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URBANIZATION, CLIMATE CHANGE AND THEIR IMPLICATIONS ON PLUVIAL FLOODING IN GOMBE METROPOLIS, GOMBE STATE, NIGERIA

ABASHIYA, M.; SULE, S.; KOLLOS, P.N.; SADEEQ, A. ADAMU, M.B
Department of Geography, Gombe State University, Gombe, Nigeria
Corresponding Author Email: E-mail: mabashiya@gmail.com *+2348029106846*

Abstract:
Pluvial flooding has become a menace in many of the world's urban areas and in particular Gombe metropolis. The paper focused on pluvial flooding in Gombe metropolis. Landuse/landcover change detection was carried-out for Gombe metropolis using the 1996, 2006 and 2016 Landsat thematic mapper. The study revealed that the Vegetation in terms of landcover in Gombe metropolis had decreased from 47.90% in 1996 to 27.51% in 2006 and 14.61% in 2016 while the built-up area on the other hand increased from 29.50% in 1996 to 47.39% in 2006 and 63.52% in 2016 respectively. The result for change detection showed that vegetation cover decreased by 33.29% from 1996 to 2016 while the urban expansion increased by 34.02%. The percentage of imperviousness also increased from 50.31% in 1996 to 70.12% in 2006 and 83.71% in 2016 which had increased the amount of runoff to cause flooding in Gombe metropolis. The authors recommended provision of adequate drainages and proper infrastructural development to meet up with urban expansion in Gombe metropolis.

Keywords: Urbanization, Climate Change, pluvial flooding, inadequate drainages, Gombe Metropolis.

1. Introduction

Urbanization and its environmental consequences in many parts of the world are amazingly wide. The frequency and severity of Man-induced disasters is increasing worldwide and particularly alarming in developing countries (Adepetu , et al., 1998; Abaje, *et al.,* 2017). In recent years, there have been an increased in pluvial flood disasters that have caused enormous damage in terms of loss of life and property. The global warming and its effects on climate has increased rainfall and runoff particularly in urban areas leading to environmental hazard such as flooding (Abaje, et al., 2016). The projection of climate change trends, indicates increase in the occurrence of rainfall events (International Panel of Climate Change, 2013 and Donat, et al.,2017), both in terms of their intensities as well as frequencies. Such high intensity rainfall events along with the changes in land use patterns, particularly in urbanized areas with inadequate drainages are expected to have implications on pluvial flooding (Abashiya, 2006).

Pluvial flooding occurs in urbanized areas with increasing intense rainfall events due to deforestation, urban heat islands and inadequate artificial drainage structures to convey the abundant overland flow into the natural drainages. For urban areas that have a major river passing through the metropolis such as Thames river in London, rivers Ganges and Bramaputra in India, Kelang river near Kuala Lumpur in Malaysia, river Lamurde in Jalingo and river Kaduna in Kaduna may have a combined effects of pluvial-fluvial flooding. In the Philippines, flooding in the southern Island of Mindanao killed 25 people, 15 missing in one night when river Rio Grande de Mindanao flowing through the city of 1.4 million people was swollen by the summer monsoon torrential rains and the flood inundated the residential areas (Chandler, et al., 1975). In many developing countries around the world, urban growth has taken place in such a way that resources to meet the demand for environmental resilient and sanitation suffer from excessive pressure. Studies have shown that the Sudano-Sahelian Ecological Zone (SSEZ) of Nigeria is subject to frequent floods and droughts as a result of its large inter-annual variability of rainfall (Abaje, et al., 2014). In Gombe metropolis the rainfall regime is concentrated within three months (July, August and September) with a single maximum in August. Cramer's test showed that rainfall of Gombe metropolis showed drier conditions during the decades 1975-1984 and 1985-1994 while the decades 1995-2004 and 2005-2014 depict wetter conditions with the annual decrease of -0.11mm,-0.49mm and increase of 0.18mm, 1.49mm respectively. This increase is as a result of the substantial increase in August and September rainfall (Abashiya et tal. 2017). Urban drainage systems are closely related to weather phenomena. When a weather event changes as a consequence of changes in rainfall and the global mean temperature may result to pluvial flooding. The likelihood of flooding is closely associated with the changes in land use linked with urban development that leads to the removal of vegetation, which affects the landscape characteristics. This transformation impedes water infiltration and increases the velocity and the amount of run-off as overland flow. Increase in extreme weather event such as flooding has become an annual recurring feature in Nigeria, especially in the northern states (Abaje, et al., 2015).Gombe town prior to the state creation in 1996 did not have a Master Plan. The choice of the town as the capital of Gombe State, carved out of Bauchi state, elevated the centrality of Gombe at the national level as the foundation of the metropolitan area of Gombe state (Gombe master plan, 2003). Since then, the metropolis has witnessed a drastic increase in infrastructural development such as roads and residential buildings (Makadi, et al., 2017), to enhance better living standard. The newly created state with continuous immigration of people has immensely contributed to the rapid growth of Gombe as a town, with a population of 18,500 in 1953 to over 300,000 inhabitants in 1990's (Balzerek, et al., 2003), and over 349,556 as in 2018 . This influx has impact on the urban soil infiltration capacity, particularly in the month of July August and September where the antecedent precipitation index (API) can be as high as 166.62mm, thus increasing flow of runoffs and possible flooding (Abashiya, et al., 2019).

