ASSESSMENT OF THE 2012 FLOODING IN MARARABA KARU LOCAL GOVERNMENT AREA OF NASARAWA STATE, NIGERIA

BY

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(MSC/SCIE/8614/2010-2011)

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AHMADU BELLO UNIVERSITY, ZARIA

NIGERIA

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Declaration

I declare that the work entitled **"**Assessment of the 2012 Flooding in Mararaba, Karu Local Government Area of Nasarawa State, Nigeria" was performed by me in the Department of Geography, under the supervision of Dr. Folorunsho, J.O and Dr. Jeb D.N. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree or diploma at any other Institution.

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Certification

This thesis titled "Assessment of the 2012 Flooding in Mararaba, Karu Local Government Area of Nasarawa State, Nigeria" meets the regulations governing the award of the degree of Master of Science in Remote Sensing and Geographic Information System of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

Flooding due to extreme rain events in urban environments is a problem and a growing concern. Urban flooding has become more frequent due to a number of factors including climate change with the different patterns of precipitation, urban growth and an increase in paved surfaces. Recent flood disasters in Mararaba sub-urban area has claimed some lives, damaged properties and threatened the socio economic live of residents. It has therefore become important to create easily read, rapidly accessible flood hazard map, which will prioritize the mitigation effects. The aim of this study is to assess the 2012 flooding in Mararaba sub-urban area and also identify parts of the study areas that are prone to flooding using GIS based tool. LULC map was prepared using Remote sensing technique of visual interpretation to identify eight classes of land use land cover from the 2005 Spot 5 satellite imagery in a GIS environment. Soil Conservation Service (SCS) model was used to determine the rainfall-runoff relationship of the study in ILWIS environment. Daily rainfall data, SPOT 5 satellite Imagery (5m resolution), Digital Elevation Model (DEM) and soil texture maps were used as input for the runoff modeling. The blind weight method was used in this study to create flood hazard map for the study area. The result from this study shows an estimated total rainfall runoff of Mararaba urban watersheds calculated for the rainy season (April to October, 2012) aggregating 831.24mm. About 52 percent of total rainfall was converted into surface runoff. Month-wise runoff contribution ranges between 3% to 21%.The peak runoff estimates was 174.21mm in the Month of July which substantiates the reported flood incident on the 14 July, 2012. Five flood hazard classes were identified: Very Low, Low, Moderate, High and Very High hazards. The study demonstrated the potentials of SCS (CN) Model / GIS applications in flood hazard mapping. Concerted efforts should be made by the local and state government, urban planning and environment control department towards containing flood hazards by the construction of new drainage channels along inlands streets in Mararaba sub-urban areas where drainages have been absent. Existing ones also be expanded to increase their capacity for detaining and conveying high stream flow especially in areas at high risk.

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ABBREVIATIONS AND SYMBOLS

% : Percentage

AMC: Antecedent Moisture Condition

CN: Curve Number

DEM: Digital Elevation Model

ERDAS: Earth Resource Data Analysis System

GIS: Geographical Information System

Ha: Hectares

HSG: Hydrological Soil Group

ILWIS: Integrated Land and Water Information System

L.G.A: Local Government Area

LULC: Land Use Land Cover

NCRS: National Centre for Remote Sensing

SRTM: Shuttle Radar Topographical Model

CHAPTER ONE:

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Flooding is a general temporal condition of partial or complete inundation of normally dry areas from overflow of inland or tidal waters or from unusual and rapid accumulation of runoff (Jeb and Aggarwal, 2008). Floods are the most common natural disasters that affect societies around the world. Dilley *et al.*, (2005) estimated that more than one-third of the world's land area is flood prone affecting some 82 percent of the world's population. The reason lies in the widespread geographical distribution of river flood plains and low-lying coasts, together with their long standing attraction for human settlement. Floods are natural phenomena, but they become a cause for serious concern when they exceed the coping capacities of affected communities, destroying lives and damaging property. They affect settlement of all types, from small villages and mid-sized market towns and service canters to major cities and metropolitan. In many regions of the world, people moving from rural areas to cities, or within cities, often settle in areas that are highly exposed to flooding thereby making them highly vulnerable if there is no flood defence mechanism (Jha *et al., 2012*).

Urban flooding can be coastal, fluvial or pluvial or even a combination of these types of floods. Coastal flooding is caused by extreme tidal conditions that occur because of high tide levels, storm surge and wave action. Fluvial (River related) flood occurs when the discharge of a river exceeds the capacity of the river channel to contain it. While pluvial flood takes place when the rainfall rate exceeds the capacity of storm water drains to evacuate the water and the capacity of the ground to absorb water (Ball *et al.*, 2008). Pluvial flooding often occurs unexpectedly in locations not obviously prone to flooding and with minimal warning and is not well understood by the general public – hence the term 'invisible hazard' (Houston *et al., 2011*). Pluvial flooding is a

characteristic of urban areas where large areas of impervious ground exist and inadequate drainage systems abound. As urban growth increases, the impervious surface area also increases; thereby rendering populations vulnerable to water inundation as natural streams and human-made drainage fails to cope with increased runoff subsequent to heavy rainfall (Youssef and Pradhan, 2011).

Urban pluvial flooding frequency is expected to increase not only due to urbanization but also to expected climate changes (Ugarelli *et al.*, 2011; Simes *et al.*, 2014). This type of flooding can happen virtually anywhere and has the potential to cause significant damage and disruption in highly urbanized areas, where the density of properties, critical infrastructure and population is usually high. The volumes involved and the risk related to pluvial flooding often result in consistent economic losses and consequent damage in the long term due to the high frequency of this kind of event (Freni *et al.,2010*). Related consequences of pluvial flooding mainly consist of economic losses such as damage to buildings and their contents and to infrastructure and intangible damages due to traffic delays, road, public and commercial function closures, and evacuation of people. Globally, the economic cost of extreme weather events and flood catastrophes is severe, and if it rises owing to climate change, it will hit poorest nations the hardest consequently; the poorest section of people will bear the brunt of it. It is therefore, urgent that the vulnerability of developing countries to climate change is reduced and their capacity to adapt increased at national, regional and community levels (UNFCC, 2007).

Excess water in itself is not a problem rather, the impacts of flooding are felt when this water interacts with natural and human-made environments in a negative sense, causing damage, death and destruction. The thing that makes natural floods a disaster is when flood waters occur in areas populated by humans and in areas of

significant human development. Otherwise, when left in its natural state, the benefits of floods outweigh the adverse effects (Bradshaw *et al., 2007*). Although generally, flooding is a bane to most people, floods can be quite beneficial. Actually, nature benefits more from natural floods than from not having them at all. The experience of flooding for a rural agriculturalist and an urban slum dweller will be very different: while to the farmer the flood is a natural force to be perhaps harnessed or endured for the long term benefits it may bring, for the urban dweller flooding is at best a nuisance and at worst a disaster which destroys everything she or he owns (Jha *et al.*, 2012).

Floods regularly account for nearly one-third of all global disasters arising from geophysical hazards (Smith and Ward, 1998). They now appear to be more prevalent and destructive than centuries ago and are projected to increase both in frequency and amount of devastation in the future (Parker, 2000). Moreover, more people are now living in flood prone areas. Despite efforts in many countries to restrict development in floodplains there is substantial evidence that exposure to floods is growing rapidly as human occupation of floodplains intensifies in many parts of the world (Jha *et al., 2012*). According to UN-Water (2011) floods, including urban flood is seen to have caused about half of disasters worldwide and 84% disaster deaths in the world was attributed to flooding. They are some of the most frequent and costly natural disasters in terms of human suffering and economic loss in the United States and world-wide (Mason 1995; Smith and Ward, 1998; Parker, 2000). Death and destructions due to flooding continues to be all too common phenomena throughout the world today, affecting millions of people annually. Flooding is one of the major natural disasters which disrupt the prosperity, safety and amenity of the residents of human settlements (Jha *et al.*, 2012).

Flooding is a global phenomenon which causes widespread devastation, economic damages and loss of human lives (ibid). Records of the devastating impact of flood around the world abound. In May 2008, floods triggered by torrential rains killed dozens of people across China, while thousands of others were victims of landslides caused by the downpours. Elsewhere in the United States of America, the Mississippi River caused damages put at several millions of dollars when it over flew its banks, flooding some cities, towns, farmlands and major industrial installations over a distance of about 250km and ravaging Iowa before it heaped downstream (Aderologba,2012). Several flooding events have occurred in Europe over the last decades with heavy rainfall as the main cause of flood.). In several parts of the Netherlands, intense rainfall in autumn of 1998 caused damage to 2470 houses, 1220 premises and 350 governmental agencies (Jak and Kok, 2000). Similarly, in the summer of 2007 the City of Hull (United Kingdom) suffered from severe pluvial flooding, causing damage to over 8600 houses and 1300 premises (Coulthard and Frostick, 2010). African nations too have had their own share of flood disasters. For example in West and Central Africa more than 1.5 million people were affected by floods between the months of July and August 2012 following heavy rainstorm in which more than 11,400 homes were destroyed in Senegal; more than 94,000 in Chad and 24,000 homes in Niger (UN-OCHA,2012).

In Nigeria, the pattern is similar with the rest of world. Flooding displaces more people than any other disaster, perhaps because about 20 per cent of the Nigerian population is at risk of flooding (Etuonovbe, 2011). Flooding is therefore a perennial problem in Nigeria that consistently causes deaths and displacement of communities. For instance, in 2010, about 1,555 people were killed and 258,000 more were displaced

by flooding (Babatunde 2011).Similarly in 2012, floods claimed 361 lives, and displaced 2.1 million people(Tokunbo and Ezigbo,2012).

Mararaba Gurku sub-urban area of Nasarawa state adjoins the Federal Capital Territory of Nigeria. It has recorded series of flooding events in recent times. On the 6th of July 2012, heavy rainstorm accompanied by torrential flood claimed two lives in the White house area and submerged many residential houses and shops beside Kabayi bridge in Mararaba Gurku, Nasarawa state (Itodo, 2012). Similarly, heavy rainfall on the 14th of July 2012 resulted in flooding of street and destruction of properties in Mararaba Gurku neighborhood as seen in plate 1.1 and 1.2 (appendix I and II). Another incident occurred on the 27th of September, 2012 when an overnight downpour that lasted for three hours flooded and submerged 50 houses and seven cars in Mararaba Gurku (Ume, 2012). Over the years serious floodings have occurred much more frequently in the last twenty-five years in Nigeria (Gobo and Abam, 1991) and there is no reason to believe that it will not continue to be a problem. There is therefore the need to be prepared to respond to dangers of floods as they are happening and to protect the public health and safety during these emergencies. The focus of this study therefore, is on rainfall-induced flooding; causes, hazards and approaches to mitigate flooding in Mararaba Gurku sub-urban area.

1.2 STATEMENT OF THE RESEARCH PROBLEM

According to Smith and Ward (1998), most floods in the humid tropics result directly or indirectly from climatological events, either extremely heavy or prolonged rainfall. This in recent times happens every year in Mararaba sub-urban area of Nasarawa state, Nigeria. Urban flooding is considered as one of the most immediate and serious environmental problem confronting municipal authorities in developing countries. It is indeed a critical environmental problem or major hazard that is

continuously affecting effective functioning of urban environment, especially in the areas of sustained infrastructure and services, which are germane to sustainable livelihood. When severe floods occur in areas occupied by humans, they create natural disasters which involve the loss of human life and property plus serious disruption to the activities of large urban and rural communities (Smith and Ward, 1998). The economy can also be severely affected by flooding as businesses may lose stock, patronage, productivity and disruption to utilities; and transport infrastructure can be adversely affected on a wider area. Adeosun (2012) reported that the Federal Ministry of Environment stated that the negative effect of climate change, which manifested in a wave of flooding across the country in recent times, is capable of derailing the process of the actualization of the Millennium Development Goals (MDG).This indeed is a big threat to the progress already made in eradicating extreme poverty and disease. The damage caused by urban flood is on the rise because of the devastating effects of floods, it is important that we consistently study flood characteristic and impact, so that appropriate disaster risk reduction strategies can be put in place to reduce the impact of floods.

Over the years, despite annual Seasonal Rainfall Prediction (SRP) by the Nigerian Meteorological Agency that there would be irregular flooding in many parts of the country, most part of the country has continued to suffer from the devastating effect of floods. The nation's response to the flood has been anything but articulate and comprehensive. All we have done is to react after the disastrous events to provide relief to the unfortunate victims, and then we wait for another deluge. Nothing has been done to ensure that the hazard is prevented and its associated risk is reduced to the barest minimum (Jeb and Aggrawal, 2008; Orok, 2011). Reduction of risk of flooding will depend largely on the amount of information on floods that is available and knowledge

of the areas that are likely to be affected during a flooding event. The lack of accurate hydro meteorological data affects the uncertainties associated with flash flooding events. There is therefore an urgent need to introduce mitigation measures to ensure that these areas are protected so that flooding is minimized. This calls for the use of modern day techniques to identify measures that will help government and relief agencies in the identification of flood prone areas; which in turn will help in planning against flooding events in the future.

Several researchers have examined the issue of flooding particularly with the utilization of Remote Sensing and Geographic Information System (GIS). Okoduwa (1999) applied Geographic Information System (GIS) in the prediction of urban flooding in Benin City, Nigeria. This was achieved by creating a digital database of selected variables such as land use, land cover and soil strength. The software used was Arcview 3.1 and the overlay technique in GIS was used for analysis. The result of the analysis showed high, medium and low flood prone areas. Ishaya, *et al.,* (2009) exploited the use of remote sensing and GIS tools to created digital terrain maps and flood vulnerability maps of Gwagwalada in Abuja showing the areas that were highly vulnerable, vulnerable, less vulnerable and free from flood hazard. The results obtained from their study showed that areas lying along the banks of River Usuma are most vulnerable to flood hazards with the vulnerability decreasing towards the northern part of the town. Jeb and Aggarwal (2008) in their studies aimed at flood inundation hazard modeling of the River Kaduna used Gumbel's Extreme value distribution statistical method of analyzing flood data and GIS to estimate the extent of flood inundation for different return period. The result of their study showed mapped areas (Ungwan Guza, Kawo new extwnsion, Ungwan Dosa, Badarawa, Malali e.t.c) along River Kaduna that fall under areas prone to threat of severe flood for different return periods. Similar

studies by Ndabula *et al.,* (2012) focused on urban flood plain encroachment of Kaduna metropolis used GIS operation to digitizing the topo map of the study area in polygon shape file and overlaying it with the digital elevation map (DEM) of their study area to delineate flood plain boundary. The result of their study showed that the highest extent and rate of encroachment was recorded by communities in the proximity of the Central business district (CBD) such as T/Wada, Ungwan. Rimi, Barnawa etc.

Although these researchers have assisted in providing some information about floods inundation, encroachment and flood prone areas in Nigeria; they have not fully assessed flood hazards in all the flood prone zones in Nigeria. More so, very few methodologies have focused on local floods in small urban watersheds and the rainfall runoff generated there off, especially in urban areas where there are no major river. Some reasons behind this fact are the complexity of the flooding processes in urban areas and lack of advanced technological methods for capturing geographical data (Ishaya *et al*., 2008; Ishaya and Ifatimehin, 2008; Ifatimehin *et al*., 2009; Freni *et al.,* 2010; Orok, 2011). Furthermore, flood studies have only been carried out in areas where appropriate data for research can easily be acquired. There is still much left to be done with regards to studies on flooding in unguaged sub-urban areas like Mararaba Gurku. This research is one of the few attempts to address issues of floods in sub-urban environment, using the GIS tool to analyze the interl-inkages of various factors that are contributing to persistent floods in Mararaba sub-urban area. This study seeks to answer the following specific questions that relate to flooding in Mararaba Gurku sub-urban area which are:

i. What is the pattern of land use land cover of the study area?

ii. What is the relationship between rainfall and runoff in the area?

iii. Which areas of the sub-urban environment are prone to flooding?

iv. What type of approach can be adopted to reduce the risk of floods in the study area?

1.3 AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to assess the 2012 flooding in Mararaba sub-urban area and also identify parts of the study areas that are prone to flooding using GIS based tool. Specific objectives are to:

i. derive land use and land cover (LULC) information of the study area
ii. determine the rainfall-runoff relationships of the study area
iii. identify flood prone areas using remote sensing and GIS techniques
iv. determine a strategic approach for flood risk reduction in the study area

1.4 JUSTIFICATION OF THE STUDY

Urban flooding poses a serious challenge to development and the lives of people, particularly the residents of the rapidly expanding towns and cities in developing countries. Mararaba sub-urban area of Karu local government area is no exception. As population and land values increase, the effect of uncontrolled runoff becomes an economic burden and poses a serious threat to health and well-being of citizens (Bari and Hasan, 2001). Due to serious flooding and it attendant problem in some areas of Mararaba sub urban area, flood control is a vital issue. More so the lack of or scarcity of reliable recorded hydro - meteorological data is another serious problem, which planners and researchers face for the analysis of the hydrology of urban watersheds. Thus , the use of new tools , like remote sensing and GIS , to generate supporting land based data for flood control and water resources in watershed planning is invaluable.

A detailed understanding of the flood hazard relevant to different localities is crucial for implementing appropriate flood risk reduction measures such as

development planning, forecasting, and early warning systems (Jha *et al*, 2012). Thus it is envisaged that the findings of this study will be beneficial to urban and infrastructure planners, risk managers and disaster response or emergency services personnel during extreme and intense rainfall events. Furthermore, public and private businesses, private house owners, housing corporations can decide whether it is worth taking out a flood insurance policy or spending additional money on private flood protection measures. The conclusions of this study can provide additional information to the existing knowledge in the field of flood assessment.

1.5 LIMITATION OF THE STUDY

The limitations of the research presented in this study are largely related to the existing problems of data availability in hydrological models and the computational difficulties of SCS Curve Number (CN) Model. There was insufficient rainfall information as the nearest rainfall station is at Abuja relative to that at Lafia the state capital which is at a greater distance from the study area. Since there was no known rain gauge station in the study area as at the time that this study was undertaken, interpolated rainfall record from Abuja meteorological station was adopted for this study. As such the result of the rainfall runoff and flood hazard prone area may not be taken as definitive of the actual situation of the study area.

SCS (CN) model is simple and easy to use model that requires a limited amount of data. However, there are some limitations (NRCS, 1999):

(a) Time independence, for a constant CN, a given amount of rainfall produces a set amount of runoff regardless of the rate of rainfall or how fast the soil can infiltrate water. The lumped system does not identify what part of loss is infiltrated. More so, the equation does not contain an expression for time and, therefore, does not account for rainfall duration or intensity.

