CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

A flood risk assessment (FRA) is an assessment of the risk of flooding from all flooding mechanisms, the identification of flood reduction or mitigation measures and it ought to provide advice on actions to be taken before and during a flood.

The sources of water which produce floods include: Groundwater (saturated groundwater), Vadose (water flowing the ground in an unsaturated state), Surface water, Artificial water (burst water mains, canals or reservoirs), Rivers, streams or watercourses, Sewers and drains Flooding of low-lying coastal regions due to sea level rise.

For each of these varying sources of water, different hydraulic intensities occur. Floods can occur because of a combination of sources of flooding, such as high groundwater and an inadequate surface water drainage system. The topography, ground water hydrology and physical characteristics of the existing or proposed development need to be appraised. A flood risk assessment should be an evaluation of the flood risk and the consequences and impact and vulnerability. Non-professional flood risk assessments can be produced by members of the public, Architects, environment assessors, or others who are not specifically professionally qualified in this field. However, it is a complex evaluation and such assessments they can be rejected by Authorities as inadequate, or could be considered as negligent in the event of a flooding event, damage and a claim to insurers being made.

Professional flood risk assessments can cover single buildings, or whole regions. They can be part of a due-diligence process for existing householders or businesses, or as mandated in England and Wales they can be used to provide independent evidence to a planning application on the flood risk. In recent years, many different cities have experienced significant flooding, resulting in the loss of lives, the endangerment of vulnerable populations, the disruption of services, and substantial damage to properties and critical infrastructure. Examples include the 2005 and 2013 floods in Calgary; Canada, the 2019 flooding in Borno and Adamawa; Nigeria, the 2018 East

Africa floods; Kenya, Ethiopia, Uganda, Rwanda, Somalia, Djibouti, Burundi. 2018 Kerala floods; India, the 2010 China floods, China, North Korea, the 2013 North India floods

While accurate flood forecasting contributes significantly to the reduction of fatalities and damages, one very important contribution is the generation of flood maps and the estimation of flood risk. Generally, “risk” is defined as the potential consequences of a hazard. Flood maps indicate the inundated areas based on the rising water levels. Earth observation (EO) datasets (space-borne, aerial, and low-altitude) together with geographic information systems can be extensively used to determine the extent of flood areas based on terrain elevation, hydrology network, land cover, and land use. Geomatics technologies such as earth observation satellites, Geographical Information Systems (GIS), Global Navigation Satellite Systems (GNSS), and geospatial infrastructures coupled with hazard modelling and analysis can offer considerable potential to reduce losses to life and property when integrated into flood risk reduction procedures Altan (2010).

Flood maps alone, however are not sufficient to determine and assess the risks to people, property, infrastructure, and services in case of a flood event. Simply put, the impact of the flood is at the minimum if the flooded region is “empty” (unpopulated, has no property, no industry, no infrastructure, and no socio-economic activity) Safaripour(2012).Therefore, socio-economic factors are critical for risk assessment. Risk assessment is a process or application of a methodology for evaluating risk as defined by the geographic coverage of the hazard, the exposure of people, property, and infrastructure to the hazard, and the vulnerability of people, property, and infrastructure to the event and impact. In previous research on urban flood risk assessments, the majority of studies have focused on the physical systems of urban flood; there are far fewer works on social vulnerability during urban flood disasters. Therefore, it is necessary to develop an approach for the determination of locations-based risk indices due to flooding by integrating flood maps, socio-economic parameters, and impacts on infrastructure and services.

1.2 Statement of Problem

Flooding

A large number of countries in various continents (whether in Europe, America, Asia, Oceania, Australia or in Africa) experience heavy rains, river overflow, hurricanes, typhoons, tsunamis that causes unexpected floods which destroys partly or wholly communities in different parts of the world. Floods are among the most recurring and devastating natural hazards, impacting human lives and causing severe economic damage throughout the world (Sadiq *et.al*, 2011)

Floods can be defined as hydrological events characterized by a rapid rise of water flow in the river. They are characterized by long, short and no warning, depending on the type of floods, speed or onset which may be gradual or sudden (Carter, 1991). Various elements either climatic or non-climatic influence flood processes resulting in different types of flood. Six types of floods are distinguished: coastal, flash, river, flood due to drainage problems, tsunamis, and tidal wave/bore floods (Jonkman, 2005). Flooding occurrs as a consequence of either natural factors, such as climate change and climate variability or anthropogenic factors, such as socio-economic and land-use developments (Balica, 2009). The frequency of these flood has been on an increase over the years, resulting in loss of life, damage to property and destruction of the environment. Over the last 50 years, there has been a growing body of evidence pointing to the effect of human behaviour on the global natural environment and on the possibility that certain types of natural disasters such as floods may be increasing as a direct consequence of human activity (Guha-Sapir *et.al*, 2004). Equally, the effects associated with global warming such as sea level rise, more intensive precipitation levels and higher level of river discharges may be consequences of this as well. These effects may increase the frequency and the extent of flood hazards on a worldwide scale and make the number of people at risk in developing countries more vulnerable to flood disasters due to high poverty level.

In Africa, floods of different kinds are one of the most common type of disastrous events, and they account for the biggest losses inflicted by natural disasters. The UN Office for the Coordination of Humanitarian Affairs (OCHA) recently stated that, compared with previous years, 2010 has seen the largest number of people affected and dying from flooding. This is consistent with the dramatic rise in flood events that have battered the world, with West Africa being a case in point.

It is understood that flood risks will not subside in the future, and with the onset of climate change, flood intensity and frequency will threaten many regions of the world (Sadiq, 2011). a study projected that warming in Africa in the 21st century is likely to be greater than the average global warming and does find that extremely wet seasons, high intensity rainfall events, and associated flooding in West Africa are expected to increase by 20% over the next decades (The Fourth Assessment Report (AR4) by the Intergovernmental Panel on Climate Change, 2007). Akintola, 1981, recorded that flooding has been a recurrent decimal in Ibadan with recorded occurrences in 1948, 1955, 1961, 1963, 1978, 1980, 1985, 1987 and 1990 claiming over 35,000 lives and properties worth millions of Naira, with the major sources of this flooding being Ogunpa and Kudeti streams. Ibadan has recorded varying degrees of flooding. For instance, there were flooding in the watersheds of Ogunpa and Kudeti streams (one of the two major streams in Ibadan) in 1955, 1960, 1961, 1963, 1969, 1978 and 1980.

However, it is noted that responses of local communities to the impact of extreme climatic events in many cases in West African states e.g. Ibadan have mostly been reactive instead of proactive. Going by the above, it is therefore necessary and expedient for a study such as this to be carried out if Ibadan is to avoid the associated problems of floods faced by many countries in the world especially in this part of the globe.

1.3 Research Questions

1. What factors are responsible for flooding in River Ona drainage basin?
2. What are the flood prone areas in River Ona drainage basin?
3. Major impacts of flooding in River Ona drainage basin
4. What measures can be undertaken in order to reduce the associated risk of flood damages to both human lives and properties?
5. How best can flood risk map be produced using GIS/RS technologies for use in flood control programs in River Ona drainage basin?