2. Study Area

Gombe metropolis is located between Latitudes $10^0 14'10''$N and $10^0 19'00''$N of the Equator and Longitudes $11^0 07'00''$E and $11^0 12'50''$E of the Greenwich meridian. It is bounded by Kwami LGA to the North, Akko LGA to the Southwest and Yamaltu-Deba LGA to the East.

In Nigeria, rainfall is influenced by two air masses: the Tropical Continental air mass (cT) which is dust-laden during the dry season and the Tropical Maritime air mass (mT) which is moisture-laden during the raining season (Oladipo, 1995). The two air-masses meet at a zone over the land called Inter-Tropical Discontinuity (ITD). The oscillation of this ITD determines to a great extent the distribution of rainfall in Nigeria and Gombe metropolis in particular. The ITD is situated to the North of Sudano-Sahelian Ecological zone in July to September, allowing Gombe to be completely under the influence of Tropical Maritime air mass hence the single maximum rainfall occurs in August. When the ITD is located south of the Sudan Savanna area from October to April, Tropical Continental air mass dominates and

Gombe experiences the dry season (Odekunle, et al., 2008; Sawa, et al., 2011).

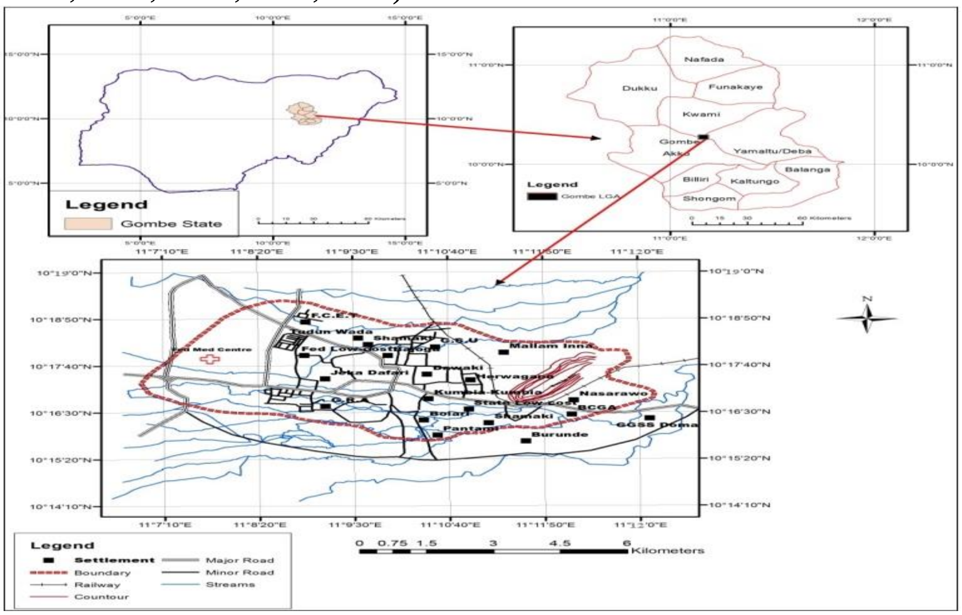


Figure 1: Gombe Metropolis
Source: Authors' GIS Compilation (2018)

Gombe metropolis is a low-lying, landscape sloping from Akko escarpment to Liji hill which is the highest point 600m high. Some inselbergs and cuestas dotted the northern and southern part of the metropolis. When approaching the metropolis from the west, it looks like a community in a basin.