(b) Fixed initial abstraction: For a constant CN, the soil moisture or soil properties are not used. While these may be a factor in initially selecting CN values, they are not used in the runoff computation. Thus the accuracy of runoff estimates is reduced for small amount amounts (0.5inc) of rainfall.

(c) One of the challenges for hydrologist is to perform analysis for unguaged watersheds because model result from unguaged watershed may have error when basin characteristics such as geography, land use and soil types are significantly different. Thus the need for SCS (CN) parameter calibration for direct runoff estimation.

1.6 SCOPE OF THE STUDY

This study is focused on the assessment of 2012 flooding in Mararaba Gurku sub-urban area in Karu L.G.A of Nasarawa State. The present study is confined primarily to the hydrologic aspects of surface runoff and does not include the hydraulics of channel flow and damage assessment of flooding which are extensive subject on their own merit beyond the scope of this study. The study is however limited to Pluvial flooding (surface runoff) estimation and flood hazard in the study area. Remote Sensing and GIS would be used as a tool to derive the land use/land cover of the study area, determine the rainfall runoff and identify flood prone areas within the study area.

1.7 ORGANIZATION AND PRESENTATION OF THE STUDY

This chapter introduces the background and related issues on urban flooding being the major subject of the research. Relevant literatures on flooding are reviewed in Chapter two. While the description of the study area, methodology for data collection and analysis is presented in chapter three. The results obtained in this study and discussions are presented in chapter four. The summary, conclusion and recommendation of the study are presented in chapter five.

CHAPTER TWO: LITERATURE REVIEW AND THEORETICAL FRAMWORK

2.1 INTRODUCTION

This chapter presents the literature review that provides the basic information regarding concept of flooding – definition of flooding, flood types, climate change and floods, urbanization and flooding, factors contributing to flood hazards, Flood Risk Management, Rainfall runoff, types of runoff, Runoff modelling, Soil Conservation Service(SCS)Model, and application of Remote sensing / GIS to flood assessment.

2.2 FLOODING

2.2.1 Definition of Flooding

Flooding is defined as a general temporal condition of partial or complete inundation of normally dry areas from overflow of inland or tidal waters or from unusual and rapid accumulation of runoff (Jeb and Aggarwal, 2008). Similarly Walesh (1989) defined Flooding as temporary inundation of all or part of the floodplain or temporary localized inundation occurring when surface water runoff moves via surface flow, gutters and sewers. Furthermore it is defined as a condition, where wastewater and (or) surface water escapes from or cannot enter into a drain or sewer system and either remains on the surface or enter into buildings (NS-EN 752-1, 1996).

A flood is relatively high flow, which overtaxes the natural channel provided for runoff (Chow, 1956). It may also be described as a body of water, which rises to overflow land that is not normally submerged (Ward, 1978).It is also a condition where an extremely high flows or levels of rivers water inundates floodplains or terrains

outside of the water-confined of major river channels. Floods also occur when water levels of lakes, ponds, reservoirs, aquifers and estuaries exceed some critical values and inundate the adjacent land, or when the sea surges on coastal lands much above the average sea level (Rossi *et al.,* 1992). Meteorological flood can be defined as a situation over a region where that rainfall is mostly higher than the climatological mean value because the natural vegetation and economic activities of the region have been adjusted to the long-term average rainfall of that region (Ologunorisa and Abawua, 2005).

Chow (1956) defines the floods in relation to rivers. Ward (1978) specifies floods to inland area. Walesh (1989), attempts to embrace floods both in floodplains and on urban surfaces. Rossi *et al.,* (1992) provide more comprehensive definition for floods from rivers, detention and retention storage as well as storm surges, while NS-EN 752-1 (1997) defines the floods scenarios on urban surfaces. Recently, Ologunrisa and Abawua (2005) defined it from the climatological perspective of the long-term average rainfall over a region.

2.2.2 Types of Flooding

There are four broad flooding categories: Coastal flooding, Groundwater flooding, River (or fluvial) flooding, and Pluvial flooding (ActionAid, 2006; Sterna, 2012).

(i) Coastal flood: Occur in low-lying coastal areas, including estuaries and deltas, when the land is inundated by brackish or saline water. Brackish-water floods result when river water overspills embankments in coastal reaches. This overspill can be intensified when high-tide levels in the sea are increased above the normal level by storm-surge conditions or when large freshwater flood flows are moving down an estuary. Saline water coastal floods may occur when extremely large wind-generated waves are driven into semi-enclosed bays during severe storm (Smith and Ward, 1998).

(ii) Groundwater flood: According to Macdonald (nd), ground water flooding is the emergence of groundwater at the ground surface away from perennial river channels, or the rising of groundwater into man-made ground under conditions, where 'normal' ranges of groundwater level and groundwater flow are exceeded. The Problems with high groundwater levels mainly occur in floodplains or low-lying areas. Damage due to high groundwater levels occurs if there is a considerable (sudden or long-term) change in the groundwater levels. Such changes can be a result of high infiltration rates (due to flooding or heavy precipitation) into the aquifer or a reduced withdrawal of groundwater (Kreibich and Thieken, 2008).

(iii) River flood: Flooding (Fluvial) in river valleys occurs mostly on floodplains as a result of flow exceeding the capacity of the stream channels and over spilling the banks. Most river floods result directly or indirectly from climatological events such as excessively heavy and/or prolonged rainfall (Smith and Ward, 1998).

(iv) Pluvial flood: Falconer *et al.* (2009) describe pluvial flooding as "the result of rainfall-generated overland flow and pond before the runoff enters any watercourse, drainage system or sewer, or cannot enter it because the network is full to capacity". Pluvial flooding is typically associated with short duration high intensity rainfall, but can also occur with lower intensity prolonged rainfall. The pluvial flood extent can be worsened if the ground is saturated, frozen, paved or otherwise has low water permeability (Falconer, 2009). Pluvial flooding often occurs unexpectedly in locations not obviously prone to flooding and with minimal warning and is not well understood by the general public – hence the term 'invisible hazard' (Houston *et al., 2011*). It is a characteristic of urban areas where large areas of impervious ground exist and inadequate drainage systems abound. As urban growth increases, the impervious surface area also increases; thereby rendering populations vulnerable to water inundation as

natural streams and human-made drainage fails to cope with increased runoff subsequent to heavy rainfall (Youssef and Pradhan, 2011).

Urban pluvial flooding frequency is expected to increase not only due to urbanisation but also to expected climate changes (Ugarelli *et al.*, 2011and Simes *et al*., 2014). This type of flooding can happen virtually anywhere and has th e potential to cause significant damage and disruption in highly urbanized areas, where the density of properties, critical infrastructure and population is usually high. The volumes involved and the risk related to pluvial flooding often result in consistent economic losses and consequent damage in the long term due to the high frequency of this kind of event (Freni *et al.,2010*). Related consequences of pluvial flooding mainly consist of economic losses such as damage to buildings and their contents and to infrastructure and intangible damages due to traffic delays, road, public and commercial function closures, and evacuation of people.

2.3 IMPACT OF CLIMATE CHANGE ON FLOODS

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2001). The major factor that influences flood is the climatic condition of a particular geographic location, and this manifests in the form of amount, duration and intensity of precipitation (rainfall). The combination of precipitation and high temperature affects the soil moisture content (percentage saturation), liquid limit, infiltration rates etc. One of the consequences of global warming in humid environments is increase and alteration of rainfall patterns (O'Hare, 2002). Climate change will likely amplify the impact of urbanization on storm water runoff, further increasing the quantity of runoff. More so climate change predictions point to scenarios for heavy precipitation events to increase in frequency and intensity (Bates *et al.,* 2008).Climate change is therefore likely to increase flood risk

significantly and progressively over time. At particularly increased risk will be low-lying coastal areas, as sea levels rise and areas not currently prone to fluvial or tidal flooding as more intense rainfall leads to significantly higher risk of flooding from surface runoff and overwhelmed drainage systems.

The primary cause of urban flooding is severe thunderstorm or rainstorm preceded by long lasting moderate rainfall that saturates the soil (Andjeikovic, 2001). In much of the tropics, most rainstorms are highly localized, often covering less than 10 square kilometres; they are intense and of short duration, usually lasting an hour or less. The most intense thunderstorm, occurring on average once every two years, can deposit as much as 90 millimetres of rain in just 30 minutes (Babatolu, 1997). The volumes of water running off roofs and paved surfaces in urban areas from such storms are enormous; all too often, drains and culverts cannot cope and localized flash flooding occurs. These flash floods happen suddenly, with little lead time for warning; they are fast-moving and generally violent, resulting in a high threat to life and severe damage to property and infrastructure; and they are generally small in scale with regard to area of impact (Douglas *et al.,* 2008).

Rainfall – induced flooding in city is caused by the occurrence of local rainfall in built up areas of cities several times a year on various scale (Mark and Chusit, 2002). There is no doubt on the effects of climate change in altering the precipitation patterns in terms of distribution, intensity and duration of extreme rainfall events and a higher frequency of strong precipitation. Due to higher temperatures and drought, lands have become more susceptible to runoff, exacerbating floods intensity. Changes in rainfall intensity and distribution influence river morphology (erosion of banks, fast sedimentation in riverbeds) introducing more dynamic changes in flood patterns (Amangabara and Gobo, 2007).

2.4 URBANIZATION AND FLOODS

Floods are natural and seasonal phenomena that play an important environmental role. However, human settlements interfere with flood patterns, majoring their magnitude and frequency of occurrence, turning higher the associated level of risk regarding people, buildings and economic activities. A significant amount of research over the last twenty years has shown a strong relationship between urban areas and local micro-climate. The "urban heat island" (UHI) effect is now well established, whereby urban areas have higher temperatures than surrounding regions (Seto and Kaufmann, 2009). In many cases, UHI can increase the rainfall in vicinity of the cities. A number of studies have found an increase in rainfall in regions downwind of urban areas, with increases as high as 25% in some cases (Shepherd, 2002; Mote, 2007). In urbanized areas, huge amounts of anthropogenic waste heat is emitted due to human activities, and the increase of energy consumption is causing environmental problems, including the temperature rise in the urban atmosphere (Aikawa *et al.,* 2008). Urban areas can enhance the build up of thunderstorms through the urban heat island effect: as cities grow, the urban heat island becomes more marked, with possible increases in thunderstorm activity. Thus, even without the climatic changes due to global warming, urban extreme rainfall intensities may be increasing, along with their severe impacts on society.

Flooding in urban areas is not just related to heavy rainfall and extreme climatic events; it is also related to changes in the built-up areas themselves. A study modelling the impacts of urbanization and climate change produced results showing that increased rainfall intensity and increased impervious surfaces will cause flashier runoff

periods, greater peak flows and heightened risk of flooding (Semadeni *et al.*, 2008). During urbanization, on one hand, the urban areas are enlarged, which increases the contributing areas to generate runoff. In addition, green lands are replaced by impervious roofs, roads and parking lots, which reduce the capacity of surface to absorb water and decreases the concentration time of surface runoff. Accordingly, both runoff volume and peak discharge in urban catchment are increased (Gardiner *et al.,* 1995; Rosenthal and Hart, 1998; Ahmed, 1999). On the other hand, however, the rehabilitation of rivers, channels and sewers lags far behind the development of municipal constructions. Consequently, the existing drainage capacities are not enough to drain away the runoff discharge and the risk of flooding is accordingly increasing. Urbanization aggravates flooding by restricting where floodwaters can go, covering large parts of the ground with roofs, roads and pavements, thus obstructing natural channels, and by building drains that ensure that water moves to rivers more rapidly than it did under natural conditions (Actionaide, 2006).Thus urbanization invariably increases the flood risk as a result of heightened vulnerability to floods due to concentration of population, wealth and infrastructure to smaller areas (Huong and Pathirana, 2011).

2.5 FACTORS CONTRIBUTING TO URBAN FLOOD HAZARDS

Factors that lead to flooding have been grouped into three main categories (table 2.1): (a) meteorological – relating to extensive torrential rainfall, cyclones, storms and tidal. surges; (b) hydrological –relating to floods caused by increased surface run off as a result of ice and snow melt, land saturation, impermeable surfaces and land erosion; (c) anthropogenic – concerned with human and natural activities such as population growth, urbanization, climate change, land use and degradation (ADPC, 2005).

Table 2.1: Factors contributing to flooding

Meteorological Factors	Hydrological Factors	Human factors aggravating Flood hazard
- Rainfall and	- Soil Moisture level	- Land use changes e.g surface Surface sealing due to (urbanization, Deforestation) increase runoff Sedimentation
- Cyclonic storm obstructing	- Ground water level Prior to storm	- Occupation of flood plain flow.
- Small scale storm of	- Natural surface Infiltration	- Inefficiency or non maintenance infrastructure
-Temperature of	- Presence of Impervious cover	- Inefficiency or non maintenance maintenance of infrastructure
-Snow fall and upstream Snow melt	- Channel cross section shape and roughness	-Too efficient drainage of area increases flood peaks
	- Presence or absence of overbank flow, channel network	-Climate change affect magnitude and frequency of precipitation and floods
	- Synchronize of runoff From various part of the Watershed	- Urban micro climate may enforce precipitation
	-High tide impeding drainage	

(Adapted from Associated Programme on Flood Management, 2012)

Some of the causal factors of flooding identified in Nigeria include high river levels, land inundation from heavy rainfall, poorly built drainages with limited

space and blockage of drainages (appendix III and V) from wastes materials, population growth, urbanization and climate change (Ologunorisa, 2004; Ishaya *et al.*, 2008;). According to Kosky and Butler, (2002) causes of urban flooding are blockage of drains and street inlets by silt and garbage and inadequate street cleaning practices.

Worsening urban flooding is affected by both global climate change and local changes to drainage systems and rivers. The local changes are due to construction, blockage of drains and increased local runoff from hard, paved and compacted surfaces. These local and global changes work together to increase flood frequency, magnitude and duration. The urban poor are suffering more than other urban residents from these changes as large-scale urbanization and population increases have led to large numbers of people, especially the poor, settling and living in floodplains in and around urban areas (Douglas *et al.*, 2008). Public health has also suffered as flooding has increased the number of outbreaks of cholera, causing several deaths (Actionaid, 2008).

Deforestation have increased the amount of run-off on land surfaces while agricultural activities affect soil compositions, making them very compact, highly impermeable and reduce water infiltration (ADPC, 2005). Flooding and other natural disasters could be future consequences of degradation of the environment and climate change (Jeyaseelan, 1999 and Ifatimehin *et al*., 2009). Urban flooding is still an annual event in most of Nigerian cities; the reason for this annual trend is because of the ever increasing shift of people from rural areas to urban cities for better livelihood, hence increasing the population of those living in flood vulnerable areas such as flood plains and river beds (Folorunsho and Awosika 2001; Ologunorisa and Abawua, 2005; Ologunorisa, 2009).

2.6 RUNOFF

The term can be applied to stream or river discharge. It can also be employed in reference to the gravitational movement of a fraction of rainfall over the surface of land or as subsurface flow from an area peripherally bound by a water divide, towards a water body. Runoff is, therefore, the water remaining from precipitation after the losses from evaporation, transpiration, and seepage into the ground water .Runoff is express in terms of volume per unit time and its generation largely depends on the amount of rain water that reaches the earth's surface (Edgar, 1948; Ward and Robinson, 1990).

Runoff in a catchment is generated by the portion of rainfall that remains after satisfying both surface and sub surface losses. Once these demands have been met, the remaining rainwater follows a number of flow paths to enter stream channel. The course it follows depends on several factors including soil characteristics, climatic, topographic and geological conditions of a catchment (Ward and Robinson, 1990). Overland flow or surface runoff is the main flow path of runoff that can largely be influence by human activities through catchment management practices (Morgan, 1995).

The central focus of any hydro-meteorological study is the hydrological cycle shown in Figure 2.1. The hydrological cycle has no beginning or end and its many processes occur continuously (Chow *et al.,* 1988). In describing the cycle, the water evaporates from ocean and land surface to become part of atmosphere; water vapour is transported and lifted in the atmosphere until it condenses and precipitates on the land or the oceans. Precipitated water may be intercepted by vegetation, becomes overland flow over the ground surface, infiltrate into the ground, flow through the soil as subsurface flow and discharges into streams as surface runoff. The infiltrated water may percolate deeper to recharge groundwater, later emerging as spring and seeping into

streams to form surface runoff and finally flowing into the sea or evaporating into the atmosphere as the hydrological cycle continues. Not all water reaches or passes through this phase, however, since large quantities are evaporated directly from the ground surface or through vegetation to pass through an abbreviated cycle. The water of precipitation that goes into deep underground seepage may complete the cycle by returning to the ocean by subterranean channels percolation (Morgan, 1995).

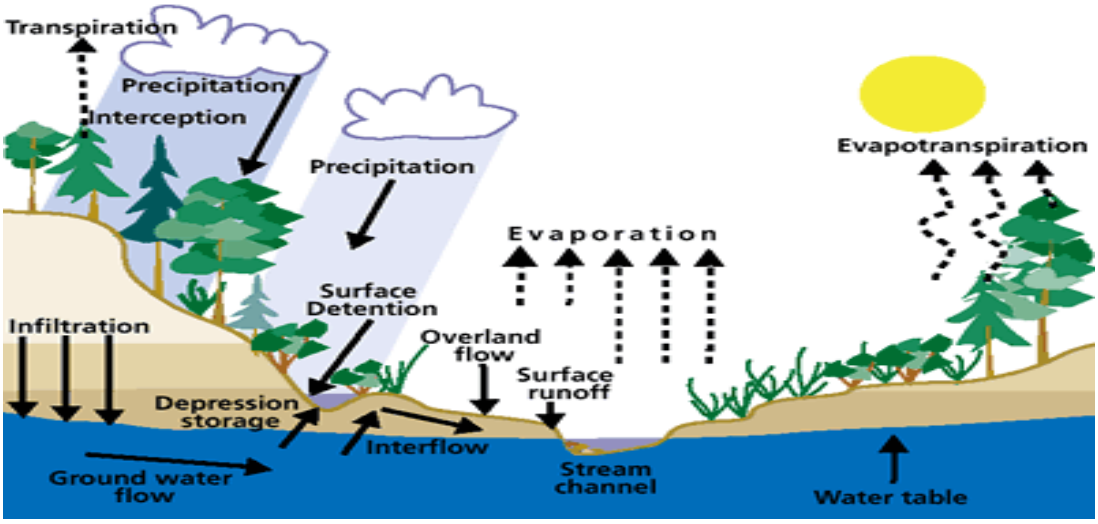


Fig: 2.1 Rainfall Runoff process in the hydrologic cycle (*mnr.gov.on.ca)*

2.6.1 Types of runoff

Suresh (2002) classified runoff based on the time delay between rainfall and runoff into three types: Surface runoff, Sub-surface runoff and Base flow.