1.4 Aims And Objectives

Aim

The aim of the study is to analyze the vulnerability of areas within the River Ona catchment to flooding with the aid of GIS and Remote Sensing

Objectives

In order to achieve the aim of the study, the following objectives will be pursued to;

1. Determine the contribution of land use pattern of the River Ona drainage basin to flood vulnerability.
2. Examine the elevation pattern within the drainage basin and how it influences flood vulnerability
3. Produce a flood vulnerability map of the area

1.5 The Study Area

Ibadan, the capital city of Oyo state and the third largest metropolitan city in Nigeria in terms of population, as only Lagos and Kano boasts a higher population than that of the 1,338,659 residents of Ibadan according to the 2006 census. Ibadan consists of eleven (11) local governments, with 5 of them being situated in the metropolis. Ibadan is located between coordinates 7023'45" N and 7.396390N, and 3055'0"E and 3.9166670E. The city ranges in elevation, from 150m in the valley area, to 275m above the sea level on the north-south ridge which crosses the central part of the city. The city's total area is 3,080km^2. The study was carried out in River Ona, one of the major rivers in Ibadan, south western Nigeria. The River Ona has an estimated length of 55km^2 and area of 81.0km^2 and its catchment occupies about 1116km^2 and it flows through the low density part of western Ibadan (Akin-Oriola 2003). The river flows in a north-south direction from its source (Ido Local Government Area) where it is dammed and also flows through Apata Genga (Ibadan south-west Local Government) to Oluyole Local Government. Geologically, the Ona Basin falls within the Pre-Cambrian rocks of southwestern Nigeria, which is part of The Ona Basin falls within the Pre-Cambrian rocks of southwestern Nigeria, which is part of types are schist-quartzites, granite-gneiss, banded gneiss, augen-gneiss, and migmatites (Jones and Hockey 1964; Olayinka *et.al*., 1999), with minor intrusions of pegmatite, aplites, quartz veins and dolerite dykes. sedimentary rocks of cretaceous and latter deposit are found in the southern section of Ona River basin; the remaining section are composed of crystalline rock of the basement complex consisting folded gneiss, schist, and quartzite complexes which belong to the older intrusive series. Gneisses are migmatized in places, and characterized by predominantly medium sized grains while schist-quartzites occur as elongated ridges striking NW-SE (Olayinka *et.al*. 1999).

The climate of Ibadan is made up of climate variables such as rainfall, temperature, humidity and wind system in the area. Ibadan has a tropical wet and dry climate (Koppen climate classification Aw), with a lengthy wet season and relatively constant temperatures throughout the course of the year. Ibadan's wet season runs from March through October, although in August, there is somewhat a pause in precipitation. This lull almost clearly divides the wet season into two different seasons. November to February constitutes the city's dry season, during which Ibadan experiences the typical West African harmattan. The mean total rainfall for Ibadan is 1420mm, falling approximately over 109 days, with there being two rainfall peaks, one in June and the other in September, the climate is under the influence of two air masses: the wet tropical maritime and the dry tropical continental. As a result of this, the area is marked with alternating wet and dry seasons. The wet season is characterized by high rainfall between April and October with double peaks and in between the two peaks is a break known as ‘August break’. The wet humid climate encourages the occurrence of highly weathered rocks. The weathering profile shows that the original rocks had been weathered to considerable depth forming thick weathering crust with thick overburden overlying the weathered and under weathered bedrocks (Faniran, 1970). The weathered mantle, regolith and saprolite store water and act as good aquifer. The mean annual temperature is about $26^{o}C$ with the hottest month in March which precedes the beginning of the wet season. The climax vegetation is tropical rain forest. Hopkins (1965) classified the vegetation under moist semi-deciduous rain forest. The mean maximum temperature in 26.46’c, for the minimum, it is 21.42’c, thus the range of temperature is low. Relative humidity in the study area is also high, reaching a maximum of 80% in the wet season and getting as low as 70% in the dry season. On average, the relative humidity is 74.55%. Relative humidity is the amount of moisture in the air compared to what the air can hold at that particular temperature

The three major landforms which dominate are hills, plains and river valleys the whole landscape of Ibadan region. Two main types of hills are recognized such as the quartzite ridge and gneissic inselbergs. The quartzite ridge are by far the most extensive, widespread and the best known within the region. The plains form the most extensive landform system in the area. The general elevation is between 180m and 210m above sea level. The landforms makes up about 80 percent of the total surface area of the region (Akintola, 1994). It essentially encompasses the area between the hill bases and usually in trenched value bottoms. The most important feature of this landform system is the prominent incision of the rivers into the flood plain (Akintola 1994). The general layout in the area conforms to the dendritic pattern, showing irregular branching in all directions with tributaries joining at all possible angles. The drainage morphology of Ibadan can be described as consisting of three river basins systems, River Ona in the western part of the region, river Ogunpa in the center and river Kudeti. The city is naturally drained by four rivers with many tributaries: Ona River in the north and west; Ogbere River towards the east; Ogunpa River flowing through the city and Kudeti River in the central part of the metropolis. Ogunpa River is mainly a third-order stream with a channel length of 12.76km and a catchment area of 54.92km2. Along the northern part of the city River Ona is the main river, adjoining streams (Agaja and Ajibade, 2003).

Soil of any geographical area to a far extent determines the nature and type of agricultural practice that the environment would adopt. The soil is freely drained, mildly acidic with colluvium deposits in the river valley and numerous outcrops of granite, gneiss rock on higher ground and underlain by resistant crystalline rocks of varying degrees and regolith of deeply weathered sedimentary rocks. The soil of this study area falls within the Okemesi soil associations (Egbinola and Amanambu, 2013) formed from quartz gneisses, schist and quartzites under moist semi-deciduous forest cover (Hopkins, 1965) and belong to the ferruginous soil group. These soils also have a high clay content and good drainage. Variations in soil types are largely influenced by slope and parent materials the nature and character of the soil profile in this study area is determined by the nature of the parent rock. According to US soil classification system, soils are oxisols. They are highly weathered and leached. They are formed in the humid tropical environment under vegetation cover. However, as a result of urban growth, agricultural and other human activities, the climax vegetation has been depleted, giving rise to secondary forest (Olusola and Fashae, 2017).

The vegetation consists of secondary forest, derived savanna, farmlands and bush fallowing. The vegetation of the study area mostly consists of a patchwork of fallow regrowth which are either forest or savanna in structure at various stages of development and also matrices of tree and food crop farms. The area which was previously covered by high forest plant species is greatly dominated by secondary regrowths of invasive herbaceous species such as the weed Imperata cylindrical, Andropogun tectorum (savanna grasses) in younger fallows with the presence of relict forest species such as the Elaies guineensis in older fallow regrowth. Ona River has characteristic aquatic vegetation growing on its surface where some macroinvertebrates like whirligig beetles do retreat and it is one of the two major rivers draining the city of Ibadan. As it flows through the city, it receives a lot of waste materials from industrial, agricultural and domestic sources in both organic and inorganic forms (Adjarho *et.al*, 2013). Adem *et.al*. (2012) reported that the Ona River is often used as 'latrine'. Some plant species found along the corridors of River Ona are Penicum maximum, Cynodon dactylon, Setara babata, Oplismenus burmanis, Eleusine. The widening of river channel has often times been attributed to increase in urbanization, but further research reveals that although within urbanized zones, river channel width is quite wide, but the widest of all is found at the agricultural zones (Olusola and Fashae, 2017). The reason for this, among other things, has been tied to the heavy grazing along the river channel corridor around these sites

(Trimble, 2007).As revealed by the analysis of variance, activity along the channel corridor significantly affects the channel dimensions (Olusola and Fashae, 2017).

