Journal of Arts and Humanities (JAH):
A Multidisciplinary Journal of the Faculty of Arts,
The University of Bamenda
https://fajournaluba.com/index.php/jah/index

Research Article
This article is published by JAH, *Journal of Arts and Humanities*, **Volume 6, N. 1, Feb., 2022.**

ISSN: **2710-3013 (Print)**
ISSN: **2788-6360 (Online)**

Article detail
Received: **July 24t , 2022**
Accepted: **Sept. 14th 2022**
Published: **Dec., 2022**
Conflict of Interest: The author/s declared no conflict of interest

Urban Flood Mapping and Vulnerability Assessment in Ilorin, Kwara State, Nigeria

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ABSTRACT

Most urban cities have suffered from natural disasters especially flooding whose frequency and intensity have increased due to human activities with devastating consequences on sanitation, human health, and property. This research employed the use of geographic information systems (GIS) as a tool in mapping and monitoring floods in Ilorin, Kwara State with a view to developing a flood risk map for urban management. The specific objectives include identifying flood-prone areas, assessing urbanization and land-use changes and their implications on flooding. A total of 220 copies of pre-tested questionnaires were administered and 163 retrieved to evaluate anthropogenic activities and their consequences on this phenomenon. Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) data and Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager (OLI) images for 1984, 2000, and 2015 respectively were used to generate flood, vulnerability, and land use maps. The result shows that there was a rapid increase in built-up areas from 41.642 km^2 in 1984 to 167.911 km^2 in 2000 and subsequently to 239.49 km^2 in 2015. Urbanization resulted in increased paved and unpaved compacted surfaces at the expense of vegetation cover and increased surface runoff possibly leading to floods. Similarly, flood vulnerability maps were produced which classified the area into; high, medium, and low vulnerable areas. The research identified factors affecting flooding at Ilorin to include developmental activities on flood plains and land use/cover changes. Enlightenment, development control, and GIS-based flood vulnerability map for urban management were recommended as a way forward.

Keywords: *Vulnerability, Flood mapping, Land use change, Urbanization, Urban Management*

1. Introduction

It is on record that all over the nations of the world, flooding is one of the most destructive naturally occurring hazards. Dewan (2013) and C40 Cities Finance Facility (2020) observed that due to climate change, both the frequency and severity of flood events are on the rise and are likely to worsen in the days ahead. Throughout the world, it has been observed that significant changes to human livelihood support, economic losses, and disruption of agricultural production have been attributed to hydrological hazards such as flash floods, droughts, and landslides (Avila et al., 2016; Njilla and Simbo, 2020). Similarly, globally, studies have revealed that more than three billion people representing over one-third of the world's population have been subjected to natural disasters in the last decade with floods and drought accounting for 86% of all such catastrophes (Aladelokun and Ajayi, 2014). This has caused about one-third of all deaths, one-third of all injuries and one-third of all damage from natural disasters (Ologunorisa and Abawua, 2005; CRED; UNISDR, 2015 and Dwirahmadi, et al.2019).

Floods in 2018 accounted for over 50% of the total disasters that affected the human population globally. The rapid growth of the world's population has escalated both the frequency and severity of natural disasters (Yalcin and Akyurek, 2001), with flooding being at the top of the list of these natural disasters. It has been noted that there is a massive movement of people from the rural areas to the cities thereby speeding up the magnitude of the urbanisation process leading to the development of urban sprawl, growth and expansion of informal settlements and slums which exposes the residents to serious dangers of flooding (C40 Cities Finance Facility, 2020). According to UNDESA (2018) and C40 Cities Finance Facility (2020), the United Nations Department of Economic and Social Affairs posited that there were significant increases in urban populations in developing countries, particularly in the lower-middle-income and low-income countries from 41% to 32% in 2018, to 59% and 50% respectively with increase vulnerability. The World Bank (2019) noted that from 1990 to 2014, floods were the costliest natural hazards nationally and globally, accounting for 62% of all economic losses resulting from natural catastrophes. It has, therefore, been observed that the brunt of the impact of these hazards is borne by the most vulnerable in society who are usually defenseless (C40 Cities

Finance Facility, 2020). Floods have claimed more lives and caused more property damage than any other natural phenomenon (Dalil et al., 2015).

2. 0. Literature Review:

2.1. Flood and its impact

A flood refers to a body of water that has risen above and overflows land that is not normally submerged (NEST, 1990: 102). Floods are natural environmental hazards that are the most recurring, prevalent, disastrous, and frequent that are widely reported world in local and international news media (Kundzewicz et al., 2013). In the tropical and subtropical regions, severe flooding hazards of grave consequences resulting from heavy thunderstorms, torrential monsoon downpours, hurricanes, cyclones, and tidal waves surges in coastal and estuarine environments are yearly occurrence (Jeb and Aggarwal, 2008). (Kundzewicz et al., (2013) have identified that anthropogenic changes have increased the flood magnitude for some particular designs which have in turn amplified the flood damage potential. The impact of flooding globally have been identified to pose potential threats to lives and livelihoods, involving structural and ecological damage, disruption of socio-economic activities, transport, communication, loss of life and property, displacement of people, destruction of agricultural land, the spread of epidemics, and contamination of food, water, and the environment (NEST,1990; Dwirahmadi et al., 2019; Fu et al., 2018; Paterson et al., 2018; Zhou et al., 2018). Records across the globe reveal that this trend has escalated in frequency and severity. From 1971 to 1995, floods affected more than 1.5 billion people, or 100 million a year; of these, 318,000 people were killed and more than 81 million were left homeless (Kolawole, Olayemi, and Ajayi, 2011).