(i) Surface Runoff. It is the portion of rainfall, which enters the stream immediately after the rainfall. It accurse when all losses are satisfied and if rain is still continued, with the rate greater than infiltration rate; at this stage the excess water makes head over the ground surface(Surface detention), which tend to move from one place to another, known as overland flow. As soon as the overland flow joins to the streams, channels of oceans, termed as surface runoff.

(ii) Sub-surface Runoff. That part of rainfall, which first leaches into the soil and moves laterally without joining water table, to streams, river or oceans, is known as sub-surface runoff or as interflow.

(iii) Base or Ground water flow. It is delayed flow, defined as that part of rainfall, which after falling on the ground surface, infiltrated into the soil and meets the water-table, and flows to streams, ocean etc. The movement in this type of runoff is very slow. It takes longer time to join the rivers or ocean.

2.6.2 Impact of Urbanization on Surface Runoff

Flood generation (from rainfall) is largely a matter of rainfall-runoff and therefore a hydrological problem, whereas flood propagation in a stream/river network is the concern of hydraulics (Beven, 2001). Rainfall-runoff from an urban catchment is similar, but in many respects simpler than runoff from a natural catchment. It is possible to say that urbanization is an inexorable trend. The urban population has been increasing significantly in the last two centuries, since industrial revolution took place. The consequences of this process incurs is great changes of the natural environment (Miguez, *et el.*, 2007). A notable aspect of urbanization is the increase of impervious surfaces, which include paved streets, roads, parking lots and roofs. High impervious surfaces are the common cause for high runoff volumes as the soil infiltration capacity decreases (Figure 2.2). Thus, the drainage system for

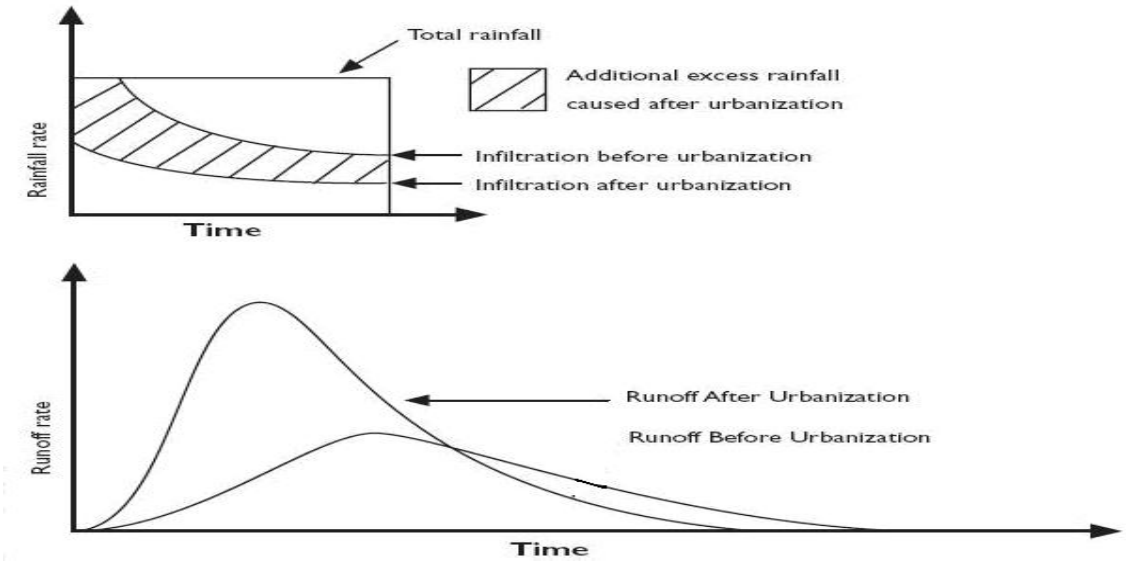


Figure 2.2: Urban hydrographs (www.uwsp.edu)

urban areas is relatively different from natural catchments whereby it is designated specifically to remove the runoff as fast as possible so that flooding can be prevented and the negative influence on transportation is minimized (Delleur, 2003 as Cited in Baharudin,2007). Undeveloped land in rural areas has very little surface runoff whereby most of the rainfall soaks into the top soil and evapotranspirates or migrate slowly through the soil mantle as interflow to the streams, lakes or estuaries.

2.7 RAINFALL RUNOFF MODELING

A rainfall-runoff model is a mathematical model describing the rainfall - runoff relations of a catchment area, drainage basin or watershed. In other words, the model calculates the conversion of rainfall into runoff (Bhola and Singh, 2010). As the computing capabilities are increasing, the use of these models to simulate a catchment became a standard. Models are generally used as utility in various areas of water resource development, in assessing the available resources, in studying the impact of human interference in an area such as land use change, deforestation and other hydraulic structure such as dams and reservoirs.

Up to 90% of the annual precipitation may become surface runoff in high density urban environments (Centre for Watershed Protection, 2003). It is well known that development alters watershed hydrology: as land becomes covered with surfaces impervious to rain, water is redirected from groundwater recharge and evapotranspiration to storm water runoff, and as the area of impervious cover increases, so does the volume and rate of runoff (Schueler 1994, Corbett, Whal, Porter and Edwards, 1997).Flooding induced by storm events is a major concern in many regions of the world (Horritt and Bates, 2002; Hudson and Colditz, 2003).

Nowadays, modelling has become a common practice in every field of endeavour, and runoff modelling is no exception (Donigian, *et el* 1995). The main reason behind the using of modelling in general is the limitations of the techniques used in measuring and observing the various components of hydrological systems (Beven, 2001). Also using hydrologic models will increase our understanding and explanation of the natural phenomena and its dynamic interactions with the surrounding systems (i.e.climatic terrestrial, pedologic, lithologic and hydrologic systems) (Chiew, and McMahon, 1994; Karvonen, *et el.*, 1999). However, under some conditions predictions can be made in deterministic or probabilistic sense. Another use of modelling is to predict how the system will respond to the future alternative conditions and actions (Donigian *et al.*, 1995). Linsley (1982) summarized the principal purposes for which hydrological model have or can be employed. In general they can be used for hydrologic research purposes, for forecasting and prediction of stream flow, and for engineering and statistical applications (record extension, operational simulation, data fill-in, and data revision).The response of hydrological systems can be predicted by simulation models (Refsgaard, 1997). Recently, modelling seems to be the only resort to address complex environmental and water resources problems (Singh, 1995).

World Meteorological Organization (WMO, 1993) defined a model in general as "a representation in any form of an object, a process or a system. In hydrology, a model is in most cases a mathematical representation of a basin, a water system, a series of data, etc." Also the model simply relates something unknown (the output) to something known (the input). Hydrological models, in general, represent the hydrologic cycle or one or more of its various components runoff, evapotranspiration, infiltration, interception etc (Thiemann, *et. al.*, 2001). In runoff modelling, the known input is rainfall and the unknown output is runoff characteristics (peak discharge, volume, time to peak, etc.) and the watershed is the system being modelled. Rainfall-Runoff modelling covers a wide range of applications and practices. This can be divided into two main groups, these are: flood studies (planning and designing new hydraulic structure, operating and/or evaluating existing hydraulic structures, preparing for and responding to flood, flood damage reduction, and regulating flood plain activities), and storage studies (catchment and reservoir yield analysis, and water resource potential) (Blandford and Meadows, 1990; Chiew and McMahon, 1994; Connolly and Silburn, 1995).

Mathematical models have been applied for decades to obtain solution for problems in many domains of water management (Scholten, 2007). Integrated Water Resources Management deals with complex problems involving technological, environmental, economical and societal aspects .Resource managers can use model to develop a conceptual understanding of complex natural systems, predict outcomes of high risk and high cost environmental investments, and set their priorities properly. For model to be useful in water planning and management it should be applicable in spite of limited availability of data, and able to produce results that are acceptable in relation to observed conditions (Olsson and Anderson, 2006). The results from modelling are

subjective and when used to predict impacts of various scenarios, the result cannot be validated until long after decision based on them have been carried out (Irwing, 1995, as cited in Olsson and Anderson,2006).

2.8 RUNOFF MODEL CLASSIFICATION

Runoff model can broadly be classified into two classes: lumped or distributed; and deterministic or stochastic models (Beven, 2000; Ward and Robinson, 1990). Lumped modelling approaches consider a catchment to be a one unit and a single average value representing the entire catchment is used for the variables in the model. The predictions obtained from such model are single values (Beven, 2000). In the distributed modelling approach, models make predictions that are distributed. The spatial variability of model variable are simulated by grid element (grid cells), that can either be uniform or non uniform (Rientjes,2004).Not only one average value over the entire catchment is considered but values of parameter that vary spatially are locally averaged within each grid elements. Model equations are solved for each element or grid square and depending on the spatial variability of a certain parameter different values are used for each grid elements (ibid). Such type of model makes prediction that are distributed in space allowing to assess the effect of changes in the catchment (land use/land cover) on the rate at which runoff is generated (Beven,2000).

Stochastic model (also known as probabilistic models) considers the chance of a hydrological variable occurring (Ward and Robinson, 1990). Both the input and output variable stochastic runoff models are expressed in terms of a probability density distribution. In stochastic modelling approach, uncertainty or randomness in the possible outcome of the model is permitted because of the uncertainty that is introduced by the input variable of the model (Beven, 2000; Rientjes, 2004). Deterministic model on the other hand focus on the simulation of the physical processes involved in the

transition from precipitation to runoff. Most runoff model use the deterministic approach in simulating the process of runoff. In this case, only one set of value per variable are input into the model and the outcome is also one set of values. At any time step, the expected outcome from a deterministic modelling approach is single values (Ward and Robinson, 1990; Beven, 2000; Rientjes, 2004,). Deterministic models can further be divided into black box, conceptual and physical based runoff modelling approach (Rientjes, 2004).

2.8.1 Empirical / Black-Box Models

Black-box models describe mathematically the relation between input (precipitation) and output (runoff) without describing the physical process by which they are related, and establish a statistical correspondence between input and output. These models are often successful within the range of data being available/collected and analyzed from a region. The reason is that the mathematical structure carries with it an implicit representation of the underlying physical system. Beyond the range of analyzed data, the prediction depends only on mathematics, since the physical significance is lost (Gosain and Mani, 2009).

The U.S soil conservation Curve Number method is another simple empirical method for estimating the amount of rainwater available for runoff in a catchment (USDA, 1986). The method was developed by the U.S Department of agriculture and Natural resources through the analysis of runoff volumes from small catchment in the US. The initial abstraction values determined by the curve number were developed for different soil types and land use practices (ibid). The main assumption of the curve number approach is that the ratio of the actual runoff to the potential runoff (Rainfall minus an initial abstraction) is equal to the ratio of the actual

retention to potential retention. This assumption has no physical basis making the approach entirely empirical base (Beven, 2000). The advantage of this approach is that it is not data demanding and very simple to use. Its prediction can be useful in identifying weather problem exist (Deursen, 1995). However very little quantitative information is available on how curve number values were developed and their application to conditions for which they were not developed may lead to questionable results. Furthermore, the lumped system does not identify what part of the infiltration is lost (ibid).

2.8.2 Physically Based Models

Physically based models are based on the best available understanding of the physics of hydrological processes. These models are thus characterized by parameters that are, in principle, measurable and have a direct physical significance (Wheater, 2005). They require intensive data in addition to the extensive computational time. Hence, such models are very costly to develop and operate (Liddament *et al.*, 1981). They are based on a continuum representation of catchment processes. These models are distributed because of the non-linear partial differential equations that describe the hydrologic processes. It has been noted that analytical solutions are generally not available to solve the equations, thus the equations of motion of the constituent processes are solved numerically using finite-difference methods (Freeze and Harlan, 1969) and finite-element methods (Beven, 1977; Ross et al., 1979). These models offer the ability to simulate the complete runoff cycle and the effect of catchment changes. They offer the internal view of the process, which enables an improved understanding of the hydrologic system. Each process of the hydrological cycle has been modelled either by the finite-difference representations or by empirical equations derived from independent experimental research (Gosain and Mani, 2009).

Physically based models can be applied to ungauged catchments, and the effects of catchment change can be explicitly represented. Two fundamental problems arise with such models; the underlying physics has been derived from small-scale (mainly laboratory-based) laws and process observations. Hence, the processes may not apply under field conditions and at field scales of interest. Although the parameters may be measurable at a small scale, they may not be at the scale of interest for application. Most of the complexity of physically based models arises from the representation of subsurface-flows and the inherent lack of their observability.

2.8.3 Conceptual Models

Conceptual models are the most common class of the hydrological models in general application. These models incorporate the hydrological processes in the form of a conceptual representation (Wheater, 2005). They serve as a trade-off between the physically based approach and black-box approach. They are formulated by a number of conceptual elements, each of which is a simplified representation of one process element of the system being modelled. Each element of the model is generally described by a (non-linear) reservoir. The basic advantage of this form of modelling is that it reflects the thresholds present in hydrological systems, which otherwise cannot be adequately incorporated in a linear model (Gosain and Mani, 2009).

This class of models is characterized by parameters that usually have no direct, physically measurable identity and thus need to be optimized. More so the information content of the data on which the parameters are calibrated is limited (Kleissen *et al.,* 1990). Parameters are non-identifiable, which leads to the problem of equifinality (Beven, 1993): for a given model, many combinations of parameter values may give a similar performance; this has given rise to the following limitation: .if the parameters cannot be uniquely identified, then they cannot be linked to catchment

characteristics. On the other hand, conceptual models cannot be applied for to ungauged catchments, as there are no data to calibrate the models. Finally, it is difficult to represent catchment changes if the physical significance of parameters is uncertain (Wheater, 2005).

2.9 SOIL CONSERVATION SERVICE (SCS) MODEL

The most simple rainfall-runoff models for small Catchment are the Rational Method (Lloyd-Davies, 1906) and the SCS-method (USDA-SCS, 1986). The Rational Method is often applied in urban areas, and the SCS-method in sub-urban and rural areas (Dingman, 2002). For this reason, the SCS method has been applied to simulate the rainfall-runoff processes in the Mararaba Sub-urban catchments. The SCS curve number method (SCS, 1972), also known as the Hydrologic Soil Cover Complex Method was developed by the Soil Conservation Service (SCS) of the U.S. Department of Agriculture for use in rural areas. It is a versatile and widely used procedure for runoff estimation. The model computes direct runoff through an empirical equation that requires rainfall (antecedent soil moisture condition, land cover and the curve number (CN), which represents the runoff potential of the land cover soil complex (SCS, 1972). The CN is a dimensionless parameter and its value ranges from 1 (minimum runoff) to 100 (maximum runoff). Since, standard table for CN values (ranges from 1 to 100), considering land use/cover and HSG are given for AMC-II (Vandersypen et al. 1972).

The SCS-CN method is based on the water balance equation and two fundamental hypotheses. The first hypothesis equates the ratio of the amount of direct surface runoff Q to the total rainfall P (or maximum potential surface to the runoff) with the ratio of the amount of infiltration Fc amount of the potential maximum retention S. The second to the potential hypothesis relates the initial abstraction Ia maximum

retention. Thus, the SCS-CN method consisted of the following equations (Subramanya, 2008).

(a) Water balance equation:

$$P = Ia + Fc + Q \quad (1)$$

Proportional equality hypothesis:

$$\frac{Q}{(P-Ia)} = \frac{F}{S} \quad (2)$$

(b) Ia - S hypothesis:

$$I_a = \Lambda s \quad (3)$$

Where ,P(mm) is the total rainfall, Ia the initial abstraction, Fc the cumulative infiltration excluding Ia, Q(mm) the direct runoff, S(mm) the potential maximum retention or infiltration and λ the regional parameter dependent on geologic and climatic factors $(0.1<\lambda<0.3)$. Solving equation (2)

$$Q = \frac{(P-Ia)\,2}{P-Ia+S} \quad (4)$$

$$Q = \frac{(P-\lambda S)}{2P-\lambda-1\ S} \quad (5)$$

The relation between Ia and S was developed by analyzing the rainfall and runoff data from experimental small watersheds and is expressed as Ia=0.2S. Combining the water balance equation (1) and proportional equality hypothesis (2), the SCS-CN method is represented as

$$Q = \frac{(P-0.2S)\,2}{P+0.8S} \quad (6)$$

the potential maximum retention storage S of watershed is related to a CN, which is a function of land use, land treatments, soil type and antecedent moisture condition of watershed. The CN is dimensionless and its value varies from 0 to 100.The S-value in mm can be obtained from CN by using the relationship.

$$S = \frac{25400}{CN} - 254 \quad (7)$$

2.9.1 Soils

In determining the CN, the hydrological classification is adapted. Here soils are classified into four classes A, B, C and D based on the infiltration and other characteristics. The important soil characteristics that influence the hydrological classification of soils are effective depth of soil, average clay content, infiltration characteristics and the permeability (Bhola and Singh, 2010). Following is a brief description of four hydrologic soil groups:

i. **Group A (Low runoff potential):** Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sand or gravels. These soils have high rate of water transmission.

ii. **Group B (Moderately low runoff potential):** Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soil with moderately fine to moderately coarse textures. These soils have moderate rate of water transmission.

iii. **Group C (Moderately high runoff potential):** Soils having low infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soil with moderately fine to moderately coarse textures. These soils have moderate rate of water transmission.

iv. **Group D (High runoff potential):** Soils having low infiltration rates when thoroughly wetted and consisting chiefly of clay soils with high swelling potential, soil with permanent high water table, soils with clay pan or clay layer at or near the surface and shallow soils over nearly impervious material.

2.9.2 Antecedent Moisture Condition (AMC)

According to SCS (1972) AMC refers to the total cumulative rainfall during the 5 days immediately preceding the rainfall event. The AMC is used as index of wetness in a particular area. Three levels are used (Table3.3): AMC- I: Lowest runoff potential. The soils are dry enough for satisfactory cultivation (rainfall < 36 mm), AMC- II: Average condition (rainfall between 36 to 53 mm) AMC- III: Highest runoff potential. The area is practically saturated from antecedent rains (rainfall > 53 mm).

Table 3.3 Antecedent moisture condition (AMC) for determining the CN

	Total rain in Previous 5 days

AMC Type	Dormant season	Growing season
(I)	Less than 13mm	Less than 36mm
(II)	13 to 28mm	36-53mm
(III)	More than 28 mm	More than 53mm

(Source; Adapted from Bhola and Singh, 2010).

