SPATIAL VARIATON OF GROUNDWATER POTENTIALS IN SOME PARTS OF KADUNA SOUTH LOCAL GOVERNMENT AREA, KADUNA STATE, NIGERIA.

BY

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS

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DECLARATION

I solemnly declare that, this work entitled ''Spatial Variation of Groundwater Potentials in Some Parts of Kaduna South Local Government Area, Kaduna State, Nigeria'' has been carried out by the researcher Nasiru, IBRAHIM in the Department of Geography under the supervision of Dr A.K. Usman and Dr D.N. Jeb. All information obtained from the literature has been duly acknowledged in the text and list of references. No part of this dissertation was previously been presented for another degree at this University or other Institution.

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	Signature	Date

CERTIFICATION

This dissertation entitled ‘‘Spatial Variation of Groundwater Potentials in Some Parts of Kaduna South Local Government Area, Kaduna State, Nigeria’’ by Nasiru, IBRAHIM meets the regulations governing the award of Degree of Masters in science Remote Sensing and Geographic Information Systems of Ahmadu Bello University, Zaria, and is also approved for its contribution to knowledge and literacy presentation.

Dr A.K. Usman Chairman(Supervisory Committee)	--------------------------- Signature	------------------------ Date
Dr D.N. Jeb (Member Supervisory Committee)	----------------------------- Signature	------------------ Date
Dr A.K. Usman (Head of Department)	--------------------------- Signature	---------------------- Date
Prof . S.Z. Abubakar (Dean, School of Postgraduate Studies)	------------------------ Signature	----------------- Date

DEDICATION

This dissertation is dedicated to my loving, caring and industrious parent whose effort and sacrifice has made my dream of having this degree a reality. Words cannot be adequately express my deep and sincere gratitude to you. I pray to Almighty Allah to reward them with Al – Jannatul Firdausi.

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Although, this dissertation represents an individual work, it would not have been written without the sincere help and support from many people. It is my pleasure to express my gratitude to all those who made this dissertation possible.
My heartfelt appreciation from the innermost core of my being goes to my parents, wives, brothers, sisters and friends for their prayers, love and care. May Allah the most Merciful reward them all.

This is an avenue also to show my appreciation to my children, and finally glory to the owner of the entire universe for whom all wisdom, knowledge, understanding and mercy flow. Thanks for the sound and good health, wisdom and grace you gave me till this moment.

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ABSTRACT

Fresh water resources are essential component of the earth hydrosphere and are indispensable for all organisms. The aim of the study is to assess the Spatial Variation of Groundwater Potentials in parts of Kaduna South Local Government Area, Kaduna State, Nigeria. Both primary and secondary sources of data were used in the work Data. Primary data that were use are satellite imageries (LANDSAT 8) and Shuttle Radar Topographic Mission (SRTM). While the secondary data include rainfall data and existing soil map of Kaduna state. The GPS locations of borehole's site were processed using Arch-GIS tool to depict the pattern of the spatial variation of the groundwater potentials in the study area. The result shows that there is good groundwater potentials in the Northern areas while the areas with low potential are in the Southern parts respectively. the result also shows that, very good groundwater potential zones occupies a coverage of about 6.2%, High potential constitute 10.1%, moderate occupies 17.8% while low and very low constitute of 36.1% and 30.0% respectively. The study therefore recommends that, these zones be combined with detailed geophysical mapping for quantitative evaluation of the groundwater potential, and that, surface water development be intensified in the low to very low zone yield areas. Finally groundwater development. Groundwater potential zones mapping should be carried out for the entire country to serve as a guide for water resource agencies.

CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Groundwater is the water beneath the surface of the ground, in other words, it is the water that flows or collects beneath the Earth's surface. Groundwater originates from rain and from melting snow and ice and it infiltrate into the ground and percolates through porous rocks. Aquifers, springs and wells are recharged by the flow of groundwater. It is also regarded as a finite resource which is very essential for agriculture, industry and human consumption and its supply has a profound impact on the quality of life. Also it is a major determinant of productivity and poverty levels.

Fresh water resources are essential component of the earth hydrosphere and are indispensable for all organisms. Although water is vital to all organisms, only a tiny proportion (0.5%) of total budget for the earth is readily exploitable Samaila (1997). Despite the scarcity in water supply, most of the global water systems have suffered serious quality depletion from human abuse. Man therefore has not sufficiently taken care of this essential resource and has often appeared not to value it. Rapid population expansion and industrialization have posed severe stress on water resource potentials, thus expanding potable water demand and the pollution of existing water bodies (Ogunrombi,2009).

Human activities are often accompanied by serious environmental consequences including the production of excessive amount of wastes which could be solid, gaseous or liquid which finally find their way into the drainage systems which rapidly deplete water quality in streams, rivers, lagoons, lakes, ponds, drains and groundwater reservoirs. Successful exploitation of groundwater requires a proper understanding of its hydrological characteristics. The hydrological properties determine its potentials and quality. These characteristics (such as slope, land cover, lineament etc.) also determine the level of water in the aquifer.

Toth (1989) state that water table is a function of topography and climate. The flow pattern of groundwater is a function of climate, topography and geology and these three terms are called the hydrological environment. Water quality comprises of several variables, which together affect the inherent physical, chemical and biological characteristics of water. Pollutants in water rarely occur singly and their interaction with each other complicates their impact, thus enhancing their toxicities

Biswarup (2000) examine some industries and found that, as a result of their production processes generate unwanted waste effluents one generated and other obnoxious by- products most of which are detrimental to human health and the marine biodiversity, water quality is depleted directly or indirectly by introducing substances that are hazardous to human leading to reduction in social amenities and interfering water activities such as recreation, irrigation, domestic uses, fishing and industrial uses. Further more Biswarup (2000) opined that, the method for water treatment is same for all sources, industrial effluents with inorganic impurities, however, the required pre- treatment before disposal into water bodies should be adhered to. Industrial processes may introduce into drainage system heavy metals such as mercury, leads, arsenic, tin, cadmium, cobalt, selenium, manganese, copper and zinc which though found in minute concentrations, yet are potential harmful substances in water (Abdulkadir,1993).

Timorthy (1994) also pointed out that groundwater potential zones can be obtained using remote sensing and geographic information system through interpretation of data based on geologic, hydrologic, topographic, vegetation and soil maps. Sander (1997) added that lineaments are often visual on remote sensing data as topographic, drainage, vegetation, or soil tonal anomalies. These factors are very essential in assessing groundwater potential of an area.

Remotely sensed information on topography, drainage, fractures- pattern is directly related to the presence or absence of ground water (Thapa et. al, 2009). Shakeel et. al (2008) observed that groundwater occurrence is a sub – surface phenomenon, its identification and location is based on indirect analysis of some directly observed terrain features like geological, geomorphologic features and their hydrologic characters. These could best be studied with the use of remote sensing and GIS and more systematic analysis of various geomorphic units' lineaments features following the integration with the help of GIS to demarcate the groundwater potential zones.

Remote sensing with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas has become a very handy tool in exploring, evaluating, and managing vital groundwater resources (Chowdhury, Roan and Sarma, 2003). The hydro-geologic interpretation of satellite data has been proved to be a valuable survey tool in some parts of the world where little geologic and cartographic information exists or is not accurate (Engman and Gurney, 1991). Satellite data provide quick and useful baseline information about the factors controlling the occurrence and movement of groundwater like geology, lithology, geomorphology, soils, land use/cover, drainage patterns, lineaments. (Bobu, 2011). However, all the ground water controlling factors have rarely been studied together because of the non-availability of data, integrating tools and/or modeling techniques. Structural features such as faults, fracture traces and other such linear or curvilinear features can indicate the possible presence of groundwater. Similarly, other features like sedimentary strata (i.e., alluvial deposits and glacial moraines) or certain rock outcrops may indicate potential aquifers (Engman and Gurney, 1991).

Based on the available data, Nigeria at large has adequate surface water and groundwater resources to meet the current demand for potable drinking water and agriculture, but due its temporal and spatial characteristics, scarcity of water is still a common phenomenon in some areas especially in study area Duraye, (2003).

Groundwater exploration is gaining greater attention due to increasing demand for water supply, especially in areas with inadequate pipe-borne and surface water. The drying up of the hand dug wells in the area worsens the problem which is becoming progressively intense with growing population. As a result of poor assessment of groundwater potential zones prior to water exploration in the area, there has been inadequate supply of water from boreholes and drying up of wells during the dry seasons. Communities therefore rely on self-water supply sources such as river, streams, and water vendors which play host to many diseases, such as typhoid fever, cholera, dysentery, and as such, the people are vulnerable to these diseases. Therefore there is need to assess the groundwater potential zones for effective yield during exploration in order to meet the water demand of the people. Hence this study focuses on the use of Remote Sensing and GIS in assessing groundwater potential zones in some parts of Kaduna South Local Government Area, Kaduna State.

1.2 STATEMENT OF THE RESEARCH PROBLEM

The utilization of groundwater is gaining more attention due to drought problem, rural water supply, irrigation project and its low cost of development. The growing importance of groundwater due to an increasing need for water has led to unscientific exploitation of groundwater that results to insufficient groundwater yield in many communities. This is often seen in the number of abandoned boreholes that have dried up or accessibility of only yield water in the rainy season. Despite the extensive research and technological advancement, the study of groundwater has remained more costly, as there is no direct method to facilitate observation of water below the surface. Its presence or absence can only be inferred indirectly by studying the geological and surface parameters (Oteze, 2006).

In Nigeria as well as many other African countries, the provision of water for the teeming population is usually stated as one of the cardinal objectives of Government. In Kaduna State, many water supply initiatives have been undertaken over the years and although achievements have been recorded in certain areas, yet water provision in the state cannot be described as a complete success story. It is estimated that there are currently about 1,805 boreholes constructed by the Ministry of Water Resources, covering all the 23 Local Government Areas in the state. In addition, the Rural Water Supply and Sanitation Agency (WATSAN) constructed an additional 400 boreholes. In 2003, it was reported that only 20% of the boreholes are productive. As a result of high cost of geophysical exploration many boreholes are left unfinished while some have stopped yielding water after sometime (WATSAN, 2006).

Severe water scarcity has been one of the major problem traced by residents of Kaduna South Local Government Areas. Of the population of Kaduna State, only those in Kaduna town the state capital, can boast of access to potable water, though not all residents of the city have access to potable water (Onugba and Eduvie, 2003). Water projects constructed over 40 years ago when the state was created are no longer capable of providing enough water for the ever-growing population. This development has subjected the people of the state to reliance on other sources of water including rain water and groundwater (WATSAN, 2006). Hand dug wells in the area yield little water which dries up eventually due to lack of information on groundwater potential zone before groundwater exploration. Likewise, the poor yields from constructed boreholes by government agencies and other private organizations have been attributed to poor maintenance and inadequate information on good groundwater potential zone in the area (Onugba and Eduvie, 2003).

Various studies have been carried out on groundwater potential with the aim of delineating area that could be developed for groundwater supply. Tesfaye (2010) used integrated method in evaluating groundwater potential of Blilate river catchment South Rift Valley of Ethiopia through generation of thematic maps using GIS. The result was validated by selective ground truth verification and four groundwater potential zones were identified which are high, moderate, low and poor for the study area. Also, Mogaji Aboyeji and Omosuyi (2011) mapped out lineaments for underground water targeting in Ondo state, Nigeria, using Remote Sensing and Geographic Information System (GIS) techniques. Their study used Landsat 7 ETM+ Imagery, ASTER digital elevations models (DEMs) and geological maps for the study. Their study showed that zones of high lineament intersection density are feasible zones for groundwater prospecting in the study area and concluded that they are the most promising for sustainable groundwater supply and hence, are areas where further geophysical survey can be concentrated.

Pandian and Kumanan (2013) identified the groundwater potential zones using remote sensing and GIS in part of Trichy and Karur District, Tamilnadu, India. They combined lineament, geomorphology, land use and land cover, lithology and soil maps as the correlative factors that appear to be important in holding / processing of recharge of water and ground water using the weighting method in GIS. Groundwater potentiality was delineated as moderate potential and some parts were classified as high potential zones, low and very low potential zones and only few areas have been classified as very high groundwater potential zones.

Waikar, Aditya and Nilawar (2014) assessed the potential zone of groundwater recharge and its importance for the protection of water quality and the management of groundwater systems of Western India. They integrated RS and GIS techniques. Their findings showed that basements in the area have very little fractures which prevent water from getting to the aquifer. Abel and Moshood (2011) mapped out the occurrence of groundwater in the Basement Complex terrain of Ekiti area, Southwestern Nigeria. They observed that, the aquifers were characteristically discontinuous (localized) warranting assessment of the groundwater potential of the area to serve as a guide for groundwater exploration. Thematic maps of geology, geomorphology, lineament, slope, drainage and drainage density were prepared and integrated using ArcGIS 9.1 software to produce the groundwater potential map of the area. They produced a groundwater potential map in which the study area was categorized into zones; very good, moderately good and poor. Furthermore, superimposition of the groundwater yield data from the study area on the groundwater potential map revealed that there were more number of high-yield wells in the favorable zones (very good to moderately good). Their study highlighted that the groundwater potential map would apart from its role as exploration guide be useful for the development of sustainable groundwater scheme in the area.

Despite the persistent scarcity of portable water supply and its attendant consequences on the health of the people health in the study area, very few study have been carried out on ground water potentials. Therefore this current study intend to investigate the spatial variation of groundwater potential in the study area the study seeks answer to the following research questions:

i. What is the ground water potentials in the area?
ii. Where are the factors contributing to groundwater potential in the study area?
iii. What is the distribution pattern of the groundwater potential zones?
iv. What is the of groundwater potentials in the area?

1.3 AIM AND OBJECTIVES OF THE STUDY

The aim of the study is to assess and analyze the Spatial Variation of groundwater potentials in some selected areas of Kaduna South Local Government Area.

The study was achieved through the following objectives:

i. assess the ground water potentiality
ii. assess the factors contributing to groundwater potential in the study area.
iii. map out the groundwater potential zones and also examine the distribution pattern.
iv. examine the level of groundwater potentiality in some districts in Kaduna South L.G.A.

1.4 SCOPE OF THE STUDY

The spatial scope of this study covers the seven (7) major districts of the Kaduna South L.G.A. namely; Badiko, Tudun Wada, Sabon – Gari, Unguwar Mu'azu, Makera, Kakuri and Barnawa. In terms spatial content, the study would assess and analyzed the Spatial Variation of groundwater potentials in some parts of Kaduna South Local Government Area. While the temporal scope will cover the wet season.

1.5 JUSTIFICATION OF THE STUDY

Due to the growing population of the study area, water from boreholes is being used to augment public water supply in urban areas. This study aimed at investigating the groundwater potential in some parts of Kaduna South L.G.A. Further more, the study was carried out to examine the characteristics of groundwater potential zones in the study area using Analytical Hierarchy Process (AHP). Six thematic maps of factors contributing to groundwater recharge was generated and integrated in ArcGIS environment using weighted sum overlay in spatial analyst tool. However, most boreholes are developed without considerations whether or not the locations have significant potentials to sustain the yield of the boreholes. This study therefore enabled the determination of the areas that have optimum potentials for borehole water yield. Although boreholes may exist and yielding some good quantity of water, however, their potential may be low and insufficient for public water supply or may not be sustainable for the very particular purpose for which the borehole was developed initially.

The study will therefore serve as a guide to the Government ,and Non – Governmental Organizations and other stakeholders involved in water exploration. Also, the Kaduna State Water Board, Local Government Areas, Water and Sanitation (WATSAN), Kaduna Agricultural Development Project (KADP), and other organizations and private individuals involved in groundwater development will also benefit from this research.

CHAPTER TWO

CONCEPTUAL ISSUES AND LITERATURE REVIEW

2.1 INTRODUCTION

The chapter reviewed relevant literature that are related or similar to this research work. It centers on conceptual issues on groundwater potentials, groundwater explorations, groundwater resource and development, remote sensing and GIS application to groundwater exploration, groundwater quality and factors affecting groundwater shortage.

2.2 CONCEPTUAL ISSUES

2.2.1 Importance of Water to Life

Water is the most abundant solvent on the earth that support all forms of life. Over 70% of the earth surface is covered by water in Oceans, lakes, rivers, ponds, lagoons and other water bodies. Groundwater is part of the available water in the globe for human utilization. Animal and plant bodies contain water for their physiological systems and regulation of body temperature. Food and beverages contain significant amount of water within them. Water serves as coolants in heavy to light industries.

Water is very essential to life that is why people are looking for it at all cost for their domestic, industrial and other uses. The physical reality of life is defined by water; it is the essence of our existence and is therefore the most critical resource supplied by earth systems (Robert, 2007). If drinking water is scarce or absent, people can spend much time on carrying it to their houses. This is because water is a medium of life, since man drinks it and utilizes it in many ways. Batmanghelidji (2004) he is of the view that, since water provide for cell functions and its volume requirements, the decrease in our daily water intake affect the efficiency of cell activity as a result chronic dehydration causes symptoms that equal diseases. Thus, Water is a basic ingredient of life.