Studies in Nigeria have shown that serious flood disasters have occurred in different parts of the nation such as Ibadan; Osogbo; Yobe; Akure; Lagos; Kwara State Sokoto and other parts of the country, posing major environmental challenges in Nigeria (Olajuyigbe, Rotowa, and Durojaye, 2012; Jimoh 2008; Akinola et al., 2013; Olorunfemi and Raheem, 2013; Aladelokun and Ajayi, 2014; Akukwe, 2014). Coastal cities like Lagos, Port Harcourt, Calabar, Uyo, Warri among others have severally experienced incidences that have claimed many lives and properties worth millions of dollars (Olajuyigbe, Rotowa, and Durojaye, 2012). Akinola et al., (2013) noted that statistics confirm that between 2011 and 2012, more than 150 billion Naira ($1 billion) was lost in Lagos, while 2105 buildings were flooded in Ibadan. Similarly, Akinola et al. (2013) reported that environmental degradation directly affects the lives of about 50 million Nigerians which translates to economic terms of Nigerian environmental losses to about N25 million or 13.0% of 1991 Gross National Product (GNP).

Similarly, the National Emergency Management Agency of Nigeria (NEMA) reported that the flood disaster which swept across the country in 2012, a consequence of climate change marked a watershed in the nation's history in disaster management as it was the most devastating in recent times. A total of 363 deaths were recorded, seven million people were affected out of which 2.3 million were displaced while 597, 476 houses were submerged (Ibileke, 2013). NEMA stated further that the total value of the loss across all sectors of economic activities was estimated at $7.3 billion while the combined value of the damages and losses was $16.9 billion. Extreme weather events especially floods affect households each year in the city of Ilorin affecting the poorest and most vulnerable people in the city and contributing to endemic poverty in most parts of Kwara State (Olorunfemi and Raheem, 2013), with people often losing both lives and properties (Jimoh, 2008).

2.2. Vulnerability

Vulnerability refers to susceptibility or exposure to physical or emotional harm. According to Nicholls (2011) and Neumayer and Barthel (2011), vulnerability is dynamic and variable across a temporal and spatial scale and therefore depends on so many factors such as the geography of the place, disaster alert, and preparedness systems, governance, and coping strategies. Characterising regional vulnerability has been a serious issue as different researchers have used different parameters. Some researchers have used loss trends with the gross domestic product (GDP) and population growth (Neumayer and Barthel, 2011; Mukherjee et al., 2009;

Hohhot Water Bureau 2015; Wang et al., 2015) while others have used the loss as a share of exposed GDP/assets or reported fatalities as a share of exposed population (Wu et al., 2018; Yasari et al., 2013; Ward et al., 2013). The United States of America is one of the countries greatly affected by floods. An estimate shows that within the last two decades from 1996 to 2016, there have been over 6520 flood-related events with huge economic losses of about 3986 million US dollars (Zhou et al., 2018). Floods in Jakarta in 2007 killed 79 persons, destroyed more than 1500 homes, rendered more than 422,000 people homeless, and inflicted heavy damage on infrastructure and facilities (World Bank, 2016). Similarly, according to CRED (2019) and Dwirahmadi et al. (2019) globally, in the past two decades floods have been responsible for 47% of all weather-related disasters affecting over 2.1 billion people, causing severe environmental changes, with global economic losses to the tune of over 1 trillion USD. Damaging floods have equally been reported in Europe in the 1990s particularly affecting the basins of the River Rhine and its tributaries (1993, 1995) and the Mediterranean region (1994), and in Central Europe (1997). Similarly, major floods have occurred in the UK, Italy, France, and Switzerland in the year 2000 while the absolute annual flood loss in Europe was recorded in 2002 with material damage exceeding 20 billion Euros in nominal value (Kundzewicz et al., 2013). Severe floods have become perennial events in Accra, Ghana (USAID, 2013). In 1998 the South of China Floods series took more than four months, affecting the socio-economic life of 20 million people, while thousands of people died and it caused the physical loss of approximately 20 billion USA Dollars (Yalcin and Akyurek, 2001).

In East African countries of Rwanda, Kenya, Burundi, Tanzania, and Uganda and the horn of Africa comprising Somalia, Djibouti Eritrea, and Ethiopia, long rains in March 2020 affected more than 1.3 million people with 481,000 displaced (OCHA, 2020). Similarly, Jones (2020) reported that the same floods in Kenya, killed about 200 people and displaced over 40,000 people due to mudslides and overflowing rivers. It was equally reported that the waters of Lake Victoria rose to the highest level in 120 years destroying infrastructures such as roads, causing thousands of people to flee their homes and businesses. Flash floods in Uganda also caused many to desert their homes and businesses. Similarly, in January 2020 in south-eastern Tanzania, flash floods destroyed 1,746 houses and 1074 latrines collapsed, affecting more than 18,000 people with 13 dead and 5 were reported missing (Relief Web, 2020).

2.3. The Problem

Although the urban flood problem is a global experience, the management practices differ according to prevailing technologies and aptness in planning concerns (Olajuyigbe, Rotowa, and Durojaye, 2012). Developing countries are presently characterized by rising flooding events resulting from urbanization (Aliyu and Sulieman 2016). In other words, the most vulnerable to the impact of floods are the urban poor because they occupy the floodplains for settlements (informal), as well as inhabit neighbourhoods that lack the necessary flood control and mitigation measures. Most vulnerable people live below the poverty line and so cannot afford the resources to purchase parcels of land or house rents in safer areas. Heavy rainfall which at times is accompanied by severe winds, unusually high tides, tsunamis and failures of dams, retention ponds or lakes, or other infrastructure that retain surface water, paved and unpaved spaces, limited capacity of drainage systems, and blockage of waterways and drainage channels by indiscriminate dumping of municipal solid waste have made flood disaster more pronounced (Adeoye, Ayanlade, and Babatimehin, 2009; Suleiman et al., 2014).

