ASSESSMENT OF GROUNDWATER POTENTIAL FOR RURAL WATER SUPPLY SCHEME USING GEOGRAPHIC INFORMATION SYSTEM (GIS) IN EDE NORTH LGA OF OSUN STATE NIGERIA

BY

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DECLARATION

I declare that the work in this dissertation entitled ASSESSMENT OF GROUNDWATER POTENTIAL FOR RURAL WATER SUPPLY SCHEMES USING GEOGRAPHIC INFORMATION SYSTEM (GIS) IN EDE NORTH LGA OF OSUN STATE NIGERIA has been carried out by me in the Department of Water Resources and Environmental Engineering. The information derived from the literatures has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma of this or any other institutions.

ADEWALE, Bamiji Zachariah

_____ _____

Signature Date

CERTIFICATION

This dissertation entitled

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By

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meets the regulations governing the award of the degree of Master of Science Water Resources and Environmental Engineering of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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Prof.Kabir Bala _____ _____
Dean, Postgraduate School Signature Date

DEDICATION

This research work is dedicated to Him who has given me strength to carry-out this work and to the entire rural dwellers particularly in Ede North Local Government Area (LGA) and Nigeria in general, of which the burden for this work actually emanated from their persistence suffering in meeting domestic water supply needs.

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ABSTRACT

Groundwater serves as a primary source of water supply in rural areas of Ede North Local Government Area (LGA) of Osun State, Nigeria. However, low access to drinking water coupled with pollution due to agricultural practices has been common problems in this LGA.This research was aimed at assessing the groundwater resourcesstatus of Ede North LGAusing Geographic Information System (GIS).

Key hydrological and climatic parameters, most of which were acquired from Landsat 7 (ETM), ASTER were digitalized in GIS environment. The respective parameters were assigned weightages and their attributerangedand ranked with reference to groundwater occurrences or pollution potential. The resulting GIS layers were overlain using overlay function of ArcGIS and further integrated one over the other using GIS add function. Finally the study area was classified into three different groundwater potential zones. Over 82km^{2}out of 112km^{2}of the study area was classified as high and moderately groundwater potential zones. The groundwater of the study area was also assessed quantitatively using Krishna model. The groundwater potential was estimated as 26.8million cubic meters annually.Analysis of groundwater pollution potential indicated that out of total area of the LGA, 27.6% of the area equivalent to 31Km^2 is highly vulnerable to groundwater pollution.

The climatic variation of the study area indicated that rainfall and temperature increase at 0.031mm and 0.36^{o}C respectively. The assessment of rural water supply scheme for investment plan and gaps to be filled to meetSustainable Development Goals (SDG)-6on universal coverage to water Supply was performed, the result revealed that 353 numbers of Boreholes and rehabilitation of 15 numbers dysfunctional scheme will be required with total cost of NGN940,332,124.

Generally the result obtained from this research showed that GIS and the models used provide a powerful tool in the assessmentsof groundwater resources for effectiveplanning and management. The study area is viable for rural water supply scheme siting. The amount of groundwater available is sufficient to meet the immediate and remotely domestic water demand of 2.0m^3/year and 3.21m^3/year respectively withexpected domestic water supply demand average increase rate of 3.43% annually while the public groundwater use rate of 7.48% and 12.0% for 2015 and 2030 respectively. It is therefore recommended that Motorized and hand pump schemes be situated in area demarcated as high and moderate potential respectively while high risk area should be avoided for well siting pending the detail assessment for pollutants identification and remediation measures.