It was reported by Tanner and Roades (2003) that the human body contains from 55% to 78% water, depending on the body size and to function properly, the body requires between one and seven litres of water per day to avoid dehydration. The intake takes place through drinking, eating of beverages and other foods that contain water. From philosophical point of view, Internet Secret Text (2010) reports that ancient Greek philosopher Empedocles held that water is one of the four classical elements along with fire, earth and air, and was regarded as the ylem or basic substance of the Universe. The classical element of water also one of the five elements in traditional Chinese philosophy, along with earth, fire, wood and metal. These show how important water is to life. Religions obligations are fulfilled in the presence of water, it is considered as a purifier in most religious of the world. Major faiths that incorporate ritual washing include Islam, Christianity, Hinduism, Rastafari movement, Shinto, Taoism, Judaism and Wicca, These happen in the form of washing (ablution, sacrament of Christianity called baptism and ritual washings of other religions (Marks,2001). Generally water is regarded as life and life is regarded as water. Since all aspects of life depend on water for domestic, industrial, religious and agricultural uses, there is need to scout for available sources of water. Among the available sources groundwater seems to be the most important one. Water has always played and continues to play a central role in human societies.

2.2.2 Water Resources Development

Water is the resource that sustains all life on earth and is a key element of sustainable development. Water is an infinite resource, worldwide there is an imbalance between water utilization and water resources management. This imbalance has brought a veritable crisis with regard to water in many regions of the world. Yatsuka (2002) reported that it is projected that by

2025, about 3.5 billion people-approximately 6.5 times as many people as in the year 2000- will live in water stressed countries. This indicates the level of water resource deterioration globally.

In most regions of the world, water availability has rapidly decreased for example in Asia water availability per capita ranks as least in the world with 4,200m3/capita per year a little more than half the world average of 7,000m^3. In the year 2025, water availability per capita in Asian region and the rest of the world including Africa will probably be between 15 and 35 less than that of 1950 (ADB, 2001).

Water shortage and scarcity necessitated for world conferences on water. WHO report (1999) shows that Ministerial Conference on Environment and Development in Asia and the Pacific (MCED) in the year 2000 identified conservation and integrated management of fresh water resources as one of the eight priority areas of the Asian region. Also ministerial declaration issued at the international conference on fresh water held at Bonn in December 2011 also made a call to the UN Secretary General to strengthen the coordination coherence of activities within the UN system on water issues in an exclusive manner. Outcomes of world water forum conducted by Global water partnership increases global awareness of water crisis and promote actions for sustainable use and development of water resources.

2.2.3 Water Resources Development in Africa

The increasing severity of water crises represents a real threat for sustainable development in the new millennium. The amount of water needed for development in the continent have increased but the population have tripled. Demand for water is set to grow markedly in coming decades due to population growth and need for more water to use. If water use continues to increase at the same rate, by 2025 almost 5 billion of the 7.5 billion inhabitants of the planet will live in areas where it will be difficult to satisfy basic water needs (UNECA,2005). Africa is a continent with great possibilities, but it also faces great uncertainties concerning exploitation and development of its water resources. Africa contains more than 57 international water ways covering more than 60% of the continent. However Africa also contains the largest desert in the world, the Sahara lying north of the equator. It also suffers from repeated and prolonged periods of drought. That is why it is necessary to develop and plan water resource of the African continent. It was discovered by scientists that the notoriously dry continent of Africa is sitting on a vast reservoir of groundwater. They argue that the total volume of water in aquifers underground is 100 times the amount found on the surface Bonsor (2012).

Africa's river systems have been the target of development planners since 1960s. Many rivers of the continent have been dammed for power generation, irrigation, flood control and water supply. Water resources development planning has been widely adopted in Africa, and often enough water resources development has come to be synonymous with river basin development Adams (1992). In spite of all these water shortage is still a problem in Africa.

2.2.4 Water resource Development in Nigeria

Water scarcity and water quality issues resulted into more concern on water resources in Nigeria. Mabogunje (1965) has reviewed the pattern of water resources development in Nigeria especially during the colonial period. He added that the primary aim is to do away with the problems of water shortage and quality deterioration. Today in Nigeria, less than 50% of the population have access to potable water supply and majority are from rural areas (WUP,2001).

A number of water development plans were established all with intention of solving problems relating to water. The first modern water supply scheme in the country was established in Lagos in 1915 and by 1953, 27 other water works had been built in various parts of the country Ayoade (1975) Most of these schemes suffered from lack of finance which lower their performance. Water consumption of the country also increased as a result of increase in population the total water consumed in Nigeria rose 13.8 million gallons in 1953 to over 57 million gallons in 1960.(Ayoade, 1976).

National Development plans from 1962 to date have invested much on water resources development but still there is need for more planning and development. Nigeria has demonstrated the need for proper management and planning of country's water resources. A comprehensive geographical survey is necessary in order to assess the extent of groundwater and exploit it for effective rural water supply (Douglas,1973).

2.2.5 Water Shortage

Water is an essential resource for life and good health. Lack of water to meet daily needs is a reality today for one out of three people around the world. Globally, the problem is getting worse as cities and population grow and the needs for water increase in agriculture, industry and household. Water scarcity is a topic of discussion globally especially in developing regions. Macdonald (2005) pointed out that there are still at least 1.1 billion people across the world that does not have access to safe drinking water. Many of these people live in rural areas and are among the poorest and most vulnerable to be found anywhere in the world. In India water supply and sanitation continue to be inadequate, despite longstanding efforts by various levels of governments and communities at improving coverage (Ayush,2010).

In sub Saharan Africa, 300 million people have no access to safe water supplies out of which approximately 80% live in rural areas Macdonald (2005).This resulted into sufferings and under developments. It was reported by Timorthy *et al* (1994) that lack of adequate potable and agricultural water supplies inhibits the progress of developing countries and is the cause of considerable hardship to humans worldwide. In another development Lean, Hinrichen and Markhem (1990), established that West African countries experience lack of safe and adequate water for their inhabitants; 25 to 50 percent of the population do not have access to safe water supplies. The trend is so everywhere, as population figures are increasing water demand also is greatly increasing thereby causing shortage.

As population increases and development calls for increased allocation of groundwater and surface water for domestic, agricultural and industrial sectors, the pressure on water resources intensifies, leading to tension, conflicts among users and excessive pressure on the environment. UNDP (2006) reported that people in the slums of developing countries typically pay 5-10 times more per unit of water than do people with access to piped water. In another development WMO (2008) revealed that by 2025, 1800 million people will be living in countries with absolute water scarcity and two thirds of the world population could be under stress condition.

For poor people, water scarcity is not only about droughts or rivers running dry. Above all, it is about guaranteeing the fair and access they need to sustain their lives and secure livelihood. In Nigeria water scarcity has been in existence as far back as even before the colonial period when people migrate from one part of the country to another in search of water. It is established that only

27.4% of the total population of the country was served with improved water supply in 1974, with rural population, accounting for not more than 0.30% Oyebende (1977) in Sheka (2005), cited in Nura and Sabo (2011).

2.2.6 Groundwater Resource and Development

Groundwater comprises water that exists beneath the land surface, held within openings or pores of soils and geological formations. According to most classical definitions, this term refers exclusively to water occurring at or beneath a surface, known as the water table. Below the water table is a region known as saturated zone, pores are completely filled with water. Trimmer (2000) defines groundwater as water that naturally occurs in porous rock materials underground.

Groundwater is a critical underlying resource for human survival and economic development in extensive drought-prone areas of south-eastern, east and western Africa especially where the average is less than (say) 1,000 mm/a Stephen, *(*Albert and Hector,2002). Robert (2007) lamented that groundwater is a resource that make up an impressive 90% of the fresh water that is readily available for human use. This is one of the reasons why groundwater is regarded as major source of drinking water in most parts of the world. United States of America has one of the safest water supplies in the world but yet the quality of drinking water has continuously been deteriorating. U S G A (2006) report that 49% of the US population depend on groundwater for its drinking water supply from either a public source or a private well. At present ¾ of the public water supply in Germany is taken from groundwater sources and only ¼ is taken from surface water (TheoGeoge, 1997).

In India groundwater accounts for large percentage of water used for irrigation and drinking for example Aditi and Tushaar (2002) states that over 60% of water supply in India is from groundwater, that is why it is regarded as poverty reduction tool in rural areas.

The potential importance of groundwater as a resource is indicated by estimates of the world's water balance. Demenico and Schwartz (1990) revealed that according to most estimates, saline oceans and seas account for 94% to more than 97% of the world's water, while another 2% is held in glaciers and polar ice caps. Although groundwater constitutes a few percentage by volume of the total water at or near the earth's surface, yet it is apparent that groundwater makes up the world's utilizable freshwater resources, 95% or more by volume.

Groundwater is widely used because of its high quality. Groundwater development unfolds rapidly once a minimum level of technology and energy become widely available Shah, (1993). Groundwater use is becoming more apparent than surface water for example UN/WWAP (2003) conclude that groundwater use often brings large economic benefits per unit volume, because of its ready local availability, drought reliability and good quality requiring minimal treatment.

2.2.7 Groundwater Resource Development in Nigeria

Provision of safe drinking water and basic sanitations are within the framework of the United Nations Millennium Development Goals (MDGs). This is only possible through development of water resource of any nation. In Nigeria, like in all parts of the world, surface water development is invariably associated with various health and environmental consequences which include drainage up-set, collapse of dams, spread of diseases and flood. This necessitated the government to embark upon groundwater resource development. In 1917 Nigerian Geological Survey was established and one of its objectives is to search for groundwater in northern Nigeria.

The following organizations are at the forefront in the timely efforts of groundwater resource management: The Earth Summit, the World Water Forum, World Bank, WHO, UNESCO, FAO, UNICEF and UNDP (Nwankwoala,2011).

Global Survey of Nigeria was carried out in early 1950s by government with the intention of developing groundwater resources. First National Development Plan (1962-1968) resulted into the establishment of river Niger and Lake Chad Basin Commissions. In 1973 and 1974 Sokoto Rima and Lake Chad Basin authorities were established for developing groundwater resources. The establishment of Federal Ministry of Water Resources in 1975 brought about extensive groundwater development. All these efforts were to develop water supply delivery in line with United Nations International Drinking water supply and sanitation decade (IDWSSD).

Establishment of National Borehole Project in 1980 and formation of Department of Food, Roads and Rural Infrastructure (DFRRI) between 1986 and 1994 and Petroleum Trust Fund (PTF) water project between 1995- 1999 improved the nations access to water supply and of recent constituency water projects by senates, members of house of representatives and members of states house of assembly.

Data on groundwater in Nigeria is inadequate for development. According to Ajayi, Sonuga, Alibon and Oloke (2003) lack of data and information for planning and shortage of manpower among others are the major obstacles to groundwater development in Nigeria.

Population growth rate and industrial development increase water demand in Nigeria and last and reliable option is groundwater. Nwankwoala (2011) reports that groundwater use in Nigeria is characterized by uncoordinated development and supply to all sectors: rural and urban users, small and large scale users, industrial and agricultural users. This shows that there is the need for formulation of efficient and effective policies on groundwater through data collection and organization for adequate water supply. Improvements of groundwater supply is essential especially in areas of formulation of adequate, efficient and effective water policies, funding and appropriate infrastructure as well as monitoring and evaluation (Custodio,2002).

All over the world, groundwater formation varies with geologic formations depending on location and others factors like climate. Ifabiyi (2005) stated that 50% of Nigeria's population and majority of rural scattered communities are found in places underlain by Basement Complex Rocks where dam construction will be an unnecessary exercise in view of the dispersed nature of settlements. Also Faniran and Omorinbola (1980) in Ifabiyi (2005) states that in Nigeria sedimentary regions are ascribed to have higher groundwater resources...Basement complex regions have appreciable quantity of water in them. This shows that groundwater development is necessary for overall national development. The cost of development of groundwater is cheaper than that of surface water and the quality of the water is which requires reasonably good requiring only minimal treatment in a readily used form (Offodile,2000).

Groundwater development is an excellent option for sustainable water supplies in Nigeria. However, to achieve a sustainable supply, planning is required hydrological and hydro geological data, as well information on water demand and general socioeconomic conditions (Onugba and Yaya, 2008).

2.2.8 Groundwater Potentials

The search for groundwater has become quite intense in history. This is due to the fact that government is unable to meet the ever increasing water demand; inhabitant have to look for alternative sources such as streams, shallow wells and boreholes. This can be achieved through groundwater potentials studies. For example Ali – elnaqa, Nezar, Khalil and Masdouq (2009) determined groundwater potential of Wadi Arabia and classified the area into 40% is of higher potential, 30% is moderate potential, 17% of low potential while the rest are undecided.

Groundwater potential is determined using remote sensing and GIS to evaluate the water resource potential. Mathew (2006) pointed out that the groundwater potential of United States is divided into principal aquifers of over 300,000km^2 principal aquifers of over 20,000km^2, principal aquifers of less than 20,000km^2 and non-principal aquifers. Classification of areas into groundwater potential zones or classes is not a new issue in the field of hydrology. An assessment of groundwater potential in Nigeria was conducted through delineation of aquifers by many researchers. Okoro (2010) for example evaluated groundwater potentials in parts of escarpment areas of south – eastern Nigeria.

When rain falls, some of it runs off the surface forming streams and rivers, some of it evaporates directly or indirectly via plants and some soak into the surface rocks. Water covers 70.9% of the earth's surface and it is vital for all known forms of life. On earth, it is found mostly in oceans and other large water bodies, with 1.6% of water below ground in aquifers, 0.01% in the air as vapour, cloud and precipitation, 97% in ocean as surface water, 2.4% as glaciers and ice caps, 0.65% in rivers and ponds as others surface water bodies. (Abegunde, 1999). In other words, groundwater is the water that sinks into the ground. That is, the water that enters the rocks through either the pore spaces separating the individual grains of rocks or through the joints or fault in the rocks. According to most classical definitions' this term refers exclusively to water occurring at or beneath a surface, known as the water table. Below the water table is a region known as saturated zone where pores are completely filled with water. Trimmer (2000) defines groundwater as water that naturally occurs in porous rock materials underground. According to Abegunde (1999) is of the view that, the depth of the groundwater depends on the following factors:

i Relief of the area: The higher or bigger the relief e.g. high mountain, the higher the groundwater.

ii Type of rocks: Presence of porous and permeable rocks leads to low water table while the presence of porous and impermeable rocks tends to favor high groundwater.

iii Seasons: Rainy season favors high groundwater recharge while dry season reduces the level of groundwater.

iv Presence of springs: The presence of springs tends to reduce the level of groundwater and vice versa.

The amount of water potentials available to form the groundwater depends to some large extent the climate and other related factors and it is very crucial for many countries and people of Africa and the world at large, particularly during the dry seasons. More so, much better sources of groundwater is confined in the artesian aquifer, this type of aquifer is confined between two layers of impermeable strata of the earth and the aquifers extends up to the mountains where it is exposed to precipitation as recharge area and it may as well extends to hundreds of miles Abegunde (1999). Furthermore, in the basement complex terrain, groundwater occurs either in the weathered mantle or joints and fracture system in the un-weathered rocks (Oguntade,2009).

The potential importance of groundwater as a resource is indicated by estimates of the world's water balance. Demenico and Schwartz (1990) observe that according to most estimates, saline, oceans and seas account for 94% to more than 97% of the world's water, while another 2% is held in glaciers and polar ice caps. Since groundwater constitutes a few percentages by volume of the total water at or near the earth's surface, thus, it becomes apparent that groundwater makes up the world's utilizable freshwater resources, 95% or more by volume. Groundwater is widely used because of its high quality. Groundwater development unfolds rapidly once a minimum level of technology and energy become widely available (Shah,1993).

2.2.9 Physical Properties that Affect Groundwater

The degree to which a body of rock or sediments will function as a groundwater resource depends on many properties, some of which are discussed here. Two of the more important physical properties to consider are porosity and hydraulic conductivity. Transmissivity is another important concept to understand when considering an aquifer's overall ability to yield significant groundwater. Throughout the discussion of these properties, keep in mind that sediment size in alluvial environments can change significantly over short distances, with a corresponding change in physical properties. Thus, while these properties are often presented as average values for a large area, one might encounter different conditions on a more localized level. Determination of these properties for a given aquifer may be based on lithologic or geophysical observations, laboratory testing, or aquifer tests with varying degrees of accuracy (Driscoll,1986).

Water is a chemical substance with a chemical formulae H_2O.Water covers 70.9% of the earth's surface and it is vital for all known forms of life. On earth, it is found mostly in oceans and others, 0.65% in rivers lakes and ponds as other surface water bodies. A very small amount of earth's water is contained within biological bodies and manufactured products (BBC report, 2007) Water scarcity is a topic of discussion globally especially in developing regions. Macdonald (2005) pointed out that there are still at least 1.1 billion people across the world that do not have access to safe drinking water. Groundwater comprises water that exists beneath the land surface, held within openings or pores of soils and geological formations. According to most classical definitions, this term refers exclusively to water occurring at or beneath a surface, known as the water table. Below the water table is a region known as saturated zone where pores are completely filled with water.