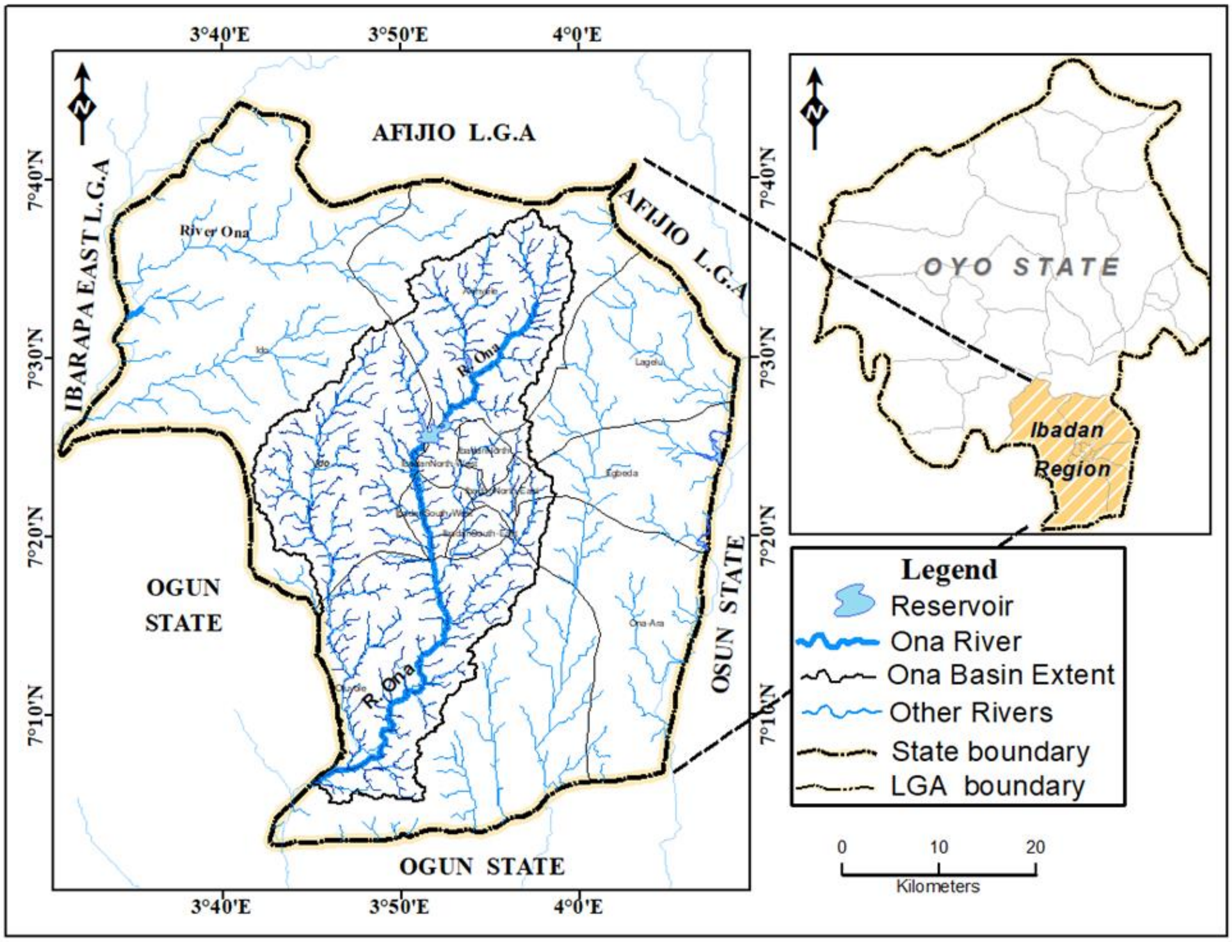

Figure 1.1 Map of Study Area (Ona river catchment).

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.0 Introduction

Flooding is the most frequently reported cost expensive disaster worldwide, accounting for more than 40% of natural worldwide disaster (tapsell and tunstall 2007). It is in fact the most common of all environmental hazards and it regularly claims over 20,000 lives per year and affects around 75 million people worldwide (smith 2006). Floods cause about one third of all damages from natural disaster (Akintola 1994). A flood happens when a body of water overflows its bank, that is; when it rises over land which it is normally submerged (National Environmental Survey/Action Team, NEST 1991). Floods are environmental hazards that regularly occur every year in different parts of the country especially during the rainy season. When there is flooding, it is usually due to an increase in the volume of water within the water body such as rivers and lakes. This causes the water to exceed the channel capacity and thus, overflow its bounds

Flooding occurs also when excess runoff is created owing to the inability of the soil to infiltrate water or when the soil has reached its field capacity or saturation. The result is excess runoff which submerges the landscape. This form of flooding is particularly the case in most urban centers of the world and Nigeria in particular, an example of this is the 2018 Ajah flood, where urbanization has disturbed or altered the natural process of infiltration.

In many urban centers in Nigeria, especially those in the south eastern parts of the country, the rainy season is synonymous with agony, pain, discomfort, the fight to keep life and properties from devastating flood, it is safe to say; weeping comes with the rain, while the dry season brings joy and relief even when there is a mini-drought . Flooding has posed serious threat to life and property and has displaced thousands of people (Report from National Technical Committee on Water on 5_{th} august, 2008). The general effect of flooding cannot be overemphasized, both in magnitude and impacts. Flooding has constantly reduced land use and property value at the same time persistently increasing the cost of living. The impact of floods in our environment can be scrutinized from two main angles. The first perspective being, the impact of flooding on the natural environment, and its impacts on artificial or anthropogenic environment on the other hand. It is worth noting that, flood impact on manmade environment is of pressing concern as it is far more devastating in nature due to human activities and increased population.

2.1 Conceptual Framework

2.1.1 The Hydrologic Cycle

Hydrological cycle is the cyclic movement of water containing never-ending processes like evaporation, precipitation and runoff e.g Runoff –> Evaporation –> Precipitation –> Runoff. .

The hydrologic cycle begins with the evaporation of water from the surface of the ocean. As moist air is lifted, it cools and water vapor condenses to form clouds. Moisture is transported around the globe until it returns to the surface as precipitation. Once the water reaches the ground, one of two processes may occur:

1. Some of the water may evaporate back into the atmosphere
2. The water may penetrate the surface and become groundwater.

Groundwater either seeps its way to into the oceans, rivers, and streams, or is released back into the atmosphere through transpiration. The balance of water that remains on the earth's surface is runoff, which empties into lakes, rivers and streams and is carried back to the oceans, where the cycle begins again.

The Hydrologic Cycle (also called the Water Cycle) is the continuous movement of water in the air, on the surface of and below the Earth. This cycle is the exchange of energy which influences climate. When water condenses, it releases energy and warms the environment. When water evaporates it takes energy from the surrounding environment, dropping temperatures.

2.1.1.1 Definitions of some processes dominant in the hydrologic cycle:

Condensation: The transformation of water vapor to liquid water droplets in the air, creating clouds and fog.

Deposition: also known as desublimation, is a thermodynamic process, a phase transition in which gas (vapor) transforms into solid (ice).

Evaporation: The transformation of water from liquid to gas phases as it moves from the ground or bodies of water into the overlying atmosphere.

Percolation: Water flows horizontally through the soil and rocks under the influence of gravity.

Precipitation: Condensed water vapor that falls to the Earth's surface. Most precipitation occurs as rain, but also includes snow, hail, fog drip, graupel, and sleet.

Sublimation: The direct change in state; from solid water (snow or ice) to water vapor.

Transpiration: The release of water vapor from plants into the air.

Drought Impact: Hotter temperatures causes more evaporation from both open water and the soil. As a result, river and lake levels drop, and soils dry out. Plants undergo more transpiration in the heat, drawing even more water from the ground, thus there would be less water on and in the ground just as hot weather increases water demand.

2.1.2 Flood Risk Management

It is important to note that a significant and crucial factor in saving lives is in trying to control these flood occurrences or at least minimize vulnerability of some areas. It is clearly known that control and management may not provide the ultimate panacea for flood hazards in the world, but it however provides a perspective in the reduction of its impacts on human activities, lives and property. Since man cannot fully control the climate that produce the rains flooding our landscape, then there is need for urgent and systematic preparations which would help mitigate the impact of flood (Afiesimama 2008)

Olowu (2010) emphasized that in many developing countries especially in Africa, the weakness of state infrastructure and absence of appropriate legal and policy framework. However, sometimes the inadequate nature of resources particularly renders them more vulnerable to the great consequences of flooding and other large scale disasters. Understanding the spatial dimension of flood hazards and initiating disaster preparedness measure would promote control and management of flood. In recent times researchers have pointed out the fact that one of the ways to study and understand flood behaviors is by generating the flood extent of flood risk map because such maps can be used for spatial planning and management of land (Ogbonna 2011).

In addition, there are also research concerning GIS- based integrated assessment of population vulnerability and agricultural vulnerability to flood (Pradhan 2010). Comprehension Geographic information is very critical for making important decision because of the spatial coverage of most disasters and the fact that disaster management work usually involves a large number of agencies working in areas. It allows sharing of information in real time, thus saving resources and time.