Owing to this, therefore, there is always the need for the production of maps of flood risk zones with a broad range of functions capable of manipulating both spatial and attribute data (Abiodun, Lanre, and Olorukooba, 2014). Salami et al., (2008) and Daffi et al., (2014) stated that although “conventional traditional methods can be used for flood hazard assessment, the use of remote sensing and Geographic Information System (GIS) techniques have been suggested to provide quick, efficient and effective results”.

Flood risk poses a serious challenge to development and livelihood across communities, particularly the dwellers of the rapidly expanding towns and cities in developing countries like Ilorin Township, Nigeria. Owing to serious flooding and its attendant problems in some areas of Ilorin, flood control is a vital issue, particularly since the poor are the ones that are more likely to reside in locations that are highly vulnerable due to their socio-economic conditions. More so, the lack of information like flood risk maps that show the degree of flooding in various areas of the town, which should guide the activities of all stakeholders especially is a major cause of concern. Thus, the use of innovative tools like GIS and remote sensing, to generate supporting land-based data for flood risk mapping are relevant to policymaking, planning and developmental activities informed this study. It was at the backdrop of all these that this study was conceived to evaluate the use of geographic information systems (GIS) as a tool in mapping and monitoring floods in Ilorin, Kwara State, Nigeria to develop a flood risk map for urban management. The specific objectives of this study include identifying flood-prone areas; evaluating how urbanization and land-use changes are exacerbating the flood problem; examining the consequences of flooding on the biophysical, social and economic conditions, and evaluating the measures taken to address it.

3.0 Materials and Methods

3.1 Study Area

The area of study is Ilorin, the capital of Kwara state in Western Nigeria (Figures 1 and 2). It is located between latitudes 8^0, 20^1 and 8^0, 30^1 N and Longitudes 4^0, 35^1 and 4^0, 40^1 E with an area of about 468 square kilometres (Ahmed, 2007). The study area comprised of three local government areas; Ilorin East, Ilorin West, and Ilorin South with a population of 847,582, making it the 13^{th}largest city in Nigeria as of 2007. Ilorin is located on a plain and is crossed by River Asa and its tributaries which flow from the North-South direction dividing the plain into two, Western and Eastern parts as illustrated in Figure 3 (Abiodun, Lanre, and Olorukooba, 2014). The eastern part is generally steeper than the western part with height ranging from 900 -1200 feet (200m to 364m) in some parts and peaking at isolated landforms, the Sobi hill which is about

1,300ft (394m) high above sea level (Abiodun, Lanre and Olorukooba, 2014).

A large part of Ilorin city is laid by sedimentary rocks which contain both primary and secondary laterites and alluvial deposits (Abiodun, Lanre and Olorukooba, 2014). Ilorin is covered mainly by ferruginous tropical soil and the soil type has both sandy and clayey deposits lying on each other (Jimoh, 2008) which are fertile. Ilorin was founded by the Yoruba, one of the three largest ethnic groups in Nigeria, in 1450 and became a provincial military headquarters of the ancient Oyo Empire.

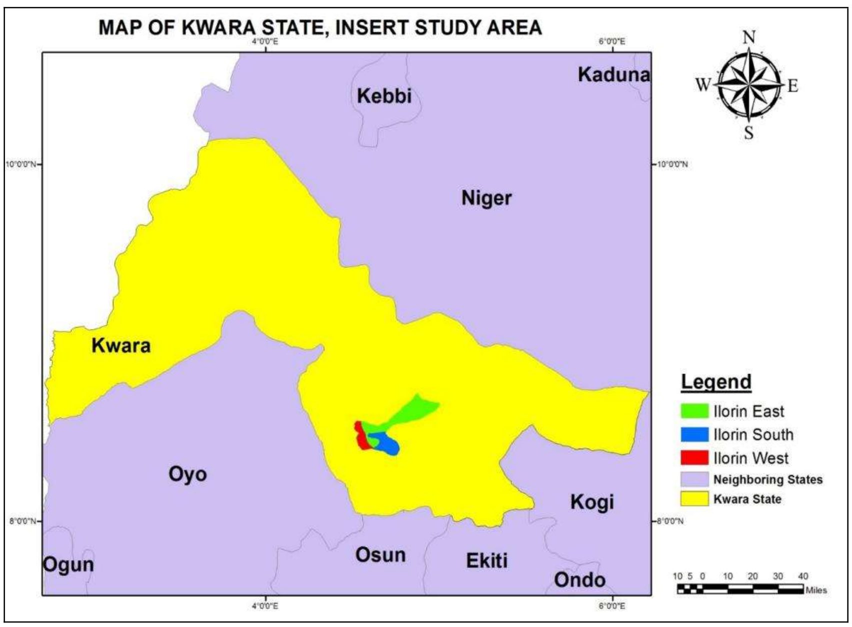

Figure 1: Map of Kwara State, insert Study Area
Source: Authors' lab work 2018.