Trimmer (2000) defines groundwater as water that naturally occurs in porous rock materials underground. Groundwater potential means having a latent possibility or likelihood of occurrence of groundwater in an area. Areas or zones of abundant groundwater available for use are referred to as areas of good groundwater potential. Productive water bearing zones referred to as good groundwater potential aquifers.

2.2.10 Groundwater Exploration

Groundwater exploration simply means investigating the presence or absence of groundwater .Successful exploration of groundwater requires a proper understanding of hydrological characteristics of any given area, and it also determines its potentials and quality, these characteristics also determine the level of water in the aquifer. Increasing demand on groundwater necessitated experts and researchers in the field of hydrological studies to look for more ways of groundwater exploration. In many parts of the world groundwater abstraction has exceeded safe yield, resulting in over exploitation and over stressing of the aquifer. Toth (1989) states that water table is a function of topography and climate. The flow pattern of groundwater if a function of climate and geology and these three terms are referred to as hydrological environment Toth (1989). It is reported by Thapa (2009) that to evaluate groundwater potential zones of an area various parameters namely: lithology, slope, lineament, hydro – geomorphology, land – use and land cover need to be properly understood. A lineament is a linear feature whose parts are aligned rectilinear or slightly curvilinear relationship, which differs a lot with neighboring features and most probably reflects a subsurface phenomenon Singal (1999). In formation on soils also forms an important input in mapping groundwater potential zones, for example coarse soils are generally permeable while fine soils indicates less permeable Thapa (2009).

Groundwater comprises water that exists beneath the land surface, held within openings or pores of soils and geological formations. According to most classical definitions, this term refers exclusively to water occurring at or beneath a surface, known as water table. Below the water table is a saturated region known as saturated zone, pores are completely filled with water.

Groundwater is a critical underlying resource for human survival and economic development in extensive drought – prone areas of southern – eastern, east and western Africa especially where the average is less than 1,000mm/a . Albert (2007) lamented that groundwater is a resource that make up an impressive 90% of the fresh water that is readily available for human use. This is one of the reason why groundwater is regarded as major source of drinking water in most part of the world. United State of America has one of the safest water supplies in the world but yet the quality of drinking water has continuously been deteriorating. United Nation General Assembly (2006) reported that 49% of the U.S. population depend on groundwater for its drinking water supply from either a public source or a private well. At present ¾ of the public water supply in Germany is taken from groundwater sources and only ¼ is taken from surface water (TheoGeoge, 1997).

2.2.11 Groundwater Exploration Techniques

Groundwater exploration is carried out in many ways ranging from traditional to modern methods. Everyday groundwater exploration is developing through new means and devices.

Meijirik (2007) reports that exploration for groundwater using photo geology was a major field of interest in the past and still is in areas covered in adequately by geological maps. This is with regards to geological point of view. The Classic Work of Ray (1960) has assisted many beginners in the field of hydrogeology.

In addition to other conventional methods, remote sensing and GIS are used in groundwater exploration. Lillesand and Kiefer (2000) stated that remote sensing is the science of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation. The main reason for using remote sensing in groundwater exploration is cost effectiveness of well sites selection.

Groundwater storage depends on aquifer parameters, rate of water movement and recharge of the aquifers. Groundwater movement like surface water is affected by the nature of slope or elevation. Thomas (2003) stated that groundwater moves from higher elevations to lower elevations and from location of higher pressure to location of lower pressure. Groundwater recharge and storage to shallow unconfined aquifer is complex and is dependent upon the occurrence, intensity and duration of precipitation, temperature, humidity, wind velocity as well as character and thickness of soil and rock above the water table and the surface topography, vegetation and land use Memon (1995) cited in Arnold *et al* (2000). Groundwater studies can be achieved using integrated approach that involves multiple methods. many researchers applied conventional methods in groundwater exploration studies. Notably among them is Saumitra (2008) who used both geophysical, remote sensing and GIS data in groundwater exploration in India.

2.2.12 Remote Sensing and Geographic Information System

The full potential of remote sensing and GIS can be utilized when an integrated approach is adopted. Integration of the two technologies has proven to be an efficient tool in groundwater studies Saraf and Choudhury (1998). For effective groundwater exploration and exploitation it is important to study the different parameters in an integrated approach. The integration of multiple data sets, with various indications of groundwater availability, can decrease the uncertainty and lead to 'safer' decisions Sander (1996). The Geographic information system offers spatial data management and analysis tools that can assist users in organizing, storing, editing, analyzing, and displaying positional and attribute information about geographical data Burrough (1986). Remote sensing data provide accurate spatial information and can be economically utilized over conventional methods of hydro-geological surveys. Digital enhancement of satellite data results in extraction of maximum information and an increased interpretability. GIS techniques facilitate integration and analysis of large volumes of data to field studies help to validate results further. Integrating all these approaches can offer a better understanding of groundwater controlling features in hard rock aquifers.

2.2.13 Remote Sensing and GI S Application to Groundwater Exploration

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sensing data provide accurate spatial information and can be economically utilized over conventional methods of hydro-geological surveys. Digital enhancement of satellite data results in extraction of maximum information and an increased interpretability. GIS techniques facilitate integration and analysis of large volumes of data. Whereas field studies help to validate results further. Integrating all these approaches can offer a better understanding of groundwater controlling features in hard rock aquifers.

2.3 REVIEW OF RELATED LITERATURES

Groundwater potentials means having a latent possibility or likelihood of occurrence of groundwater in an area. A zone of abundant groundwater available for use are referred to as areas of good groundwater potentials, and productive water bearing water zones are referred to as aquifers. Groundwater storage depends on aquifer parameters, rate of water movement and recharge of the aquifers. Groundwater movement like surface water is affected by nature of slope or elevation, Thomas (2003) stated that groundwater moves from higher elevations to lower elevations and from location of higher pressure to location of lower pressure. Groundwater recharge and storage to shallow unconfined aquifer is complex and is dependent upon the occurrence, intensity and duration of precipitation, temperature, humidity, wind velocity as well as character and thickness of soil and rock above the water table and the surface topography, vegetation and land use.

Water supply is an important aspect of development and more so, is a finite resource, an essential part of an ecosystem and sustain life on the earth and of course every community depends on it for domestic, agriculture and industrial needs.

Availability of water has been a factor in the development of various civilizations near lakes, and rivers (Rainer,1996). Despite these basic attributes of water as a resource, its potentials and quality has been greatly deteriorating in the contemporary world due to industrialization, increasing population and other human activities. The persistent decrease in groundwater potentials and also quality of water for various human uses and the instability of ecosystem that characterize several areas in the contemporary world is technically referred to as water resource degradation (Rainer,1996).

Groundwater resources are crucial for many countries and people in Africa, particularly during the dry season and in large arid zones. Groundwater is the main source of water in the rural areas including for nearly 80% of human and population in Botswana. Government of Botswana (1993). And at least 40% in Namibia Heyns (1993). In Libya, groundwater accounts for about 95% of the country's freshwater withdrawals FAO (1997). While in the areas such as the Pangani Basin of Tanzania, groundwater is a significant source for irrigated agriculture (World Bank, 1995).

In many parts of the continents, groundwater resources have not been fully explored and tapped. The demands for water are increasing rapidly in most countries due to population growth and economic development. Although, some African countries have high annual average of available water per capita, while many others are already or will soon face water stress (1770m^3or less per person annually). Currently fourteen (14) countries in Africa are subjected to water stress or scarcity with those in Northern Africa facing the worst prospects (Hopkins, 1998).

Groundwater potentials is higher in limited areas of sedimentary rocks and it occurs in perched aquifers. While the potential is low in some basement complex, the success ratio of boreholes is lower because of the limited depth of regolith, its clay content and localized occurrences of fractures and joints. However, the basement complex areas have higher surface run off potential.

Based on the above, many researchers applied conventional methods in groundwater potentials/ explorations studies. Notably among them is Rilwanu (2014) who used geophysical, remote sensing and GIS data to determine/ obtain groundwater potentials for some rural water supply in parts of Kano State Nigeria Others who used the same approach are Samaila (1997), Abdulkadir (1993), Shakeel (2008), Thapa (2009), Reynold (1987) Biswarup (2000), Josrolia (2007), and Carlo (1998).

2.3.1 Exploration of Groundwater

Groundwater exploration simply means investigating the presence or absence of groundwater .Successful exploration of groundwater requires a proper understanding of hydrological characteristics of any given area, and it also determines its potentials and quality, these characteristics also determine the level of water in the aquifer. Increasing demand on groundwater necessitated experts and researchers in the field of hydrological studies to look for more ways of groundwater exploration. In many parts of the world, groundwater abstraction has exceeded safe yield, resulting in over exploitation and overstressing of the aquifer. Toth (1989) states that water table is a function of topography and climate. The flow pattern of groundwater is a function of climate and geology and these three terms are referred to as hydrological environment Toth (1989). It is reported by Thapa (2009) that to evaluate groundwater potential zones of an area various parameters namely: lithology, slope, lineament, hydro – geomorphology, land – use and land cover need to be properly understood. A lineament is a linear feature whose parts are aligned rectilinear or slightly curvilinear relationship, which differs a lot with neighboring features and most probably reflects a subsurface phenomenon (Singal,1999).

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CHAPTER THREE
STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

This chapter provides the general background of Kaduna South L.G.A. It also considered the methodology adopted for the study as well as the procedure adopted for this research work.

3.2 THE STUDY AREA

3.2.1 Location

Kaduna South Local Government Area is one of the 23 Local Government Area of Kaduna State. It is geographically located between latitude $10^{o}\ 05^{1}$ N and $10^{o}\ 37^{1}$ N of the equator and between longitudes $7^{o}\ 22^{1}$ E and $7^{o}\ 31^{1}$ E of the Greenwich Meridian. The study area occupies an area of approximately 123.88 kilometers square of land mass. The study area comprises of Barnawa, Kakuri, Makera and Tudun-Wada areas found in Kaduna South L.G.A. of Kaduna State. The location of the study area is shown in Figure 3.1.

3.2.2 Weather and Climate

The study area has a tropical continental climate (Aw) with distinct wet and dry seasons reflecting the influences of tropical maritame air masses (mT) and tropical continental air masses (cT) which ultimately cover the country. When mT which originates over the Atlantic Ocean, prevails over the area brings in rainy season. While cT originates from Sahara desert, it brings in the dry seasons with cold and dusty air that occasionally limits visibility in hammattan condition in the area (Iguisi,1996).

The area has mean monthly minimum and maximum temperatures of 15.9^{0}C and 35.35^{0}C with an annual mean of about 19.45^{0}C, the highest temperatures are being recorded in December and January Iguisi (1996). The annual rainfall in the area is about 1530mm; it range from 0.0mm in November through February to 825.0mm in August, which is the wettest month (Field work,2009).

3.2.3 Relief

The general relief of the area is undulating, with areas along the flood plains of the rivers being lower than those on the upland sections and also with occasional rock outcrops in some parts of the city. Eastern part of the city which is mostly bounded by the River Kaduna is low lying area, while the North – Western part of the city is comparatively higher. The relief is to the extent controlled by the geology, that is, areas more resistant to denudation are higher than those that are susceptible Udoh (1978). The area has an average elevation of 200m above sea level and the relief nature of the area helps in a great way to its industrial development.

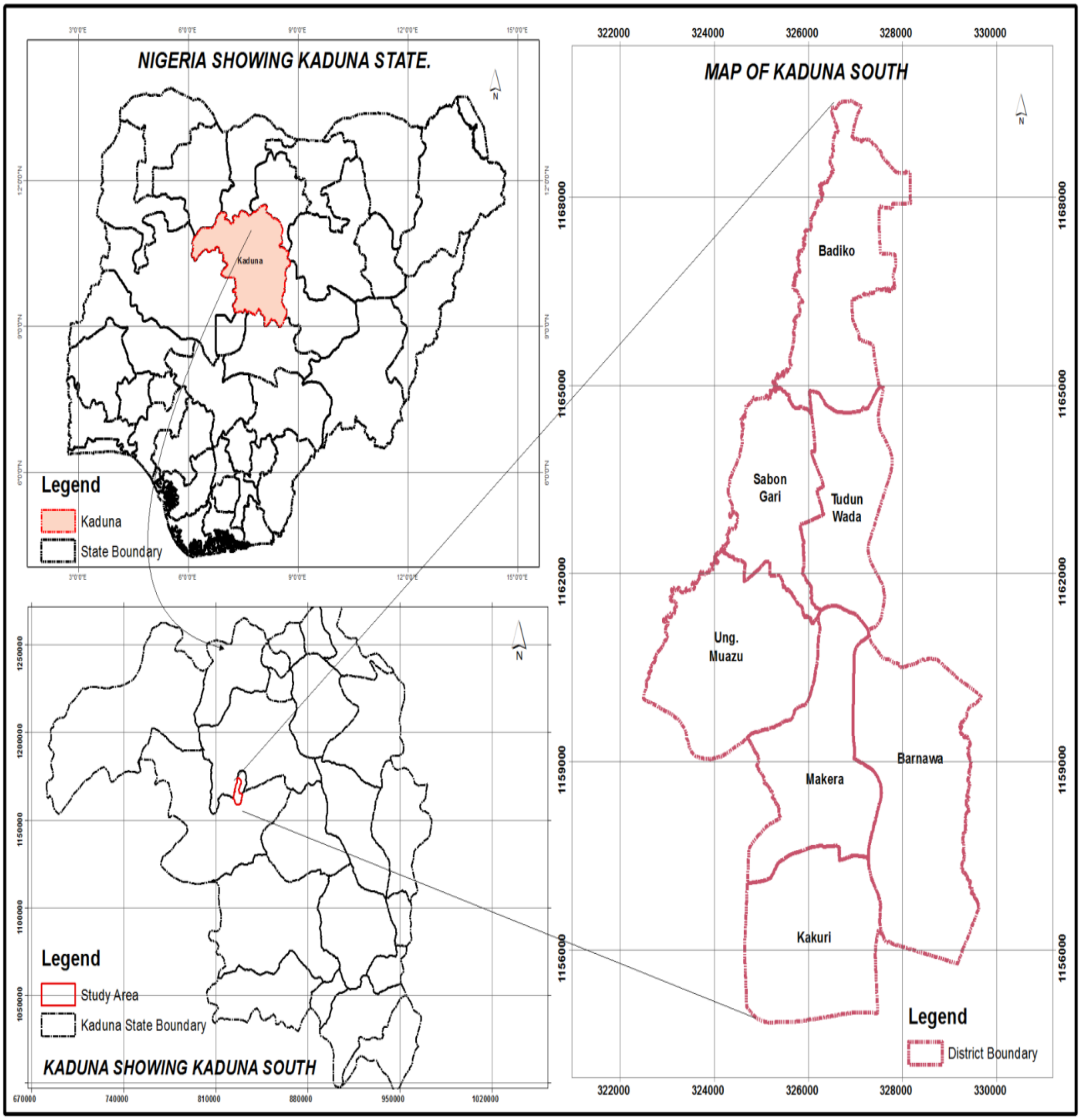

Figure 3.1: Map of the Study Area

Source: Adapted from the administrative map of Kaduna state

3.2.4 Soils

The soils of Kaduna South local government area are typically red -brown to red – yellow of tropical ferruginous soils derived from the regolith of the basement complex. In the cultivated areas, these soils are covered by a layer of wind drift material. Soils in the upland areas are rich in red clay and sand but poor in organic matter. While soils within the flood plains are rich in kaolinitic clay and organic matter and are referred to as fadama soils and this type of soil do well in the production/cultivation of cereals and vegetables which at the end would enhance the supply of raw materials for Beverage industries in the area.

Olofin (1987) observed that, areas in the extreme west or south west are characterized by clayey loamy soils. The soils are deep, well drained except for hydromorphic soils and poorly structured soils. The texture of soils in Kaduna South ranges from sandy – loam in the south to loamy sand in the north (Aminu, 2014).

3.2.5 Vegetation

Kaduna South is located within the northern Guinea savanna vegetation zone of Nigeria. The natural vegetation of this zone consists of scattered trees interspersed with tall grasses. However, human activities associated with urbanization have seriously modified the vegetation to the extent that now, trees are most often found only as ornamental ones, comprising mostly of exotic species.

3.2.6 Hydrology

The availability of underground water can be determined through ascertaining the hydrology of the study area, Kaduna south is underlain by rock of basement complex consisting of biotate, gneiss and older granites and the rocks have been subjected to weathering to produce fairly deep regolith which has been subjected to lateralization. There are also the occurrences of hardpan (laterite) and rocks of basement complex at different locations within the Metropolis (Bello,2009).

3.2.7 Geology

The southern parts of Kaduna in the north-central Nigeria forms a part of the West African Mobile zone which extends from east to west from Nigeria, and Ghana where it is "sutured" to the West African craton by the Pan African Dahomeyan (or Beninian) belt. The whole ensemble of rocks in this zone had undergone an extensive episode of "remobilisation and reactivation" during the Pan-African thermotectonic event some 600 my ago (Mbonu,1989).