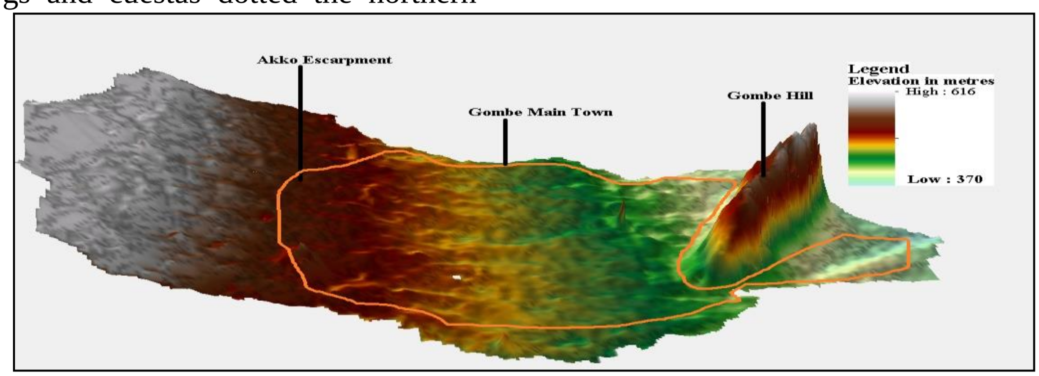


Figure 2: 3D View of the Study Area
Source: Authors' GIS Compilation (2018)

The metropolis is drained by ephemeral streams in a dendritic pattern such as Kundulun, Kurba, and Arawa in the north-east and Bagadaza, Pantami and Bogo, in the south, which take their sources from the Akko escarpment and flow eastwards. There are also ravines and gullies that serve as waterways, "death traps" during sudden storm events particularly in the months of July-September (Abashiya, *et al* 2017). Soil distribution reflects the climatic conditions and the geological structure of the area. Gombe metropolis has light textured, sandy soils which drain rapidly with low moisture retention capacity that may lead to leaching of plant nutrients. The alluvial deposit of fine-coarse sands, silts and clays are found in layers which formed the floodplains along the lower course of stream channels. The soils are formed from the intensive weathering of the Basement Complex rocks (Obaje, 2009). They consist of unconsolidated wind-blown or water deposited sand and clay-rich mostly to the southeast of the metropolis along the valley of Pantami catchment (Orazulike, 1992; Mbiimbe, et al., 2019). There is extensive leaching, low plant nutrients and susceptible to water erosion that has left scars of gullies in the metropolis.

The inherently infertile soils of the tropics, becoming degraded chemically and organically when utilized. Soil nutrients except aluminium and iron decrease substantially, this gives the ferric red soils or the Kerri-Kerri formation that have lost the topsoil organic matter (Amos, et al., 2015). This is attributed to traditional agricultural practices such as slash and burn over the years that has made the soils susceptible to soil erosion and reduced the water holding capacity and increase in surface water flow leading to pluvial flooding. These soils that have been subjected to degradation are mostly; nitosols, leptosols, cambisols, or luvisols (Ikusemoran, et al., 2018). The vegetation is the Sudan savanna type which has replaced the guinea savannah of the 1970s due to anthropogenic activities and climate change with many tree species becoming extinct (Mbaya, 2016). It is characterized by; shrubs, scattered trees and grasses. The predominant tree species include; Locust bean tree (*Parkia clappertoniana*), Baobab (*Adansonia digitata*), Tamarind (*Tamarindus indica*), Date palm *(Phonis doctylifera*) and Neem (*Azadirachta indica*). The population of Gombe town in 1919 was only about 300 people. In 1986, the figure rose to 130,000 people (Balzerek, et al., 2003). According to the National Population Census report (2009), Gombe metropolis had a population of 266,844 people. Using the exponential method of population projection as recommended by the NPC with growth rate of 3% the figure was projected to 377,341 for 2017.