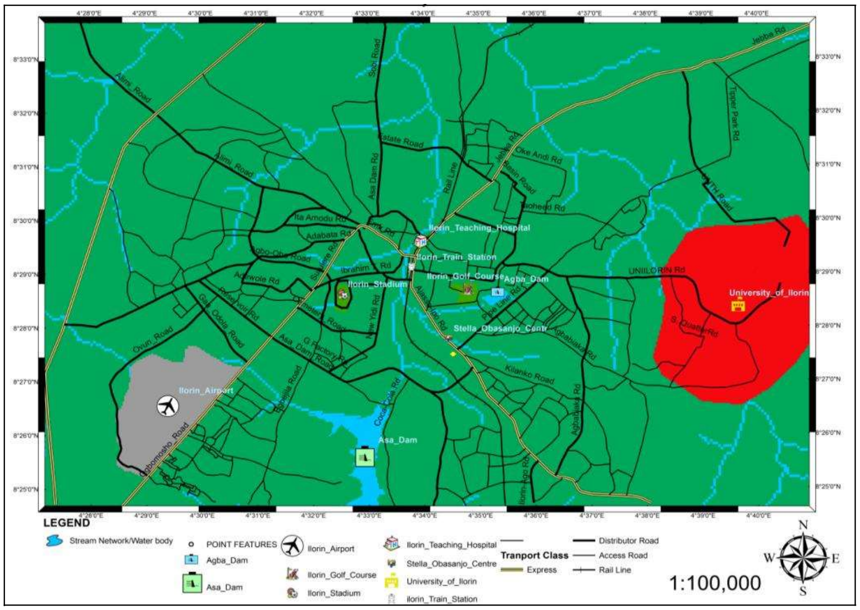

Figure 2: Map of Ilorin
Source: Authors' lab work 2018.

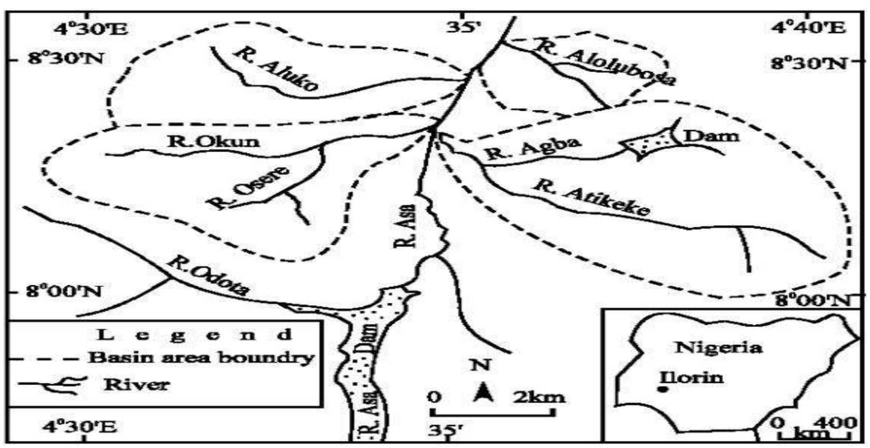

Figure 3: The major drainage basins in Ilorin
Source: Adopted from Jimoh (2008).

The city is situated in the transition zone between the forest and savannah region of Nigeria between the very North and West coastal region dominated by guinea savannah interspersed by trees of different species (Olorunfemi and Raheem, 2013). The city has a humid tropical climate characterized by wet and dry seasons (Kolawole et al., 2011). The wet season in Ilorin begins towards the end of March when Tropical maritime air mass is prevalent and ends in October with a mean annual rainfall of 1000mm to 1500mm based on 1991 -2000 data with a double maxima in June and September (Abiodun, Lanre, and Olorukooba, 2014; Kolawole, 2011).

The dry season begins with the onset of Tropical continental air mass which is predominant between the months of November and March (Oriola and Bolaji, 2012). According to Abiodun, Lanre, and Olorukooba (2014), the temperature of Ilorin is uniformly high throughout the year with a mean monthly temperature of between 25º to 29.5º.

The principal ethnic groups residing in Kwara State are the Yoruba, Nupe, Bariba, and Fulani. The skilled craftsmanship of the people of this central region includes pottery workshops, traditional textile weaving of Aso-Oke style, carved stools out of wood, others include, glass-making, weaving, tailoring, blacksmithing, and iron mining.

3. 2. Data Collection and Analyses

Both primary and secondary data were used for this study. Primary data were obtained from a field survey which includes personal observation, in-depth interviews, and questionnaires. The questionnaires were designed to collect data on issues related to flood activities in various areas such as socio-economic characteristics of the inhabitants, characteristics of the environment, and other information considered necessary in attaining the objectives of the research. Structured and pretested questionnaires were systematically administered on residents of buildings located within 1000 metres of the stream network of Asa River and its tributaries, which was identified using the stream network buffer created from the SRTM DEM of the study area, adopted from the method by Orok (2011) in the mapping of flood risk in Kano city. A total of 220 pre-tested questionnaires were administered systematically on residents at ten houses intervals and 163 were returned for analysis. Secondary data were obtained from relevant textbooks, journals, periodicals, published and unpublished works, maps, internet materials, and other information. Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) data and Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager (OLI) images for 1984, 2000, and 2015 respectively downloaded from the internet and processed geospatially, to generate flood vulnerability and land use maps. Materials used include Laptop, A3 printer, ESRI's ArcGIS 10.1, Ilwis Academic 3.3 software, Google Earth Window's desktop, Photoshop CS3, and Microsoft office pack for data processing. Series of analysis was performed on the processed Landsat images, SRTM 90m DEM, and the Kwara State data to generate flood risk maps as well as detection of changes and Normal Differential Vegetative Index (NDVI) Changes in vegetation and land cover in the study area. Statistical Packages for Social Sciences (SPSS) made use of descriptive statistics in the form of frequency and percentages to analyse the socio-economic characteristics of residents in the study area.