G.I.S provides a mechanism to centralize and visually display critical information during an emergency by showing an interactive flood Risk map. Flood Risk mapping determines the area at risk and should be the basis for all flood damage reduction program and subsequent action. The purpose of the risk map is to;

1. Increase public awareness of the areas at risk of flooding
2. Provide information of areas at risk by defining flood risk zone to give input to spatial planning.
3. Perform spatial planning and land management which provide various tool to prevent natural hazards.

Spatial planning according to Samarajiwa *et.al* (2007) is to support hazard early warning system, Risk assessment and mapping. Burton *et.al* (1968) categorized the alternative measures of reducing flood losses into two types;

1. Corrective measures and
2. Preventive measures

The corrective measures are divided into two; flood Control and other methods. The preventive measures include two component parts; flood regulation and other preventive methods. Flood control measures involve the construction of reservoirs, levees and walls, channeling of streams and construction of drainage systems. This means that flood control measures and structural and technological adjustments to flood hazards (Zevenbergen *et.al* 2008) preventive measures includes flood regulation, evacuation of flood prone areas, land use planning, etc. also the provision of flood insurance will help in so many ways to compensate affected occupants.

2.1.3 Flood Mapping

Flood maps are maps designed to identify flood hazards and promote ways to reduce the impacts of those and other hazards. They are used for floodplain management, flood insurance rating and to determine flood insurance requirements. In developing countries like Nigeria, the concept of flood insurance is virtually nonexistent.

Flood maps generally show a community's flood zones, floodplain boundaries, and Base flood Elevation; which when computed together, shows the risk of flooding. Flood maps are useful in flood risk assessment, flood management and flood control as they help to provide warning if flood water level exceeds a certain point. Flood maps also helps in locating places at higher levels that are relative safe from flood and are easily accessible in case there is need for flood relief operation or flood rescue. It can also provide floodplain map and floodline map for streams and rivers and effect of sea level rise or sea level change can be seen on the map. This could be helpful in coastal areas.

It helps in performing elevation analysis of an area for any purpose like city/town planning, new construction etc. use of flood maps are not just restricted to flood risk assessment as it can be used in planning irrigation system and water management.

2.1.3.1 Reasons for flood mapping

Flood is the most common and main cause of loss of the social aspects, economy and loss of life worldwide. The increasing settlement in the coastal; areas, river basins and lakeshores also aggravates the losses (Shannon Doocy, 2013). Deforestation and climate change increases the frequency and manifolds its impact. Flood losses can be expected to increase fivefold by 2050 and up to 17-fold by 2080 in Europe.

Flood mapping is a crucial element of flood risk management. It is an essential tool to avoid or minimize the damage to life and property caused by flood and for communicating flood risk, however, maps does not prevent floods from occurring.

2.1.3.2 Types of Flood Maps

1. Flood hazard map: shows the extent and expected water depths/levels of an area flooded in three scenarios, a low/medium and if appropriate high probability scenario or extreme events.
2. Flood risk map: shows the potential population, economic activities and the environment at potential risk from flooding.

Flood map is useful in establishing zoning, land use, and building standards, to support land use, infrastructure, transportation, flood warning, evacuation and emergency management planning, and also to prepare for and respond to floods. Communities can use the map and thus generated data to determine the risk areas, safe evacuation routes and to update the response plan. In lack of the potential and accurate flood maps, it affects the development activities in or near the hazard area. The community also lacks tool to guide development to be safer and also to mitigate future losses.

2.2. Literature Review

2.2.1 Introduction:

Flood, according to Rosenzweig (2009) can be defined as an unusual accumulation of water above the ground, which is caused by high tides, heavy rainfall, or rapid run off from paved surfaces. Some rivers are known to have natural flood plains. The most serious floods occur along coastal areas. In these areas, heavy rainfall and poor soil combine to cause flooding.Hendrick (2007) defined flood as any overland flow over urban land sufficient to cause significant property damage, traffic obstruction, nuisance and health hazards which include river flood, flash flood and damages. This research is focused on the problems, vulnerability, prospects and possible risks of flooding in Ibadan metropolis and its environs. In this definition, we can say that flood vulnerability and its hazard are directly proportional to the level of floodrisk. When the level of flood vulnerability, as well as its hazard value, will get higher than level of the flood risk will also get higher. Dang *et.al*. (2010) suggest that flood risk assessment requires interdisciplinary approaches and studies.

They specifically suggest that the potential flood risk can be reduced by decreasing the level of vulnerability, reducing the exposure value and by reducing the hazard. Mapping and prediction of flood hazards are an important aspects of flood risk assessment. Flood nature, intensity, and frequency of occurrence are better understood through mapping and simulating of both the already occurred and potential flood hazards. They are essentially used for assessment of the level of risk (knowing the affected people and properties), providing early warning in case of future reoccurrence and hydraulic design, especially for potential flood management and disaster risk reduction (Akinola *et.al*, 2015).

Smith and Petley (2009) analyzed that risk is a statistical concept and probability refer to a negative event or condition which affect people, infrastructure and environment. For the last two decades advancement in the field of remote sensing and geographic information system (GIS) has greatly facilitated the operation of flood mapping and flood risk assessment. It is evident that GIS has a great role to play in natural hazard management because natural hazards are multi- dimensional and the spatial component is inherent (Coppock, 1995). The main advantage of using GIS for flood management is that it not only generates a visualization of flooding but also creates potential to further analyze this product to estimate probable damage due to flood (Hausmann *et.al*., 1998; Clark, 1998). Smith (1997) reviews the application of remote sensing for detecting river inundation, stage and discharge.

U.N Hydrologist Wisler and Brater (2009) viewed flood as extreme hydrological event which occur when the infiltration capacity of the soil is lower than rainfall intensity. Rain water reaches the surface of the earth, percolates into the ground to form part of the shallow sub-surface flow and saturation overland as well as ground water flow (odemeuro 1990). Smith (2006) discussed infiltration as the maximum rate at which rain can be absorbed by the soil in a given condition. Excess rainfall which is not infiltrated due to soil saturation is accumulated at the ground surface and runoff will commence. Due to the nature of flood occurrence, the full analysis of the effect of the flood requires us to link the physical hazard to the socio-economic impact resulting from them. It is believed that the most proper evaluation of effect of any environmental problem including flooding will involve assessing physical hazard to acquire their impact in socio-economic terms.
Burrus T.L. (1990) defined floods as when more water is brought into drainage channel than the channel can carry. The excess overflow the banks and spread out to the surrounding lands, producing the flood condition (flooding).
Due to the nature of flood occurrence, the full analysis of the effect of the flood requires the linking of the physical hazard to the socio-economic impact resulting from them. It is believed that the most proper evaluation of effect of any environmental problem including flooding will involve assessing physical hazard to acquire their impact in socio-economic terms (Nwoko A.U, 2013). Examples of similar studies dealing with the flood hazard and flood risk assessment (Beffa 1998; Werner 2001; Baddiley 2003; Dutta *et.al*. 2006; Kubal *et.al*. 2009; Masood & Takeuchi 2012, Merz *et.al*. 2007 etc.) suggest that there are several problems and tasks that need to be tackled.

2.2.2 Flood Prediction

The prediction and forecast of floods is greatly dependent on the consistency of available meteorological database. The development of the hydrological operational multipurpose sub-programme (HOMs) has been one of the greatest achievements in this regard. However, there is need for improvements in the method of forecasting and in promoting public awareness because of the enormous benefits. The network of instruments, satellite, and other meteorological flood prediction devices can be employed, coupled with the appropriate model to forecast in real time the onset and other features of the phenomena in question (Blanford 2006).

Development of some of these hydrological forecast systems in a number of countries has resulted in substantial saving of lives and some reduction in damages. Installation of similar systems would also reduce vulnerability of some areas and promote early evacuation of vulnerable areas. However, problems have been identified in relation to evacuation of people due to the resistance of population that has been subjected to flood. (Plister 2002), observed that this was a significant factor in the lack of response to an evacuation order in New South Wales, Australia and noted that the effect of crying wolf as a factor that might make future evacuation more difficult if not impossible.