The entire land area is underlain by Precambrian migmatite-gneiss complex, metasediments/metavolcanics (mostly schists, quartzite, and banded iron formations). Pan African granitoids and calc-alkaline granites, and volcanics of Jurassic age. These various rock units, especially the gneisses and the schists, have been affected by many periods of orogenic movements, resulting in extensive deformation and migmatization. McCurry(1976) reported that the oldest rocks of the area are the gneisses and older metasediments believed to be Birrimian in age (about 2500 my).

The groundwater prospects of Basement areas have mixed reviews in the literature. The igneous and metamorphic rocks constituting the Basement Complex of Nigeria as a whole has an undeserved reputation as poor aquifers Hazell, Cratchley and Jones (1992); Egboka (1988)

Groundwater occurrence in the area could be grouped into three. These are:

(a) The Weathered/Fractured Basement Complex

(b) The Newer Basalts

(c) The River Alluvium

The weathered granular sandy zone is composed of coarse-grained sands, which form a level below the loose clayey laterite. The granular sands may consist of sands or gravels derived from the disintegrations of the crystalline rock. There are good prospects for groundwater production in the horizon of the intermediate zones with an average thickness of about 6 m (Jones,1985). The majority of hand-dug wells in the study area terminate in this part of the zone.

The Newer Basalts occur in the vicinity of Kafanchan and Manchok along the western edge of the Jos Plateau. The Basalts were erupted after the Plateau had achieved almost its present-day topography and are themselves mildly affected by erosion McCurry (1976). Thus, they often overlie alluvial deposits. Zones of weathering and beds of alluvium also occur between individual basalt flows. The aquifer potential of the fluvio-volcanic sequence is good and yields of 370 to 500 m^3/d have been obtained. Also, a borehole (No. GWR/21/l) drilled at Tum village, within the Newer Basalts, produced a yield of l2.6 m3/h. A highly productive spring (Kajim) emerges from the Newer Basalt at Manchok. The dry season flow of this spring is about 11,000 m^3/day MRT Consulting Eng. Nig Ltd (1978). It forms the headwater of a tributary of the Kaduna River.

3.2.8 Economic Activities

The economic activities of the study area is second only to Kano in Northern Nigeria due to the presence of various kind of industries. Some of the industrial establishments include Peugeot Automobile Assembly Plant, Agro – allied industries and the Textile industries. More so, the study area still plays an important role in the politics of Northern Nigeria and of course, these teaming populations will invariably determine the quality and quantity of the underground water of the study area (Okonkwo,2008).

3.2.9 Population

The population of Kaduna South according to National Population Commission (1991) stood at 391,575 persons, and available evidence shows that, the area is inhabited by different ethnic groups, with Hausa and English as the most general languages used as a means of communication. The study area also accommodated industrial layout of Kaduna State.

3.2.10 Land Use of Kaduna South

Kaduna South is one of the largest part of the Metropolis in the state which is inhabited by multi-ethnic groups who migrated in as a result of industrial activities, trade, commerce, education and other various job opportunities, a such this is in line with the land use pattern of the study area, that is, the major land – uses in Kaduna South ranges from industrialization which is the most predominant, farming activities, irrigation and fishing especially in the river Kaduna (Okonkwo,2008).

Water is the major ingredient of all forms of development in the study area, human population demand lots of water for its commercial, agricultural, industrial and other activities for a complete survival. This is the more reason why both rural and urban areas of Kaduna State need a sustainable and adequate water supply for development.

3.3 METHODOLOGY

This section explains the methodology used in achieving the objectives of study

This section explains the methodology used in achieving the objectives of the study.

3.3.1 Reconnaissance Survey

A reconnaissance survey and physical field observation of the study area was undertaken, in order to have adequate knowledge of the study area. It also helped the researcher to gain good knowledge on water problem in the study area

3.3.2 Types and Sources of Data

Both primary and secondary data were utilized in this study. Primary data that were used are satellite imageries (LANDSAT and Shuttle Radar Topographic Mission, SRTM) and the secondary data include rainfall data and existing soil map of Kaduna state. Other literature were sourced from newspaper, journal, textbooks etc.

S/no	Type of Data	Source	Purpose
1	SRTM-30	United States Geological Survey Website.	For DEM creation, topography and Slope map
2	LANDSAT 8 (2015)	United States Geological Survey Website.	Production of Land use/ land cover and lineament map
4	Soil Map 1:50000	Department of Agricultural Science, ABU Zaria.	Soil map of the area
5	Rainfall data (2004-2015)	Nigeria Metrological Agency (NIMET).	Production of Rainfall map

3.3.3 Hardware and Software

The following software were used for the underground water potential zones in the study area:

i. ERDAS IMAGINE: For image processing and classification.

ii. ArcGIS for digitizing and Groundwater analysis.

iii. PCI Geomatica v10.0 for lineament extraction.

iv. Microsoft Excel for statistical analysis.

v. The hardware used for this study include a HP Pavilion laptop computer, Garmin 76 CSX handheld GPS

3.3.4 Data Processing

3.3.4.1 Image Processing and Classification

The LANDSAT 7 was utilized to obtain different layer and the layer was stacked together using ERDAS Imagine 9.2 software; subset of the study area was obtained using the ERDAS imagine software subset tool. ERDAS imagine was used for the pixel-based classification. Supervised classification was carried out using maximum likelihood classifier since it is a land-use/land cover classification which will produce the output raster layer. This method of classification involves the procedure of identifying pixels possessing the same spectral features. ERDAS Imagine software was used in digitally processing and identifying the spectral signatures of different features. Maximum likelihood algorithm was used to classify the images and the digital numbers of the pixels will be grouped with pixels arranged and organized otherwise known as land cover classes built-up, vegetation, bare land, agricultural area, water bodies as suggested by U.S.G.S classification system Anderson's Classification(1976).

Figure 3.3: Landsat ETM+ 2015 imagery of the study area.

Source: http://glovis.usgs.gov/

3.3.4.2 Processing of Thematic Maps

The thematic maps were processed as follows:

a. **Annual Rainfall Map:** An annual rainfall map of the study area was prepared by the Inverse Distance Weighting (IDW) interpolation method using the annual rainfall measured at the NIMET meteorology stations bordering Kaduna-South Local Government Area.

b. **Drainage Map:** Drainage is one of the most important indicators of underground water, because drainage pattern, texture and density are controlled in a fundamental way by the underlying lithology. The drainage pattern is a reflection of the rate that precipitation infiltrates compared with the surface runoff. The drainage map was digitized from the SRTM data and topographic map. The Drainage density map was produced using the ArcGIS Spatial Analyst Tool.

c. **Topographic/Slope Map:** Topographic data is a vital element in determining the water table elevations. The Digital Elevation Model (DEM) from the SRTM data was used to produce the contours and slope map for the study area. Steps followed to prepare the slope amount of the project area are described as follows:

    i. Shuttle Radar Topographic Mission.

    ii. Derivation of Slope in degree was generated using Spatial Analysis and reclassification into appropriate classes.

d. **Land Use/Land Cover Map:** The landuse/landcover for the study area was characterized by a mixture of built-up, vegetation, bare land, agricultural area, water bodies. The land-use/land-cover was interpreted from the landsat satellite imagery by using visual interpretation. Unsupervised classification and supervised classification was carried out using the appropriate bands combinations. Unsupervised classification was used to have a general idea of the study area and supervised classification was used for production of the final land-use map.

e. **Lineaments Map:** Lineaments give a clue to movement and storage of groundwater (Subba *et al*. 2001) and therefore are important guides for groundwater exploration. Recently, many groundwater exploration projects made in many different countries have obtained higher success rates when sites for drilling were guided by lineament mapping (Teeuw, 1995). The lineament map was derived from landsat imagery by image enhancement and digitizing.

3.3.5 Techniques for Data Analysis.

3.3.5.1 Nature of the LandCcover

The nature of the landuse/land cover was mapped in Erdas Imagine version 9.2 using supervised classification according the Anderson's (1976) classification scheme. The classes are water body, urban built-up land, bare land, vegetated land and farmland.

3.3.5.1 Factors Contributing to Groundwater Potential Zones.

Prior to integration of the data sets, individual class weights and map scores were assessed based on Satty's and Vargas (1991) Analytic Hierarchy Process (AHP); in this method the relative importance of each individual class within the same map were compared to each other pair-wise and eight importance matrices were prepared for assigning weight to each class. The AHP was used to characterize the zones into very good, good, moderate, low and very low. These zones were characterized based on the aquifer properties, soil type, geology and topography. Table 3.1

shows the processes involved in weight assignment using AHP and Table 3.3 shows weight for the factors according to Solomon (2003).

Table 3.1: Procedure of Assigning Weightages in Analytical Hierarchy Process

Scale	Degree of preference	Explanation
1	Equal importance	Two elements contributes equally to the objective
3	Moderate importance	Experience and judge slightly favor one element over another
5	Strong or essential importance	Experience and judgment strongly favor one element another
7	Very strong importance	One element is favored very strongly over. It dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
2,4,6,8	Values for inverse comparison	Can be used to express intermediate values

Source: Saaty and Vargas (1991).

Table 3.2: Weights of Factors influencing Groundwater Potentiality.

	Rainfall	Lineament	Slope	Elevation	Drainage	LULC	Weight	Weight (%)
Rainfall	1	3	5	5	7	9	0.46	46
Lineament	1/3	1	3	5	7	9	0.24	24
Slope	1/5	1/3	1	2	4	5	0.12	12
Elevation	1/5	1/3	1/2	1	4	5	0.10	10
Drainage	1/7	1/5	1/3	1/3	1	3	0.08	8
LULC	1/9	1/7	1/5	1/5	1/3	1	0.03	3

Source: Author's Analysis, 2016.

3.3.5.3 Groundwater Prospect Zones and Pattern of Distribution

Integration of the thematic maps (i.e. rainfall, lineament, slope, elevation, drainage and landuse) was carried out in ArcGIS 10.1 using the weighted overlay in spatial analysis tool by using the formula by Mogaji *et al.*, (2011). The formula from equation (1) was used to determine the groundwater potential zones by integrating the various maps of the factor contributing to groundwater potential.

Underground water potential zones = GL+RF+LD+DD+SL+LU+TP--------------------------- (1)

Where:

GL= Geological map

RF= Rainfall map

LD= lineament density map

DD= Drainage Density map

SL= Slope map

LU= Landuse Map

TP= Topographic Elevation map.

3.3.5.2 Level of Groundwater Potential at the various wards in Kaduna South.

Each layer (i.e. the very good, good, moderate, fair and low zones) from the ground water potential zones raster map was converted individually to shape file in ArcGIS. The calculate geometry tool was used in calculating the area of the various potentiality of the groundwater in the study area.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter is concerned with the presentation and discussions of results from the analysis of data collected from the field.

4.2 LAND USE / LAND COVER OF THE STUDY AREA

The Landuse /Landcover of Kaduna South L.G.A was determined based on modified classification scheme of Anderson, Hardey, Roach and Witmer (1976). The land use/land cover considered for the analysis include: urban/built-up areas, farmland, vegetation, bare surface and water body. The area occupied by the various land cover is presented in Table 4.1 and Figure 4.1 shows the classified map of the study area.

Table 4.1: Land Use / Land Cover of Kaduna South

LULC	Area in sq. km	%
Urban Built-up	79.1	63.9
Water body	1.57	1.3
Farmland	25.1	20.3
Bare surface	3.01	2.4
Vegetation	15.1	12.2
Total	123.88	100

Source: Author's Analysis, 2016.

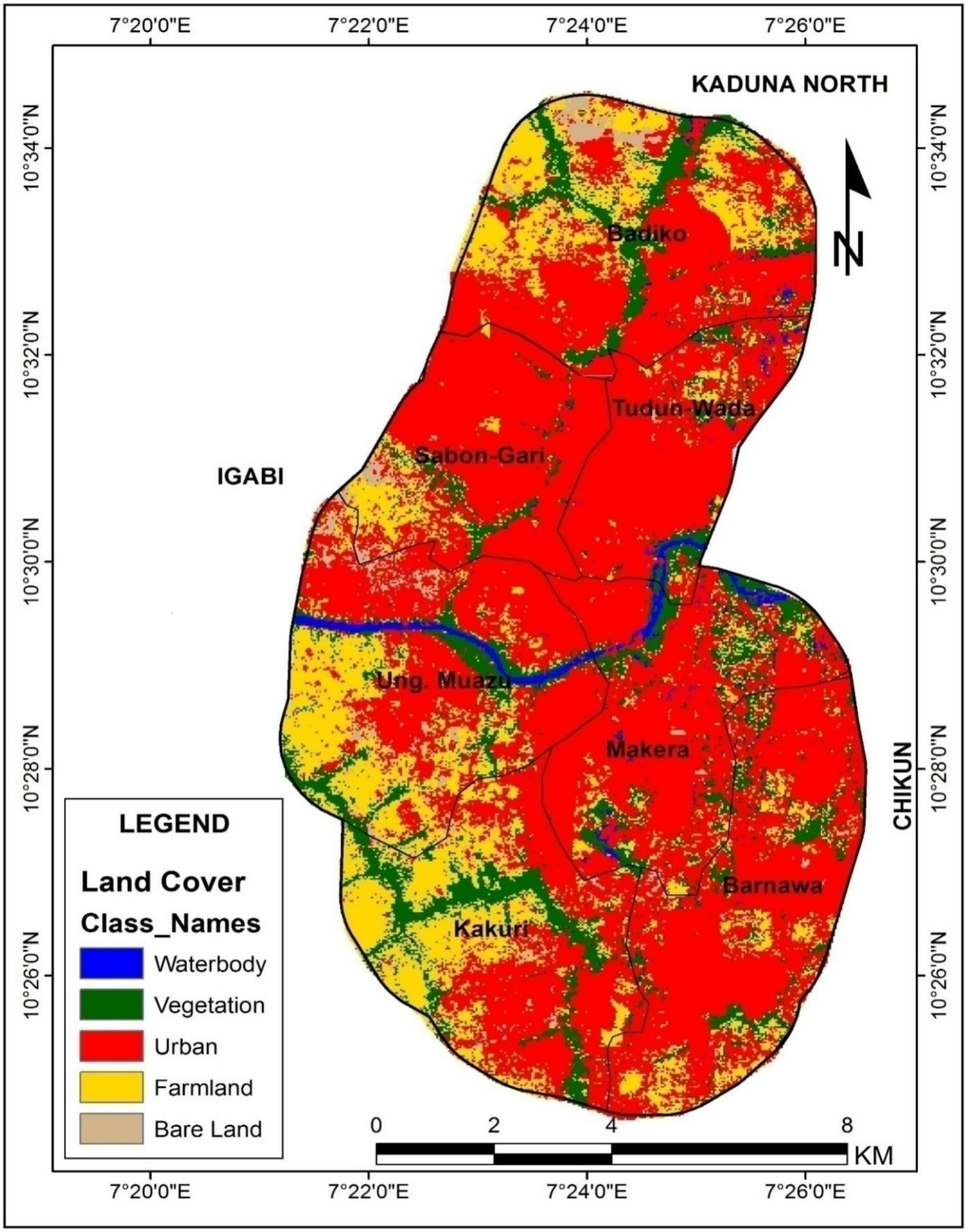

Figure 4.1 LULC of Kaduna South South L.G.A.
Source: Field work, 2016.

Table 4.1 shows that urban built-up areas was the dominant land cover in Kaduna South as at 2015, occupying about 79.1 sq. km(63.9%) of the entire area. This is followed by farmland, which covers an area of about 25.1 sq.km (20.3%) of the study area. Next is vegetation which is covering an area of15.1 sq. km (12.2%). Bare land and water body occupies an areal extent of 3.01 sq. km (2.4%) and 1.57 sq. km (1.3%) respectively. Since the greater part of the study area is occupied by urban land use, it means that demand for portable water supply will continue to increase. Also, the high coverage of the urban land use may be attribute to the fact that Kaduna South L.G.A. forms part of the metropolis and has influx of people coming into city in search of employment and to carry out their businesses.

4.3 FACTORS CONTROLLING GROUNDWATER IN KADUNA SOUTH L.G.A.

In examining the groundwater potential zones in the study area, the groundwater controlling factors were classified and mapped. The rankings/weightages of factor contributing to groundwater prospects in the study area were evaluated using Analytical Hierarchy Process (AHP) pair wise comparison. The thematic maps of the groundwater controlling factor were classified into very good, good, moderate, fair and low. The results are presented in Figure 4.2 to Figure 4.9 while the weightages of the factors are represented in Table 4.2 to Table 4.8

4.3.1 Elevation: The DEM was generated from the shuttle radar topographic mission (SRTM-90) data. Figure 4.2 shows the Digital Elevation Model (DEM) used to build the topographic elevation factor values and Table 4.1 represents the weight of elevation and potentiality for groundwater prospects in the area of study.