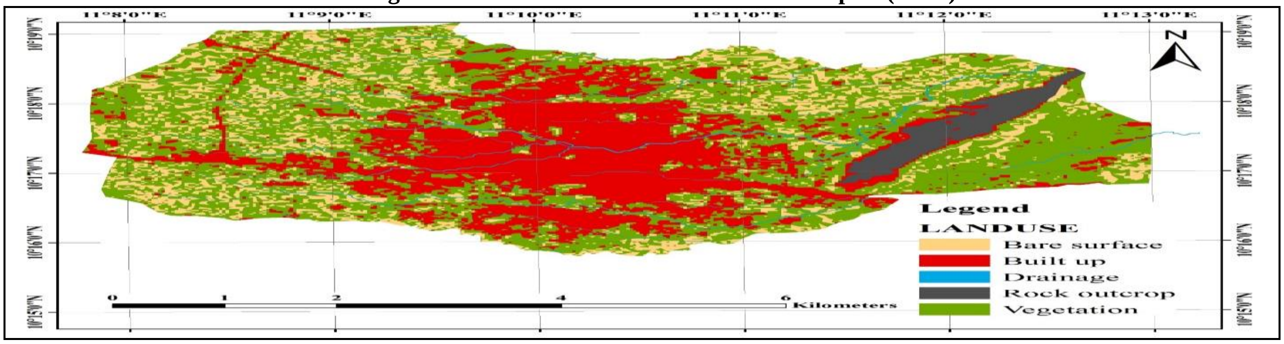
3. Materials and Methods

The land-use/landcover maps were generated from Landsat TM satellite imagery of 1996, 2006 and 2016 obtained from the National Centre for Remote Sensing (NCRS) Jos, and was imported into ArcGIS 10.5 environment for classification.The imageries were resampled so that they conform to a uniform cell sizes. ArcGIS 10.5 application using maximum likelihood classification scheme also known as supervised image classification (Lillesand, et al., 2008). The Normalized Difference Vegetation Index (NDVI) was used for land cover change detection. A subset covering Gombe metropolis was extracted from the full scene of the imageries. Image classification is a procedure to categorize all pixels in an image of a terrain into land cover classes. The land-use/land cover classes were; Built-up, Vegetation, Rock outcrop, bare surfaces and drainages Urban areas are commonly dominated by man-made impervious surfaces, changes in which are often used as an indicator of urban development (Carter et al., 2015). Most urban areas are almost exclusively characterized by a combination of impervious surfaces and vegetation and in some Cases Rivers, which are easily distinguishable and the information on vegetation cover from remote sensing can be utilized to provide accurate and cost-efficient estimates of the quantity and spatial distribution of impervious surfaces (Arnold and Gibbons, 1996).

4. Results and Discussion

The landuse/landcover classification of Gombe Metropolis (1996) is presented in Figure 3 and the statistics of Landuse/Landcover is also presented in Table 1

Figure 3: Landuse/landcover of Gombe Metropolis(1996)



Source: Authors' GIS Analysis (2018)

Urbanization with increases in population may cause an increase in the demand for infrastructure resulting from the increase in built-up areas and reduction in landcover. Increase in urban built-up areas has also increase the level of imperviousness, thus decreasing the ability of the land to absorb rainfall-runoff and hence, causing rapid surface runoff. The transformation of space due to urbanization results in the replacement of permeable soil with impermeable surfaces (such as roads, roofs, parking lots, and sidewalks), thus decreasing the ability of the land to absorb rainwater. In addition, it reduces infiltration of water into the ground, causing rapid surface run-off. Furthermore, it increases the flow volume of pluvial flooding of the study area. The urbanization scenario for Gombe Metropolis by 1996 from Table 1 showed that bare surfaces covered 17.62%, built-up areas 29.50%, rock outcrop 3.19%, vegetation 47.90% and drainage 1.79%. The percentage of imperviousness considered as the percentage sum of built-up areas, rock outcrop and bare surfaces (Arnold and Gibbons, 1996) is 50.31%.