4. **Findings**

4.1. Socio-economic characteristics of respondents

The result in table 1 shows that 58.3% were females while 41% were males. The table reveals that 60.2% of the respondents were within the age group of 31-60 while 28.8% were between the ages of 18-30 years. Similarly, the result shows that 33.4% of the respondents do not have formal education, 27% had primary education, 25.8% secondary, and 13.8% tertiary. The occupation of the respondents shows that most of the respondents were self-employed representing 44.8%, artisans 17.2%, civil servants 15.3%, farmers 9.8%, employed in the private sector 8% while retirees were 4.9%. Furthermore, results show that 34.4% earn between N30,001 – N45,000, 30.7% earn between N45,001 – N60,000, 22% earn between N18,000 – N30,000, 8% earn up to N18,000 while 4.9% earn above N60,000 monthly income.

Table 1: Socio-Economic Characteristics of Respondents

Socio-Economic Characteristics		Frequency	Percentage
Sex	Male	68	41.7
	Female	95	58.3
	Total	163	100
Age	Less than 18 Years	3	1.8
	18-30 years	47	28.8
	31-60 years	98	60.2
	Above 60 years	15	9.2
	Total	163	100
Level of Education	No formal Education	30	33.4
	Primary	44	27.0
	Secondary	42	25.8
	Tertiary	47	13.8
	Total	163	100
Occupation	Student	11	6.7
	Self-employed	73	44.8
	Civil Servant	25	15.3
	Artisan	28	17.2
	Private Sector employed	13	8.0
	Retiree	8	4.9
	Farmer	5	3.1
	Unemployed	-	-
	Total	163	100
Monthly Income/salary	Below #18000	13	8.0
	#18000-#30000	36	22.1
	#30001 - #45000	56	34.4
	#45001 - #60000	50	30.7
	Above #60000	8	4.9
	Total	163	100

Source: Field Survey, 2018.

4.2. Flood Vulnerable Areas

Results in Figure 4 show the flood risk map of the area reclassified into three categories, denoted by; red colour (High-risk zone) for likely most vulnerable, yellow (Moderately vulnerable) for less vulnerable, and green (low-risk zone) for likely least vulnerable. The results of the land cover changes and Normal Differential Vegetative Index (NDVI) calculations are presented in Figure 5 and Table 2. The areas of vegetative indices vary in the different Landsat images.

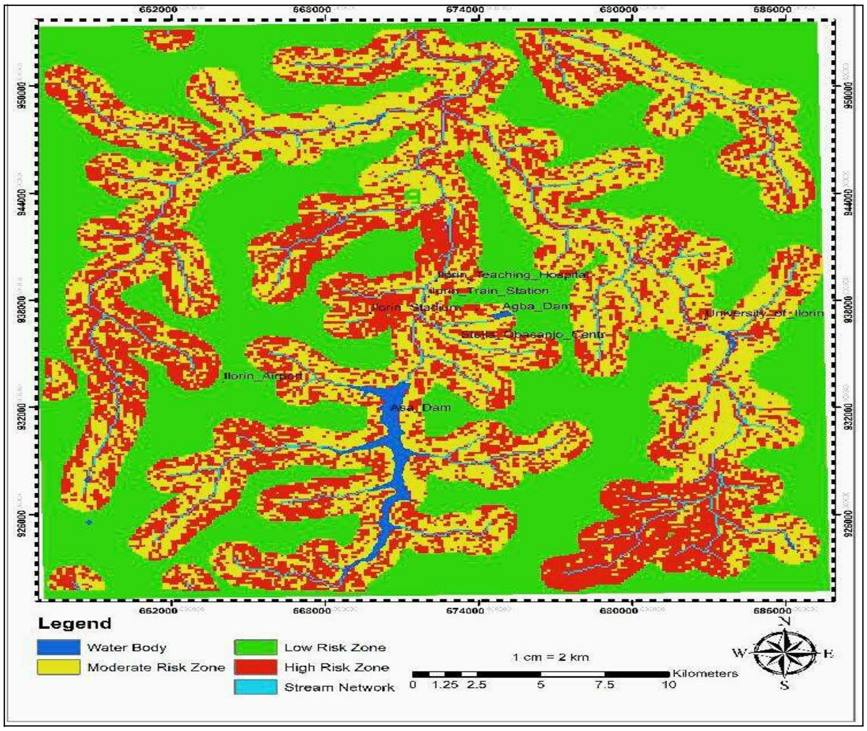

Figure 4: Flood risk assessment map of Ilorin depicting the vulnerability zones
Source: Author's Lab Work, 2018

4.3 Land Use and Land Cover Changes and their influence on flood

The result in Table 2 shows that the built-up area in 1984 was 41.642 km^2 while in 2000 and 2015, it increased to 167.911 km^2 and 239.5 km^2 respectively. However, the other classes of land use recorded decreases, and this could be due to the accompanying developmental activities that took place in the city from 1984 to 2000 and 2015.