Olowu (2010) emphasized that in the many developing countries, especially in Africa, the weakness of state infrastructure, absence of appropriate legal and policy framework and sometimes inadequate resources particularly render them more vulnerable to the consequences of flooding and other natural disasters.

2.2.3 Flood Occurrences

It is difficult to determine the extent of flood damages and to compare in satisfactory manner one flood with another due to the relative tendency to overestimate flood damages particularly at the time of the flood (Smith 2006). In 1913, the damages from flood along the Mississippi and Ohio River were computed to be the excess of $ 162,000,000. The same magnitude of flood also occurred in Mississippi and Ohio in 2003. In 1955, Northern and Central California was subject to severe flood which resulted from continued heavy rains in the Mountainous areas. In March to May of 1965, the upper Mississippi and the Missouri river basin and the Red River of the North were flooded as a result of the melting of a heavy snow cover, whereas in Nigeria, snow has never been experienced due to our tropical location and perpendicular position to the sun. In 2007 Pakistan, in the Middle East experienced an unusual flood which destroyed over 70 acres of land with properties worth over $2 million.

In Nigeria, the occurrence of flooding is mainly due to excess rainfall, urbanization and poor waste disposal. Flooding in Nigeria occur in three main forms; River flooding, Urban flooding and Coastal flooding (Gwary 2008, Adeoti 2010). Flooding of Ogunpa stream in Ibadan killed several people and completely grounded socio-economic activities. It also submerged 500 houses in different parts of the city. The flood occurred as a result of heavy rainfall and about 32 people died and 1000 injured from the incident (Nigerian tribune, 8th September 1980). In Ilorin, Kwara State, flood disasters has been recorded in 1973, 1976 and 1979. Recently, in August 2008, the residents of Makurdi were thrown out their houses and farm lands, left impoverished after two days of heavy down pour of rainfall which was described as disastrous (Taiwo, 2008).

Akani and Bilesanmi (2011) reports how a flood in Lagos forced lagosians to relocate as a result of heavy rainfall of 7th and 8th July 2011, without knowing that there was going to be a more devastating torrential rain that will result in more disastrous flood in Lagos metropolis in the following week. Flooding in Nigeria have at various time affected Nigeria cities, especially in the densely populated cities like Kano, Lagos, Port-harcourt, Aba, Ibadan, etc, destroying life and properties (Mordi 2011, Amaize 2011). In early October of 2012, the River Benue, one of the two major rivers in Nigeria, which rises from North West Cameroun, was flooded due to excess rainfall which prompted to release more water from their dam. The result was increased unprecedented river overflow which flooded the whole states close to the river Benue and the states in the lower course of the river. At least 325 people have been confirmed dead and hundreds of thousands has been dislodged and a million farmlands has been submerged since the start of floods in July, raising concern about food security (National Emergency management Agency, NEMA, 2012.) The popularized September -October 2012 flood destroyed more than 2 million houses in twenty cities and countless communities. (The Punch, 2012.) The flood occurrence caused panic in the whole countries and caused an astronomical rise in price of food crops, resulting to an estimated 2% rise in inflation rate in the country (Sanusi 2012). The September -October 2012 was in fact the worse flood experience the country has seen as the impact is still felt all over most parts of the country. The government spent over 100billion Naira (N100, 000,000,000) on relief materials for flood victims in the country. (NEMA 2012).

Poor and unavailable flood prediction and flood control systems and techniques is seen as the major cause that aggravated the flood disaster in a country

2.2.4 Causes of Flooding

Flood is generally caused as a result of many conditions working either as a unit or in synergy. These conditions are mainly natural and anthropogenic in nature. Natural causes of flooding are enhanced mostly by nature of weather and landscape, while anthropogenic causes of flooding are enhanced by human activities.

Hoyt (2009) however suggested that flood are natural events and that man does not create floods, though his actions in deforestation and urbanization especially in flood prone areas, has increased flood occurrences in the world. "Thus in real sense, the flood problem is caused by people. If man had left the flood prone areas, there would have been no flood damages and problem and hence, flood would have been perceived as Natural Phenomena rather than a Natural Disaster".

According to Wright (2011), the problem of flooding gets progressively worse because the creation of artificial condition that produces excessive runoff which as stated earlier, is the most common cause of flood. Man's activities in replacing natural soils and rocks that absorbs water similar to a sponge, with structures of concrete i.e. tiles, and asphalt which are unable to absorb or infiltrate water into the groundwater. General causes of flooding includes:

Heavy Rainfall: Heavy rainfall is experienced in some parts of the world especially in the tropical regions. This region is found within latitude 00 to 300 North and South of the equator. Rainfall intensity is high in this region averaging about 1500mm annually. This intense rainfall is most prevalent in the rainy or wet season of the year from March to September.

Heavy rainfall makes it difficult for most soils in the tropics to infiltrate rain water at the rate of rainfall intensity. The situation is further worsened by the amount of paved surfaces that characterizing the urban environment which prevents infiltration of rain water.

1. Deforestation: large scale deforestation in the forest and vegetation covers of the world has contributed to increase in flood occurrence. This statement is made in lieu of the fact that forest and vegetation hold off direct impact rain water and release it gradually to the soil such that rainfall intensity matches the rate of infiltration. This enables proper infiltration to be achieved thus discouraging flooding. High rate of infiltration is usually maintained in the forest areas, hence removal of trees and vegetation (deforestation) without replanting

(afforestation) or even exploiting them in any manner exceeding its replacement or replenishment would create inadvertently more floods in the world.

2. Nature of The Soil: the nature of the soil through which rain water flows or percolates, determines to a great extent the rate of infiltration and the volume of water that is generated as run-off. The infiltration capacity of soil varies as some soils have high infiltration capacity others have low infiltration capacity. Research shows that an average soil in West Africa reaches saturation at soil moisture storage of 200mm. this saturation is achieved mostly in September in Nigeria. This assertion implies that most parts of the Nigeria landscape especially the low relief areas are liable to flooding in September which is the peak of the rainy season.
3. Heavy Rainfall: Heavy rainfall is experienced in some parts of the world especially in the tropical regions. The tropical region is found within latitude 00 to 300 North and South of the equator. The rate of rainfall is very high in this region averaging about 1500 to 2000mm annually. This intense rainfall is most prevalent in the rainy or wet season of the year from March to September. Heavy rainfall makes it difficult for most soils in the tropics to infiltrate rain water at the rate of rainfall intensity. The situation is further worsened by the amount of paved surfaces that characterize our urban environment which also frustrates infiltration of rain water.
4. Poor Waste Disposal: poor waste disposal especially in our urban centers cause blockage of drainage channels. These channels which are supposed to allow free flow of water are blocked with debris and most times refuse and sewages. These substances increase the bed load of the drainage channels and rivers causing them to rise. The result is rivers overflowing its bounds into adjourning flood plains. Bridges and dams are also constructed across rivers and this obstructs river flow and cause occasional flash floods.
5. Poor Land Use Policy Planning and Management: Poor land use policy planning and management constitute a major problem to urban flooding in the world especially in the developing countries of the world. Land use policies and adequate planning which should ensure proper sitting of buildings, structures, road construction, drainage construction and land use ordering, is virtually nonexistent in the developing nations (Adelye and Rustum 2011). It is unavailability of these control tools that have permitted the uncontrolled development as witnessed in the developing nations of the world. It is unfortunate to note

the inability of most developing countries like Nigeria to properly plan and order use of land which has at least promoted the occurrence of flooding or failed to control it. (Adegboye, 2011).