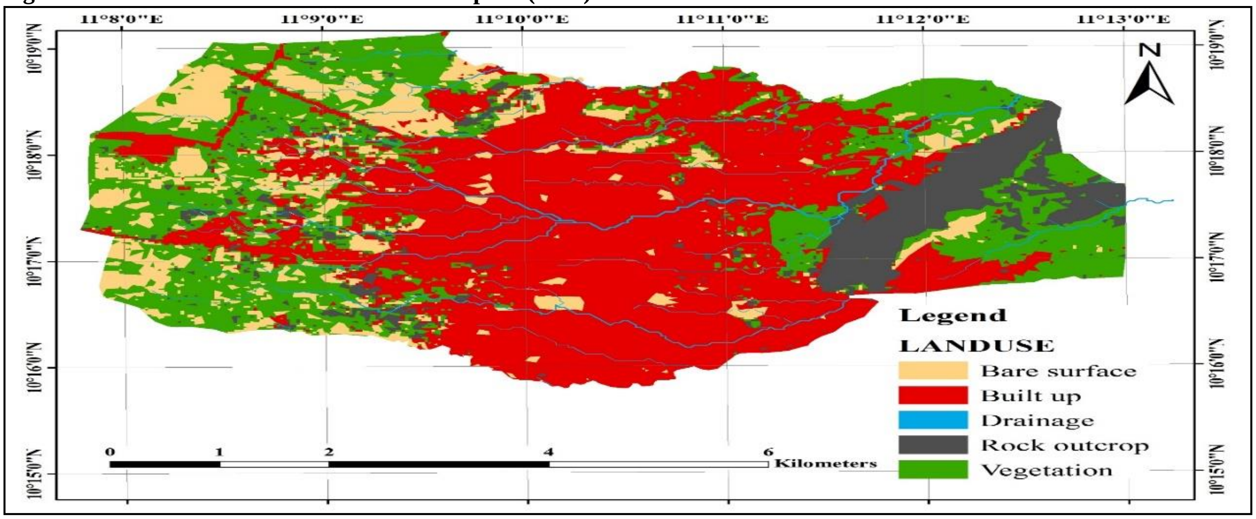
The landuse/landcover classification of Gombe Metropolis (2006) is presented in Figure 4 and the statistics of Landuse/Landcover is shown in Table 2.

Table 1: Landuse/Landcover of Gombe Metropolis (1996)

Landuse	Hectare	M^2	Km^2	%
Bare surfaces	734.67	7346717.05	7.35	17.62
Built up	1230.06	12300548.22	12.30	29.50
Rock outcrop	133.12	1331171.29	1.33	3.19
Vegetation	1996.75	19967488.88	19.97	47.90
Drainage	74.58	745830.52	0.75	1.79
Total	4169.18	41691755.96	41.69	100.00

Source: Author's GIS Analysis (2018)

Figure 4: Landuse/landcover of Gombe Metropolis (2006)



Source: Author's GIS Analysis (2018)

The landuse/landcover of Gombe metropolis for the year 2006 was classified into five classes namely: bare surfaces covered 13.07%, built-up areas 47.39%, rock outcrop 9.66%, vegetation 27.51% and drainage 2.37 %. The percentage of imperviousness is 70.12 %. The results revealed increase in built-up areas from 29.50% in 1996 to 47.39% in 2006 while vegetation has decrease from 47.90% in1996 to 27.51% in2006. The percentage of imperviousness has also increased from 50.31% in 1996 to 70.12% in 2006.