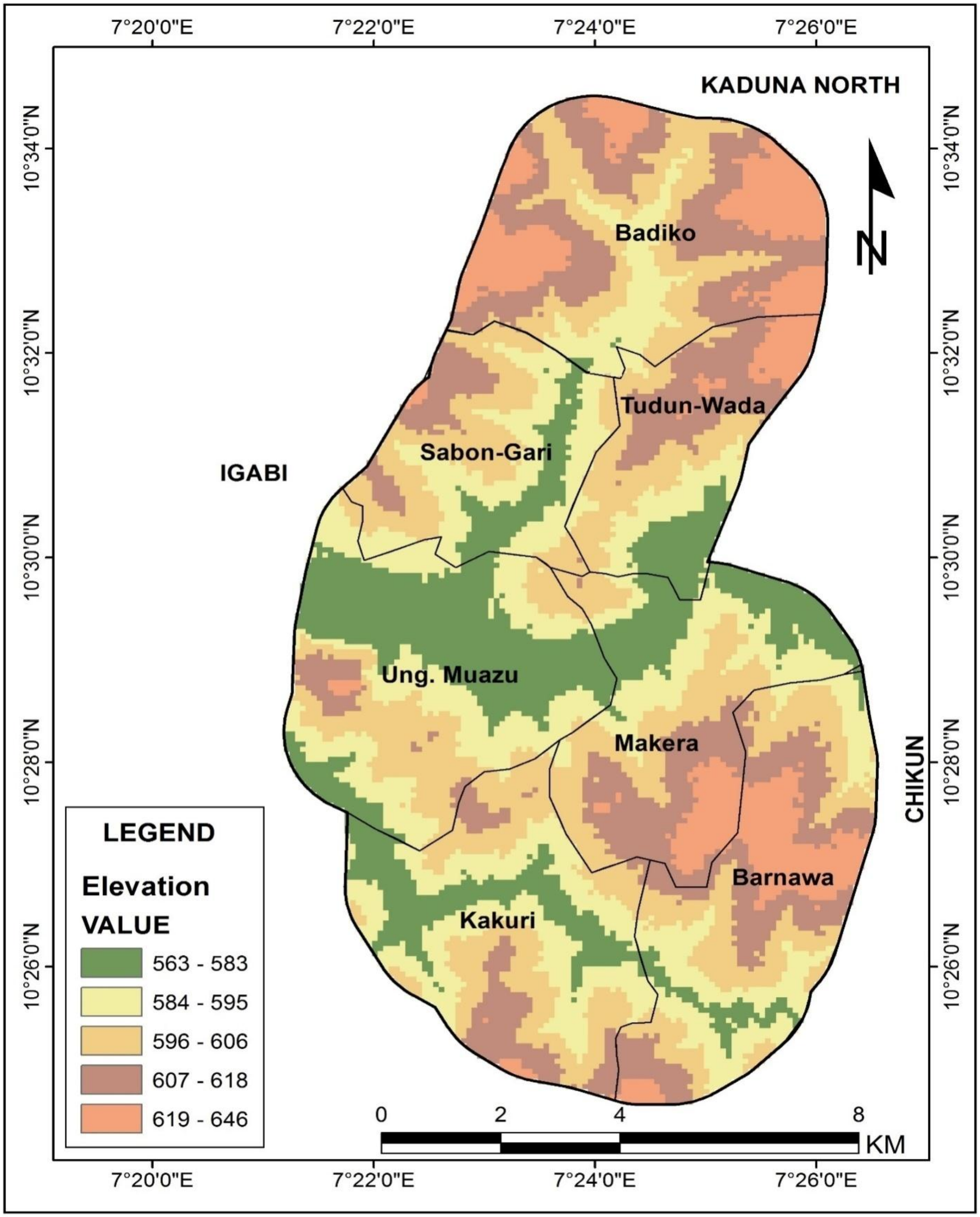

Figure 4.2: Elevation of Kaduna South L.G.A.
Source: Field work, 2016.

Table 4.2: Groundwater Potential for Elevation

Elevation	563-583	584-595	596-606	607-618	619-646	Weightage	Potential
563-583	1	3	4	5	7	0.49	Very Good
584-595	1/3	1	1	3	5	0.20	Good
596-606	1/4	1	1	3	5	0.19	Moderate
607-618	1/5	1/3	1/3	1	3	0.08	Fair
619-646	1/7	1/5	1/5	1/3	1	0.04	Low

Source: Author’s Analysis, 2016

Table 4.2 shows that areas with low elevation values have very good groundwater potential and places on high elevation have low water potential. Places on low elevation then will give more chance for groundwater accumulation Solomon (2003). Topographic data is a vital element in determining the water table elevations Sener, Davraz and Ozcelik (2005). The combination of fractures with topographically low ground can also serve as the best aquifer horizon (Subba, 1992).

4.3.2 Rainfall: The amount of rainfall is one of the major factors that contribute to groundwater recharge. In Figure 4.3, the precipitation ranges between 952-970 mm is low in the southern areas where the elevation is high and in northern areas where the elevation is moderate, rainfall appears to be high ranging between 1,036 – 1,065mm. A pair wise comparison was carried out for the mean annual precipitation of the study using AHP and the result is presented in Table 4.3.

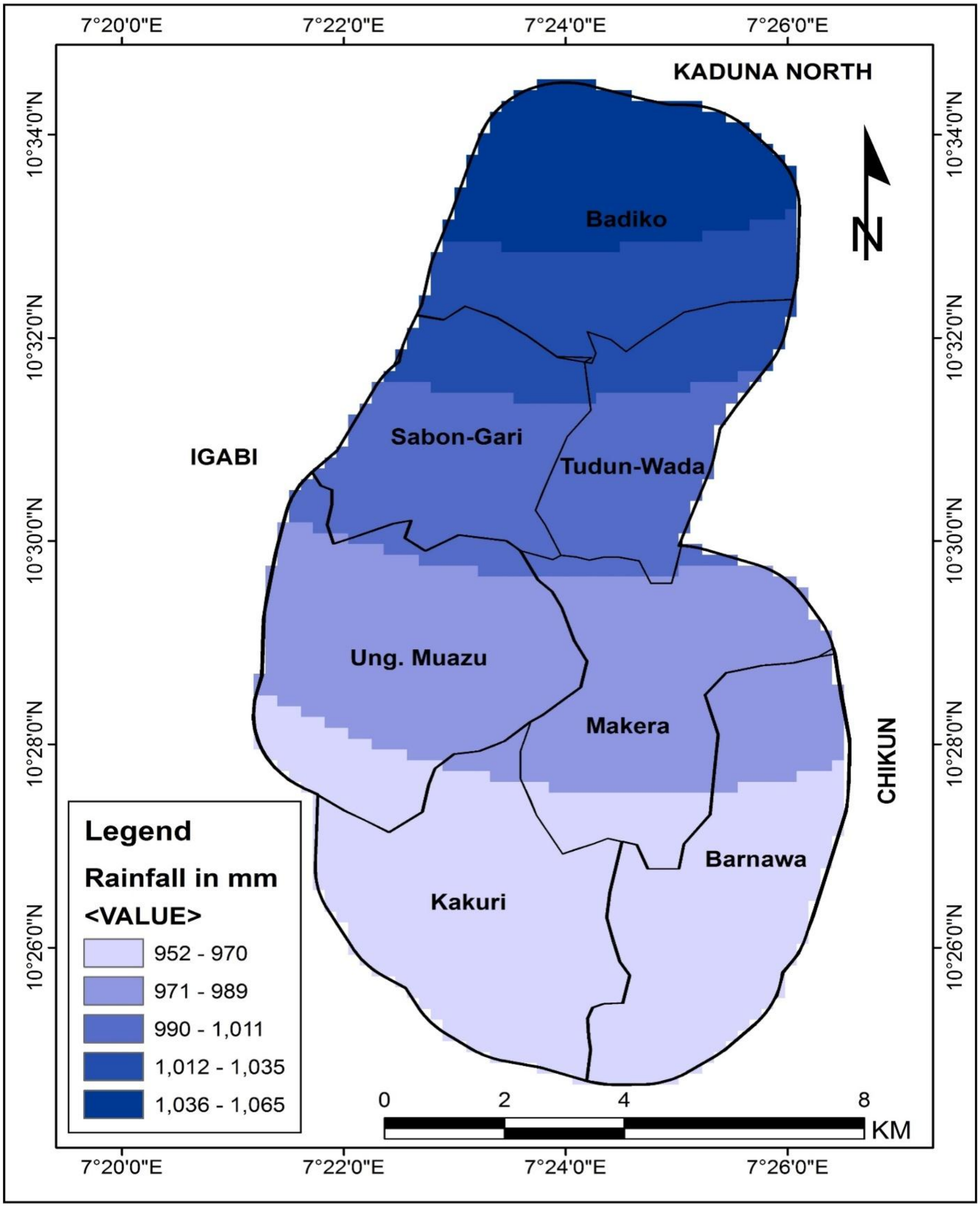

Figure 4.3: Range of Rainfall of Kaduna South L.G.A.
Source: Field work, 2016.

Table 4.3: Groundwater Potential for Rainfall

Rainfall	971-989	964-995	990-1011	1012-1035	1036-1065	Weightage	Potential
952-970	1	2	2	2	2	0.11	Low
971-989	½	1	2	2	2	0.14	Fair
990-1011	½	1/2	1	2	2	0.19	Moderate
1012-1035	½	1/2	1/2	1	2	0.24	Good
1036-1065	½	1/2	1/2	1/2	1	0.32	Very Good

Source: Author's Analysis, 2016

These precipitation values were weighed to reflect the influence of perception on groundwater. As we have more precipitation, more water will be available for surface runoff and infiltrations will naturally recharge the groundwater. Table 4.3 shows that the higher the precipitation the higher the potential of the groundwater.

4.3.3 Slope: Slope which one of the factor that influence groundwater in the study area was generated from the DEM and is shown in Figure 4.4 and the weight of the slope map is represented in Table 4.4.

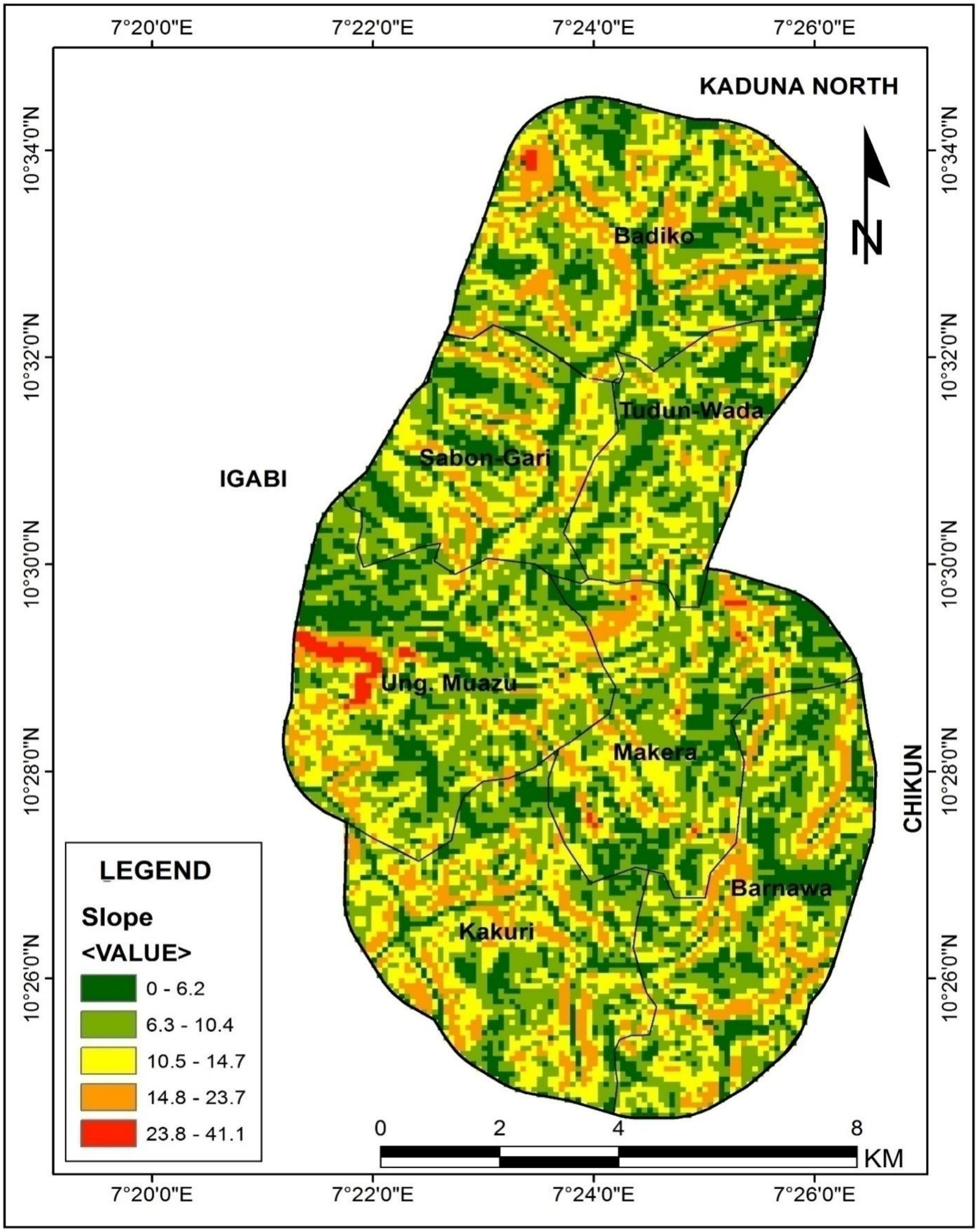

Figure 4.4: Slope Steepness of Kaduna South L.G.A.
Source: Field work, 2016.

Table 4.4: Groundwater Potential for Slope

Slope (degrees)	0-6.2	6.3-10.4	10.5-14.7	14.8-23.7	23.8-41.1	Weightage	Potential
0-6.2	1	2	5	7	9	0.47	Very Good
6.3-10.4	½	1	3	5	9	0.3	Good
10.5-14.7	1/5	1/3	1	3	7	0.14	Moderate
14.8-23.7	1/7	1/5	1/3	1	5	0.07	Fair
23.8-41.1	1/9	1/9	1/7	1/5	1	0.03	Low

Source: Field work, 2016

The result in Table 4.4 shows that very low slope (0-26.2 degrees) with darker green are evenly distributed across the study area. But places characterized by high slope (23.8 - 41.1 degrees) represented with the red colour are more concentrated within the western part (Ungwan Muazu) of the study area. Also, the results in Table 4.4 revealed that the slope ranging from 0-6.2 degrees have very high groundwater potential and those areas with high slope ranging from 23.8-41.1% have low water potential. Generally speaking, flat and gently sloping areas promote infiltration and groundwater recharge, and steeply sloping grounds encourage run-off and little or no infiltration. The areas that have gentle slopes supports low discharge of overland flow and high rate of infiltration. Therefore, groundwater potentiality is expected to be greater in the flat and gently sloping area (Solomon, 2003).

4.3.4 Drainage Network and Drainage Density: The drainage network of the area was derived from SRTM data through on screen digitization as shown in Figure 4.5.The drainage density was calculated directly in Arcmap using spatial analyst extension. Five (5) drainage density categories were identified and mapped as shown in Figure.4.5 and the corresponding weightage value shown in Table 4.5.

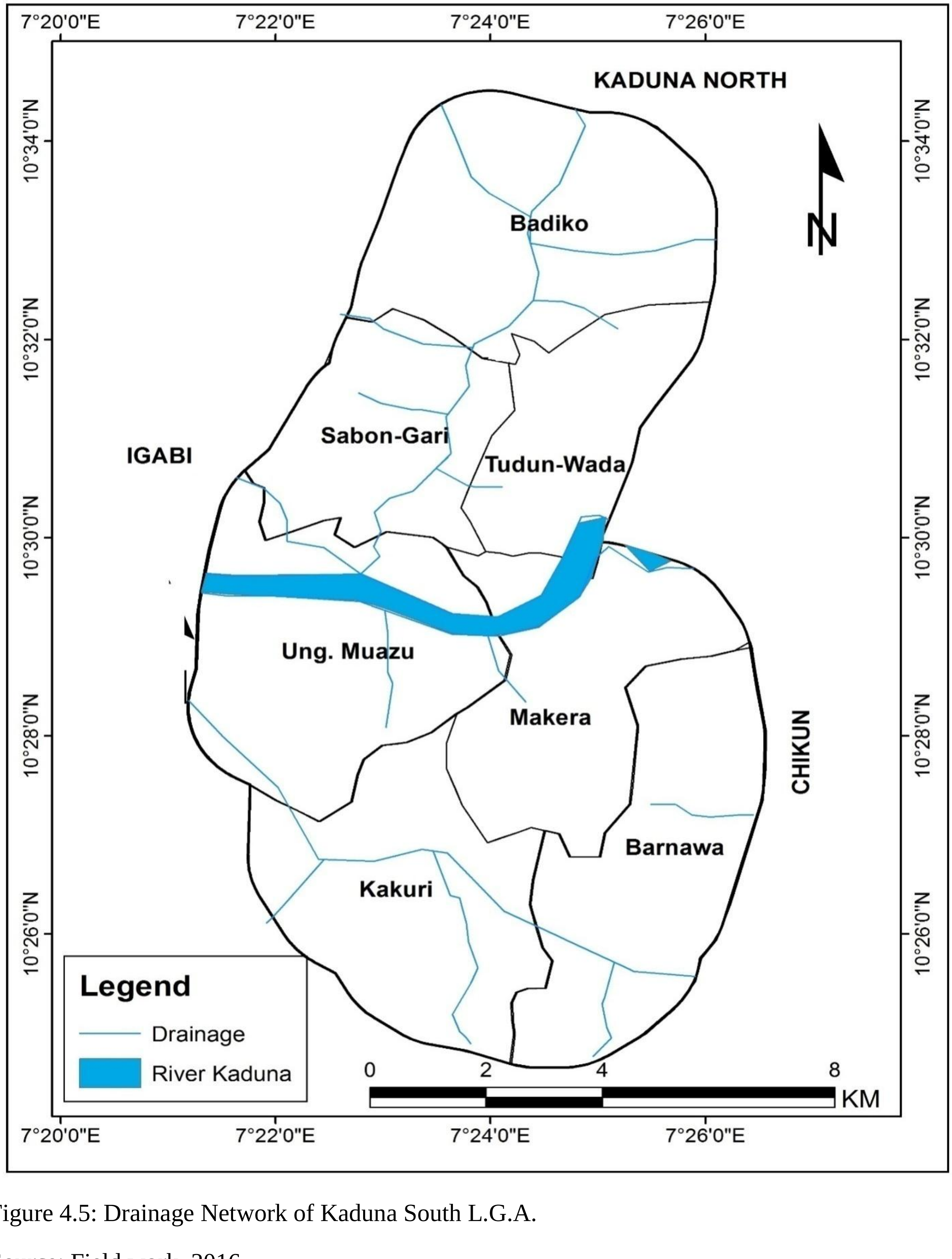

Figure 4.5: Drainage Network of Kaduna South L.G.A.

