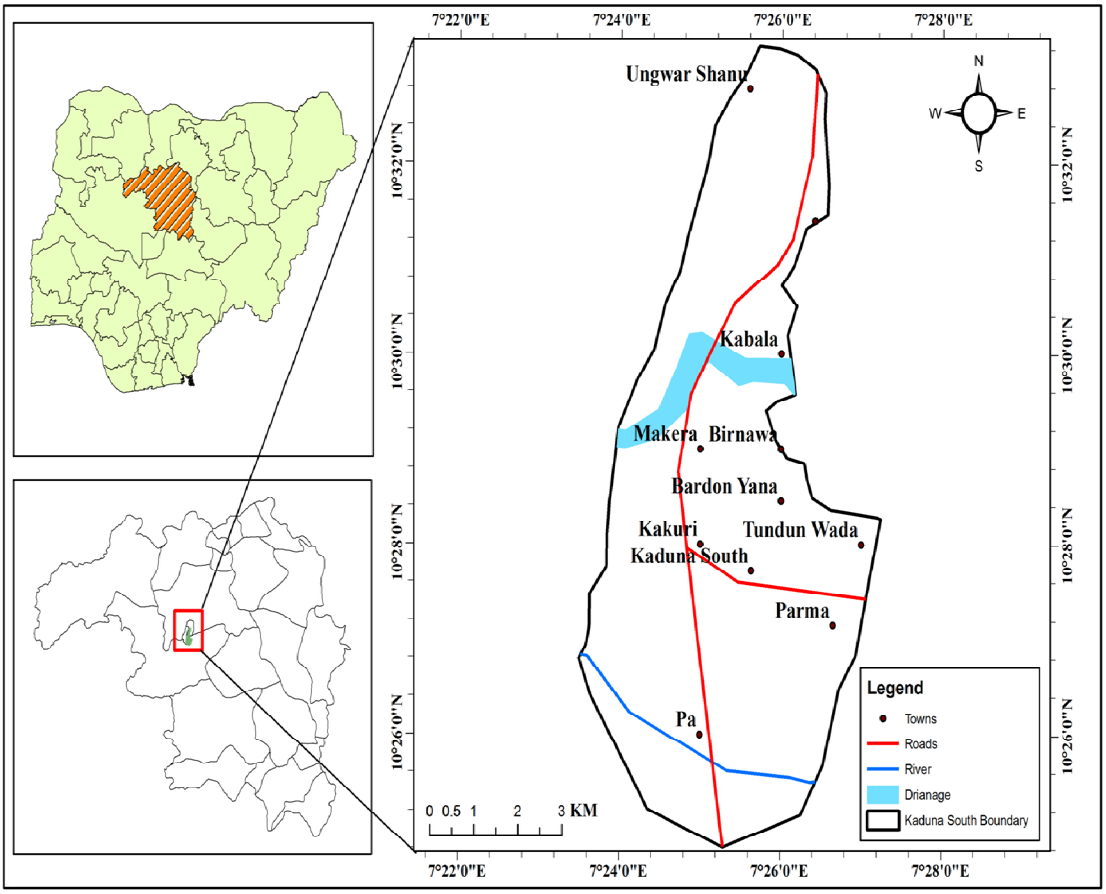

Fig. 1: Study Area

Methodology

Images were imported one after the other using the geo-tiff format with the aid of ENVI 4.7 software. To produce a vulnerability map for the settlements, the proximity analysis was applied. The proximity analysis was used to discover proximity relationships which tools output information with buffer features or table. The buffer tool outputs polygon features were used as inputs to overlay tools. This helped in delineating protected zones around features showing areas of influence. The river was buffered using the multi-ring buffer method, and various settlements were overlaid on the buffer ring to determine settlements at risk. After image preparation and classification, the change detection function in ENVI 4.7 basic tools was utilized in computing for change between 1990 and 2010. Since the image is classified, the detection statistic was used. In this case the initial dates were first input followed by the final state image. The equivalent classes were defined and the needed pair was added. This operation generated the change detection statistic output (table 2).The output result shows the rate of change of the flood vulnerable areas and other land use/land cover classes of the study area.

Results and Discussion

Table 1: Settlements at risk to flooding due to encroachment.