The following conversion formulas were used to convert CN from AMC-II (average condition) to the AMC-I (dry condition) and AMC-III (wet condition) (SCS, 1972).

For dry condition (AMC-I):

$$CN\ (AMC\ I) = \frac{4.2 * CN\ (AMC\ II)}{(10 - 0.058 * CN\ (AMC\ II)} \quad (8)$$

For wet conditions (AMC-III):

$$CN\ (AMC\ III) = \frac{23 * CN\ (AMC\ II)}{(10 - 0.13 * CN\ (AMC\ II)} \quad (9)$$

2.10 FLOOD RISK MANAGEMENT

"'Flood risk' means the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event" (European Parliament Council,2007). According to Ologunorisa and Abawua, (2005), flood risk is a product of hazard and vulnerability and a real risk level involves a certain level of hazard and vulnerability for a particular location. Flood risk management plans involve three phases including: preparedness, prevention and the mitigation phases (European

Parliament Council, 2007). The three stages in flood risk management are very essential for policy makers both at the national and international levels, as well as those responsible for making decisions at the state and local levels, relief and non-governmental organizations, consultants and producers (such as farmers) suppliers and traders (Jeyaseelan, 1999). The preparedness phase would involve activities such as predicting and identification of zones or areas that have high risk and mapping of these vulnerable areas long before the flooding event occurs. The prevention phase would involve activities such as forecasting, early warning, observation and monitoring, and putting in place contingency plans in case of an eventuality. The final stage is the mitigation and response/reaction phase that handles activities after the disaster and this phase includes damage assessment and relief management (Ishaya *et al*., 2009).

Flood mitigation can be effective when areas vulnerable to flooding are identified and measures are put in place for preparedness, effective prevention and response. Identification of flood risk areas is of utmost important for policy planners and decision makers especially for management activities (Yahaya *et al*., 2010).Such information are required by government and other relevant authorities for planning purposes and thus must be collated, processed and presented in a manner that can be understood by the public (Ishaya *et al*., 2009). Detailed knowledge about the issues such as rainfall distribution, demography of area, vulnerability of people, built-up areas, economic activities, frequency and magnitude of hazards in a potentially hazardous area is necessary for effective mitigation (Van Westen and Hofstee, 2001). Scientific methods can be applied to this information to develop measures that would be useful in flood risk management. In the developed world, these measures are already in their implementation phase as is seen in the European Parliament Council (2007) but in Nigeria, management of floods is still in its policy level (FME, 2009).

2.11 APPLICATION OF REMOTE SENSING AND GIS IN FLOOD ANALYSIS

Remote sensing is a useful tool to rapidly acquire land surface information over large scale area and the derived data such as DEM and LULC which can be used as input for hydrologic models, the geographic information systems (GIS) provides a platform for simulation of hydrologic models (Gambolati, 2002; Knebl, 2005). In fact one of the best possible approaches for identifying flood prone area is to use spatial analysis tools available in Geographic information system (GIS). GIS analysis is developed to examine spatial and temporal pattern to find association between various geographical factors(Mitchell,1999; Lagason,2000), since flooding is a spatial phenomenon and is a consequence of a number of factors (including soil type, vegetation cover and type, rainfall intensity, rain frequency, built up areas etc).GIS will allow the user to handle , manage and analyze the spatial data set to determine which factor have what effect and to foresee the resulting consequence (Lagason, 2008). In addition, GIS has the ability to carry out temporal analysis, which is essential for flood, soil types, river channel size etc. It is possible to create a model of peak flow, discharge and runoff. In term of impact of land use/cover changes as well as indentifying the trend, both visually and statistically, resulting from land use changes and flooded areas (ibid).

Several researchers have examined the issue of flooding particularly with the utilization of Remote Sensing and Geographic Information System (GIS). Okoduwa (1999) applied Geographic Information System (GIS) in the prediction of urban flooding in Benin City, Nigeria. This was achieved by creating a digital database of selected variables such as land use, land cover and soil strength. The software used was Arcview 3.1 and the overlay technique in GIS was used for analysis. The result of the analysis showed high flood prone areas, medium flood prone areas and low flood prone

areas. Ishaya *et al.*, (2009) exploited the use of remote sensing and GIS tool to created digital terrain maps and flood vulnerability maps of Gwagwalada in Abuja showing the areas that were highly vulnerable, vulnerable, less vulnerable and free from flood hazard. The results obtained from their study shows that, areas lying along the banks of River Usuma are most vulnerable to flood hazards with the vulnerability decreasing towards the northern part of the town.

Jeb and Aggarwal (2008) in their studies aimed at flood inundation hazard modeling of the River Kaduna used Gumbel's Extreme value distribution statistical method of analyzing flood data and GIS to estimate the extent of flood inundation for different return period. The result of their study showed mapped areas (Ungwan Guza, Kawo new extension, Ungwan Dosa, Badarawa, Malali e.t.c) along River Kaduna that falls under areas prone to threat of sever flood for different return period. Similar studies by Ndabula, *et al* (2012) focused on urban flood plain encroachment of Kaduna metropolis used GIS operation to digitizing the topo map of the study area in polygon shape file and overlaying it with the digital elevation map (DEM) of their study area to delineate flood plain boundary. The result of their study showed that the highest extent and rate of encroachment that was recorded by communities in the proximity of the Central business district (CBD) such as T/Wada, Ungwan Rimi , Barnawa etc.

Ologunorisa and Abawau (2005) in their review on flood risk assessment concluded that meteorological techniques especially those involving rainfall parameter; hydrological parameters involving the use of runoff data; socio-economic factors, and a combination of hydro-meteorological parameters and socio-economic factors, and those based on the application of Geographical Information System (GIS) are all methods of flood assessment. They however observed that the GIS techniques is the most recent

and holds a lot of promises as it is capable of combining all the known techniques and parameters of predicting flood hazard. In this regard, it is to be adapted for the analysis of rainfall induced floods in the study area.

CHAPTER THREE: THE STUDY AREA AND METHODOLOGY

3. 1 INTRODUCTION

The description of the study area is presented and the methodology of the research is explained thoroughly in this chapter. A flow chart is presented to summarize the research activities. Data such as rainfall, Satellites imagery and digital maps were collected and analyzed thoroughly.

3.2 THE STUDY AREA

3.2.1 Location and Extent

The study area (figure 3.1 and 3.2) is located between Latitude 9°00'30"N - 9°03'00"N and Longitude 7°35'00"E -7°37'00"E in Karu L.G.A which has a common boundary with the Federal Capital Territory (FCT) Abuja to the West; Kokoma LGA and Keffi L.G.A.s to the east, Kaduna state to the north and it is bounded by Nasarawa L.G.A. to the south((Marcus and Bimbol, 2007).

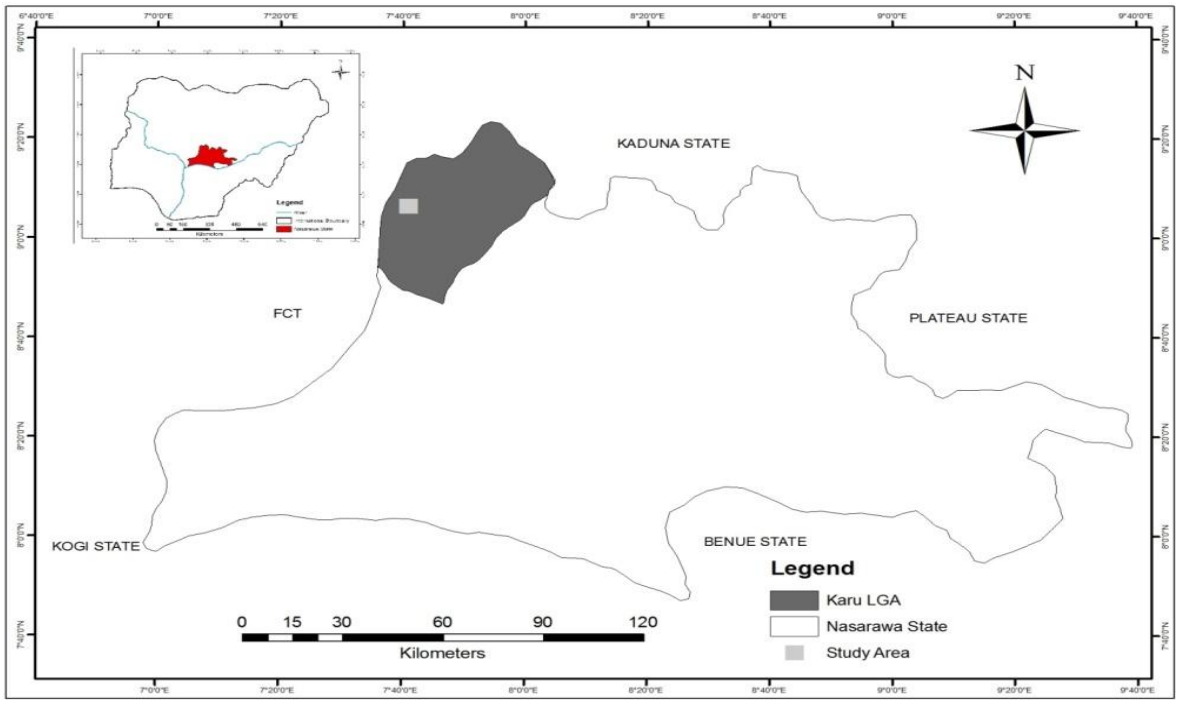


Figure: 3.1The Study Area

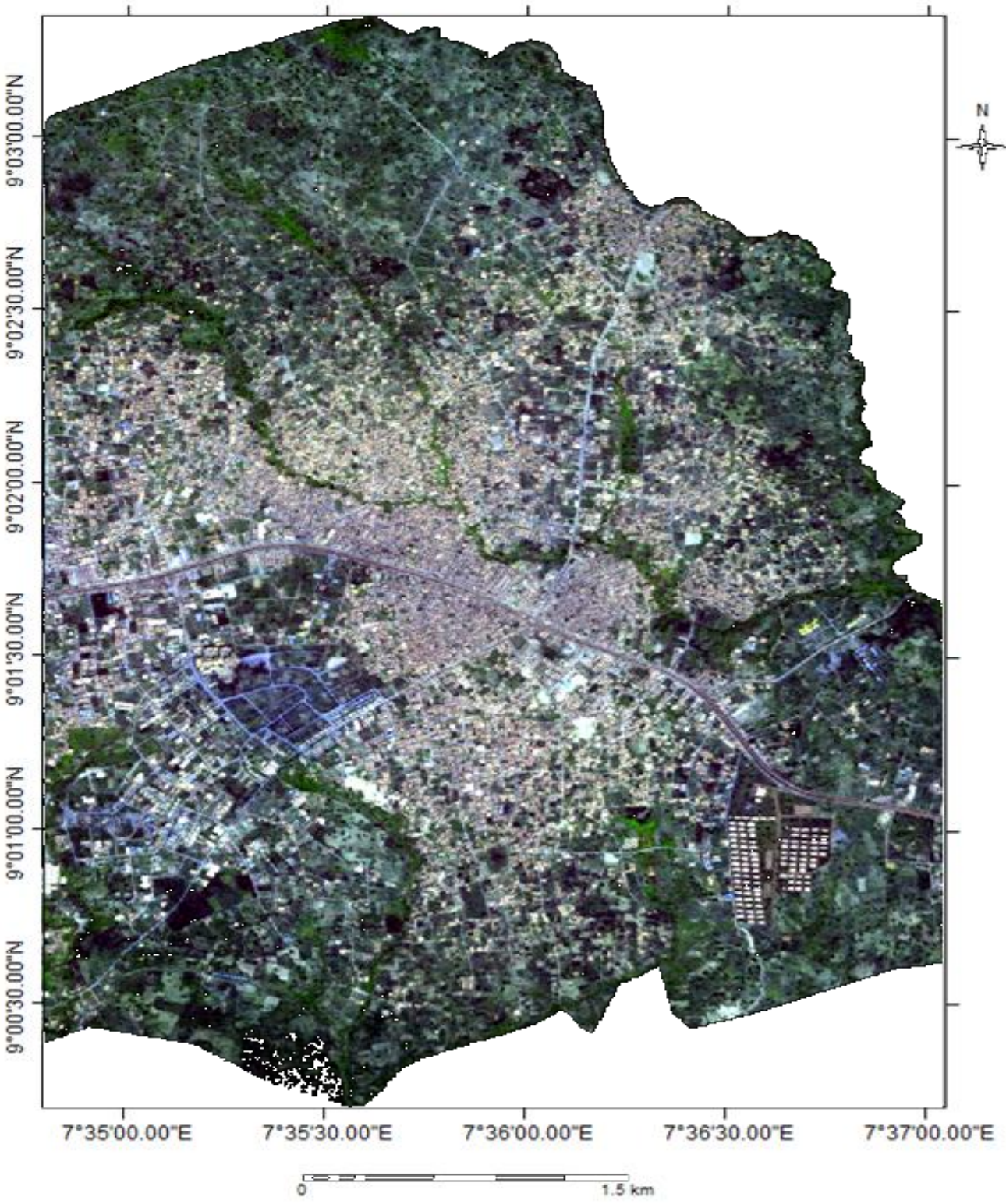


Figure 3.2 Spot 5 Image of the Study Area

(National Centre for Remote Sensing Jos, Nigeria)

3.2.2 Climate

Tropical humid climate characterized by two distinct seasons is experienced in the Karu local government area where the study area is located. The wet (rainy) season last from the ending of March and ends in October while the dry season is experienced between November and February; monthly total can vary widely, and so the annual total. Annual rainfalls range between 1100mm to about 2000mm with about 90 percent of the rainfalls between May and September (Yari *et al.*, 2001). The months with the heaviest rain are July and August. The early rains in the study area are characterized by thunderstorms and squally activities. These phenomena are also noticeable towards the cessation period of rainfall. The spatial pattern of rainfall in the area is slightly influenced by the north central highlands. The entire region represents a wet "island", disturbing the otherwise east- west alignment of the isohyets in this part of Nigeria. Such rainfall distinctiveness is as a result of the position of the land mass of the Jos Plateau and associated hill ranges in relation to the south-westerly and westerly rain-bearing prevailing winds (Binbol, 2007).

Temperature is generally high in the area during the day between the month of March and April partly because of its location in the tropical sub-humid climatic belt. There is a marked seasonal variation in temperature in the area with gradual increase in temperature from January to March. The onset of rains in April ushers in a noticeable decline in temperature due to the blanket effect of cloud cover over the region. This continues in the cessation periods by October ending when further decline is made possible in November/December by the coming of the harmattan winds. A single maximum is achieved in March when maximum temperatures can reach 39^{o}C. Minimum temperatures on the other hand can drop to as low as 17^{o}C in December and January (ibid).

3.2.3 Soil type and Vegetations

According to Samaila and Ezeaku (2007) the major soils units of Karu where the study area is located belong to the category of the tropical ferruginous soils derived mainly from the basement complex formation and older sedimentary rocks and are classified into three broad soil types. These are: Arenosols soil which consist of sandy and loamy soils; Lithosols made up of ferruginised fragments of rocks, and a variable amount of quartz gravel and stones overlying weathered rocks and Lixisols which are soils with subsurface accumulation of low activity clays and high base saturation.

The natural vegetation in Karu local government area where Mararaba sub urban area is located is Largely characterized by Northern Guinea Savannah or park Savannah with dense tropical woodland with trees, shrubs grasses, and leguminous fauna that provide dry season grazing grasses with interspersion of thicket, grassland, tree savannah, fringing woodlands or gallery forest common along major streams, valleys and pronounced depression (Illoeje, 1985). The wildlife population in the bushes of the area comprises of grass cutters, monkeys and antelopes; though the number and composition is now being threatened by mainly deforestation and hunting (Yari *et al*., 2002). The influence of relief, soil and human activities leads to variations in the general pattern of the vegetation in the area. These can be identified as natural vegetation along stream beds characterized by tropical rain forest; sparse vegetation on the slope of the hills especially on the granitite outcrops and Shrubs savannah with are less density in the tree cover and more of the grasses and shrubs where cultivation occurs (ibid).

3.2.4 Geology and Drainage

The geological feature is founded on basement complex structure that characterizes much of the country; with the major formation being a combination of different metamorphic, igneous and sedimentary rocks including alluvial deposits found mainly in the stream-beds and consisting largely of sands, gravels and clay. The soils derived from this bedrock structure are generally deep and well drained with high fertility rating and variable run-off potential, with variations mainly along the stream-beds where the soils are higher in clay content (Yari *et al.,* 2002).

The general relief of Karu urban area where Mararaba sub urban area is located is an undulating lowlands and a network of hills developed on granites, migmatites, pegmatites and gneisses. Mararaba Gurku is drained by Kabayi stream. Karu area is well endowed with enormous water resources both surface and underground and is drained by many rivers most of which originate from the North Central Plateau and have a dendritic pattern outlook because the streams and rivulets join the main rivers at oblique angles (Samaila and Binbol, 2007). Three main types of stream flow pattern have been recognized in the area:

(i) Perennial flows: low dry season discharges; flash floods superimposed on high rainy season discharges. This flow pattern occurs on the largest stream;

(ii) Seasonal flow: zero dry season flow; flash floods superimposed on rainy season flow which may be high or low depending on catchment area;

(iii) Flash flow only i.e., there is flowing water in the stream channel only during and for a short while after run-off-producing storms (Yari *et al.,* 2002).

3.2.5 Economic Activities

The Greater Karu Urban Area where Mararaba suburban is located has a well-developed banking sector, and many construction firms carrying out a large number of construction projects. It is also emerging as an industrial base. Given Karu's strategic location, it acts as a gateway for trade between Abuja and the eastern regions of Nigeria consequently; around one-third of Karu's labour force is employed in the trade and commerce industries. The agriculture, construction and manufacturing industries employ the bulk of the remaining labour force. The majority of labour is carried out in the informal sector – an issue that governing authorities would no doubt like to address (Badiane *et al.*, 2012). The growing economy and the commercialization of the Karu Urban Area have given the city a middle-income status. In fact many of the civil servants working in the Federal Capital City reside in Mararaba sub-urban area. Farming is the main occupation of the people in rural area of Mararaba , the crops produced include cassava, yam, rice, maize, guineacorn, beans, soya beans, asha and millet. (www.onlinenigeria.com/links/Links).

3.3 METHODOLOGY

The basis of this research study has been a case study of flooding in Mararaba urban catchments within Karu Local government area of Nasarawa state Nigeria. The selection criteria for the catchment have to do with the occurrence of pluvial floods within the area in recent years especially 2012.