Source: Field work, 2016

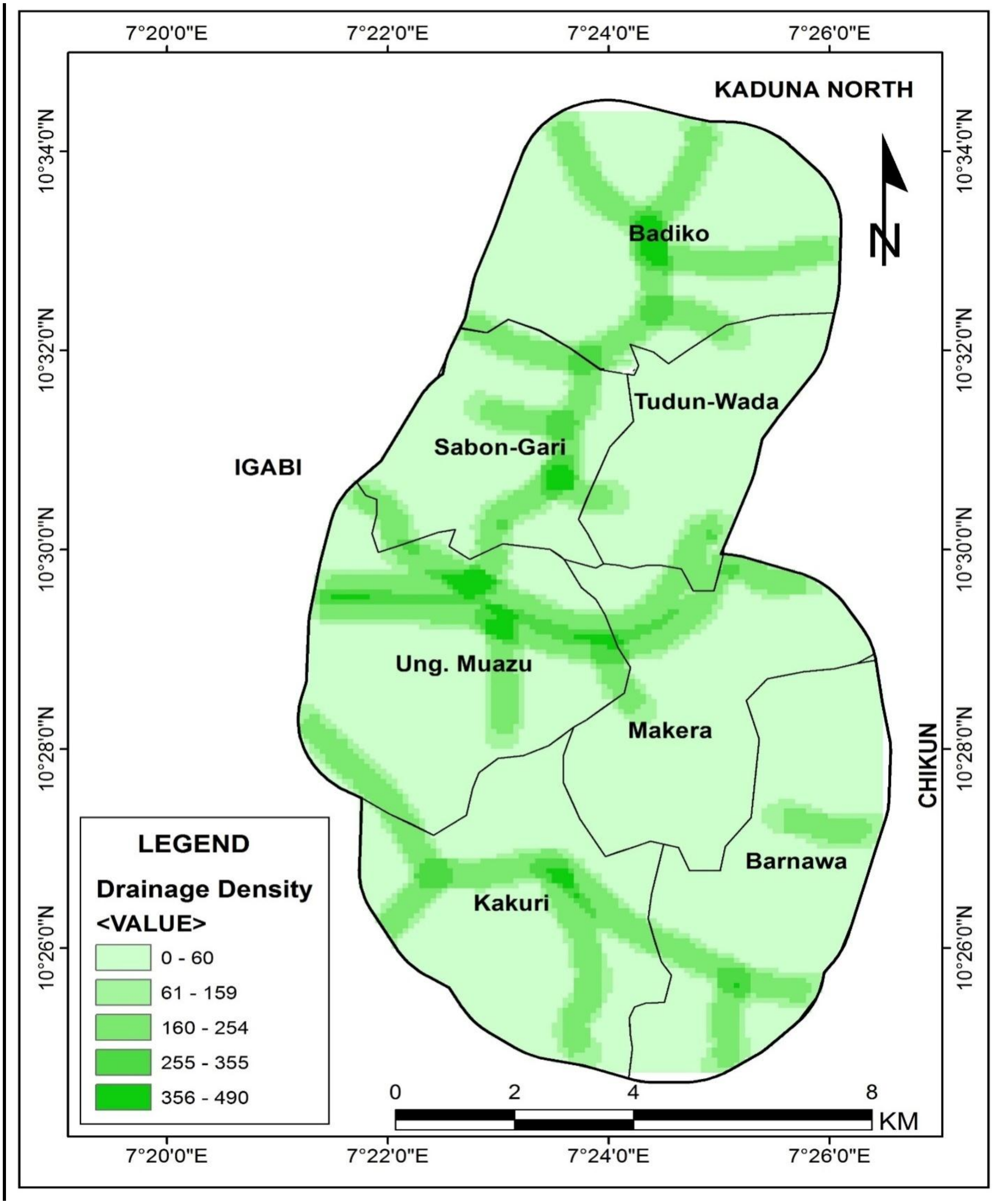

Figure 4.6: Drainage Density of Kaduna South L.G.A.

Source: Field work, 2016.

Table 4.5: Groundwater Potential for Drainage Density (DD)

Drainage Density	0-60	61-159	160-254	255-355	356-490	Weightage	Potential
0-60	1/6	1/6	1/4	1/2	1	0.05	Low
61-159	1/6	1/4	1/2	1	2	0.07	Fair
160-254	1/5	1/3	1	2	4	0.12	Moderate
255-355	1/3	1	3	4	6	0.26	Good
356-490	1	3	5	6	6	0.49	Very Good

Field work, 2016.

The drainage network of the study area was found to more dense along the Kaduna river within the Unguwan Muazu and Makera with the tributaries passing through Sabon Tasha and Badiko towards the northern part, Kakuri and Barnawa in the southern part. The result in Table 4.5 revealed that areas with low drainage density were found in all places where there are no drainages and area with high drainage density are found within the main river and the tributaries of river Kaduna. According to Chandra (2010) the drainage pattern is one of the most important indicators of hydrogeological features, because drainage pattern and density are controlled in a fundamental way by the underlying lithology. In addition, the stream pattern is a reflection of the rate at which precipitation infiltrates compared with the surface runoff. The infiltration/runoff relationship is controlled largely by permeability, which is in turn a function of the rock type and fracturing of the underlying rock or surface bedrock Okereke, Teme, and Esu, (1998). When comparing two terrain types, the one that contains the greatest drainage density is usually less permeable (Edet *et al*., (1998). According to the authors, it is well known that the denser the drainage network, the less is the recharge rate and vice versa.

4.5.5 Lineament and Lineament Density: Lineaments map was extracted from satellite image using automated extraction techniques. The lineament was imported into the ArcGIS environment and the spatial analyst tool was used in generating the lineament density map for the study area. Figure 4.6 represents the lineament map and figure 4.7 represents the lineament density map. The result of the pair wise comparison is also shown/ given in Table 4.6

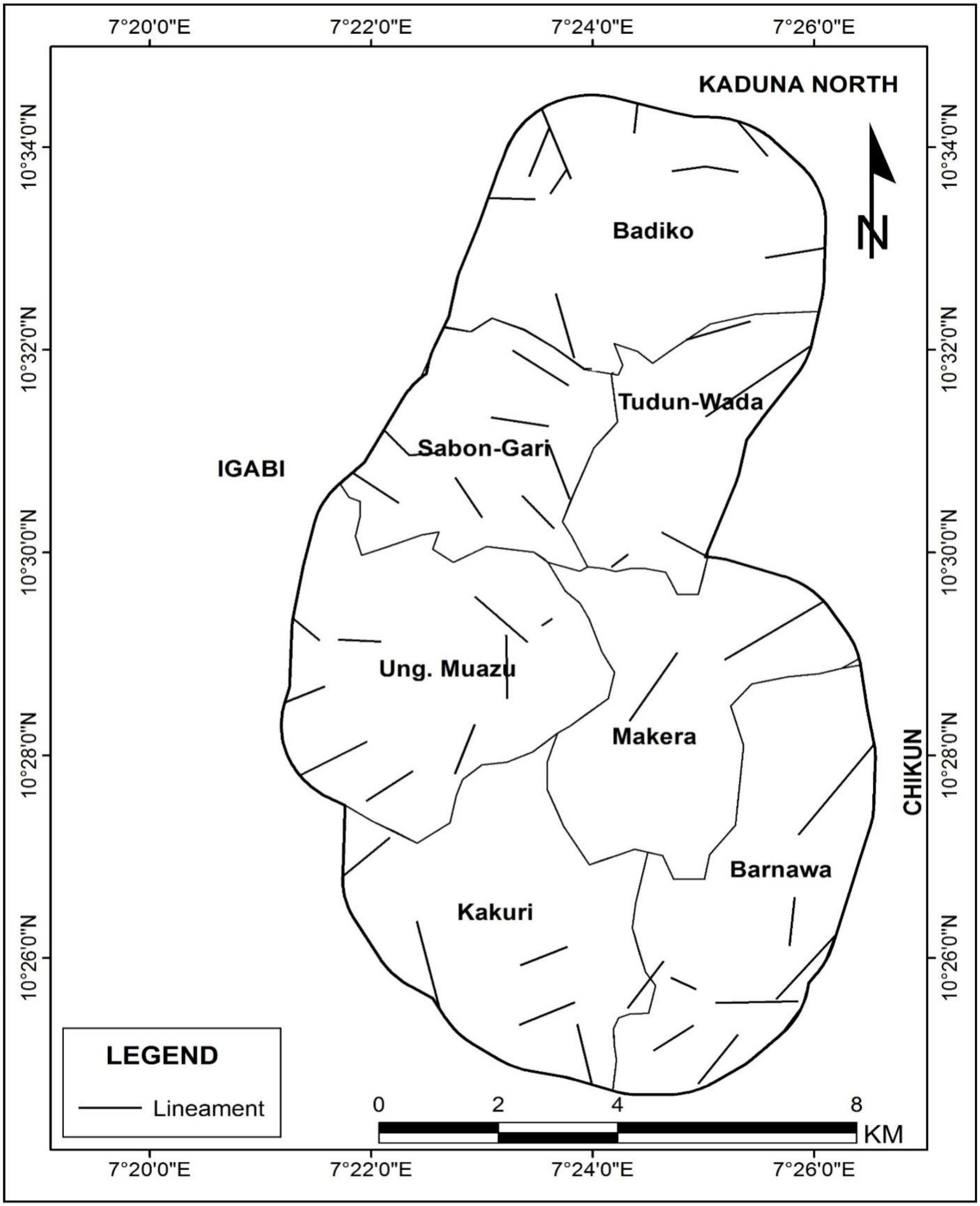

Figure 4.7: Lineament of Kaduna South L.G.A.

Source: Field work, 2016

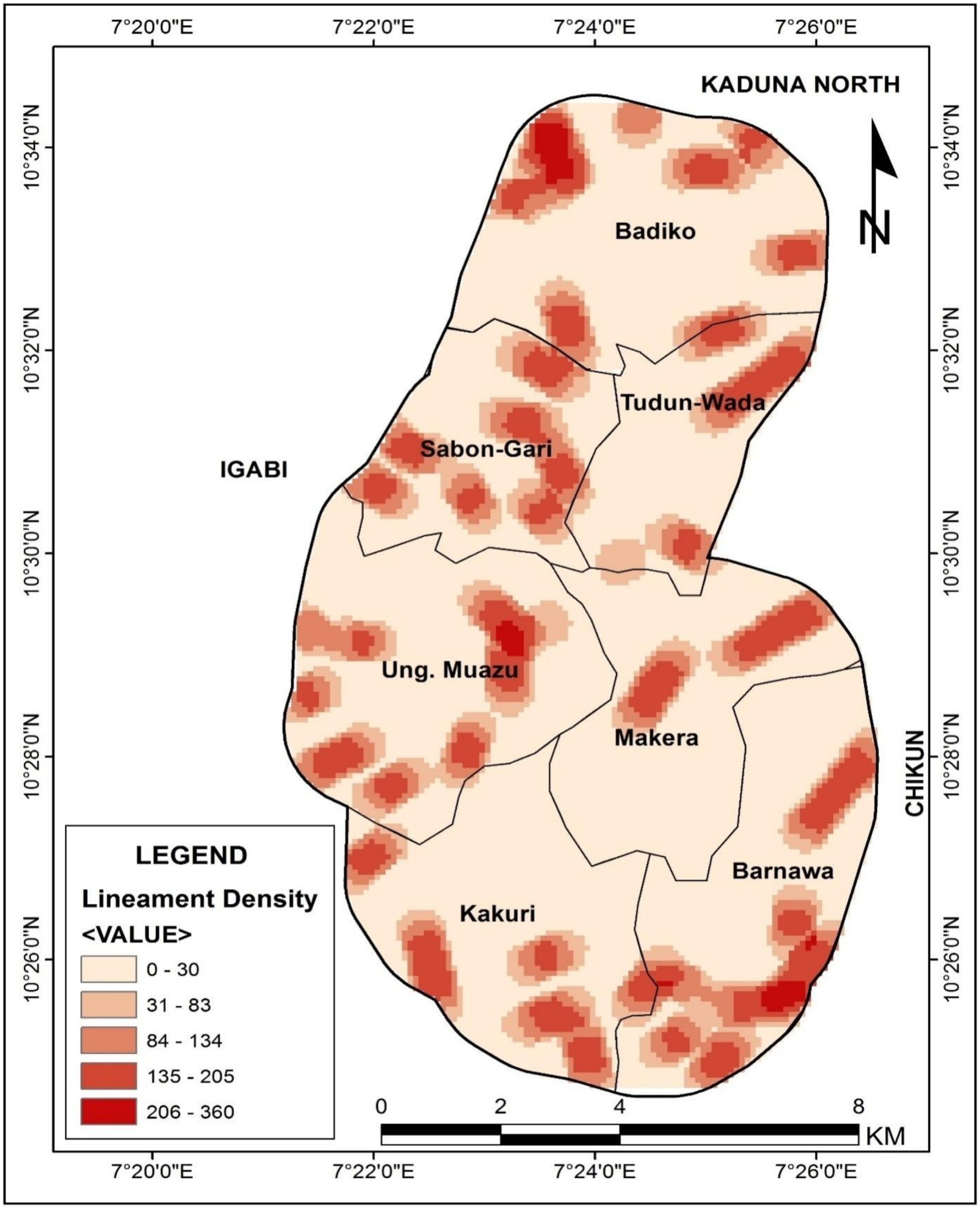

Figure 4.8: Lineament Density of Kaduna South L.G.A.

Source: Field work 2016/

Table 4.6: Groundwater Potential for Lineament Density (LD)

Lineament Density	0-30	31-83	84-134	135-205	206-360	Weightage	Potential
0-30	1/9	1/7	1/5	1/3	1	0.03	Low
31-83	1/7	1/5	1/3	1	3	0.06	Fair
84-134	1/5	1/3	1	3	5	0.13	Moderate
135-205	1/3	1	3	5	7	0.26	Good
206-360	1	3	5	7	9	0.51	Very Good

Consistency Ratio=0.08

Lineaments are simple and complex linear properties of geological structure such as faults, cleavages, fractures, and various surfaces of discontinuity, that are arranged in a straight line or a slight curve, as detected by remote sensing. Table 4.6 shows that the lineament density in the study range between 0-360Km^{-2}. It can be deducted from the result that areas with low lineament density range are between 0-30 Km^{-2} while the areas 206-360 Km^{-2} are areas with high lineament density

Lineaments are underlain by zones of localized weathering and increased permeability and porosity. Previous studies have revealed a close relationship between lineaments, groundwater flow and yield Magowe and Carr (1999). The extension of large lineaments representing a shear zone or a major fault and can extend from hilly terrain to alluvial terrain Mondal, S. et al (2012). It may form a productive groundwater reserve. Similarly intersection of lineaments can also be probable sites of groundwater accumulation. Therefore, areas with high lineament density may have important groundwater prospects even in hilly regions which otherwise have no groundwater prospects than area with low density.

4.3.6 Landuse/Landcover: One of the parameters that influence the occurrence of groundwater is the land cover and land use of the area. The landuse and land map was generated from the Landsat imagery by supervised classification and shown in Figure 4.9.