Settlement	Vulnerability level
Parma	Less vulnerable
Tudun wada	"
Bardn Yana	"
Ungwar Shanu	"
Kakuri	"
Kaduna South	"
Romi	Highly vulnerable
Pa	"
Makera	"
Birnawa	"
Kabala	"

Source: Authors' GIS Results

Table 2: Land use/land cover change detection statistic (1990-2010)

Land use/ land cover	1990		2006		2010	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Built – up area	8.95	14.97	19.57	31.35	33.41	56.69
Bare land	13.05	21.85	14.65	28.2	16.65	15.9
Vegetation	28.44	47.6	15.34	25.85	12.9	21.81
Water body	9.31	15.58	9.66	14.6	3.3	5.6
Total	59.75	100	59.22	100	59.03	100
Kappa coefficient	0.893		0.931		0.967	
Overall accuracy %	90.39		94.23		97.22	

Source: Authors'fieldwork.

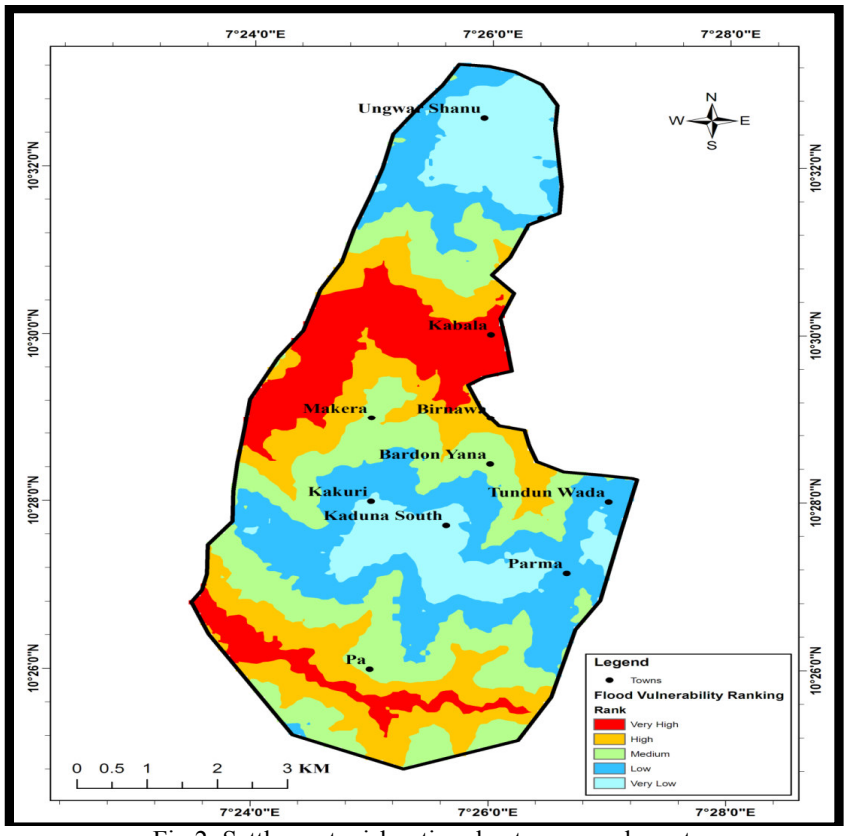

Fig 2: Settlements risk rating due to encroachment

Table 1 and fig. 2 show that settlements around, Romi, Kabala, Birnawa, Makara and Pa areas are within the highly vulnerable flood prone areas of the river Kaduna while areas like; Kakuri, Parma, Bardn Yana etc fall within the less vulnerable areas. The elevation of the surrounding area relative to the river contributed more in determining their vulnerability levels as well as distance from the river. For example, an area that lies right beside the river may not be liable to flood if it is at a great height, however, an area that this further away may become flooded if the intervening land is flat or a gentle slope or if the area lies on a depression. Since settlements can be observed within the very high risk zones to the right or left of the river, this suggests that the area has a very high risk of flood as corroborated by the results of the GIS analysis. In the event of a flood, the blue zone may be used as a staging area for rescue operations within the area. There is also need to control land use within the red zone by government using legislations.