6. Climate Change: change in our climates has also caused an increase the occurrence of floods in the world. Climate is a vital environmental factor that shapes and reshapes various human activities (Etuonovbe 2011). The United National Framework Convention on Climate Change (UNFCCC) define climate change as change in the climate which is attributed directly or in directly to human activities that alter the composition of the global atmosphere and which increases climate variability observed over a comparable time period(Sani-sidi 2012). The National Emergency Management Agency (NEMA), attributed climate change to the worst flood disaster witnessed in the country in 2012. Climate change acts indirectly to aggravate urban flooding by altering pattern of flooding in flood prone areas, thereby frustrating efforts of flood prediction (Adjugo 2009).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

There are many approaches to defining areas vulnerable to flooding. However this work emphasizes floods as related to the land use/land cover pattern and elevation pattern with reference to distance. In order to analyze the problem of flood vulnerability in River Ona catchment data would be collected from secondary sources. This will enhance proper analysis of flood problem in the study area with the aid of GIS and remote sensing techniques.

3.2 Software Used:

The software used were the ArcGIS 10.4.1 software and ENVI 5.1. They were used for carrying out the entire analysis.

3.3 Sources of Data and Method of Data Collection

The data used for this research was collected from both primary and secondary sources and for the purpose of this study, the primary data was downloaded from the website of the United states Geological Survey (USGS) (http://earthexplorer.usgs.gov), landsat8 satellite image for 2019, Landsat OLI (Operation land imager) image was used, taking into consideration data quality and availability. The image had a resolution of 30m. The secondary data was the digital elevation model (ALOS PALSAR DEM) was downloaded from the Alaska satellite facility. The local government boundary map and Administrative map of Nigeria was the source from which the study area shape file was clipped out, this was done using ArcGIS. A flood risk map of the study area was also developed to reveal the areas that are prone to flooding.

3.4 Methodology

Image classification was the first step in the analysis and the Landsat OLI image for the study of the year 2019 was classified into 6 (six) classes. These classes are namely: Agricultural land, Built up areas, Peri-Urban, Light vegetation, Dense vegetation and Waterbody. After the classification, the Digital elevation model was processed into 3 (three) classes which are: low vulnerability, moderate vulnerability and high vulnerability classes

The drainage map was gotten as a result of some processes which were carried out with the aid of the hydrologic tool in ArcMap. These processes are:

1. Fill - The DEM, this was done to correct for the imperfection on the surface of the DEM.
2. Flow direction, this shows the direction of streamflow
3. Flow accumulation, this was done to show the flow of one cell into another and how they converge, that is; it was done to show the connection between the stream order
4. Stream delineation, the purpose of this was to extract the streams from raster data

The multiple ring buffer in the ArcGIS analysis tool was used to create buffered distance along the river channels so as settlement that are prone to flooding, a distance of 50m, 100m and 150m were used.

Finally, for the flood vulnerability map,

Reclassify

The Elevation dataset was reclassified in to four classes, this is to give the continuous value integar values and to be useable in the weighted overlay tool. The Buffered distances were first of all rasterized (converted to a vector data) before the reclassify tool was applied to it.

Reclassifying the Elevation data

Previous values	New values
100 - 150	15
150 - 200	10
200 - 250	5
250 - 418	0

Reclassifying the Distance data

Previous values	New values
Above 200	0
150 -200	5
100 - 150	10
50 - 100	15

Weighted Overlay

The distance dataset, Elevation, and Land use were overlaid using the weighted overlay tool, by giving common scale of 5 to all the classes according to level of importance, and weight of 100% was divided among the classes according to level of influence, Land use was given 20% influence, Elevation given 30% influence, while distance was given 50% distance.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 ANALYSIS OF LANDUSE PATTERN OF ONA RIVER DRAINAGE BASIN

Land use pattern for the study area was analyzed with the aid of GIS. The result revealed that in 2019, Vegetation (Light vegetation and dense vegetation) covers 12.44% of the entire landmass. The natural vegetation cover is on a decline, this is evidenced by a reduction in the amount of the Natural vegetation (Light vegetation and Dense vegetation), similarly, the amount of land used for Agriculture has also been on a decline and with knowledge of previous research it shows that much of the land previously used for cultivation and as forest zones are being converted into other land use types. The dense vegetation covers no longer occur in stretches as they did in prior years, rather they now occur in patches and this has also increased the vulnerability of these areas to flooding as deforestation, urbanization (as urbanization brings about a change in the nature of surfaces from soils, which enable water to flow through them into more concrete, non-permeable solid surfaces. These harder surfaces do not allow water to pass through them, hence, more amount of water is retained on the ground surface). It is important to note that presence of vegetation in an area has been shown to directly offer protection in some capacity against flooding as the vegetation cover prevents the direct impact of the rain on the soil. For Urban and peri-urban areas, the lack of vegetation cover and presence of concretes as roads which accelerate runoff serves as a proponent to the possibility of flooding in these areas

Table 4.1 Total Landuse of the study area

Class Name	**Area(sq m)**	**Percentage (%)**
Agricultural land	139288245.88	54.78
Built up	47399801.82	18.64
Dense vegetation	1821576.75	0.72
Light vegetation	29792096.62	11.72
Peri-urban	34701728.28	13.65
Waterbody	1257393.81	0.49