ABBREVIATIONS AND SYMBOLS

AfDB	African Development Bank
ARIMA	Autoregressive Integrated Moving Average
ASTER	Advance Space bound Thermal Emission Reflection Radiometer
CGCM	Coupled General Circulation Model
CMCC	Euro-Mediterranean Centre on Climate Change
DEM	Digital Elevation Model
EM	Electromagnetic
EPA	Environmental Protection Agency
ESRI	Environmental System Resources Institute
ETM	Enhance Thematic Mapper
FMWR	Federal Ministry of Water Resources
GIS	Geographic Information System
HA	Hydrologic Area
HDW	Hand Dug Well
HPBH	Hand Pump Boreholes
ILWIS	Integrated Land and Water Information System
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Report
LGA	Local Government Area
MBH	Motorized Boreholes
MCM	Million Cubic Meter
MDG	Millennium Development Goals
MSS	Multispectral Scanner
NGN	Nigeria Naira
NGO	Non-Governmental Organization
NGSA	Nigeria Geological Survey Agency
NIMET	Nigerian Meteorological Agency
NPC	National Population Census
NUWSS	National Urban Water Supply and Sanitation
OSMA	Osun State Ministry of Agriculture
PET	Potential Evapotranspiration
PPWF	Public Point Water Facility
RCM	Regional Climatic Model
RS	Remote Sensing
RUWESA	Rural Water and Environmental Sanitation Agency
SDG	Sustainable Development Goals
SRTM	Shuttle Radar Topographic Mission
SSA	Sub-Saharan Africa

TDS	Total Dissolved Solid
UN	United Nations
UNDP	United Nation Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nation's Children Fund
US	United States
USGS	United State Geological Survey
VES	Vertical Electric Sounding
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
C_a	Pesticide Concentration
Q_a	Mass of pesticide per unit area of aquifer
T	Travel time
H	Aquifer thickness
Q_p	Pesticides Application Rate
Fe	Iron
Mn	Manganese
Cu	Copper
Ni	Nickel
Pb	Lead
Hg	Mercury
As	Arsenic
Cd	Cadmium
Zn	Zinc
ϕ	Aquifer porosity
χ	Pesticides Degradation Rate
γ	Pesticides half life

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CHAPTER ONE

INTRODUCTION

1.1 General Background on the Study

Water supply is threatened by increasing population growth and climate change. Since the last century, the population of the world has increased three times and industrial production has increased 50 times. This means demand for water is increasing and resources with suitable quality are depleting because of urban, agricultural, and industrial uses (Karamouz*et al*.,2011).

The need of water to human cannot be overstressed. He can survive longer without food than without water. Water has been identified as essential factor for the wellbeing of mankind, vital input to economic development, a basic requirement for the healthy functioning of all the World's ecosystems and a critical index for the attainment of other facets of sustainable development.

Due to uneven distribution of rainfall both in time and space, the surface water resources are unevenly distributed and also, its development, operation and maintenance is highlycapital intensive. These have made human to depend on groundwater as a source of drinking water in Nigeria and in particular Ede North Local Government Area of Osun State, Nigeria.However low access to drinking water supply in the study area has been attributed partly to lack of adequate planning and management apart from low capital investment inwater infrastructure in most part of "abandoned" areas of rural communities. Also, lack of coherent data management structurewhich causes severe impedimentto planning and design which resulted toinefficient, less accurate and consequently many

wastes in the system. In fact most of organizations' that implement groundwater development keep borehole data without unification and coordination with the other organizations. Many borehole data are scattered and lost without effective use during their custody (FMWR-JICA, 2014).

Currently, the water supply -related data/information such as schemes types, location/geographic coordinate, depth of installation, qualityof productive wells is not uniformly managed at all. It makes it difficult to grasp rapidly andcorrectly on the existing condition of groundwater resources facilities and taking adequate decision in any kind of water resources plans and projects in the study area.

Quantification of a catchment water balance is a fundamental requirement in the assessment and management of water resources, in particular under the impacts of human-induced land use and climate change(Nebo and Sumaya, 2012). Effective planning and managing of the groundwater resources for utilization will therefore involve critical assessment of groundwater potential qualitatively and quantitatively vis-à-vis prevalent climate changes, and facilities for water abstraction to meet the present as well as future population water demand of the entire communities.

Remote Sensing (RS) technology produces an authentic source of information in identifying, classifying, mapping and planning of natural resources(Ifatimehin*et al*., 2009). Remote Sensing and Geographic Information System (GIS) in water resources data acquisition, processing and storage are now increasingly used to solve challenges in water resources planning, development and management. The use of a GIS system within water

utility can provide benefits at different organizational level and different users (Roland and Zoran, 2011).Multiband, multidate and multistage satellite imaging has been extensively used in Asian countries and developed countries of the world for water resources studies and management of land uses (Akingbogun and Oloyede, 2012).