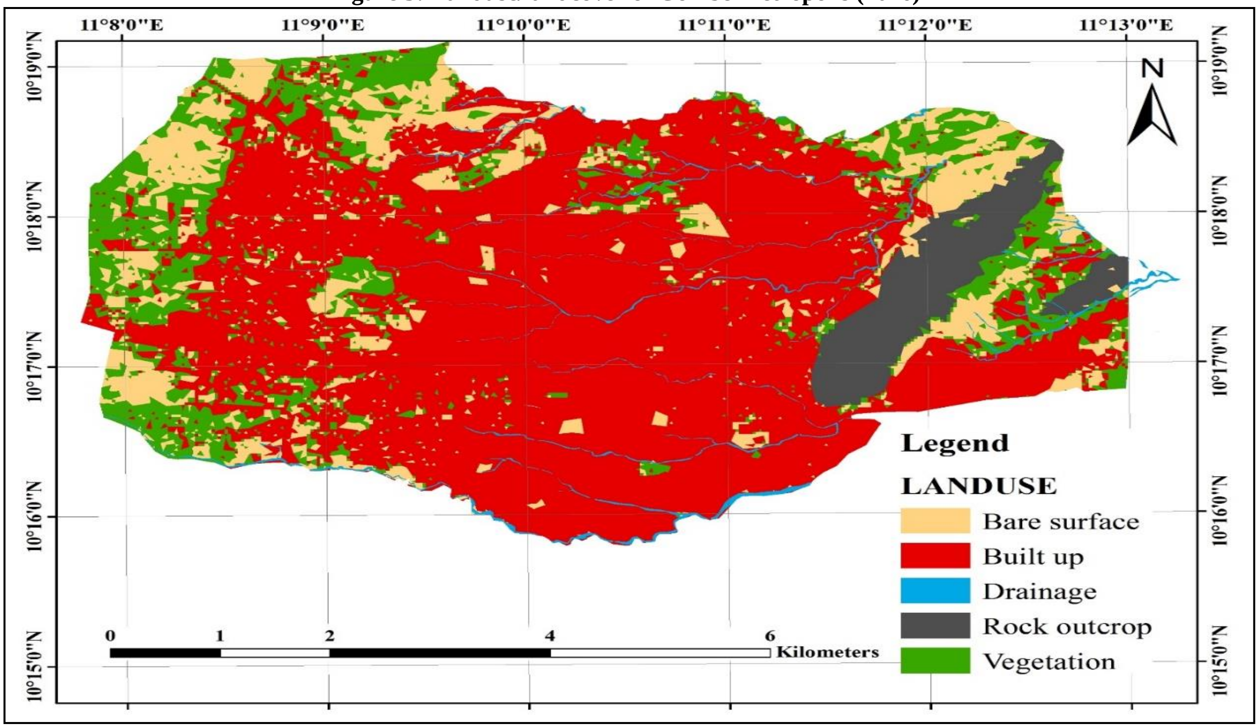
Table 2: Landuse/Landcover of Gombe Metropolis (2006)

Landuse	Hectare	M^2	Km^2	%
Bare surfaces	544.88	5448779.04	5.45	13.07
Built up	1975.78	19757811.75	19.76	47.39
Rock outcrop	402.62	4026248.45	4.03	9.66
Vegetation	1146.52	11465249.18	11.47	27.51
Drainage	99.37	993667.54	0.99	2.37
Total	**4169.18**	**41691755.96**	**41.69**	**100.00**

Source: Author's GIS Analysis (2018)

The landuse/landcover classification of Gombe Metropolis (2016) is given in Figure 5 and the statistics of Landuse/Landcover is also presented in Table 3.

Figure 5: Landuse/landcover of Gombe Metropolis (2016)



Source: Author's GIS Analysis (2018)

The landuse/landcover of Gombe metropolis for the year 2016 showed that bare surfaces covered 14.27%, built-up areas 63.52%, rock outcrop 5.92%, vegetation 14.61% and drainage 1.68 %. The percentage of in 2006 to 14.61% in 2016. The percentage of imperviousness has also increased from 70.12% in 2006 to 83.71% in 2016.

imperviousness is 83.71 %. The results showed that there is increase in built-up areas from 70.12% in 2006 to 83.71% in 2016 while vegetation has decreased from 27.51%

Table 3: Landuse/Landcover of Gombe Metropolis (2016)

Landuse	Hectare	M^2	Km^2	%
Bare surfaces	595.24	5952407.05	5.95	14.27
Built up	2648.05	26480544.68	26.48	63.52
Rock outcrop	246.67	2466728.70	2.47	5.92
Vegetation	608.87	6088700.08	6.09	14.61
Drainage	70.34	703375.44	0.70	1.68
Total	**4169.18**	**41691755.95**	**41.69**	**100.00**