3.3.1 Reconnaissance Survey

This was embarked upon in order to have good understanding of the study area. Field observation was undertaken to determine the land area and cover description. The fist point of call was the Mararaba Chief Palace where one Mr. Bulus Allahyayi

gave the names and detailed description of various neighbourhoods in Mararaba Suburban area .These includes:

i. Areas to the left of the express from Nyaya: Pmaptache/ Sharp corner(Crispark to Mararaba shopping center), Kabayi (areas beyond River Kabayi),Agopma (Check point to Gbagalape in the F.C.T), Bwagbaayi (Shopping Center to Federal Medical center),Korodna , Gope wi Akweyi Aba

ii. Areas to the right of Nyaya- Keffi express from Nyaya: (Check point to old Karu road) Shaebwo (old Karu road axis),Dagbadna (Jukwe boundary area), Nuwalakpe (Aunty Alice Secondary school axis) and Juwa (Overhead bridge across Nyaya - Keffi express to Karu International market.

3.3.2 Types and Sources of Data

i. Rainfall Data for the year 2012 was obtained from Nigerian Meteorology Agency Abuja.

ii. Spot 5 Satellite imagery of the study area with 5meter resolution for the year 2005 was obtained from National Centre for Remote Research (NCRS) Jos. Shuttle Radar Topographical Mission (SRTM) DEM with 90m resolution was downloaded from TPL and was used to derive slope maps.

iii. A digital map of dominant soil of Nigeria developed by Sonneveld, B.G.J.S. (1996) was obtained from National central for remote sensing and GIS Jos, Plateau state Nigeria. PDF downloadable at European Digital Archive of Soil map(EUDASM);http://eusoils.jrc.ec.europa.eu/esdbarchieve/eudasm/africa/lists/s1cng.htm

iv. Soil Conversation Service (SCS) Curve number (CN) Model Table (appendix IV).

3.3.3 Hardware and Software

i. Hardware: High speed memory digital electronic computer hardware consisting of Pentium 4 Hewlett Packard desktop and Pavilion DV6 Laptop was used for this study.

ii .Software: Erdas Imagine, ArcGis 10 and ILWIS 3.1, was used for data processing and analysis.

- Microsoft Excel was used for the computation and analysis of Rainfall Runoff.
- 3DEM189 was used for extracting SRTM DEM from Hgt format to Tiff

3.4 METHOD OF DATA ANALYSIS

The steps followed to reach the proposed goals in this study are presented in the form of a flow chart (figure.3.3).

3.4.1 Land use/ land Cover classification (LULC)

In the creation of the LU/LC map of the study area, 2005 Spot 5 Satellite image of the area has been analyzed. The digital spot 5 satellite image of the study area was sub-stetted, resample from the dominant soil map of Nigeria in ERDAS 9.2 and imported into ArcGIS environment. Remote sensing technique of visual interpretation was used to identify and digitize features in polygon form using ArcGIS trace tool into eight classes namely: Bare land, Earth Dam, Farm Land, High density area, Low density, Medium Density area, Stream, and Wet Land .Values were then assigned for different class polygons, which help in the calculation of curve numbers. These classes were then reclassified by assigning weight to each of them to produce the LULC Map of the study area. Finally, Curve number (CN) was assigned to each class of the LULC of the study area.

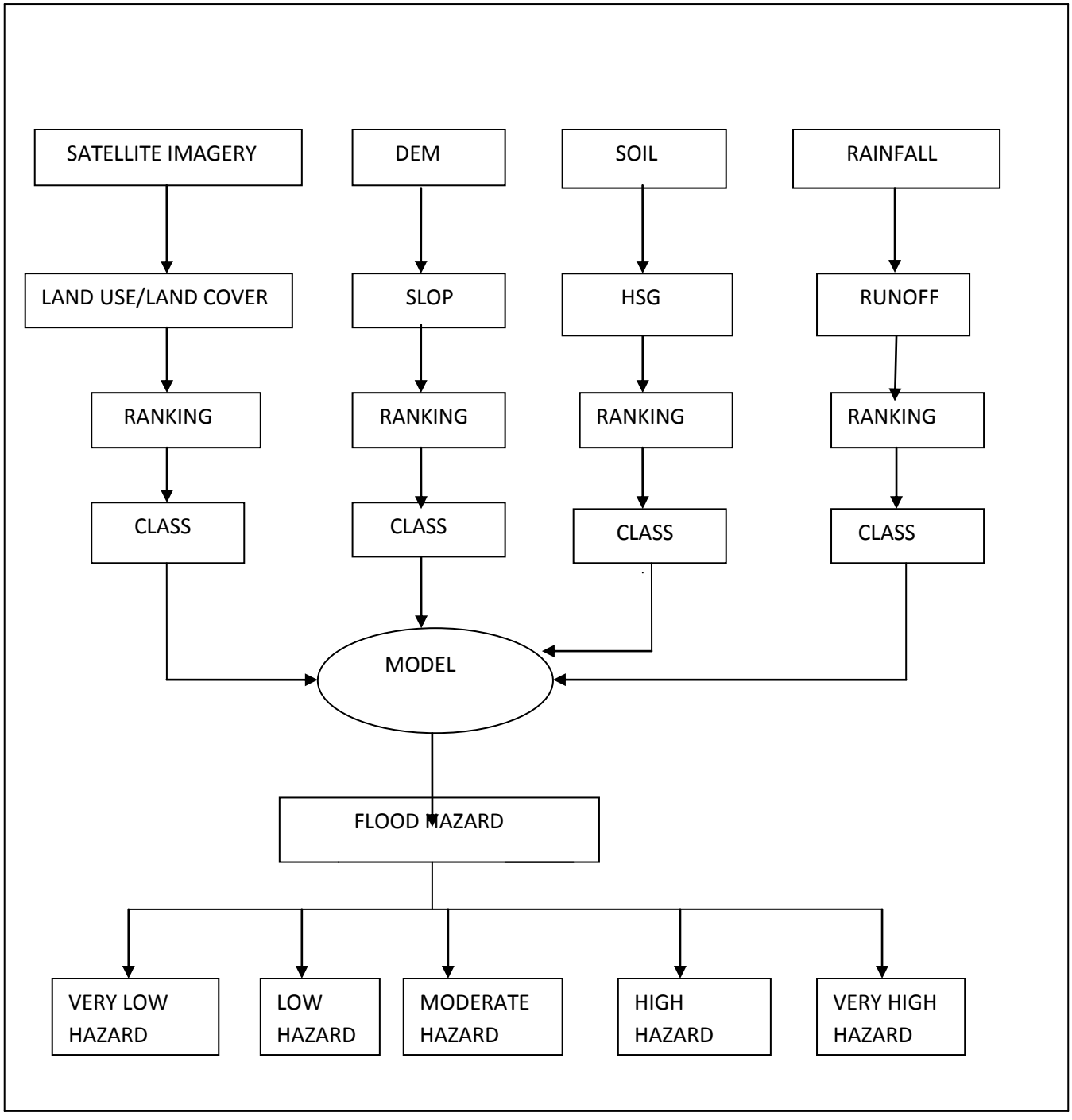


Fig 3.3 Flow Chart of the Methodology of the study

3.4.2 The Rainfall-runoff Relationships of the Study Area

3.4.2.1 Creation of Slope Map.

The slop map was prepared from a shuttle radar topographical mission (SRTM) image of the study area using ILWIS (3.1) software to generate digital elevation map (DEM). This was then used as input map in calculating the height difference as output map DX and DY in the X and Y directions of a two-dimensional matrix respectively using linear filter operation:

- DX direction>filter operation>SelectDEM as input map>liner filter dfdx
- DY direction>filter operation>Select DEM as input map>linear filter dfdy

The slop map was created by applying dfdx(dx) and dfdy(dy) filters. The following ILWIS map calculation formula (10 and 11) was used to calculate the slop map in percentages.

SLOPEPCT = 100 * HYP (DX, DY)/ PIXSIZE (DEM) (10)

SLOPEDEG = RADDEG (ATAN (SLOPEPCT/100)) (11)

The slope degree was then reclassified to topography of the map .Further reclassification by slicing the slope class into flat, very gentle, gentle, undulating and upland to create a slop map.

3.4.2.2 Generation of Hydrological Soil Map as an attribute of Soil Map

The digital copy of the soil map of Nigeria was subsetted and resample to generate a soil raster map of the study area using ERDAS Imaging. The raster image was then inport into ILWIS environment where the attribute table was created .Classes

was entered into the table to generate the hydrological soil group raster map. Finally, the attribute raster option in ILWIS operation was used to select soil raster map and Hydrological Soil group (HSG) table to generate HSG map as the output with three hydrological soil groups namely: (A) Clay loam, (B) Coarse Loam, (C) Fine loam.

3.4.2.3 Generation of Rainfall Runoff Map of the study area

ILWIS Cross operation was used to overlay landuse/landcover Map and HSG Map. Antecedent moisture conditions were computed considering the summation of last five days rainfall using Microsoft office excel spread sheet as shown in appendix (A). Daily changes in the AMC condition and its distribution due to variation in the rainfall estimate were used to modify base CN map for AMC-I and AMC-III using formulas presented in equation 10 and 11, respectively. The initial abstraction (Ia), runoff (Q)in mm was inputed manually and the model was ranked qualitatively (1-10), to produce the Rainfall runoff map.

3.4.3 Method Adapted for generating the flood Hazard map

Flood hazard mapping is a vital component for appropriate land use flood areas. It creates easily read, rapidly accessible charts and map which facilitates the identification of risk areas and prioritizes their mitigation (Bapalu and Sinha, 2005).The degree of flood hazard of a certain area is determined by a number of factors like: slope, land use land cover type, soil type and the rainfall runoff). These factors are provided in form of parameter maps. The blind weight method was used in assigning weight to each parameter map. The step for the application of the parameter map by Van Westen (1997) was adopted as follows:

Step 1: Assigning weight values to the classes of the parameter maps.

The weighting values were assigned in tables connected to the raster maps. Tables were created for each map and then a column weight values for the different classes to create factor maps (i.e LUCL map, Soil map, Slope map and Runoff map).

Step 2: Renumbering the parameter maps to weight maps. The combination of each parameter map with the weight values derived from the table created in the previous step is called renumbering. Classes Maps were changed into value maps, with weight value map.

Step 3: Combining the weight maps into one single hazard map. The weight maps were combined in this study by simply summing them up using equation (12) in the command line in ILWIS environment.

$$\text{Flood hazard} = \text{WLULC} + \text{WSlope} + \text{WSoil} + \text{WRunoff} \quad (12)$$

Step 4: Classifying the combined weight map into a final hazard map. The combined weight map was further simplified by classifying the values into five classes: Very low, low, medium, high and very high flood hazard zone. The final flood hazard map was obtained after an analysis of the flood hazard of the study area applying weights to various degree of flooding across the study area based on the slop characteristics, soil, Land Use Land Cover, and the Rainfall runoff of the study area. Flood hazard indicators are primarily knowledge base. It recognizes that the principle of assigning rank to the variable is very crucial in the entire process of hazard mapping. After the final flood hazard index was devised, it was represented in a graduated colour map using ILWIS Software.

CHAPTER FOURE: RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

This chapter presents three main results. The first result is on the created land use map and the details on the land use characteristics. The second is on the determination of rainfall – runoff –runoff relationship and its estimation. The final result involves the created flood hazard map. The results are discussed within each section throughout this chapter.

4.2 LAND USE/ LAND COVER (LU/LC) MAP.

Land use land cover maps developed for a particular region are very useful in estimating the surface characteristics and the various uses that are being carried out over the particular region. Figure 4.1 shows the percentage of LU/LC classes of the study area namely: farmland areas with the highest percentage coverage 612.31 hectares (approximately 31%); Low density is next 562.80 hectares (approximately29%); High density area is 531.12 hectares (27%), medium density area 167.88 hectares(9 %),while Earth dam is the list 1.30hectars (approximately 0.01%).Bare land area 17.00 hectares (Approximately 0.9%), wet land 29.25 hectares (approximately 2%), and stream 50.01 hectares (Approximately 3.0%)

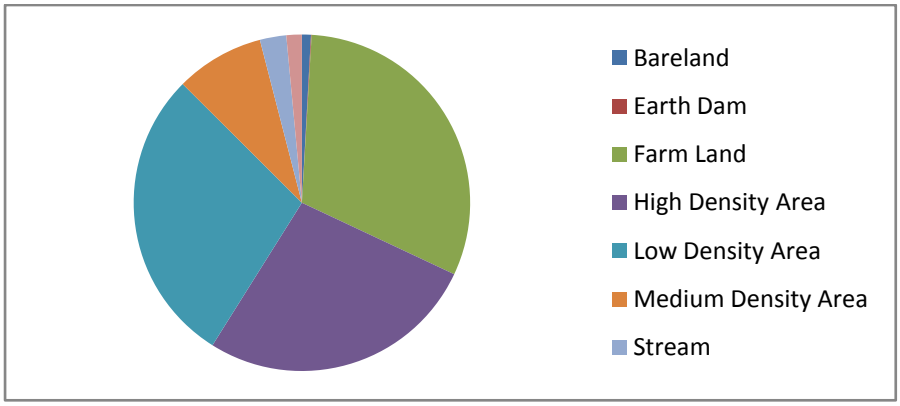
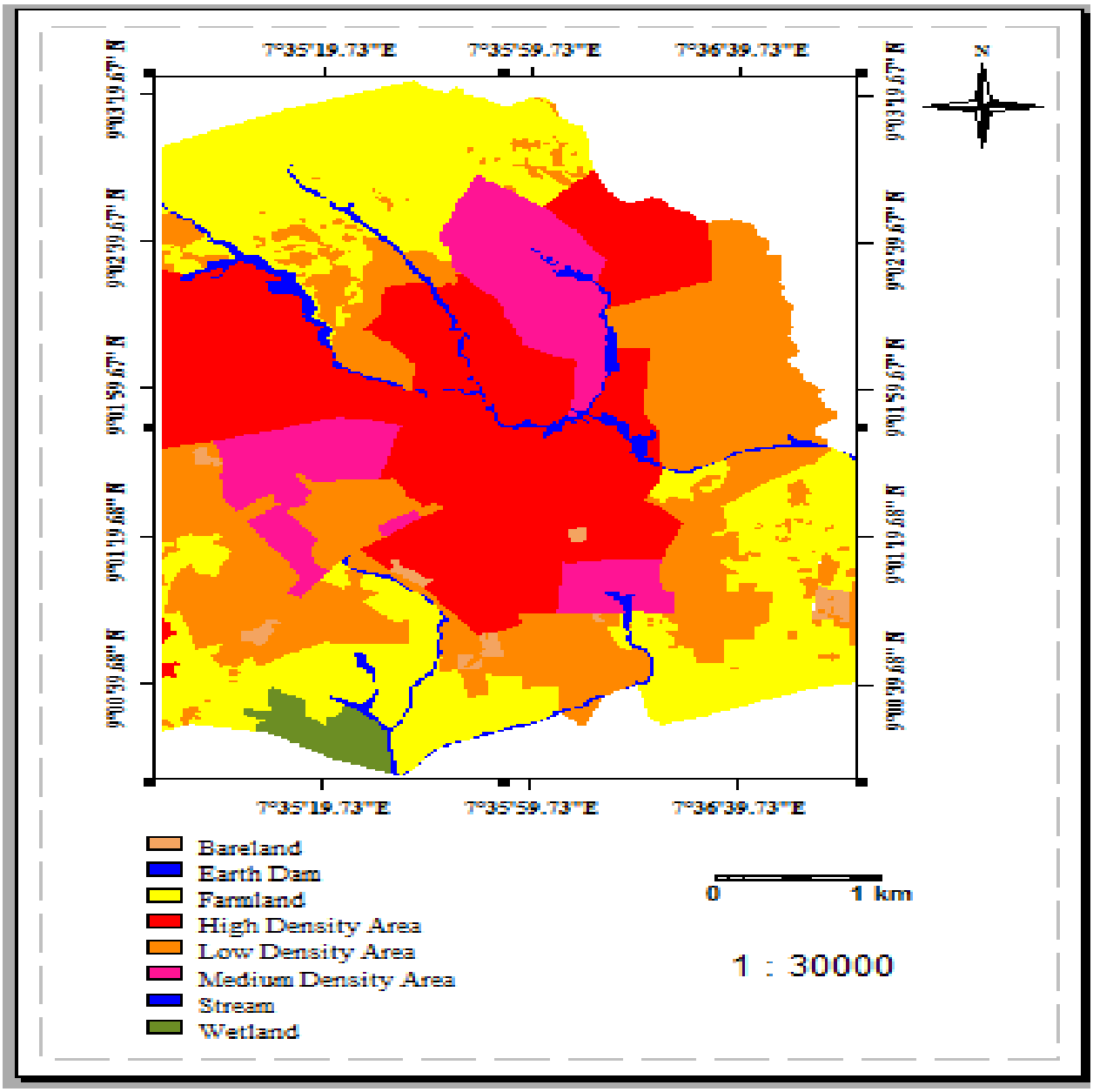


Figure 4.1 Land Use Land Cover in Percentage
Source: Authors Analysis, 2014.