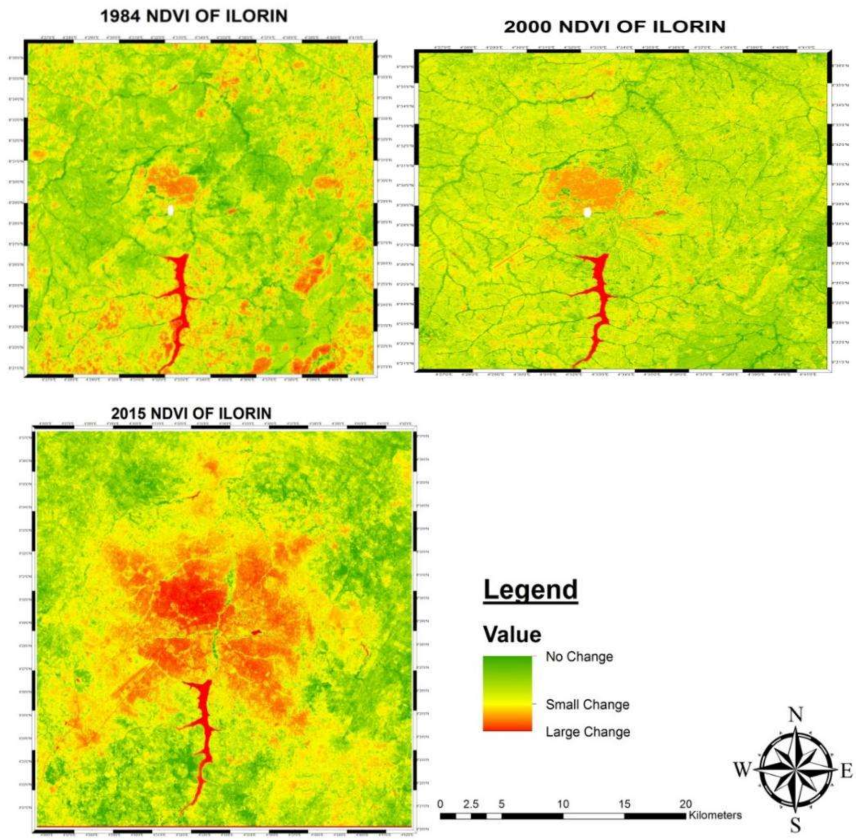

Figure 5: NDVI Images of Land Use / Land Cover Changes and NDVI of Ilorin.
Source: Authors' Lab Work, 2018.

Table 2: Land use/Land Cover Changes of Ilorin for 1984, 2000 and 2015

Land Use Land Cover Category	**1984**		**2000**		**2015**		**% Change 1984– 2000**	**% Change for 2000 - 2015**
	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)		
Built-up Area	41.642	4.34	167.911	17.50	239.490	24.96	13.16	7.46

Vegetation	896.935	93.48	783.331	81.64	711.849	74.19	11.84	7.45
Water Body	20.917	2.18	8.252	0.86	8.156	0.85	1.32	0.01
Total	959.494	100	959.494	100	959.494	100		

Source: Field Survey, 2018.

4.4 Incidence of flooding in the study area

Table 3: Property Loss due to Flooding in Ilorin

Property lost to flood	Frequency	Percent
Those who lost property	83	50.9
Those who did not	80	49.1
Total	163	100

Source: Field Survey, 2018.

Table 3 reveals that 50.9% of the respondents established losing the property to flooding, while 49.1%did not lose anything to flood.

Table 4: Impact of Floods on the Respondents buildings in Ilorin

Impact of flood on buildings	Frequency	Percent
Collapse of Buildings	41	25.2
Sinking of Buildings	17	10.4
Carrying Away of Building By Flood Water	5	3.1
Soaking / Wetting the Wall of the Building	100	61.3
Total	163	100

Source: Field Survey, 2018.

The result in Table 4 reveals that due to the incidence of flooding in the area, 61.3% of the respondents indicated that their buildings suffer from wetting of the walls due to capillary action, 25.2% of buildings have collapsed, 10.4% of buildings are sinking while 3.1% of the buildings have been swept away by ravaging floods. Plate 1 shows a property that has been wrecked by flood at Unity area of Ilorin while Plate 2 shows a stream clogged by refuse with partially collapsed buildings and shops at Unity/Taiwo area. These plates illustrate a high degree of vulnerability as the shops are built with corrugated iron sheets, sticks, and solid waste clogging the water channels.

Plate 1. Building Destroyed by Flood.
Source: Field Survey, 2018.

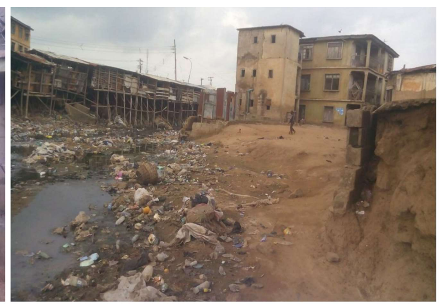

Plate 2: Partially collapsed building due to the flooding and waste clogging a stream.

Plate 3: Partially collapsed Road at Alalawu area due to floods and waste blocking drainage.
Source: Field Survey, 2018

Plate 3 shows the partially collapsed road in Alalawu area of the city. The road was damaged due to flooding resulting from poor drainage conditions.

Table 5: Duration of Flood Incidence

Flood duration	Frequency	Percent
Days	75	46.03
Matter of Hours	32	19.63
More than a Week	26	15.95
No response	17	10.43
Matter of Minutes	13	7.96
Total	163	100

Source: Field Survey, 2018.

Table 5 shows the duration of flooding where 46.03% of the respondents reported that the incidence lasts for days, 19.63% reported it lasts for hours, 15.95% opined it lasts for more than a week while 7.96% opined it lasts for a matter of minutes.

Table 6: Dominant Land Use Types of the Built-Up Areas

Land Use Type	Frequency	Per cent
Residential	75	46
Mixed-Use	43	26.4
Commercial	26	16
Recreational	12	7.4
Industrial	7	4.2
Total	163	100

Source: Field Survey, 2018.