Total	254260843.20	100.00

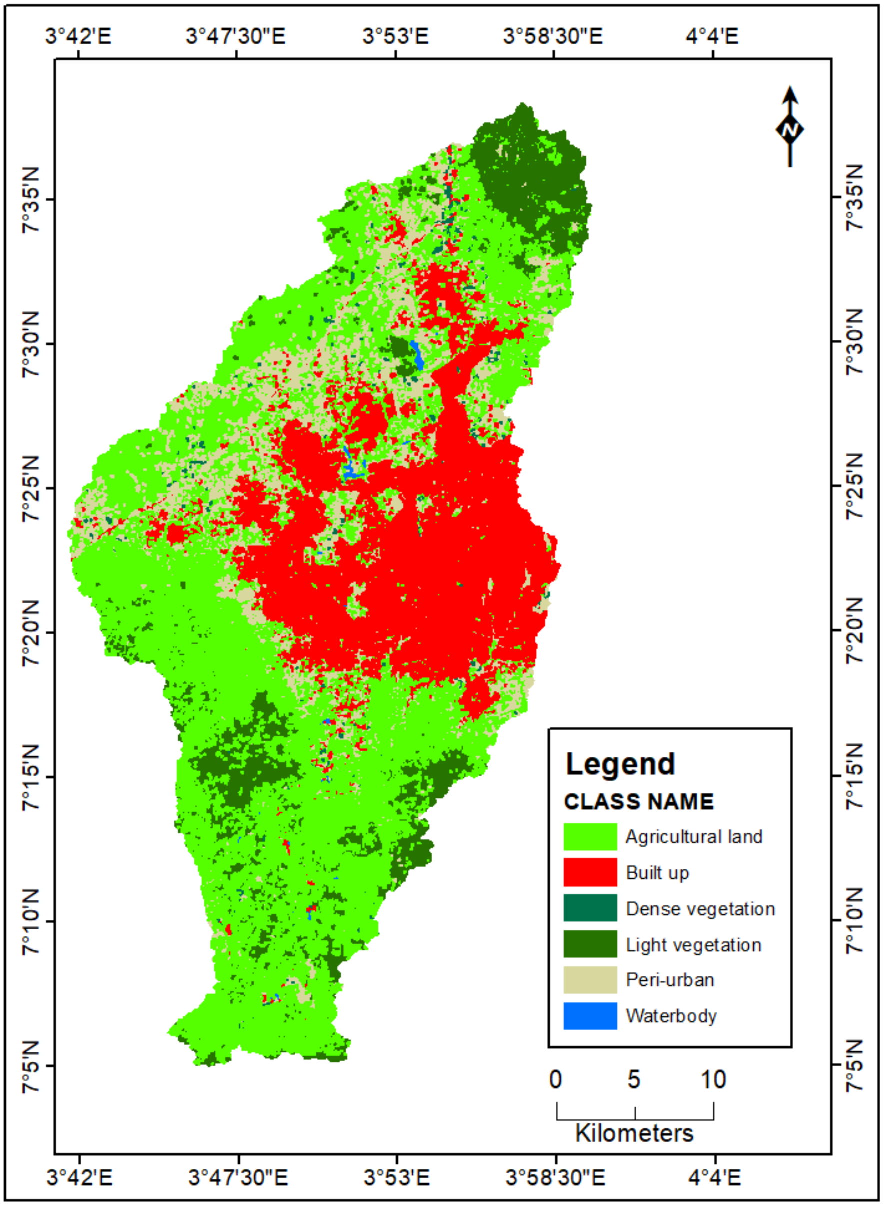

Figure 4.1 Map showing the Landuse pattern of River Ona Drainage Basin

Agricultural land occupies about 55% of the entire catchment; these are land devoted to agriculture, which includes land used for crop farming or pastoral farming. Agricultural land is expanded to include areas that are either arable, under cultivation or in use for pastoral farming e.g IITA. Built up areas occupies 18.64% of total land in the area. Built up areas are defined as land which is urban in character, that is; they consist of residential, industrial, commercial and institutional land. Examples of these areas are Oluyoye estate, Dugbe, Mapo. Dense vegetation are predominatly areas with thick forest, their area extent in the study area has been on a decline, from being a dominant part of the landuse/land cover type, dense vegetation now occupies less than 1% of the total land mass. As the areas with dense vegetation reduces, chances of floods are higher as presence of vegetal cover reduces the vulnerabilty of an area, this is erstwhile not the case in the study area, so areas in the catchment have a higher chance of being flooded than it would be if the vegetation cover occupied a larger extent.

Light vegetation may include shrubs which help in intercepting water from precipitation, thus reducing the chances of runoff which reduces the chance of flooding. Light vegetation can be found on around 11.72% of the land in Ona River catchment. Oloronbo is a prime example of areas with light vgetation. The term Peri-Urban is used to denote areas located immediately adjacent to a built-up area;. It is described as the landscape immediately surrounding/abutting an urban area. In the study area, the Peri-Urban areas occupies 13.65% of the land. Examples of these area is Omin Adio and Oloyo. Waterbody is any significant accumulation of water on the earth surface. The term waterbody mostly refers to oceans, seas and lakes but it can be expanded to include smaller pools of water such as ponds, wetlands and even puddles in rare cases. The waterbody occupies 0.49% of the total land area.

Table 4.2 Landuse of areas within 50m distance

Class name	**Area(sq m)**	**Percentage (%)**
Agricultural land	53278032.28	59.86
Built up	13156388.71	14.78
Dense vegetation	427254.01	0.48
Light vegetation	10093053.33	11.34
Peri-urban	11447714.61	12.86
Waterbody	605750.36	0.68
Total	89998193.31	100.00

Landuse of areas within 50m of the stream network, this areas within 50m of the stream network are highly vulnerable to flooding because of their close distance to the channel network. Agricultural land occupies the bulk of the land area with about 60%, the next most dominant landuse type is the Built up areas which encompasses about 14.78%. the Peri-urban which abutt the built up areas covers 12.86% of the land. Vegetation both Light and Dense are also present within 50m and they occupy 11.34% and 0.48% of the total land mass. The remaining 0.68% is covered by water.

Table 4.3 Landuse of areas within 50m to 100m distance from the stream channels

Class Name	**Area(sq m)**	**Percentage(%)**
Agricultural land	45784054.88	54.44
Built up	15973763.53	18.99
Dense vegetation	615082.10	0.73
Light vegetation	9764174.72	11.61
Peri-urban	11558784.51	13.74
Waterbody	408765.90	0.49
Total	**84104625.63**	**100.00**

Landuse of areas within 50m to 100m of the stream network, this areas of the stream network are moderately vulnerable to flooding because of their distance to the channel network. Agricultural land also occupies the bulk of the land area with about 54.44%, the next most dominant landuse type is the Built up areas which encompasses about 18.99%. the Peri-urban which abutt the built up areas covers 13.74% of the land. Vegetation both Light and Dense are also present within 50m and they occupy 11.61% and 0.73% of the total land mass. The remaining 0.49% is covered by water

Table 4.4 Landuse of areas within 100m to 150m distance

Class Name	Area(sq m)	Percentage (%)
Agricultural land	40226153.23	49.57
Built up	18269646.75	22.51
Dense vegetation	779240.64	0.96
Light vegetation	9934868.78	12.24
Peri-urban	11695221.11	14.41
Waterbody	242877.59	0.30
Total	**81148008.10**	**100.00**

Areas of 150m are at little to no risk of flooding, that is; they have low or no vulnerability and the majority of the landuse at this distance is occupied by agricultural land with about 49.57%, after which is the Built up areas which encompasses about 22.51%. the Peri-urban areas covers 13.74% of the land. Vegetation both Light and Dense increases and the area covered by dense vegetation is extended to 0.96% while that of Light vegetation is 12.24% of the total land mass. The remaining 0.30% is covered by water.

4.2. Elevation Pattern Analysis

It is worth noting that for this catchment, any area below 100m is sea level. For areas within 100m-187m above the sea level. There is high level of flood vulnerability because they are flat or lowland altitude areas and runoff and erosion from highland are deposited here. Thus, it is pertinent to say that areas of low elevation are at a high risk to flooding. Areas around the southern part of the study area are the most liable to flooding.

The moderately vulnerable areas to flooding in this study, stretch from the southern part (where they occur in patches) to the central part of the catchment area. They range in elevation from 187m-245m, while areas above 245m to 418m (which is the peak height in the study area) have little to no vulnerability to flooding according to the elevation model.