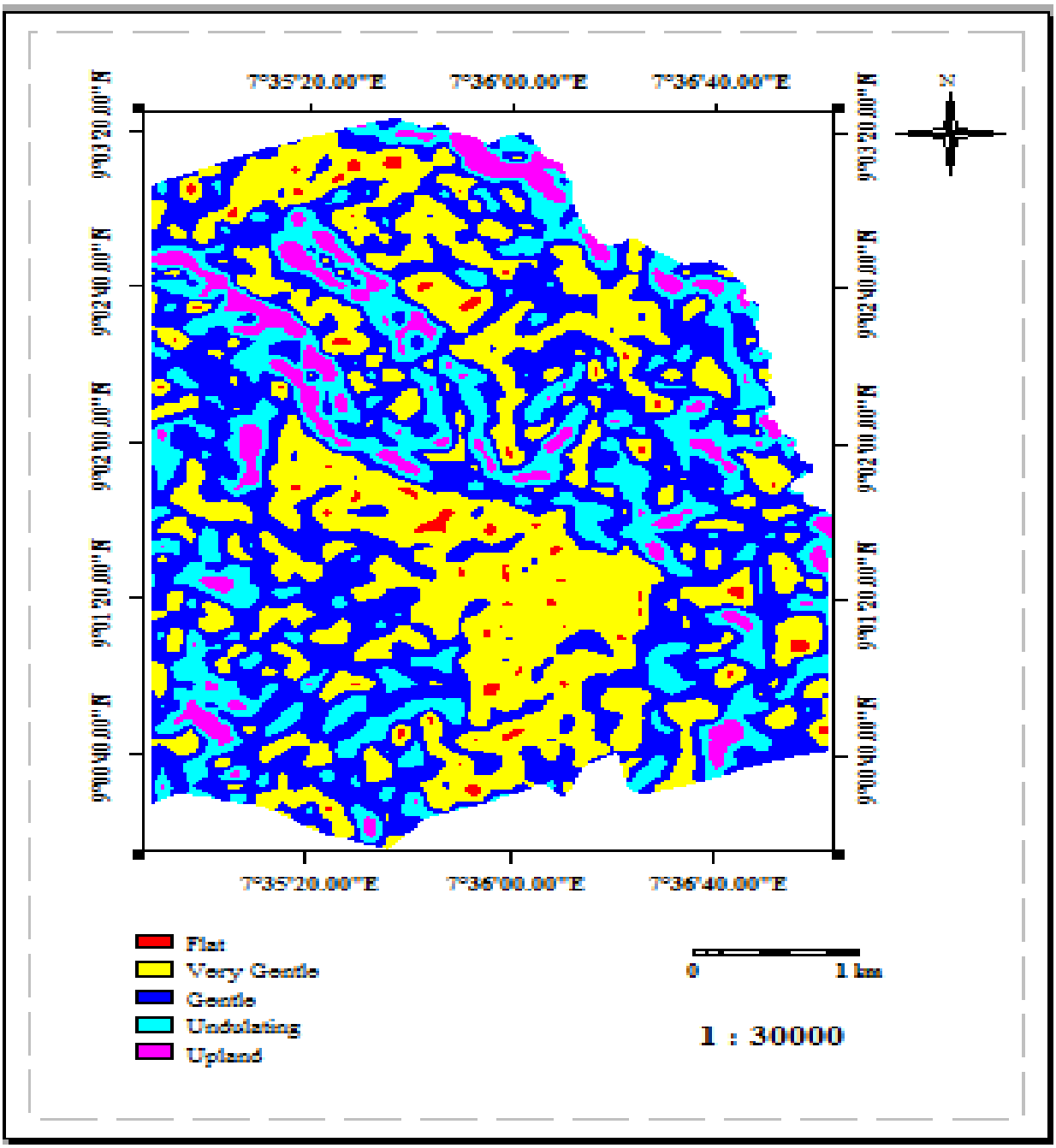
From this statistics, the study area is more of an agrarian suburban area that is gradually been urbanized. This process invariably increases or aggravates flooding by restricting where flood water can go, covering large parts of the ground with roofs, roads, and pavements, thus obstructing natural channel (Actionaide, 2006). The spatial distribution of the pattern of Land Use / Land cover in the study area is displayed as a map (figure: 4.2)



Figur 4.2 Land Use Land Cover of Study Area
Source: Authors Analysis, 2014

4.3 RAINFALL RUNOFF RELATIONSHIP

The second objective of this study was to establish the rainfall runoff relationship. Table 4.1 shows five classes of slopes that were identified in the study area namely: flat, very gentle, gentle, undulating and upland area. Spatial distribution of the slope characteristic is displayed on figure 4.3.



Figur: 4.3 Slope of the Study Area
Source: Authors' Slope Analysis July 2014

Table 4.1 Slope Class of Study Area

Value	Weight	Rank
0-0.33	1	Flat
0.33 – 1.44	3	Very Gentle
1.44-2.56	5	Gentle
2.56-3.67	8	Undulating
3.67-7.73	10	Upland

Source: Authors Slope analysis July, 2014

The result of the Soil analysis in table 4.2 shows three predominant HSG groups in the study area namely: clay loam, coarse loam and fine loam. Spatially the HSG is displayed in figure 4.4.

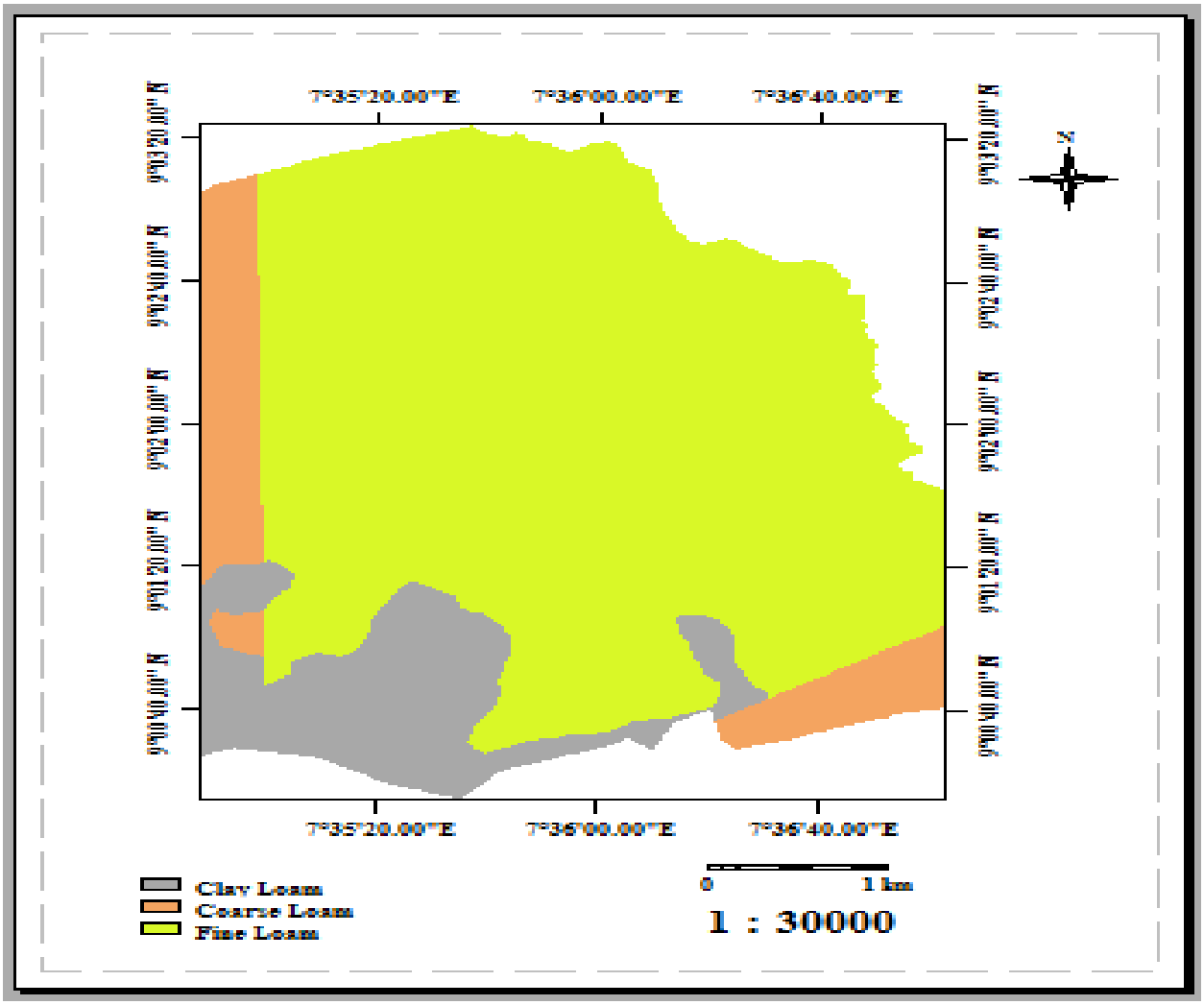


Figure 4.4: Hydrological Soil Group of the Study Area

Source: Authors' Analysis July, 2014

Table: 4.2 Hydrological Soil Group of Study Area

Class	Weight
Clay Loam	10
Coarse Loam	7
Fine Loam	4

Source: Authors' Analysis July,2014

Aggarwal et al. (2002) presented that rainfall-runoff relationship is determined using United States Department of Agriculture (USDA) SCS method. From the result of 2012 monthly rainfall data (appendix VI) analyzed, the histogram (figure 4.5) result shows that there was an early onset of rainy season in the month of February 2012 and late cessation in the month of November of the same year. This is indicative of long wet season in the year under review, a good condition for surface runoff generation, all other condition being constant. However the rainfall in the month of July had the highest rainfall amount and so was selected for computation of the 5days antecedent moisture using micro soft excel.

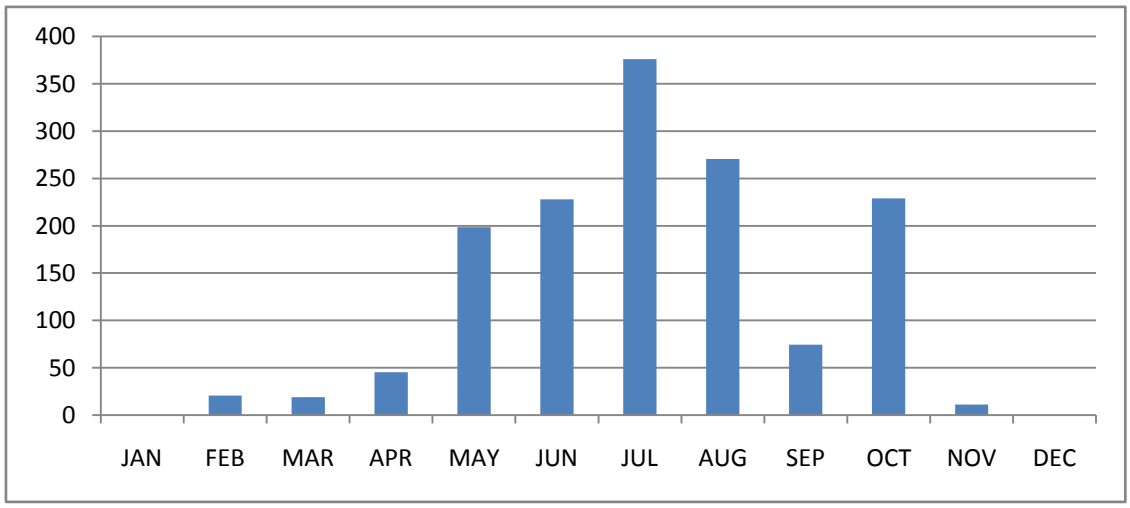


Figure 4.5 :2012 Rainfall amount of Study area
Source: Authors Analysis,2014

The SCS runoff equation (6 and 7) derived in chapter two were used to compute estimates of direct runoff

$$Q = \frac{(P - 0.2\,S)^2}{(P + 0.8\,S)} \qquad (6)$$

Where Q =accumulated direct runoff (mm)

P= accumulated rainfall or potential maximum runoff

S= potential maximum soil retention (mm)

$$S = \frac{25400}{CN} - 254 \qquad (7)$$

The result of the rainfall - runoff computation (appendix VII) for the month of July, 2012 plotted on a scatter diagram shows (figure 4.6) a second order polynomial mathematical correlation between the amount of rainfall and volume of runoff generated during the individual storms.

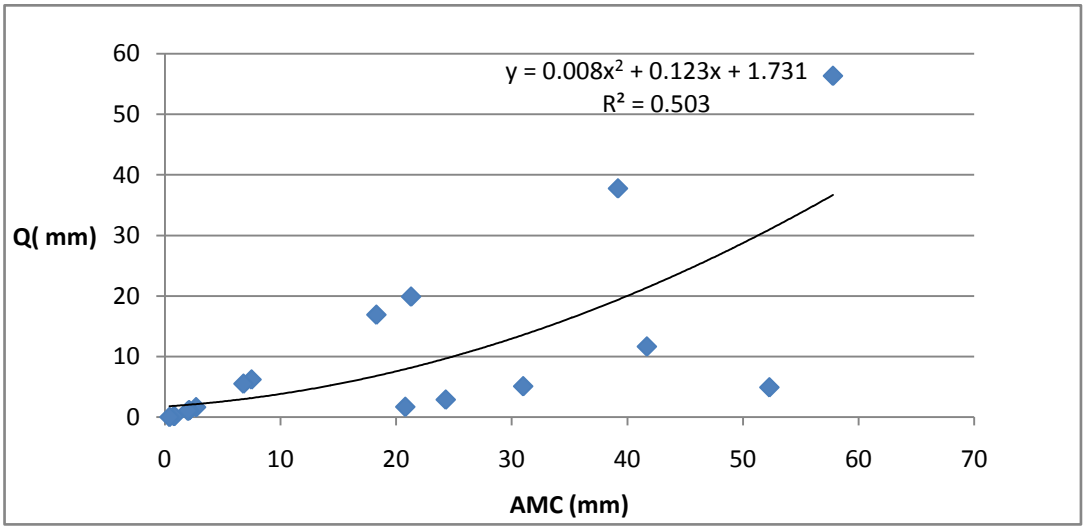


Figure 4.6: Rainfall–Runoff relationship of the study area
(Source: Authors Analysis, 2014).

Using the derived equation from Figure (4.6) equation (12) was used to calculate Rainfall- runoff estimates as shown in table 4.2 for the months of April to October, 2012.

$$Y=0.008x^2+0.123x+1.731 \quad (12)$$

Table: 4.3. Percentages of Monthly Estimated Rainfall-Runoff of the study area

Months	AMC(mm)	Runoff (mm)	% Runoff
April	45.2	25.52	3.07
May	184.9	86.28	10.38
June	228	125.00	15.04
July	331.9	174.21	20.96
August	270.5	135.11	16.25
September	274.4	139.09	16.73
October	278.9	146.05	17.57
Total	1613.8	831.24	100

Source: Authors Analysis July, 2014

Results from the estimated monthly rainfall-runoff data (Table 4.3), shows that the month of April and May recorded lower runoff of 25.52mm (3.07%) and 86.28mm (10.38%) respectively. The reason is not farfetched as this period is more or less the onset of the rainy season and as such the rainfall amount precipitated was not enough to satisfy the antecedent moisture condition (other conditions being constant) to generated high runoff as it were. Higher runoffs were generated for other months especially in the month of July when it peaked at 174.21mm (20.96%). This substantiates the reported flood incident that occurred on 14th of July 2012 as seen in appendix I and II. The cumulative rainfall- runoff generated for the seven months analyzed is 831.24mm.Table 4.4 shows five classes of rainfall runoff identified in the study area. The spatial result of the rainfall runoff generated over the study area (Figure 4.7) shows that very high runoff are limited to

the gully areas, Streams and lake, while high runoff areas were generated in the high density areas which according to TR 55 Curve number table (appendix IX) constitute about 65% impervious area (i.e. areas around Sharp corner, Building material market, Royal dream hotel junction, Aso bridge junction, Kabayi, Nuwalakpe and Nyaya- Keffi Expressway.

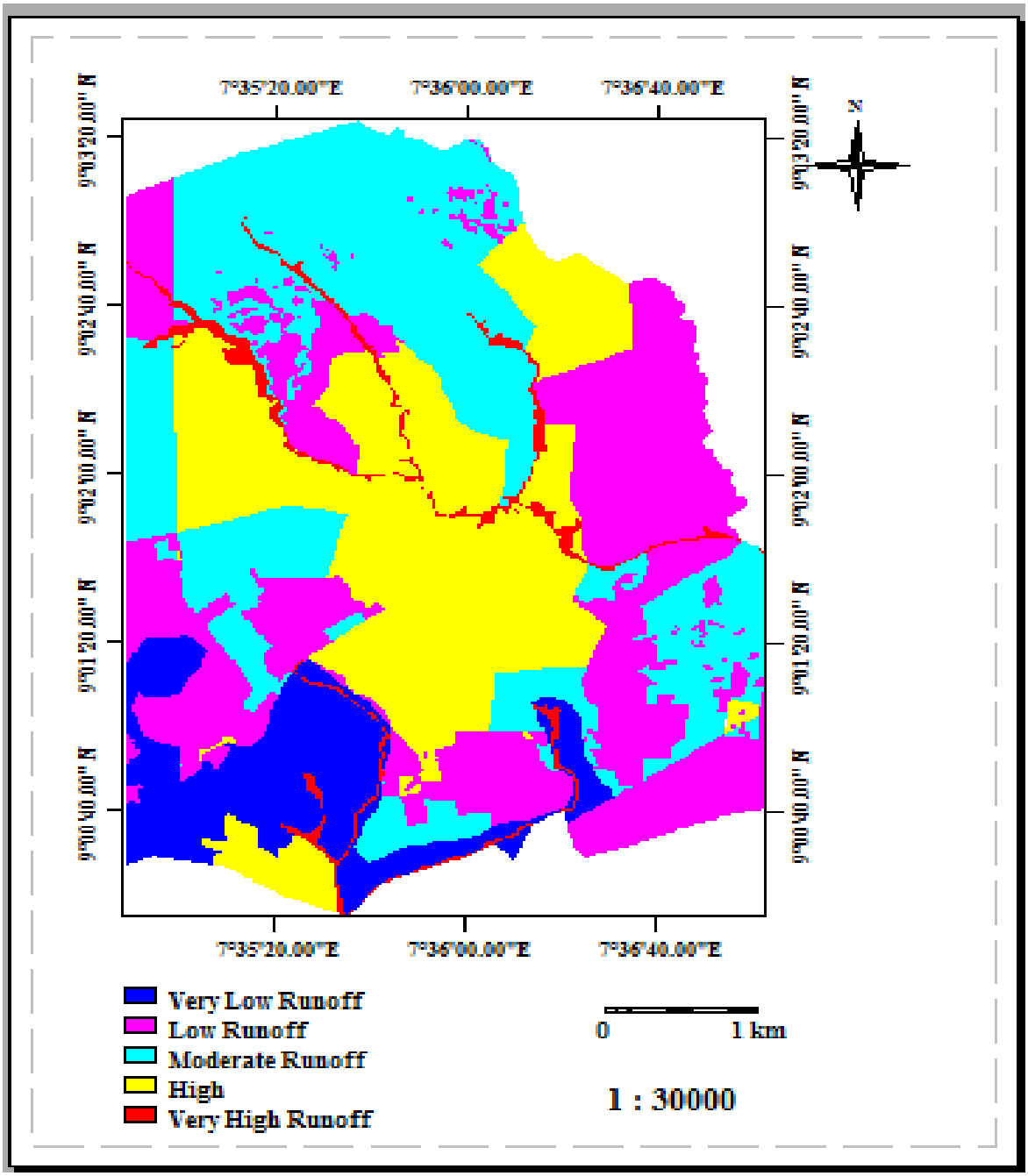


Figure 4.7: Rainfall-Runoff of the Study Area

Source: Authors Run off Analysis, 2014

Table 4.4: Rainfall-Runoff Class of the Study Area

Theme	Weight	Ranking
0-4	1	Very Low Runoff
4-10	3	Low Runoff
10-30	6	Moderate Runoff
30-45	8	High Runoff
45-60	10	Very High Runoff

Source: Authors Runoff Analysis, 2014

The Medium density area which is made up of about 38% impervious areas (TR 55 Curve number table) which are more like the extension of the high density areas because of population pressure. The very low and Low runoff is generated around the areas along Karu / Jokwai axis.