Source: Author's GIS Analysis (2018)

A key feature of urban areas is a high degree of imperviousness, as roads, buildings, parking lots and other paved surfaces occupy a main portion of urban land areas. As a result, changes to impervious surfaces are often used as an indicator of urbanization and urban development. The abundance and location of sealed surfaces is a key determinant of environmental quality as it has important implications for many bio-physical processes (Arnold and Gibbons, 1996). For major urban areas, these processes are primarily linked to the hydrological cycle. Thus changes in the quantity and location of impervious surfaces alter an area's hydrological response, since replacing natural land cover with artificial sealed surfaces reduces infiltration capacity, surface storage capacity and evapotranspiration (Hale, 2016). Moreover, it leads to increased run-off volumes, discharge rates, flood peaks and flood frequencies. This in turn decreases the ability of the land to absorb rainfall-runoff, reduces infiltration of water into the ground, and accelerates runoff to ditches and drainage systems. The drainage systems under this scenario are overwhelmed resulting in pluvial flooding. In highly urbanized areas, over half of rainfall becomes surface runoff, and deep infiltration is only a small fraction of the natural situation. For this reason, past and present urban areas development patterns may prove to have and will continue to have important implications in exposing urban systems to pluvial flooding. A general examination of the landuse/landcover in Figures; 3, 4 and 5 revealed that while the vegetation cover decreased from 47.90% in 1996 to 27.51% in 2006 and 14.61% in 2016, the built-up areas on the other hand increased from 29.50% in 1996 to 47.39% in 2006 and 63.52% in 2016 as shown in Tables; 1, 2 and 3 respectively.

The result showed that vegetation cover decreased by 33.29% from 1996 to 2016 while the urban expansion increased by 34.02%. The percentage of imperviousness also increased from 50.31% in 1996 to 70.12% in 2006 and 83.71% in 2016, reducing infiltration and caused more runoff that may cause flooding in the metropolis. This urban expansion when compared with the drainage of 1.79% in 1996 to 2.37% in 2006 and 1.68% in 2016 indicates inadequate drainage system and when these drainages are not efficient and effective; the urban area is bound to be subjected to pluvial flooding. This observation is in agreement with the report of Abaje, et al., (2015), that urban drainage structures should complement the stage of urban development.

Field observations carried out during the rainy season showed that artificial drainages are inadequate in some parts of the metropolis particularly around Pantami, Madaki, Barunde and Nasarawo. The drains are either shallow or clogged with refuse dump and are often undermined by excess runoff causing flash flooding in the neighbouring compounds. In some areas the debris dams sometimes become swollen up and burst to unleashed flow water spilling over roads causing difficulties in movement within the affected locations. The construction of buildings very close to the flood prone areas has serious implications under flood scenario (Plate 1 and 2).

Plate 1: Residential encroachment to water-ways in the metropolis
Source: Authors' Fieldwork.

Plate 2: Flood scenario in the metropolis.
Source: Authors'Field work

5. Conclusion and Recommendations

The findings showed increase in built-up areas but decreased in vegetation cover in Gombe metropolis from 29.50% in 1996 to 47.39% in 2006 and 63.52% in 2016 while vegetation cover on the other hand decreased from 47.90% in 1996 to 27.51% in 2006 and 14.61% in 2016, respectively. The result for change detection showed that vegetation cover decreased by 33.29% from 1996 to 2016 while the urban expansion increased by 34.02%. The percentage of imperviousness also increased from 50.31% in 1996 to 70.12% in 2006 and 83.71% in 2016, reducing infiltration and increasing runoff. This scenario has implications on recent flooding in Gombe metropolis. Suitable measures such as provision of adequate drainages to accommodate excess runoff in Gombe metropolis, as well as adopting a blue-green infrastructure (BGI) approach to stormwater management to restore predevelopment hydrologic function which will include rain gardens and porous pavement in the area. However, Urban planning guidelines and flood management strategies should, therefore, be part of an integral approach to the problem of flooding for the Gombe State Ministry of Lands and Survey and Urban Town Planners.

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