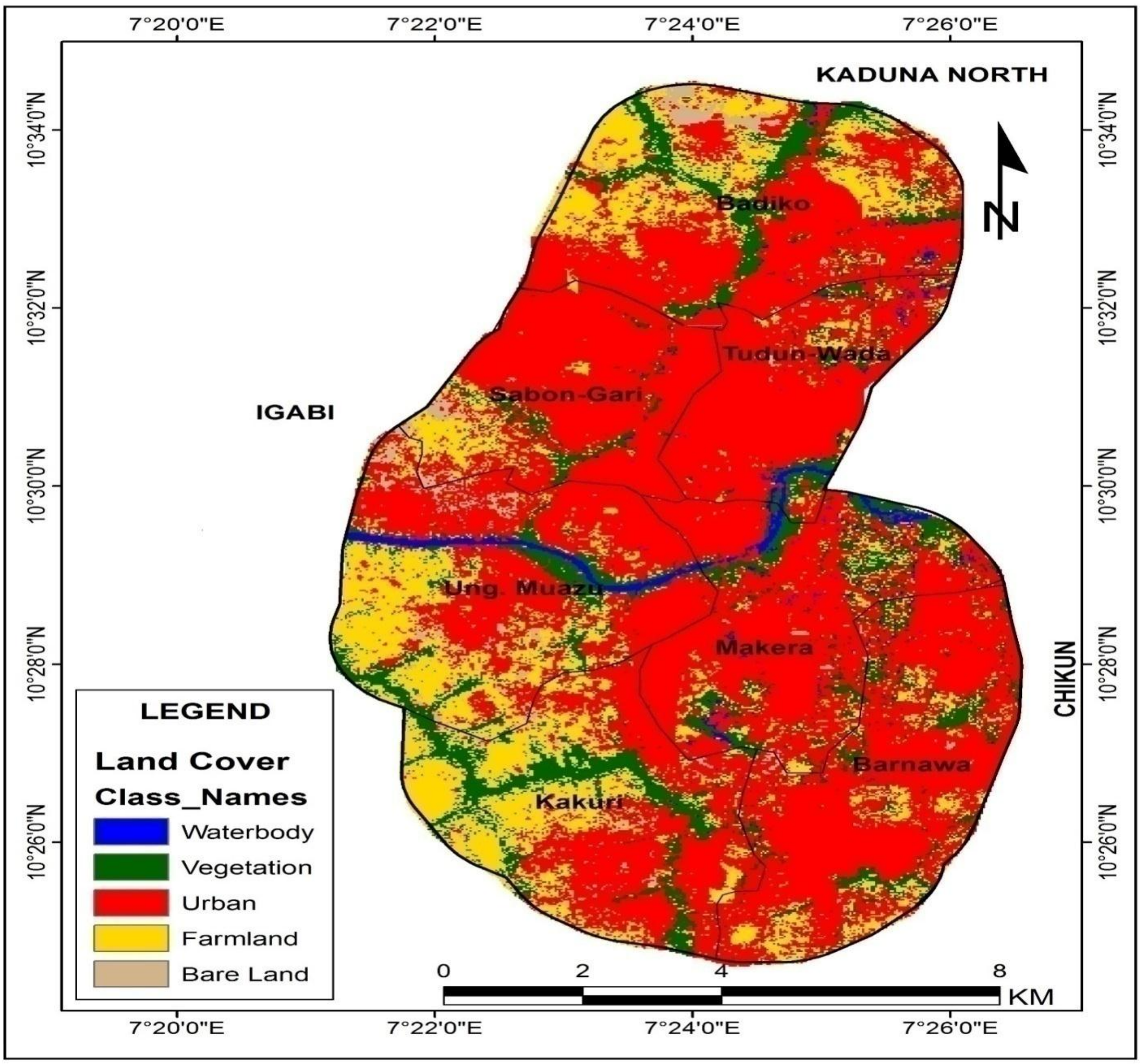

Figure 4.9: LULC of Kaduna South L.G.A.

Source: Author's Analysis, 2016

Table 4.7: Groundwater Potential for Land use/Land cover

LULC	Water body	Vegetation	Bare Land	Cultivated Land	Build-up Areas	Weightage	Potential
Water body	1	5	7	6	9	0.56	Very Good
Vegetation	1/5	1	3	4	9	0.23	Good
Bare Land	1/7	1/3	1	2	7	0.11	Moderate
Farmland	1/6	¼	1/2	1	4	0.07	Fair
Urban Areas	1/9	1/9	1/7	1/4	1	0.03	Low

Consistency Ratio=0.12

The effect of land use / cover is manifested either by reducing runoff and facilitating, or by trapping water on their leaf. Water droplets trapped in this way go down to recharge groundwater. Land use/cover may also affect groundwater negatively by evapotranspiration, assuming interception to be constant. From Table 4.7, the result shows that area around the water body have very good ground water potential, followed by vegetated areas with good water potential. The bare land was weighed moderate while cultivated land and built-up land were noticed to fair and low ground water potential respectively.

4.4 GROUNDWATER PROSPECT ZONES AND DISTIBUTION PATTERN

In an attempt to determine the groundwater prospects zones in Kaduna South L.G.A., all the thematic maps of the factors influencing the groundwater recharge in the area were weighed and integrated in the order suggested by Saraf and Choudary (1998). Table 4.9 represents the weight of the groundwater controlling factors while figure 4.10 represents the groundwater prospect zones within the study area.

Table 4.8: Weights of the entire Groundwater Factor Map in the Study Area

	Rainfall	Lineament	Slope	Elevation	Drainage	LULC	Weight	Weight (%)
Rainfall	1	3	5	5	7	9	0.46	46
Lineament	1/3	1	3	5	7	9	0.24	24
Slope	1/5	1/3	1	2	4	5	0.12	12
Elevation	1/5	1/3	1/2	1	4	5	0.10	10
Drainage	1/7	1/5	1/3	1/3	1	3	0.08	8
LULC	1/9	1/7	1/5	1/5	1/3	1	0.03	3

Consistency Ratio=0.05
Source: Author's Analysis, 2016

From Table 4.9 it can be seen that rainfall was weighed the highest with (34%) followed by lineament (24%), geology is weighed (14%) The least groundwater contributor in the study area is the landuse/landcover is with 3%.

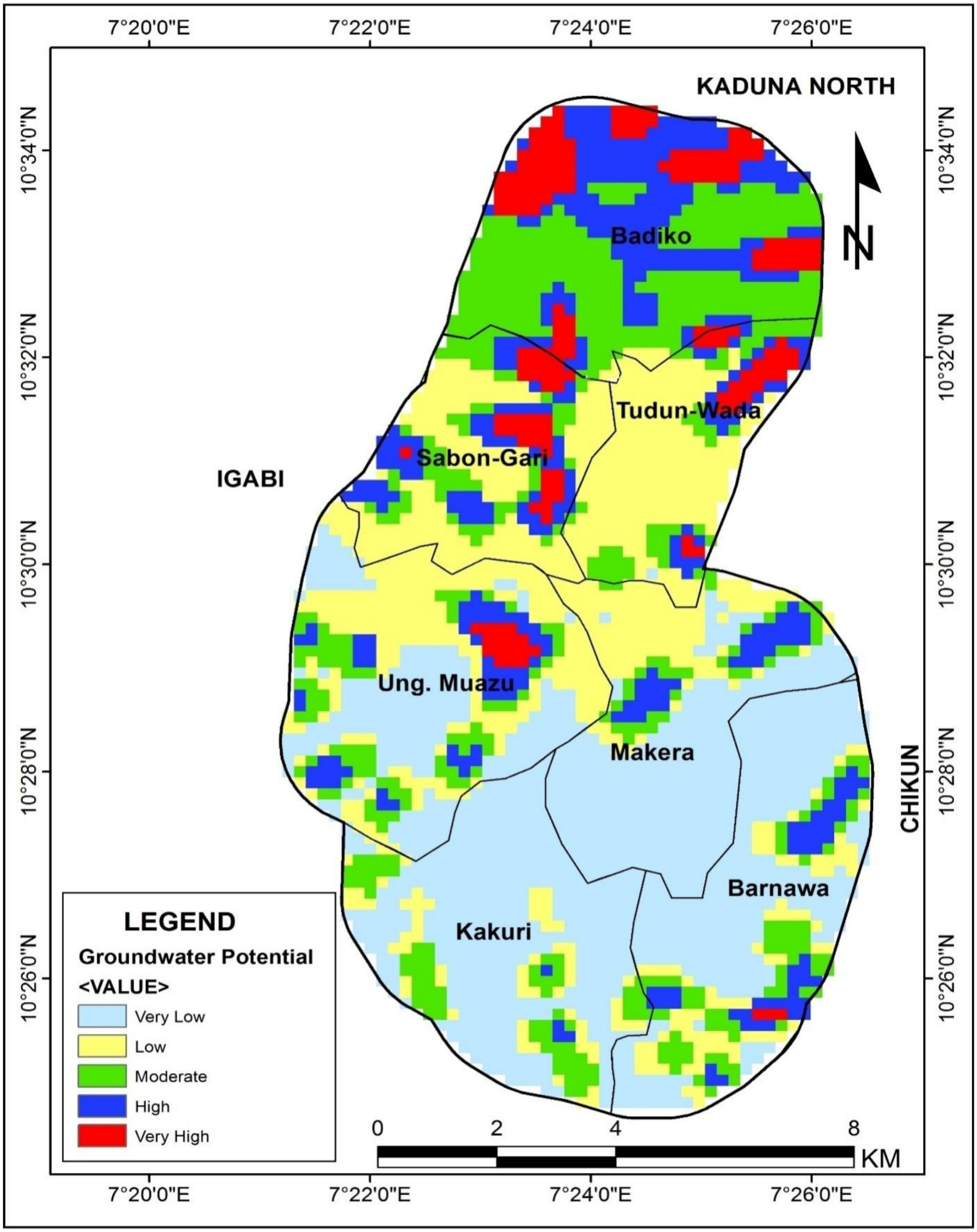

Figure 4.10: Groundwater Potential Zones of Kaduna South L.G.A.

Source: Author's Analysis, 2016

The groundwater potential zones were reclassified into five (5) different potential zones; very high, moderate, moderate, low and very low (Figure 4.10). The map produced shows that the groundwater potential of the study area is related mainly to rainfall, lineaments, slope, elevation, drainage and landuse/landcover. It can be seen from the result that the areas with very high groundwater potential are within the northern areas while the areas with low groundwater potential are within the southern area. It can be observed from the thematic maps generated that the areas with very high groundwater potential in the northern area were characterized by high range of rainfall and are typically flats areas or gentle slope. This is not contrary to the study of Khalek and Ahmed(2008) that identified lineament and slope as the major factors that contribute to groundwater recharge in their study area.

4.4 LEVEL OF GROUNDWATER POTENTIAL IN VARIOUS DISTRICTS OF KADUNA SOUTH

The areal coverage occupied by the groundwater potential zones was estimated in ArcGIS by converting the groundwater potential sites to shapefiles and using the calculator geometry tool. The levels of groundwater potential was estimated for various district in the study area. Table 4.9 represents the estimated area coverage of the groundwater potential zones in square kilometer and in percentage.

Table 4.9: Level of Groundwater Potential Zones at various districts

		AREA IN SQ. KM				
District	Very Low	Low	Moderate	High	Very High	Total
Badiko	0.00	1.04	10.08	6.68	4.55	22.35
Sabon-Gari	0.00	9.41	2.10	0.65	1.27	13.43
Ung. Muazu	2.34	14.98	2.49	1.28	0.63	21.72
Tudun-Wada	0.11	7.67	1.45	1.34	1.01	11.58
Makera	10.08	4.53	1.86	0.58	0.00	17.05
Kakuri	14.57	1.25	2.22	0.41	0.00	18.45
Barnawa	10.01	5.79	1.80	1.55	0.16	19.31
Total	37.11	44.66	22.00	12.49	7.62	123.88
%	30.0	36.1	17.8	10.1	6.2	100

Source: Author's Analysis, 2016

Table 4.9 shows that the very good groundwater potential occupies 7.62 sq. km (6.2%), the good potential zones constitute about 12.49 sq. km of the study area; the moderate potential areas constitute 22.0 sq. km (10.1%). The fair and low occupies the highest coverage constituting about 44.66 sq. km (36.1%) and 37.11 sq. km (30.0%) respectively

It can be seen from the Table that Badiko District occupies 4.55 sq. km out of the 7.62 sq. km occupied by the very high ground water potential zones, this result is an evident that the Badiko district have the highest ground water potential in the study area. Areas characterized with very low ground water potential area are Barnawa, Kakuri and Makera occupying an area of 10.01 sq. km, 10.08, sq. km and 14.57 sq. km respectively. The very good groundwater potentiality observed in Badiko could be attribute to the fact that Badiko has high amount of rainfall, lie on low elevated land in the central area also highly vegetated. The result of this study is not contrary to the observation of Solomon,(2003) that observed that area characterized with high rainfall, low elevation and highly vegetated may be considered as areas with very good groundwater potential.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter highlights the summary of findings, conclusion and the recommendation made in study.

5.2 SUMMARY OF FINDINGS

This study aimed at investigating the groundwater potential zones in Kaduna South L.G.A. The study was carried out to examine the characteristics of groundwater potential zones in the study area using Analytical Hierarchy Process (AHP). Six thematic maps of factors contributing to groundwater recharge was generated and integrated in ArcGIS environment using weighted sum overlay in spatial analyst tool. The coverage of the groundwater potential was estimated using the geometry calculator.

Topography, rainfall, drainage density, lineament density, slope steepness and land use/land cover contribute significantly to groundwater prospects in the study area. Weightages of the factors influence groundwater prospects in the study area and shows that rainfall and lineament density were weighed the highest with 46% and 24% respectively, while others were slope (12%), elevation (10%), Drainage (5%) and LULC (3%). The very good groundwater potential zones were identified in the Northern areas while the areas with low potential lie in the Southern areas. Very good groundwater potential zones occupies a coverage of about 6.2%, High potential constitute 10.1%, moderate occupies 17.8% while low and very low constitute of 36.1% and 30.0% respectively. Badiko District was found to be the highest ground water potential while Barnawa, Kakuri and Makera were found to be the lowest.

5.3 CONCLUSION

The ground water potential zones have been derived for the entire Kaduna south Local Government Area of Kaduna State Nigeria, and it has been divided into mainly five categories namely very good, good, moderate, fair and low potential. It is observed from the study that the very good ground water potential zones are located in the Southern part of the study area.

This study has shown that large spatial variability of ground water potential. The variability closely followed variability in the rainfall, topography, slope, drainage density, lineament density and land use/cover in the study area. The most promising potential zone in the area is related to High rainfall, low slope and high lineament density. Most of the zones with low to very low groundwater potential lie far from lineaments. This study generally shows that GIS and Remote sensing techniques in combination with field data could be used for investigating of ground water potential zones in an area.

5.4 RECOMMENDATIONS

Based on the outcome of this research on assessment and analysis of the spatial variation of groundwater potentials in some selected areas of Kaduna South Local Government Area., the following are recommended:

a) Surface water development is recommended in the low to very low zone yield areas, against the prevailing groundwater development.
b) The zones with high groundwater potential are feasible zones for groundwater prospecting in the study area, and hence, it is suggested that these zones be combined with detailed geophysical mapping for quantitative evaluation of the groundwater potential of the study area.

c) Groundwater potential zones mapping should be carried out for the entire country to serve as a guide for water resource agencies.

d) The groundwater potential map produced are sources of vital information and data base which can be updated from time to time by adding new information for development.

REFERENCE

Abdulkadir, A. (1993) Water Quality for irrigation in Northern Nigeria Bauchi state. Nigerian *Journal of Water Resources.* Vol. No 1 page 13 - 25.

Abegunde, M.A. *et al*, (1999), Senior Secondary School Geography I, Longman Nigeria, Lagos.

Abel, O. T., and Monshood, N. T. (2011) Integrated remote sensing and GIS approach to groundwater potential assessment in the basement terrain of Ekiti area south western Nigeria. *Material and Geo environmental Journal,* 58 (3) 303-328

Adams, W.M (1992) *Green Development Environment and Sustainability in the third World. London Routledge.*

ADB (2001) *water for all:* The water policy of the Asia development Bank.

Aditi, D.R. and Tushaar, S.(2002) The Scio Ecology of Groundwater in India. Water Policy Briefing IWMI- Tata water Policy Programme. Issue 4www.iwmi.org/org/iwmi-tata.

Ajayi . J.O., Sonuga, F.A. Aliboh, O.P., Oloke, D.A.(2003) Sustainable Potable Water Supply to Nigeria Through Conjunctive Development of Surface and Groundwater Research. International Journal of Geoscience 2(3)pp.23 – 45 USGS.

Albert T. and Hector G.(2002) ‘‘Groundwater Management Strategies’’. GWMATE Briefing Note 3. Sustainable Groundwater Management: Concepts and Tools Series. Available online http://www.worldbank.org/gwmate assessed on 13/12/2014.

Ali E.L. – Naqa, Nezar H, Khalil I. and Masdouq E. (2009) Integrate Approach for groundwater exploration in wadi Arabia using remote sensing and GIS*: Jordan journal of civil Engineering*, 3 (3) ,2009.

Anderson, J.R. Hardly, E. Roach, T.J. and Wiremer, R.E. (1976). A Land use and Land cover Classification system for use with Remote Sensing Data. Professional Paper No.(964), USGS. Reston Virginia, pp.28.