Table 6 shows that residential that make up to 46% is the largest land use and the most dominant land-use type is followed by mixed-use 26.4%, commercial 16%, recreation 7.4%, and industrial 4.7%.

Table 7: Building Setback from Water Channels

Distance	Frequency	Percent
6-14 Meters	56	34.4
Below 6 Meters	43	26.4
15-30 Meters	32	19.6
Above 30 Meters	32	19.6
Total	163	100

Source: Field Survey, 2018.

The result in Table 7 shows that 34.4% of buildings are between 6-14 meters, 26.4% are below 6 meters, 19.6% are within 15-30 meters and 19.6% are located above 30 metres from the closest water channel.

Plate 4: (A) Building located directly along a major water channel at Gada Aluko area a tributary of the River of Asa while (B) shows a building located on a flood channel at Mubo area.

Source: Field Survey, 2018.

Table 8: Method of Waste Disposal

Method	Frequency	Percent
Disposal in Drainages/Along River	50	30.7
Burning	32	19.6
Taken to Dump Sites	29	17.8
Public Waste Collector	26	16
Burying	15	9.2
Private Waste Collector	11	6.7
Total	163	100

Source: Field Survey, 2018.

Table 8 reveals that 30.7% of respondents dispose of their waste in drainages / along river channels, 19.6% dispose of by burning, 17.8% on dumpsites, 16% by public waste collectors, 9.2% by burying, and 6.7% by private waste collector and all these practices increases vulnerability to floods of all these areas.

5. 0. Discussions

5.1. Socio-economic characteristics and susceptibility to flood

The result of the socio-economic characteristics reveals that the majority of the population(89.2%) were within the active age group of 18-60 years (Table 1). Residents on the flood-prone areas especially the flood plains are actively involved in developmental activities such as housing development and other infrastructural activities. Similarly, the result shows that the majority 33.4% of the population do not have formal education which implies that environmental education awareness on the consequences and severity of occupying the flood plain will not be easily understood. The majority of the inhabitants(79.8%) were employed in the informal sector mostly located on the flood plains which continue to attract more people and thereby putting more pressure on infrastructural facilities especially housing and schools; and generating more waste and increasing the vulnerability of such areas. The implications are that the individuals may not afford to maintain a flood reduction lifestyle, such as the construction of drainage systems within their community. Results also show that 34.4% of the inhabitants earn N30, 001 – N45, 000 which does not place them in the income level that will enable them to acquire land in saferlocations, thus exerting continuous land use pressure on the flood plain. The planning implications of this are that immigrants who are usually the poor who portray these socio-economic characteristics are attracted to the flood plains who are mostly involved in informal activities which contribute to the growth and expansion of informal settlements and slums which increases vulnerability and further exacerbates the flood problem. These findings are in tandem with those of Aladelokun (2014); Njilla and Simbo (2020) and C40 Cities Finance Facility (2020).

5.2 Land Use / Land Cover Changes and Flood Occurrence

Changes in land use / land cover can be explained by the large negative values derived from the calculation which indicate a drop in Normal Differential Vegetative Index (NDVI) in those years (Figure 5). This drop could be a result of the rapid increase in the percentage of the built-up area resulting from urbanization and could be attributed to anthropogenic activities such as agriculture, road construction, housing, deforestation and government policy. From the analysis, negative vegetative indices were associated with the 'large change' symbol in the legends of the different images which shows significant land cover changes in the 2015 and 2000 images compared to the 1984 image, as corroborated by Table 2. It could be observed that significant changes in the growth and spread of the built-up areas have taken place outwardly from the city centre along transport routes, flood plains and around establishments in the city at the expense of vegetation and other land-use feature classes. The removal of vegetal cover especially on wetlands and riparian forests exposes the area to erosion and flooding, and increases vulnerability since wetland and riparian vegetation serve as sponges that absorb excess flood water and stabilize the environment. Mengistu and Salami (2007) and Gasu et al., (2016) identified land-use dynamics as the major agents of change in human land-use activities which is similar to the findings of this study.

5.3 Flood Vulnerability Mapping

The flood risk map shows the area is reclassified into three categories, denoted by; red colour for likely most vulnerable (high-risk zone), yellow for less vulnerable (moderately vulnerable), and green for likely least vulnerable (low-risk zone) (Figure 4). The classification of vulnerable areas was in tandem with the work of Oriola and Bolaji (2012) who used highly, moderately, and low vulnerability categorization in their description. Therefore, this research presents a valuable tool that could help public and private agencies as well as concerned stakeholders and NGOs; in planning towards flood management especially intervention, relocation, and emergency operations. Built-up or urban areas around these stream networks especially Asa, Aluko, Amule, and their tributaries are likely to be inundated after heavy rainfall (Akinola, 1994), and extreme weather events (Dwirahmadi et al., 2019; Zhou et al., 2018) because these flood plains are inhabited by the most vulnerable group, the poor. It is therefore strongly advised that buildings within the high-risk zone of the flood plains should be removed to protect lives and property. Plate 1 shows a property that has been wrecked by flood at the Unity Area of Ilorin which has partially collapsed and abandoned. Plate 2 shows a stream clogged by refuse with partially collapsed buildings and shops at Unity/Taiwo area built with wood, mud, sticks, zinc, and other materials which have increased the vulnerability of these areas (Ojolowo and Wahab, 2017). It should be noted that the flood plains of the three dominant rivers of Asa, Aluko, and Amule are favourable areas for Fadama activities but the farms and crops are usually washed away during serious flooding leading to serious economic losses.