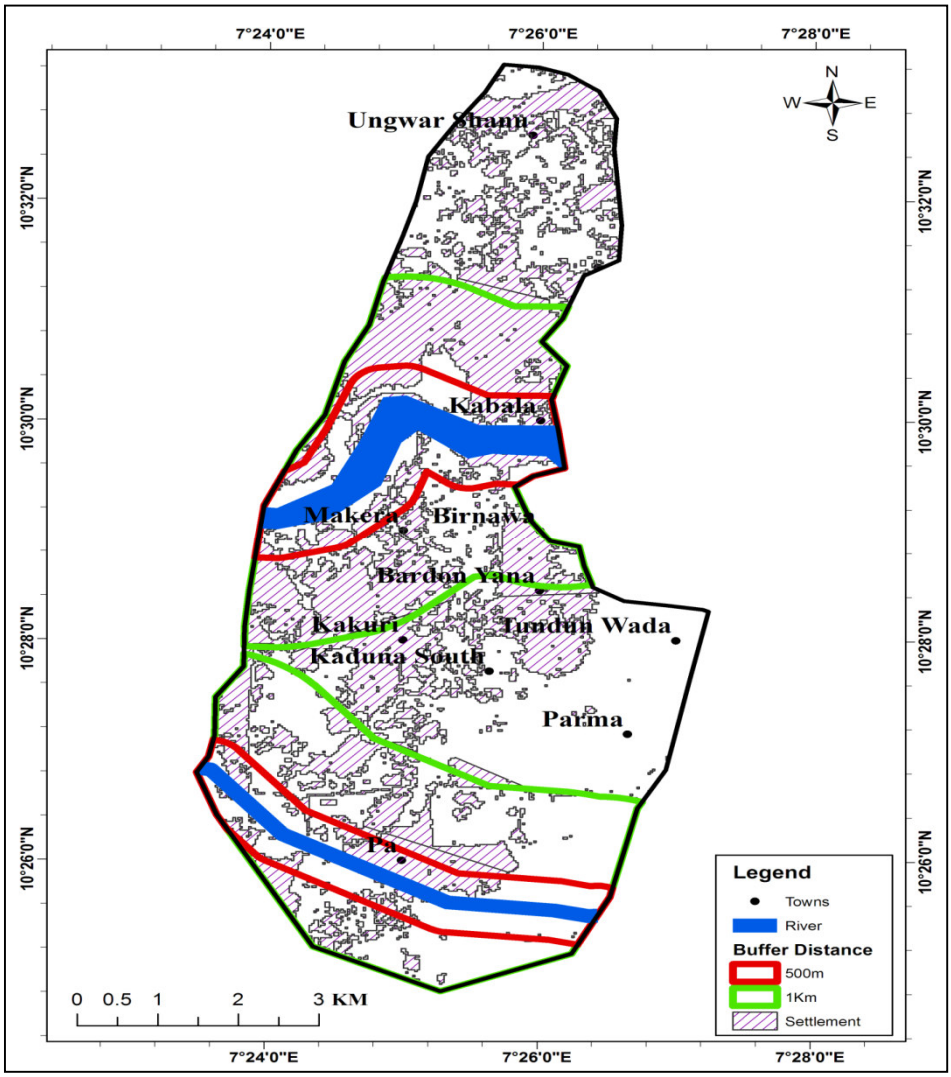

Fig. 3: Patterns of settlement encroachment along floodplains in the area.

Conclusion

The tremendous expansion that the study area (Kaduna South) experienced has created encroachment by the settlements along the floodplain and environmental degradation consequent to the growth. There is dense agglomeration of people and economic activities associated with settlement expansion which imposes pressure on the environment that can shape the physical landscape and the functional state of the ecosystem. Also there are social ills such as unemployment, poor quality of housing, traffic congestion, poverty, low standard of living and overcrowding which put pressures on the state and local governments to provide basic social amenities and infrastructure for the growing population. The high growth rate of settlements in the African continent makes flood management in settlement planning an issue that cannot be negotiated. This is pertinent since settlement growth is acknowledged as an important contributor to flooding as the paving over natural surfaces increases runoff during extreme rainfall events hence reducing infiltration of water into soils and sub-surface strata. In all,

a well applied remote sensing and GIS will go a long way to help in controlling the problem of river flooding all over the nation. Their application is only literally limited by the imagination of the operators. These gaps have been clearly demonstrated in this paper.

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