4.4. FLOOD HAZARD OF THE STUDY AREA.

Flood hazard mapping is a vital component for appropriate land use in flood areas. It creates easily read, rapidly accessible charts and maps (Bapalu and Sinha, 2005) which facilitates the identification of hazard areas and prioritizes their mitigation effects.

Table: 4.5 Flood Hazard Intensity of the Study Area

Theme	Weight	Rank
0-10	1	Very
10-15	5	Low
15-25	7	Moderate
25-30	8	High
30-40	10	Very High

Source: Authors Hazard Analysis July, 2014

The flood hazard result (Figure 4.8 and 4.9) showed that the hazard in the study area is more concentrated within the urban built up area. Five classes of flood hazard were identified: Very Low, Low, moderate, high and very high flood hazard.

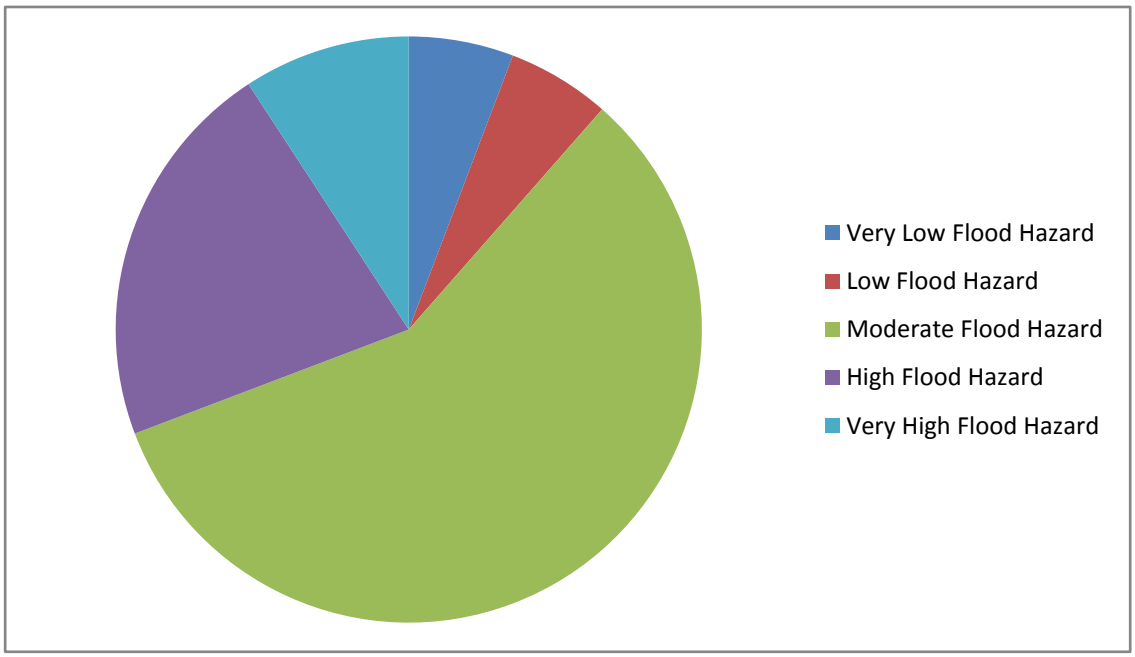


Figure 4.8 Flood Hazard of the Study Area in Percentge

Source: Authors Hazard analysis, 2014

4.4.1 Very Low Flood Hazard

The area covered by very low flood hazard is about 110.01 hectares(5.78%) of the whole study area. This ocured mostly withing some portions of the wetland agricultural landuse area and corresponds to the areas of very low runoff in Figure 4.7.

4.2.2. Low Flood Hazard

The area covered by low flood hazard is 108.01 hectars(5.69%) of the study area. This occurs mostly within some parts of the agricultural Land use area and also corresponds to the very low and low runoff areas in the study area.

4.3.3 Moderate Flood Hazard

However, the most predominant zone is the moderate flood hazard zone (Figure 4.9) covering an area of about 1098.8 hectars(58%) of the entire study area. This area covers mostly the agricultural land use area and may not portend serious danger to residents of the area but wider implication to sheet and gully erosion in farming practices if it is not adequately checked.

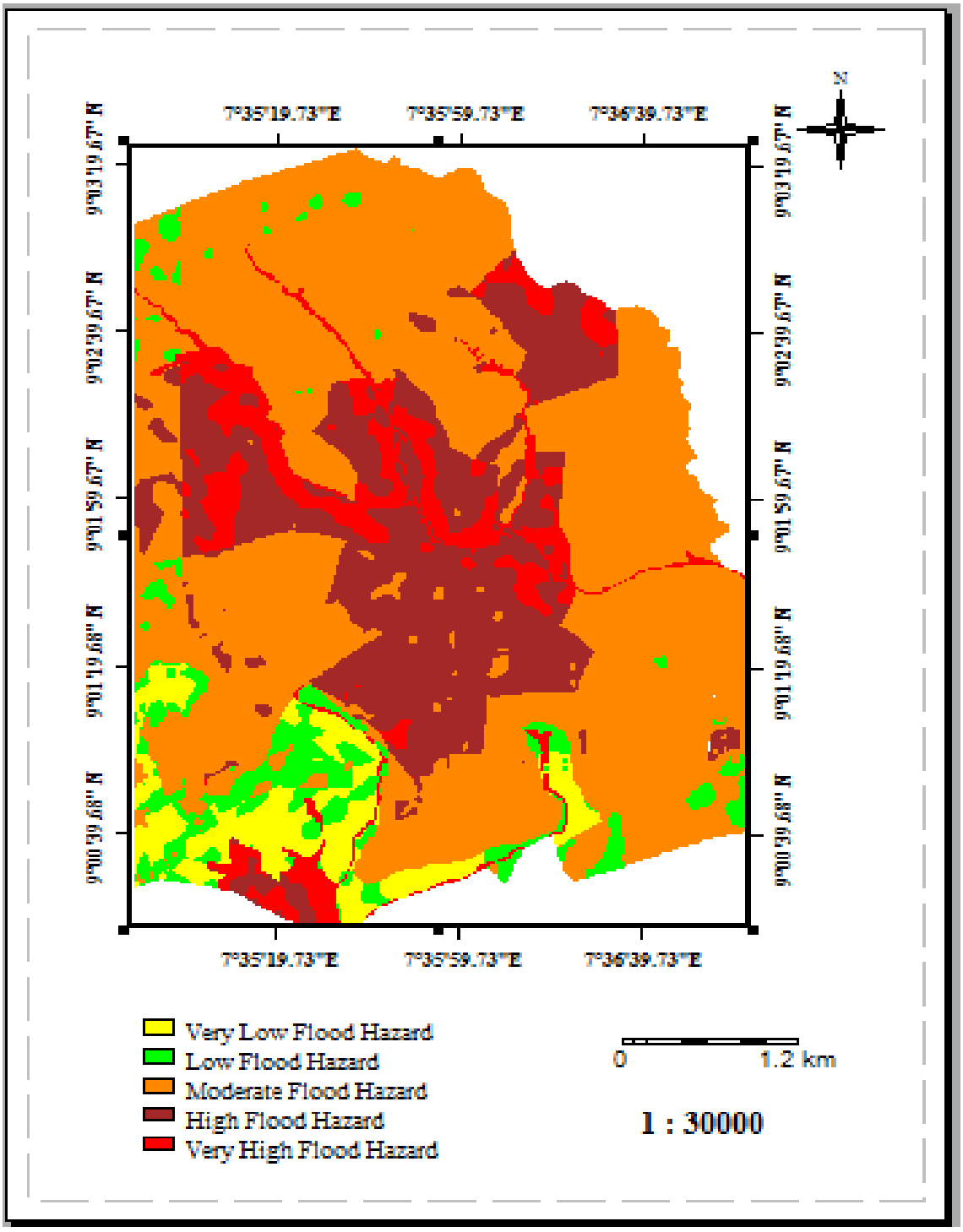


Figure 4.9 Flood Hazard of the Study Area

Source: Authors Analysis 2014.

4.3.4 High Flood Hazard

These areas 410.34 hectares (22%) fall within the high hazard zone. This corresponds with the high density residential areas. The high concentration of buildings / settlement in addition to narrow /blocked gutters as seen in appendixes III and IV or nonexistent drainages by implication creates more impervious surfaces that leads to accelerated runoff thereby exacerbating the incidence of flooding in the area like Pmaptache/Sharp corner (i.e Crispark to Mararaba Shopping centre); Agopma (Check point to Gbagalape in the Federal Capital Territory); Mararaba I(Bwagbaayi: Shoping Center to Federal Medical centre) and Nualapke (Aunty Alice school and environ).

4.3.5. Very High Flood Hazard

Areas along the gully such as Aso Bridge Junction, Kabayi River and areas beyond covering about 175 hectares (9.2%) of the total area have very high flood tendency. These are marginal land areas along the gully that have been encroached by urban developer who build on cheap if not free land thus making them very vulnerable to flood hazard.

CHAPTER FIVE: SUMMARY OF WORK, CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter highlights the summary of this study, recommendations and areas of further studies on the related topic.

5.2 SUMMARY OF WORK

Flooding due to extreme rain events in urban environments is a problem and a growing concern. Recent flood disasters in Mararaba sub urban area has claimed some lives, damaged properties and threatened the socio economic live of residents. It has therefore become important to create easily read, rapidly accessible flood hazard map, which will prioritize the mitigation effects. The study sets four objectives, the first is to derive land use and land cover (LULC) information of the study area; the second is to determine the rainfall and runoff relationship; the third objective is to identify flood prone areas using remote sensing and GIS techniques, and the fourth is to determine a strategic approach for flood risk reduction in the study area.

The LULC map was prepared using Remote sensing technique of visual interpretation to identify eight classes of land use land cover from the Spot 5 satellite imagery 2005 with 5m resolution of the study area in a GIS environment. Soil Conservation Service (SCS) have been used for runoff modelling over Mararaba sub urban area to establish the rainfall runoff relationship. Daily rainfall data was used as input data to compute the antecedent moisture condition and estimation of monthly runoff amount using Microsoft excel spread sheet. DEM (SRTM) and soil texture maps

were used as input for the runoff modelling. SCS model setup was done in ILWIS (GIS) environment to generate the Rainfall Runoff map. Since SCS model doesn't take into account flow of runoff. Therefore, another overland model was setup by taking SCS model as input along with DEM data. The blind weight method by Van Westen (1997) was adapted to create flood hazard map for the study area.

Eight classes of land Use land cover were identified. Farmland areas has the highest percentage coverage 612.31 hectares (31%), Low density is next 562.80 hectares (29%), High density area is 531.12 hectares (27%), while on the lower side , Earth dam is the list 1.30hectars (0.01%) ,Bare land area 17.00 hectares (0.9%), wet land 29.25 hectares(2%), stream 50.01 hectares (3.0%) and medium density area 167.88 hectares (9%,) respectively . The spatial distribution of the pattern of Land Use / Land cover in the study area is displayed as LULC map.

The Rainfall runoff analysis revealed that the estimated total runoff of Mararaba urban watersheds calculated for the rainy season (aggregating 1 April to 31 October, 2012) is 831.24mm. About 52% of total rainfall was converted into surface runoff. The peak runoff estimates was 174.21mm (21%) in the Month of July which substantiated the reported flood incident on the 14 July, 2012.

The final output of this research is a flood hazard map which showed that flood hazard especially High flood Hazard area 410.3 hectares (22%) is more concentrated in the built up areas, this corresponds especially with high density residential areas like Pmaptache/Sharp corner (i.e Crispark to Mararaba Shopping centre); Agopma (Check point to Gbagalape in the Federal Capital Territory); Mararaba I(Bwagbaayi: Shoping Center to Federal Medical centre) and Nualapke (Aunty Alice school and environ). While Medium Flood hazard 1098.8 hectars,(58%) is the predominant flood hazard of the entire study area corresponding with the agricultural

land use area which may not portend serious danger to residents of the area in the immediate, but wider implication to sheet and gully erosion in farming practices if it is not adequately checked. However on the long run threat of flooding may manifest with urbanization because of population pressure and development from the adjourning Federal Capital Territory which may escalate Medium flood hazard to high flood hazard area if strategic measures are not taken to prevent flooding.

5.3 CONCLUSION

Remote sensing data are of great use for the estimation of relevant hydrological data when conventional hydrological data are inadequate for the purpose of design and operation of flood control mechanism. Remote sensing data can be used as model input for determination of catchment characteristics, such as land use/ land cover, topography, depth elevation model, drainage maps. By using the SCS-CN curve number, calculate the rainfall runoff for the study area and with this develop a frequency curve which can predict the rainfall as well as the runoff at any recurrence time interval. Thus by implication this work unlike the previous studies reviewed in this study that focused more on flood inundation and encroachment along river (fluvial). This study has been able to provide hydrological data on rainfall runoff contribution to urban flooding as well as the flood Hazard map for ungauge urban watershed.

5.4 RECOMMENDATION

The probability of flooding (pluvial) can be reduced but never eliminated. For sustainable development to take place in neighbourhood within the hazard zone, flood risk intervention to prevent additional exposure or reduce flooding should be implemented. Flood risk can be reduced by reducing the flood hazard or reducing flood vulnerability, or both. Some strategic ways of reducing flood hazards are suggested.

Accurate flood hazard maps coupled with good planning of land use and infrastructure can help prevent flood damage and protect public safety. Such maps are lacking for Mararaba sub-urban area until now, the local and state government could fund such research to cover the entire state. Concerted efforts should also be made by the local and state government, urban planning and environment control department towards containing flood hazards by the construction of new drainage channels along inlands streets in Mararaba suburban areas were drainages have been absent and expand existing ones to increase their capacity for detaining and conveying high stream flow especially in areas at high risk. Pluvial flood risk can be heavily mitigated in new development through a combination of avoiding the high risk locations, investment in drainage system, flood proof building designs and innovative water management system. Further studies on Community-base flood risk reduction could be undertaken to find ways of encouraging environmental sanitation. Also, further research on draining storm (rainfall runoff) water to areas where it can be stored temporarily with the least possible damage will in no small measure help in finding ways to mitigate urban floods.

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APPENDICES



APENDIX I: Plate 1.1 Flooding along Aunty Alice School in Mararaba on the 14th of July 2012. (Source: Researchers field work, 2012)



APPENDIX II Plate 1.2: Same road in Plate 1.1 shortly after the rain storm

(Source: Authors field observation, 2012).



APPENDIX III: Plate 2.1. Narrow drainage in Mararaba Sub Urban area.

(Sources: Authors Field Observation, 2013)



APPENDIX IV: Plate 2.2. Blocked drainages in Mararaba Sub Urban area

(Source:Authors Field Observation, 2013)



APPENDIX V Plate 3:Buiding of Curvet to control flooding in Maraba Sub-Urban area.

(Source: Authors Field Observation, 2013)

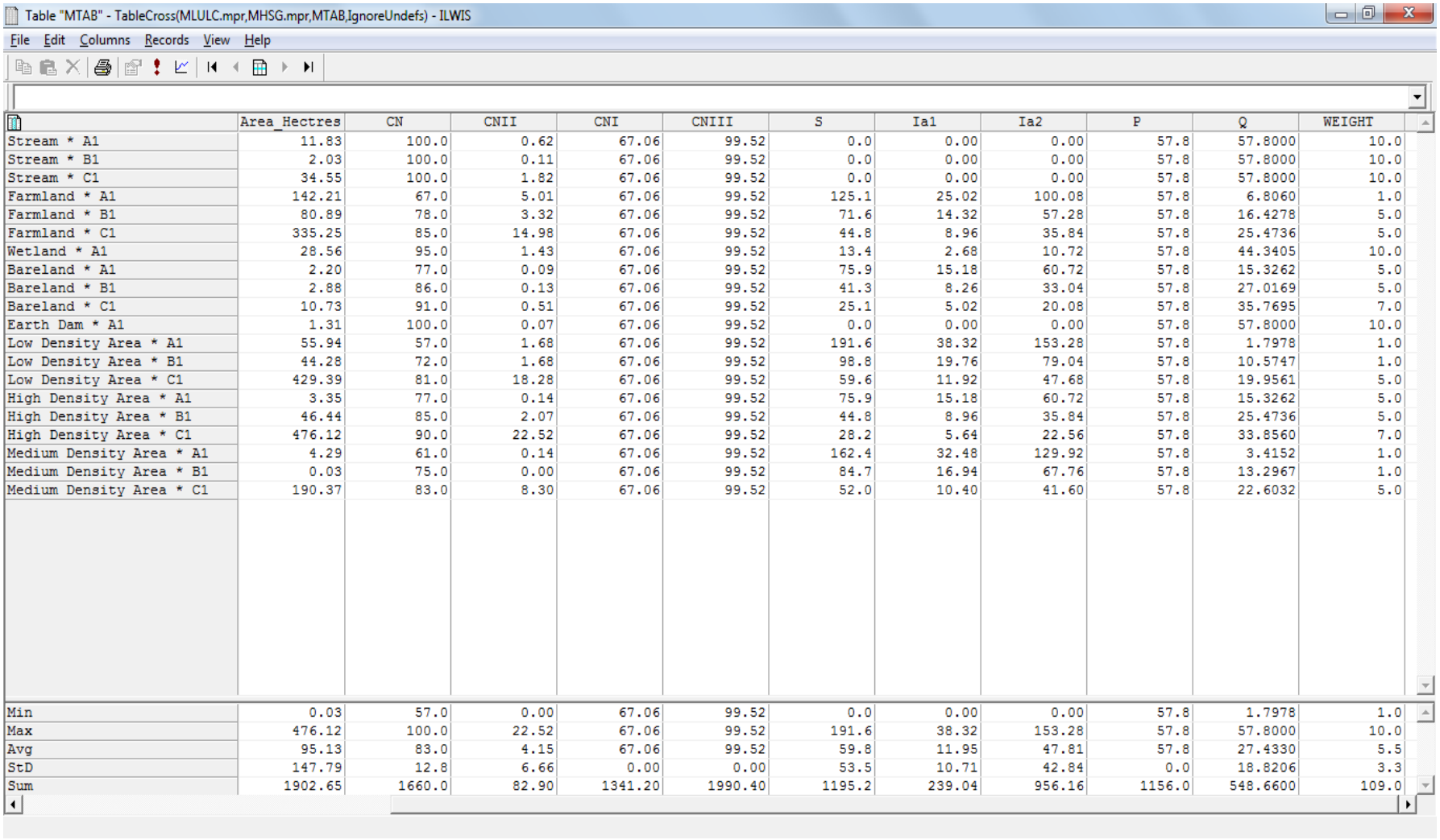
APPENDIX VI: 2012 Rainfall Data of Abuja, Nigerian