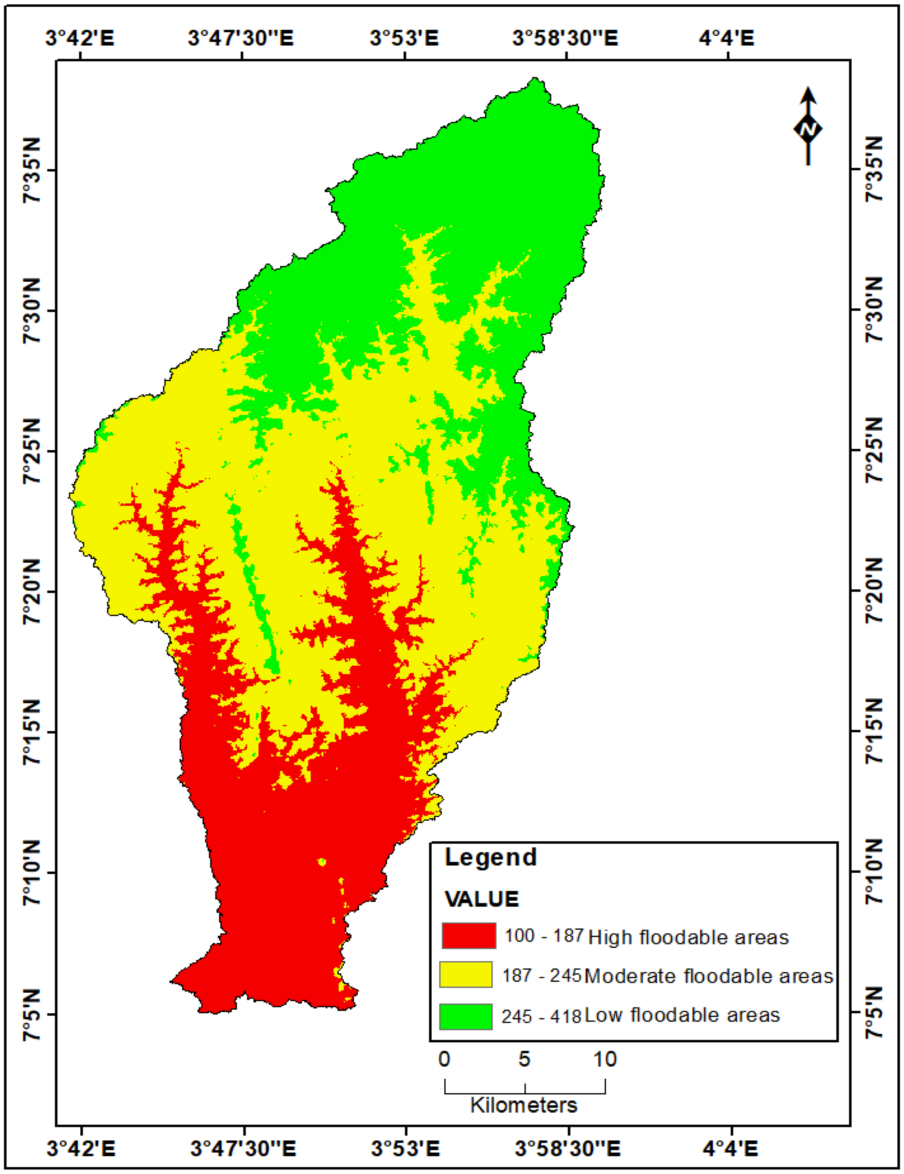

Figure 4.2 Map showing the Elevation Pattern of River Ona drainage basin

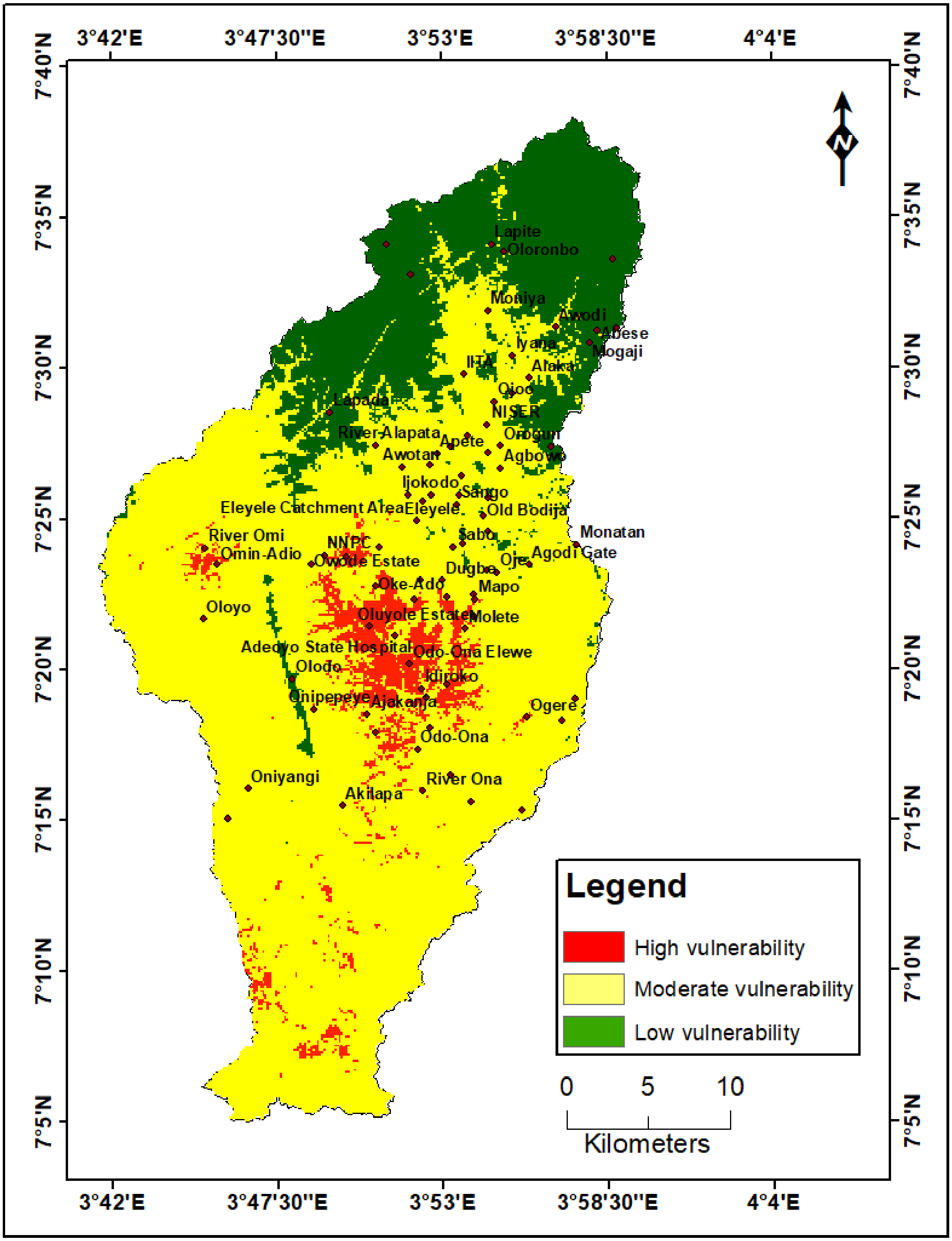

Figure 4.3 Flood Vulnerability map of River Ona drainage basin

The figure 4.3 above shows the flood vulnerability map of River Ona drainage basin. Areas in red denote places with high vulnerability to flood. Places like Oluyole and Akilapa have high susceptibility to flooding. This is because of their location with relation to elevation as they are located on relatively flat plains and this is also where all the catchment streams of River Ona empty their water, thus making them highly vulnerable to flooding

For locations in yellow, they are moderately susceptible to flooding. Areas like Dugbe, Mapo, Molete etc. fall under this category. This is because of the high presence of built up areas and relative lack of vegetation cover. The chances of these areas to flooding are moderate but because of the increasing presence of paved roads and pollutants which block the channels, as a result of urbanization, the possibility of flooding exists.

Locations in green show areas that have little or no vulnerability to flooding, the lack of susceptibility is attributed to high elevation, their relatively far distances from the stream channels and presence of vegetal cover in these areas. These areas include Oloronbo, Moniya, IITA etc.

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CHAPTER FIVE

5.0 Summary

Analysis of the elevation map produced show that the southern areas of the study area are highly liable to flooding as the land is made up of relative lowland, while towards the more central locations in the study area, there is a balanced opportunity for flooding to occur as these parts are moderately vulnerable to flooding. The increasing urbanization of the area is a major proponent for the possibility of flooding as ‘increasing blockage of drainage channels, pollution of stream channel networks, lack of vegetal cover, presence of concrete/paved surfaces instead of natural soil (that has absorptive capacities) accelerate runoff which then leads to flooding. In the upper regions of the study area, there is little to no risk or vulnerability to flooding, this is associated with presence of vegetal cover, their relatively high elevation, the further distance from the stream network and a lower level of urbanization in these areas.

5.1 Conclusion

This study was initiated with the aim of mapping out areas that are vulnerable to flooding in the River Ona catchment using GIS & Remote Sensing techniques. To address this, a methodology was developed involving, generation of a flood vulnerability map of the area using Landsat OLI imagery, and a Digital elevation model of the area, buffering the river layers and using the buffer information to estimate landuses that would been vulnerable to flood hazards within the study area at different levels. Areas lying 50m along the banks of the River Ona stream network are considered as areas that are most vulnerable to flood hazards. While the vulnerability of the locations with reference to elevation in the study area to flood hazards experiences a steady decrease in level of vulnerability at 187m to 418m above. Much of the area is built up and this gives rise to high vulnerability to flash flood hazards. The study found out that one of the major causes of flooding in the study area is uncontrolled urbanization of the area, such that some of the houses are built during the dry season on what constitutes the river bed itself. Large scale encroachment into the river floodplains is observed throughout the area.

5.2 Recommendations

Arising from the study, the following recommendations have been made based on the knowledge gained in this research as has been discussed in prior sections, as well as the need to protect the environment while limiting its adverse effect on man and his properties. It is on this basis that the following recommendations are suggested:

1. Improvement of land use planning: Government should enforce compliance with physical planning and development regulations within Ibadan and the country at large
2. Sensitize and raise public awareness on the dangers of building on floodplains and the immediate removal of structures within the reach of River Ona's flood plains around the study area
3. Government and capable NGO's should ensure that Drainages, gutters and surface water bodies remain unclogged throughout the study area so as to allow for free flow of urban storm water and urbanization induced runoff
4. Review existing laws and regulations on delimitation of setbacks to conform to the natural flood plain of the rivers, in lieu of urbanization.

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