GIS approach produces GIS-generated maps with user friendly, robust and extensible database system which makes features such as query, groundwater potential and pollution vulnerability zone and distribution patterns of rural water supply facility possible from which comprehensive assessment can be inferred. This is the focus of this work for realization ofthe Sustainable Development Goal of water supply, sustainability of Water infrastructure, protection of groundwater aquifer from over exploitation and pollution which will bring about, high level and prompt decisiontaken by political leaders and operators within the study area.

1.2 **Aim and Objectives**

Theaim of this study is touse Geographical Information System to carry out an assessment ofgroundwater resources for rural water supply scheme with a view to providing powerful tools for the scheme planning and management.

Specifically the objectives of this study are as follows:

a. Determine the groundwater potential zones.
b. Determine the groundwater pollution potential zones
c. Evaluate climatic variation using trend analysis
d. Establishrural water supply scheme point mapping with spatial distribution.

1.3 **Justification**

Human right to water is recognized in international legal instruments as to provide for sufficient, safe, acceptable, accessible and affordable water. According to Kofi Annan (2011), former Secretary General of United Nations (UN)"Access to safe water is a fundamental human need and therefore a basic human right".Access to safe water is central to basic right of every human beings, the right to safe water remains a promise unfulfilled for the inhabitant of Ede North LGA particularly thoseliving in rural communities. Every year, huge numbers of people, most of which are children, die from diseases associated with inadequate water supply. Water scarcity and poor water quality negatively impact food security, livelihood choices and educational opportunities for poor families.

Moreover, the aim of managing any resources like water is to find a way to ensure its sustainability. Acquiring and establishing a robust and workable data base of groundwater and scheme with geographic coordinate provide a needed platform for sustainability which would guide against over exploitation of groundwater resources within the study area.

Above all, the benefits to be realized from this research work include the following:

a. Mapping of various rural water supply schemes in the study area will be produced.
b. Mapping of groundwater potential andpollution vulnerability zones shall be determined so that the vulnerable areas could be easily monitored.
c. Land use changes of the area will be examined.
d. The result will enable right and prompt decision being taken by decision makers.
e. Inconsistency in actual data of those facilities will be eradicated.
f. The outcome of the research will contribute to the realization of human right to water

1.4 **Statement of Research Problem**

Low access to safe drinking water supply is a major problem of the inhabitants of the Ede North LGA. Most of their rural dwellershave no access to the minimum required 30 litres/capital/day of drinking water from safe sources which had made them to depend on thewater from streams, rivers and unprotected wells to meet their drinking water needs.The consequence of which has led to the untimely death of many lives from diseases associated withinsufficient water and poor water quality.Despite the involvement of government at various levels, development partners, Non-Governmental Organisation, religious bodies as well as philanthropic in the provision of water supply schemes in Ede North LGA, access to safe drinking water is still low(FMWR, 2007). Inadequate water supply in the study area has been attributed partly to lack of adequate data information for planning and management apart from low and uncoordinated capital investment in watersupply infrastructure. In addition, water supply scheme are usually located on the political consideration not on the community needs and sound technical consideration.

The quality of groundwater being utilized by the rural population is largely unmonitored. Deterioration of groundwater quality in the study area are due to infiltration of contaminated surface water and chemical fertilizers leaching into groundwater as well as bacterial presence in boreholes due to poor sanitation practices. In 2014 it was reported that for the drinking water sources in parts of the LGA, the toxic metals such as Pb (0.01-0.03), Hg (Nd-0.03), As (Nd-0.03), and Cd (Nd-0.04) recorded values higher than the safe limits set by WHO hence, the water sources are capable of constituting serious health hazards(Odebunmi,*et al.*, 2014). Residences of rural communities are predominantly farmers who engaged in subsistence agriculture and poultry production. The generated

wastes from poultry production serve as potential contaminants and cultivation of cash crop such as cocoa and annual crops is usually sustained with application of pesticides and fertilizer, all of which make the groundwater at risk to contamination.

1.5 Research Scope and Limitation

The scope of this research work covered determination of groundwater potential zone and pollution risk assessment. The aim is not to pinpoint sources of contamination but to analysis characteristic that affects groundwater potential and contamination zones and produces the maps showing areas/zones viable for water facilities siting and identify zonesthat are more susceptible to contamination. It also covered an estimation of mean annual groundwater potential, climatic variation, water supply schemes mapping and gaps to be filled in meeting the SDG.