This result confirms that the majority of the inhabitants indiscriminately dispose of their refuse. This makes such areas more vulnerable, particularly refuse dumped in and along with major natural storm sewers/streams/rivers which goes to exacerbate flooding (Ojolowo and Wahab, 2017). The situation is further compounded by the materials used for construction, their habits, and attitudes towards indiscriminate refuse dumping which block drainages thereby exacerbating the problem. as The findings of this study are in consonance with those of Ojolowo and Wahab (2017), Olajuyigbe et al., (2012) who also observed indiscriminate dumping of waste in open spaces, drainages, river channels and valleys which compounds the flooding problem in Lagos.

5.4 Flood Incidence

The duration of the incidence depends so much on the vulnerability of the area wherein some cases it lasts for more than a week in the most vulnerable areas leading to devastating consequences on farms in the community, property, and at times threats to lives (Kundzewicz et al., 2013; NEST, 1994; Dwirahmadi et al., 2019; C40 Cities Finance Facility, 2020). The implication is that residential land use is the leading land use function to meet the growing population needs for housing that is putting a lot of pressure on the flood plain in the form of illegal development of slums which compounds the problem of flooding in these areas (Kundzewicz et al., 2013). This implies that a greater percentage of the buildings were located within the flood plain which is vulnerable to flood disaster (Douglas et al., 2018; Viljoen and Booysen, 2006), with no minimum setback observed as required by Planning Authorities. The Planning Authorities require that every building must have a setback of 15m from a stream or valley and 30 from a Major River. This is evidenced by plates 4 and 5 where buildings are located along major water channels on the flood plains in the city with some looking dilapidated and others suffering from complete abandonment due to the severity and intensity of flood as observed by similar studies by Oriola and Bolaji (2012).

The destruction caused by floods in these areas is not only limited to private properties alone but also infrastructures like roads and bridges. This is evidenced by Plate 3 which shows the partial collapse of a road at Alalawu area of the city. The road was damaged due to flooding resulting from lack of drainages and poor drainage conditions blocked by waste. The destruction of such pertinent infrastructures like roads, bridges, and abutments would further exacerbate the incidence of the flood are issues such as rescue operation, evacuation, distribution of relief materials would be seriously impaired (World Bank, 2016; CRED, 2019; Relief Web, 2020). At times property loss to flood incidence amounts to thousands and sometimes millions of naira/dollars (Zhou et al., 2018; Kundzewicz et al., 2013; OCHA, 2020; Jones, 2020) which is similar to the results of earlier studies by Akinola (2013) who held that between 2011 and 2012 the total losses attributed to floods in Lagos stood at $1 billion while Ibileke (2013) upheld that losses resulting from the devastating 2012 floods in Nigeria, the worst in the nation's history in recent times were estimated at $16 billion.

6. Policy issues and conclusion

This study has expounded on the importance and usefulness of GIS in flood risk mapping and evaluation for urban development and management using Landsat images for 1984, 2010, 2015, and SRTM DEM for the area. It employed this scientific method in the delineation of drainage basins from the DEM data of Ilorin city. A combination of the SRTM and Landsat were used in mapping flood-prone areas while questionnaires and field surveys were instrumental in evaluating the effect of flood incidence in the area. The flood risk maps produced for the area identified three categories, denoted by; red colour (High-risk zones) for likely most vulnerable, yellow (moderately vulnerable) for less vulnerable, and green (low-risk zones) for likely least vulnerable. However, buildings constructed within these areas should be removed to save lives and property. The result shows that there was a rapid increase in built-up areas from 41.642 km^2 in 1984 to 167.911 km^2 in 2000 and subsequently to 239.49 km^2 in 2015. The land use/land cover and NDVI changes over the years (1984 - 2015) indicate a great reduction in vegetation, the rapid growth of the city resulting from increased population growth and human activities. The factors that influenced flooding in this region were highlighted to include: urbanization, unplanned development, nature of the terrain, and other anthropogenic activities.

This research presents a valuable tool that could help public and private agencies as well as concerned stakeholders and NGOs; in planning towards flood management. However, this tool cannot be used in isolation and more information is needed for a full assessment and evaluation of flood risk. Environmental education of the populace at all levels (community, local, state, and national levels) on climate change, flood risks, and appropriate response techniques are required. Urban Development and Environmental Protection agencies must ensure full compliance of development guidelines for the city of Ilorin as regards the setback from the flood plains especially along River Asa, Aluko, Okun, Agba, Osere, Odota, Alolubisa Atikeke, Agba Dam, and the Asa Dam and as well as their tributaries. Riparian flora should be planted to act as flood breaks or buffers. The Kwara State Government should provide flood warning systems integrating the use of GIS and Remote Sensing. Flood control structures should be constructed and the existing ones should be cleared of blockages (refuse), particularly in high vulnerability or high-risk areas. Land use planning and development should be undertaken with the incorporation of data from flood maps and appropriate land-use policies. More research utilizing GIS and higher resolution remotely sensed data for flood risk analysis and mapping of the entire region and why not the whole country should be undertaken for flood disaster assessment evaluation for planning and mitigation.

Urbanization has resulted in increased paved and unpaved surfaces at the expense of vegetation cover and increased surface runoff possibly leading to floods. The research identified factors affecting flood vulnerability at Ilorin to include, developmental activities on flood plains and land use/cover change and recommended enlightenment champagnes, strict enforcement of development control measures, and development of GIS-based flood vulnerability maps to guide urban management.

FUNDING

This research paper received no internal or external funding.

ORCID

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