Arnold, J.G., Muttiah, R.S., Srinivasan, R. and Allen, P.M. (2000) Regional estimation of base flow and groundwater recharge in the Upper Mississippi river basin. *Journal of hydrology*, 22(7) 21- 40.

Ayoade J.O (1975) Water resources and their development in Nigeria. *Hydrological Science bulletin*.Xx1412/1975.

Ayoade, J.O., (1993). Introduction to Climatology for the Tropics, Spectrum Books limited, Ibadan.

Ayush,O. (2010) Health and Family 11th Five Year Plan: Planing Commission of India Retrieve 19 – 09-2010.

Batmanghelidji (2004) *your body many cries for water beta 3/c/ importance of water* 3. Htm.

BBC News World (2007) Healthy water living: BBC World news online edition accessed February 1st ; 2007, at http//news.bbc.co.uk/2/hi/Africa/40730063.stm.

Bello A.A. and Makinde, V.(2009) Delineation of the Aquifer in South Western Part of the Nupe Basin, Kwara State, Nigeria. Academic Arena Journal,1(3).

Biswarup, M, (2000) Environmental Management, Basic and Applied Aspects of Management of Ecological and Environmental Systems, Wikas Publishing House PUT LTD, New Delhi.

Bobu, M. J.R. (2011). Assessment of Groundwater Pollution in Parts of Guntur District Using Remote Sensing & GIS. 1024 International *Journal of Earth Sciences and Engineering* ISSN 0974-5904, Volume 04, pp 1024-1030.

Bonsor H. (2012) Huge Water Resources Exist Under Africa. Journal of Environmental Research Letters of British Geological Survey and University College London(ULC) 11(8) .

BBC News World (2007) *Healthy water living*: BBC World news online edition accessed February 1st; 2007, at http//news.bbc.co.uk/2/hi/Africa/40730063.stm.

Botswana Government,(1993). Botswana Country Paper. In proceedings of the workshops on water resources management in Southern Africa, Victoria falls, Zimbabwe, 5 – 6 July, 1993.

Burrough, P.A. (1986). Principles of Geographical Information Systems for Land Resources Assessment Oxford: Oxford University Press, pp.193.

Carlo, T. (1998) *Groundwater exploration by satellite Remote Sensing in the Syrian Arab Republic:* Part 1, General organisation of Remote sensing Syrian Arab Republic.

Chandra, A.S.B., Goridhir, M.V.S.S. and Viswanadh,G.K.(2010) Identification of Groundwater Potential Zones Using RS and GIS. Department of Environmental Information Study and Analysis (EISA) Institute of Geography Hong Quoc Viet R.D. cau Giay, Hanoi Vietnem.

Chowdhary, V.M, Roan, N.H. and Sarma, P.B.S, (2003). GIS Based Decision Support System For Groundwater Assessment In Large Irrigation Project Areas. Agricultural Water Management 62:229-252.

Custodio E. (2002) Aquifer over Exploitation: What Does It mean *Hydro geological journal* 10:254 – 277.

Domenico P.A and Schwartz, F.W (1990) *Physical and Chemical Hydrogeology*. John Wiley and Sons New York.

Douglas I. (1973) *Water resources in evaluating human environment* (edited by Dawson J.A and Doorakamp J.C) Arnold London.

Driscoll (1986). Groundwater and Wells: A comprehensive study of groundwater and the technologies used to locate, extract, treat, and protect this resource. Second Edition.

Duraye, I (2003) Water Quality Monitoring in Nigeria: Case study of Nigeria's Industrial Cities. Journal of American Science 6(4).

Edet, A.E, Okereke, C.S., Teme, S.C. and Esu, E.O. (1998). Application of remote sensing data to groundwater exploration: a case study of the cross-river state, Southeastern Nigeria. *Hydrogeology Journal*, 6:394–404.

Egboka, B.C.E. (1988). The Hydrogeological Provinces of Nigeria, Water Quality Bull. 13(4):117-125.

Engman E.T. and Gurney R.J. (1991). Remote Sensing in Hydrology. Chapman and Hall, London, pp 225.

FOA (1997). Irrigation in the near East region in Figures water Report 9 Rome, Italy.

Hazell, J.R.T. Cratchley C.R. and Jones C.R.C. (1992).The Hydrogeology of Crystalline Aquifers in Northern Nigeria and Geophysical Techniques Used in their Exploration. In: Wright, E.P. and Burges, W.G. A Publication of Geological Society Publication No.66.

Heyns, P. (1993), Water management in Namibia. In proceedings of the workshops on water resource management in Southern Namibia.

Hinrichman, D. and Markham, A. (1990). Atlas of the Environment, Prentice Hall Press, New York, NY. pp.192. ISBN.

Hopkins, J. (1998) Solutions for water – shortage, world population reports, Vol, xxvi, No. 1 September 1998, John Hopkins population information programme, Baltimore, Maryland United State.

Ifabiyi I.P (2005) Spatial pattern of Ground water contribution to total Runoff in the upper Kaduna catchment: A hydro Geographic study: *Zaria geographer, 16 (1) 2005 Department Of Geography ABU Zaria* 106 – 121

Iguisi, E.O. (1996). Variation of soil loss in two sub-basins near Zaria, Nigeria. Department of Geography, A.B.U. Zaria.

Internet Secrete Text Archives home (2010) *secrete texts.com retrieved* 2010 – 07 – 25.

Jasrotia, A.S., Kumar, R. and Saraf, A.K. (2007) Delineation of groundwater recharge sites using integrated remote sensing and GIS in Jammu district India. *International Journal of remote sensing,* 28 (22). Tailor and Francis,Inc Bristol.PA.USA.

Jones, M. J. (1985). The Weathered Zone Aquifers of the Basement Complex area of Africa. Q. Journal of Eng. Geology 18:35-46.

Khalel, M.H. and Ahmed, K.S. (2008). Integrated Geophysical, Remote Sensing and GIS Studies for Groundwater Assessment, International Journal of Geosciences, Vol.5, pp. 882 – 907.

Krejcie, R.V. and Morgan, D.W. (1970) *Determining sample size for research activities, educational and psychological measurement,* 30, pp 607-610.

Lillesand, T.M. and Kiefer, R. (2000) *Remote Sensing and Image Interpretation, 4th edition:* New York wiley, cop ISBN 0-471255-7.

Mabogunje, A.L (1965) *Water Resource and Economic Development.* In Ecology and economic development in Africa (Edited by D.W brockenshe) university of Califonia press.

Macdonald, A. M. (2005) *Developing ground water a guide for rural water supply:* ITDG publishing http://www, Development book shop.com/

Magowe, M. and Carr, J.R. (1999). Relationship between Lineaments and Groundwater Occurance in Western Botswana. Groundwater, 7(2): 282 – 286.

Mark, willian E (2001) *The holy order of water healing earth waters And ourselves.* Bell pond Books Great Barrington ISBN 0 – 088010483.

Mathew Becker W. (2006) Potential for satellite remote sensing of groundwater: *Groundwater.*

Mbonu, M.C. (1989). Contribution to Knowledge Relative to the Hydrogeology of the Basement Rocks of North-Central Nigeria. A Paper Presented at the University Pierre et Marie Gurie, Paris VI, Paris-France.

McCurry, P. (1976). The Geology of the Precambrian to Lower Palaezoic Rocks of Northern Nigeria - A Review. In: Kogbe C.A. (Ed) Geology of Nigeria. Elizabethan Publishers Co., Ibadan, Nigeria pp.15-38.

Meijerink, A.M.J. (2007) *Remote Sensing Applications to Groundwater:* IHPVI, Series on Ground water No. 16, a UNESCO Publication.

Mogaji, K.A., Aboyeji O.S. and Omosuyi G.O. (2011). Mapping of lineaments for groundwater targeting in the basement complex region of Ondo State, Nigeria, using Remote Sensing and Geographic Information System (GIS) techniques. *International Journal of Water Resources and Environmental Engineering* Vol. 3(7), pp. 150-160, August 2011. Available online at http://www.academicjournals.org/ijwree.

Mondal, S.(2007) Remote Sensing & GIS Based Groundwater Potential Mapping of Kungshabati Irrigation Command Area,West Bengal. Journal of Geography and Natural Disaster1:104.

MRT Consulting Eng. (Nig) Ltd (1978). Kaduna State Water Board Master Plan 1980-2005. Cambridge, U.K.

National population Commission (1991) *Provisional census result:* NPC Nigeria.

Nura A.D and Sabo M (2011) Determinants of household demand for water in Kano metropolis: a crisis sectional analysis. *Kano journal of arts and social sciences*, 8 (1) Sa'adatu Rimi College of Education Kano State.

Offodile M.E (2000)*The Development and Management of Groundwater for water supply in Nigeria*: paper presented at 2nd fellows workshop of MMGS on Monday 6th march 2000 mean services ltd Jos.

Ogunrombi, J.A. (2009) Water Quality of Kubanni Reservoir Savannah; a Journal of the Environmental and social science. Ahmadu Bello University press Zaria, Nigeria. Vol.9, pages 28 – 31.

Oguntade, A.K. and Ariyo, S.O. (2009) Remote Sensing Application to Groundwater Studies. *on line journal of Earth Sciences,* 13(6): Medwell publishing 2010.

Okereke, C.S. Esu, E.O., Edit, A.E.(1998). Determination of Potential Groundwater Sites Using Geological and Geophysical Techniques in Cross Rivers, Southern Nigeria, Journal Africa, Earth Science, 27(1): 149 – 163.

Okonkwo, A. N.(2008) Kaduna State the Giant Heart of Nigeria. Loveagle Ventures, Kaduna.

Okoro, E.I., Egboka, B.C.E., Anike, O.L. and Enekwechi, E.K. (2010) Evaluation of Groundwater Potentials in Parts of the Escarpment area of South Eastern Nigeria. *International journal of Geomatics and geosciences,* 1(3), 2010.

Olofin, E.A. (1987) Some *Aspect of Physical Geography of Kano Region and Related Human Responses:* Debis Press Kano.

Onugba, A. and Eduvie, O.M.(2003). Groundwater Potential on the Jos – Bukuru Plateau North Central Nigeria. Using Lineaments from Gravity Measurements. ‘‘Hydrogeology of Nigeria Paper on Groundwater Workshop.’’ Organized by United Nations Children’s Fund, Jos, 2003, pp.20.

Onugba A. and Yaya O.O (2008) *Sustainable Ground Water Development in Nigeria*. Taylor and francis Group, London UK.

Oteze, G.E.(2006) Water Supply, Groundwater and Flood Control in Benin City, Presented at the NMGS, Benin Chapter Sensitization Workshops on Water Resources Management and its Implications in Benin City, 22nd March, 2006.

Oyenbende, O.(1977) An Emphirical Resistivity Model for Predicting Shallow Groundwater Occurance in the Basement Complex. Pp. 183. Unpublished M.Sc Thesis, Department of Geology University of Ibadan.

Pandian. M and Kumanan. C. J. (2013). Geomatics Approach to Demarcate Groundwater Potential Zones Using Remote Sensing and GIS techniques in part of Trichy and Karur district, Tamilnadu, India. Archives of Applied Science Research. Retrieved from http://scholarsresearchlibrary.com/archive.html

Rainer, E. (1996), Development Scene. Gate- 1/96 Habitat Conference: Development scene, Innovation the key to sustainable development.

Reynolds, J.M.(1987) *Surface Geophysical Survey of Southern Kano State, Nigeria* .An online Publication of Geological Society of London.

Rilwanu, T.Y.(2014) Assessment of Groundwater Potential for Rural Water Supply in Parts of Kano State, Northern , Nigeria. Unpublished Ph’D Thesis Submitted to the Department of Geography Ahmadu Bello University, Zaria.

Robert, W. C. (2007) *An Introduction to physical Geography* (8^{th} edition) Prentice Hall Print England Republic.

Satty, T.L. and Vegas, L.G.(1991) Prediction, Projection and Forecasting. Dordrecht: Kluwer Academic Publishers, pp.251.

Samaila, K.I. (1997), Influence of industrial Liquid waste on Water Quality for irrigation in Kaduna South. Bayero University, Kano.

Sander, P., Minor, T.B. and Chesley, M.M. (1997) Groundwater exploration based on lineament analysis and reproducibility test. *Groundwater Journal Dubin,* 35(5)888-894 ISSN: 0017467X.

Saraf, A.K. and Choudhury, P.R.(1998) Integrated remote sensing and GIS for groundwater exploration and identification of artificial recharge sites. *International Journal of Remote Sensing,* 19(10) 1825-1841.

Saumitra, M.(2008) Role of Satellite Sensor in Groundwater Exploration,*Journal of environmental sciences, 2(3)* Jawaharlal Nehru University New Delhi.

Shakeel, A., Ramaswamy, J. and Abdin, S. (2008) Application of Remote Sensing and GIS in Groundwater Exploration. *Indian society of Remote sensing Journal,* 19 (4) 89-92.

Sheka, N. (2005) Determinants of Household Demand for Water in Kano Metropolis: A Crisis Sectional Analysis. Kano Journal of Arts and Social Sciences, 8(1). Sa'adatu Rimi College of Education Kano State.

Singal, B.B.S, and Gupta P.R (1999), Applied Hydrogeology of Fracture Rocks. ISBN: 0 – 412-75830-X.

Solomon, S. (2003). Remote Sensing and GIS: Applications for Groundwater Potential. *Environmental and Natural Resources Information Systems*

Subba, R.N. Chakradhar, G.K.J. and Srinivas, V.(2001) Identification of Groundwater Potential Zones Using Remote Sensing Techniques in and Around Guntur Town. Andhra Predesh, India, 29(1&2), pp. 69-78.

Tanner G.A and Road R . A (2003) *medical physiology* (2nd ed) Baltimore: lippineott willions and wilkins ISBN 0781719363. OCLC 50554808

Teeuw, R.M.(1995) Groundwater Exploration Using Remote Sensing and a Low-Cost Geographical Information System. Hydrologeology Journal, 3(3), pp. 21-30.

Tesfaye, T.G. (2010) *Grounwater potential evaluation based on integrated GIS and Remote sensing Techniques, in Bilate River Catchment: south Rift valley of Ethiopia:* An unpublished Msc theasis Department of Eath science Adis Ababa University.

Thapa, R. Ravindra, K. and Sood R.K. (2009), Stenholm study of morphotectonic and hydrogeology for groundwater prospective using Remote sensing and GIS in North western Himalayas, India.

TheoGeorg S. (1997) Water Protection Human Beings, A triangular Relationship in changing times. *Journal of Applied Geography and Development.* No 49. Institute for scientific cooperation Tubingen Federal institute for scientific republic of Germany Maier, Rottenburg.

Thomas, H. (2003) *Basic concepts of Groundwater Hydrology*: University of California reference sheet division of agriculture and natural resources in partnership with natural resources conservation service (NRCS) http://www.nrcs.usda.gov

Timothy, B.M., Jerome, A.C., Mattwa, M.C. and Robert, B.K. (1994) *AN integrated Approach to Groundwater Exploration in Developing Countries using GIS and Remote Sensing*: U.S Army Corp A Engineers topographic Engineering center Alexandria, VA 22310

Toth, J. and Ophori, D.U. (1989) theoretical analysis of groundwater flow in small drainage basin. *Groundwater Journa,l* 27(2)

Trimmer, W.L. (2000) Measuring well water level, *Extension Service:* Oregon State University Sea Grant Extension Ec 136.

Udoh, R.K. (1978*). Geographical Regions of Nigeria*. Heinemann Educational Books LTD, London.

UN/WWAP (united Nation / *world water Assessment programme) (2003). UN world water development Report: water for people: Water for life. UNESCO (United Nations Educational, Scientific and culture, organization* and berghahn Books, Paris New York Oxford.

United Nation Economic commission for Africa (2005) *water resource Development in North Africa* summary of the sub regional report

United Nations Development Programme (2006) *Beyond scarcity: power, poverty and the Global water crisis:* Human Development Report 2006, Human Development office, UNDP, Palgrave Macmillan, New York.

United State Groundwater Association Report (2006) *Ground water protecting committee as drinking water* July, 2006.

Waikar, M.L. and Aditya, P.N.(2014) Identification of Groundwater Potential Zones Using Remote Sensing and GIS Technique. International Journal of Innovative Research, Science, Engineering and Technology. 3(5).

WATSSAN, (2006) Water and Sanitation Target – Meeting the MDG's Drinking a Mid Term Assessment of Progress. By World Health Organization.

WHO (1999) *would heath organization Annual report* observation (ICT) Hengelosestraat Netherland.

WMO (2008) *water and climate change,* no 970. Geneva, Switzerland .

World Bank and Danida, (1995) Rapid Water Resources Assessment Report, Vol. 2, Basin Report. Dar –Salam, Tanzania.

WUP (2001) *Strengthening the Capacity of Water Utilities to Deliver Water and Sanitation Services, Environmental Health and Hygiene to low Income Communities*. Case study for Kano (town), Nigeria context and practices WUP no 5.

Yatsuka Kataoka (2002) Water for Sustainable Development in Asia and the Pacific. Asia Pacific forum for Environment and development*:* First substantive meeting Jan. 12 – 13, 2002 Bangkook, *Thailand Journal of water resources.*