DATE	JAN.	FEB.	MAR	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV	DEC.
	Mm	mm	Mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	0	0	17.7	0	6.8	3.5	18.3	0	61	9.9	0	0
2	0	0	0	0	0	0	0	0	TR	TR	6.7	0
3	0	0	0	0	17	0	1	1.9	2.4	20.4	2.4	0
4	0	0	0	2	0	39.2	15.5	25.5	11.9	0.4	1.3	0
5	0	0	0	TR	6.9	0	0.4	0	0.5	2.3	0	0
6	0	0	0	0	0	0	20.8	0.2	5.9	34.8	0	0
7	0	0	0	0	10.2	TR	0	50.5	TR	10.8	0	0
8	0	0	0	1.7	0	0	24.3	40	43.5	0	TR	0
9	0	0	1.3	0	0	4.7	0	0.6	5.9	0	0.6	0
10	0	0	0	6.8	0.7	0	TR	36.2	11.3	5.5	0	0
11	0	0	0	0	0.8	41	31	23.4	0	TR	0	0
12	0	0	0	6.1	TR	1.5	2.1	0	TR	0	0	0
13	0	0	0	13.5	14.5	0	2.7	0	0	24.2	0	0
14	0	0	0	0	TR	21.3	41.7	2.4	4.6	0	0	0
15	0	0	0	0	0	15.6	21.3	0	12.9	TR	0	0
16	0	0	0	0.6	13.6	0	0.8	8.8	42.2	0	0	0
17	0	0	0	0	0	2	0.8	3.1	0	31.6	0	0
18	0	0	0	3.2	5.5	TR	0.4	3	2.4	28.6	0	0
19	0	0	0	TR	0	27.9	7.5	0	0	0	0	0
20	0	0	0	0	35.7	0	16.1	25.3	TR	0	0	0
21	0	0	0	0	1.6	TR	0	3.7	0	0	0	0
22	0	0	0	0	1	0	52.3	2.5	0	2.4	0	0
23	0	0	0	0	0	0	2.1	1.1	0.1	76.8	0	0
24	0	20.6	0	2.5	0.7	0	TR	TR	5.6	27.2	0	0
25	0	0	0	0	0	0	2	0.8	18.1	0	0	0
26	0	0	0	3.5	21.1	TR	39.2	24.8	23.5	0	0	0
27	0	0	0	0	0	70.4	6.8	0	0	0	0	0
28	0	0	0	TR	23.5	0	11.2	TR	20.6	4	0	0
29	0	0	0	5.3	35.3	0	TR	0.2	2	0	0	0
30	0	XXX	0	TR	3.1	0.9	57.8	10.1	0	0	0	0
31	0	XXX	0	XXX	0.5	XXX	TR	6.4	XXX	0	XXX	0
TOTAL	0	20.6	19	45.2	198.5	228	376.1	270.5	74.4	228.9	11	0

Date	Rainfall (mm)	AMC (mm)	AMC Class	CN	S (mm)	Q	Q (mm)
1/7/2012	18.3	71.3	3	99.52	1.225080386	16.90774674	16.90774674
2/7/2012	0	19.2	1	67.06	124.7652848	6.238264241	0
3/7/2012	1	19.2	1	67.06	124.7652848	5.691263353	0
4/7/2012	15.5	20.2	1	67.06	124.7652848	0.774941978	0
5/7/2012	0.4	34.8	1	67.06	124.7652848	6.015758947	0
6/7/2012	20.8	35.2	2	82.9	52.39324487	1.698652211	1.698652211
7/7/2012	0	37.7	2	82.9	52.39324487	2.619662244	0
8/7/2012	24.3	37.7	2	82.9	52.39324487	2.88500959	2.88500959
9/7/2012	0	61	3	99.52	1.225080386	0.061254019	0
10/7/2012	0	45.5	2	82.9	52.39324487	2.619662244	0
11/7/2012	31	45.1	2	82.9	52.39324487	5.775604222	5.775604222
12/7/2012	2.1	55.3	3	99.52	1.225080386	1.117173218	1.117173218
13/7/2012	2.7	57.4	3	99.52	1.225080386	1.637728462	1.637728462
14/7/2012	41.7	35.8	2	82.9	52.39324487	11.65792586	11.65792586
15/7/2012	21.3	77.5	3	99.52	1.225080386	19.89726519	19.89726519
16/7/2012	0.8	98.8	3	99.52	1.225080386	0.173031476	0.173031476
17/7/2012	0.8	68.6	3	99.52	1.225080386	0.173031476	0.173031476
18/7/2012	0.4	67.3	3	99.52	1.225080386	0.017404998	0.017404998
19/7/2012	7.5	65	3	99.52	1.225080386	6.206885916	6.206885916
20/7/2012	16.1	30.8	1	67.06	124.7652848	0.676172127	0
21/7/2012	0	25.6	1	67.06	124.7652848	6.238264241	0
22/7/2012	52.3	24.8	1	67.06	124.7652848	4.916470582	4.916470582
23/7/2012	2.1	76.3	3	99.52	1.225080386	1.117173218	1.117173218
24/7/2012	0	78	3	99.52	1.225080386	0.061254019	0
25/7/2012	2	70.5	3	99.52	1.225080386	1.033524196	1.033524196
26/7/2012	39.2	56.4	3	99.52	1.225080386	37.76725594	37.76725594
27/7/2012	6.8	95.6	3	99.52	1.225080386	5.522809648	5.522809648
28/7/2012	11.2	50.1	2	82.9	52.39324487	0.009796691	0
29/7/2012	0	59.2	3	99.52	1.225080386	0.061254019	0

30/7/2012	57.8	59.2	3	99.52	1.225080386	56.35543638	56.35543638

APPENDIX VII: Computation of Rainfall Runoff using Microsoft Excel spread sheet


Table "MTAB" - TableCross(MLULC.mpr,MHSG.mpr,MTAB,IgnoreUndefs) - ILWIS

File Edit Columns Records View Help

	Area_Hectres	CN	CNII	CNI	CNIII	S	Ia1	Ia2	P	Q	WEIGHT
Stream * A1	11.83	100.0	0.62	67.06	99.52	0.0	0.00	0.00	57.8	57.8000	10.0
Stream * B1	2.03	100.0	0.11	67.06	99.52	0.0	0.00	0.00	57.8	57.8000	10.0
Stream * C1	34.55	100.0	1.82	67.06	99.52	0.0	0.00	0.00	57.8	57.8000	10.0
Farmland * A1	142.21	67.0	5.01	67.06	99.52	125.1	25.02	100.08	57.8	6.8060	1.0
Farmland * B1	80.89	78.0	3.32	67.06	99.52	71.6	14.32	57.28	57.8	16.4278	5.0
Farmland * C1	335.25	85.0	14.98	67.06	99.52	44.8	8.96	35.84	57.8	25.4736	5.0
Wetland * A1	28.56	95.0	1.43	67.06	99.52	13.4	2.68	10.72	57.8	44.3405	10.0
Bareland * A1	2.20	77.0	0.09	67.06	99.52	75.9	15.18	60.72	57.8	15.3262	5.0
Bareland * B1	2.88	86.0	0.13	67.06	99.52	41.3	8.26	33.04	57.8	27.0169	5.0
Bareland * C1	10.73	91.0	0.51	67.06	99.52	25.1	5.02	20.08	57.8	35.7695	7.0
Earth Dam * A1	1.31	100.0	0.07	67.06	99.52	0.0	0.00	0.00	57.8	57.8000	10.0
Low Density Area * A1	55.94	57.0	1.68	67.06	99.52	191.6	38.32	153.28	57.8	1.7978	1.0
Low Density Area * B1	44.28	72.0	1.68	67.06	99.52	98.8	19.76	79.04	57.8	10.5747	1.0
Low Density Area * C1	429.39	81.0	18.28	67.06	99.52	59.6	11.92	47.68	57.8	19.9561	5.0
High Density Area * A1	3.35	77.0	0.14	67.06	99.52	75.9	15.18	60.72	57.8	15.3262	5.0
High Density Area * B1	46.44	85.0	2.07	67.06	99.52	44.8	8.96	35.84	57.8	25.4736	5.0
High Density Area * C1	476.12	90.0	22.52	67.06	99.52	28.2	5.64	22.56	57.8	33.8560	7.0
Medium Density Area * A1	4.29	61.0	0.14	67.06	99.52	162.4	32.48	129.92	57.8	3.4152	1.0
Medium Density Area * B1	0.03	75.0	0.00	67.06	99.52	84.7	16.94	67.76	57.8	13.2967	1.0
Medium Density Area * C1	190.37	83.0	8.30	67.06	99.52	52.0	10.40	41.60	57.8	22.6032	5.0
Min	0.03	57.0	0.00	67.06	99.52	0.0	0.00	0.00	57.8	1.7978	1.0
Max	476.12	100.0	22.52	67.06	99.52	191.6	38.32	153.28	57.8	57.8000	10.0
Avg	95.13	83.0	4.15	67.06	99.52	59.8	11.95	47.81	57.8	27.4330	5.5
StD	147.79	12.8	6.66	0.00	0.00	53.5	10.71	42.84	0.0	18.8206	3.3
Sum	1902.65	1660.0	82.90	1341.20	1990.40	1195.2	239.04	956.16	1156.0	548.6600	109.0

Appendix: VIII Generation of Rainfall Runoff Map for the Mararab Sub-Urban area using ILWIS Softwars

APPENDIX: IX Runoff Curve Numbers Table (SCS, 1986)

Description of Land Use	**Hydrologic Soil Group**			
	A	**B**	**C**	**D**
Paved parking lots, roofs, driveways	98	98	98	98
Streets and Roads:				
Paved with curbs and storm sewers	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89
Cultivated (Agricultural Crop) Land*:				
Without conservation treatment (no terraces)	72	81	88	91
With conservation treatment (terraces, contours)	62	71	78	81
Pasture or Range Land:				
Poor (<50% ground cover or heavily grazed)	68	79	86	89
Good (50-75% ground cover; not heavily grazed)	39	61	74	80
Meadow (grass, no grazing, mowed for hay)	30	58	71	78
Brush (good, >75% ground cover)	30	48	65	73
Woods and Forests:				
Poor (small trees/brush destroyed by over-grazing or burning)	45	66	77	83
Fair (grazing but not burned; some brush)	36	60	73	79
Good (no grazing; brush covers ground)	30	55	70	77
Open Spaces (lawns, parks, golf courses, cemeteries, etc.):				
Fair (grass covers 50-75% of area)	49	69	79	84
Good (grass covers >75% of area)	39	61	74	80
Commercial and Business Districts (85% impervious)	89	92	94	95
Industrial Districts (72% impervious)	81	88	91	93
Residential Areas:				
1/8 Acre lots, about 65% impervious	77	85	90	92
1/4 Acre lots, about 38% impervious	61	75	83	87
1/2 Acre lots, about 25% impervious	54	70	80	85

1 Acre lots, about 20% impervious	51	68	79	84

APPENDIX: X Daily Rainfall Runoff Estimates of Mararaba (April –October, 2012)

MONTH/DATE APR	MONTH/DATE APR	X RAINFALL(mm)	Predicted Y Q(mm)
4/4/2012	4/4/2012	2	2.01
8/4/2012	8/4/2012	1.7	1.96
10/4/2012	10/4/2012	6.8	2.94
12/4/2012	12/4/2012	6.1	2.78
13/4/2012	13/4/2012	13.5	4.85
16/4/2012	16/4/2012	0.6	1.81
18/4/2012	18/4/2012	3.2	2.21
24/4/2012	24/4/2012	2.5	2.09
26/4/2012	26/4/2012	3.5	2.26
29/4/2012	29/4/2012	5.3	2.61
MAY	MAY	RAINFALL(mm)	Q(mm)
1/5/2012	1/5/2012	1	2.94
3/5/2012	3/5/2012	17	6.13
5/5/2012	5/5/2012	6.9	2.96
7/5/2012	7/5/2012	10.2	3.82
10/5/2012	10/5/2012	0.7	1.82
11/5/2012	11/5/2012	0.8	1.84
13/5/2012	13/5/2012	14.5	5.2
18/5/2012	18/5/2012	5.5	2.65
20/5/2012	20/5/2012	35.7	16.32
21/5/2012	21/5/2012	1.6	1.95
22/5/2012	22/5/2012	1	1.86
24/5/2012	24/5/2012	0.7	1.82
26/5/2012	26/5/2012	21.1	7.9
28/5/2012	28/5/2012	23.5	9.04
29/5/2012	29/5/2012	35.3	16.04
30/5/2012	30/5/2012	3.1	2.19
31/5/2012	31/5/2012	0.5	1.8
JUN	JUN	RAINFALL(mm)	Q(mm)
1/6/2012	1/6/2012	3.5	2.26
4/6/2012	4/6/2012	39.2	18.85
9/6/2012	9/6/2012	4.7	2.49
11/6/2012	11/6/2012	41	20.22
12/6/2012	12/6/2012	1.5	1.93
14/6/2012	14/6/2012	21.3	7.98
15/6/2012	15/6/2012	15.6	5.6

17/6/2012	17/6/2012	2	2.01
19/6/2012	19/6/2012	27.9	11.39
27/6/2012	27/6/2012	70.4	50.4
30/6/2012	30/6/2012	0.9	1.85

JUL	JUL	RAINFALL(mm)	Q(mm)
1/7/2012	1/7/2012	18.3	16.91
6/7/2012	6/7/2012	20.8	1.7
8/7/2012	8/7/2012	24.3	2.89
11/7/2012	11/7/2012	31	5.1
12/7/2012	12/7/2012	2.1	1.12
13/7/2012	13/7/2012	2.7	1.64
14/7/2012	14/7/2012	41.7	11.66
15/7/2012	15/7/2012	21.3	19.9
16/7/2012	16/7/2012	0.8	0.17
17/7/2012	17/7/2012	0.8	0.17
18/7/2012	18/7/2012	0.4	0.02
19/7/2012	19/7/2012	7.5	6.21
22/7/2012	22/7/2012	52.3	4.92
23/7/2012	23/7/2012	2.1	1.12
25/7/2012	25/7/2012	2	1.03
26/7/2012	26/7/2012	39.2	37.77
27/7/2012	27/7/2012	6.8	5.52
30/7/2012	30/7/2012	57.8	56.36

AUG	AUG	RAINFALL(mm)	Q(mm)
3/8/2012	3/8/2012	1.9	2
4/8/2012	4/8/2012	25.5	10.06
6/8/2012	6/8/2012	0.2	1.76
7/8/2012	7/8/2012	50.5	28.34
8/8/2012	8/8/2012	40	19.45
9/8/2012	9/8/2012	0.6	1.81
10/8/2012	10/8/2012	36.2	16.67
11/8/2012	11/8/2012	23.4	8.99
14/8/2012	14/8/2012	2.4	2.07
16/8/2012	16/8/2012	8.8	3.43
17/8/2012	17/8/2012	3.1	2.19
18/8/2012	18/8/2012	3	2.17
20/8/2012	20/8/2012	25.3	9.96
21/8/2012	21/8/2012	3.7	2.3
22/8/2012	22/8/2012	2.5	2.09
23/8/2012	23/8/2012	1.1	1.88
25/8/2012	25/8/2012	0.8	1.84
26/8/2012	26/8/2012	24.8	9.7
29/8/2012	29/8/2012	0.2	1.76

30/8/2012	30/8/2012	10.1	3.79
31/9/2012	31/9/2012	6.4	2.85
SEP	SEP	RAINFALL(mm)	Q(mm)
1/9/2012	1/9/2012	61	39
3/9/2012	3/9/2012	2.4	2.07
4/9/2012	4/9/2012	11.9	4.33
5/9/2012	5/9/2012	0.5	1.8
6/9/2012	6/9/2012	5.9	2.74
8/9/2012	8/9/2012	43.5	22.22
9/9/2012	9/9/2012	5.9	2.74
10/9/2012	10/9/2012	11.3	4.14
14/9/2012	14/9/2012	4.6	2.47
15/9/2012	15/9/2012	12.9	4.65
16/9/2012	16/9/2012	42.2	21.17
18/9/2012	18/9/2012	2.4	2.07
23/9/2012	23/9/2012	0.1	1.74
24/9/2012	24/9/2012	5.6	2.67
25/9/2012	25/9/2012	18.1	6.58
26/9/2012	26/9/2012	23.5	9.04
28/9/2012	28/9/2012	20.6	7.66
29/9/2012	29/9/2012	2	2
OCT	0CT	RAINFALL(mm)	Q(mm)
1/10/2012	1/10/2012	9.9	3.73
3/10/2012	3/10/2012	20.4	7.57
4/10/2012	4/10/2012	0.4	1.78
5/10/2012	5/10/2012	2.3	2.06
6/10/2012	6/10/2012	34.8	15.7
7/10/2012	7/10/2012	10.8	3.99
10/10/2012	10/10/2012	5.5	2.65
13/10/2012	13/10/2012	24.2	9.39
17/10/2012	17/10/2012	31.6	13.61
18/10/2012	18/10/2012	28.6	11.79
22/10/2012	22/10/2012	2.4	2.07
23/10/2012	23/10/2012	76.8	58.36
24/10/2012	24/10/2012	27.2	11
28/10/2012	28/10/2012	4	2.35

Appendix XI: Percentage of LULC Coverage of the study Area.

S/N	Land Use Land Cover	Area_Hectars	% of Area In Hectares
1	Bareland	16.997545	0.86
2	Earth Dam	1.300725	0.07
3	Farm Land	612.310714	31.06
4	High Density Area	531.115981	26.94
5	Low Density Area	562.800201	28.54
6	Medium Density Area	167.883738	8.51
7	Stream	50.013154	2.54
8	Wetland	29.246698	1.48
	Total	1971.67	100

Appedix XII: Percentages of areas covered by flood hazard in the study area

Hazard Class	Area_Hectare	%
Very Low Flood Hazard	110.01	5.781936
Low Flood Hazard	108.27	5.690484
Moderate Flood Hazard	1098.8	57.75103
High Flood Hazard	410.34	21.56676
Very High Flood Hazard	175.23	9.209786
Total	1902.65	100