The research work has been greatly hampered as a result of insufficiency of rainfall measuring instrument in the areas, absence of data on well water level monitoring and lack of river flow data. The water schemes assessed are limited to public water points. The maps produced, are reliable to the level of information used.

1.6 Description of the Study Area

The study area is Ede North LGA, located in Osun State, South-Western part of Nigeria. Figure 1.1 is a map of Nigeria shown Osun State while Figure1.2 is a map of Osun State shown Ede North LGA.

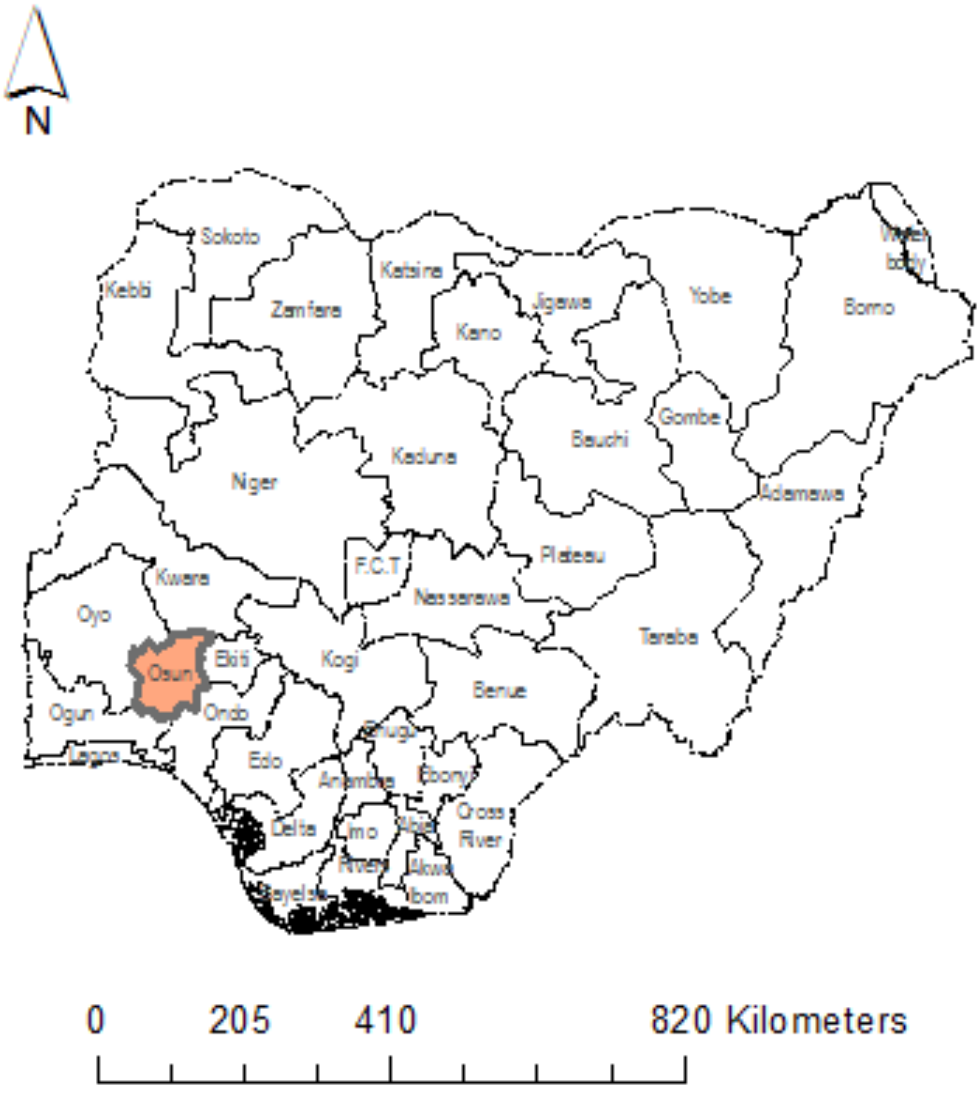


Figure 1.1 : Map of Nigeria Shown Osun State

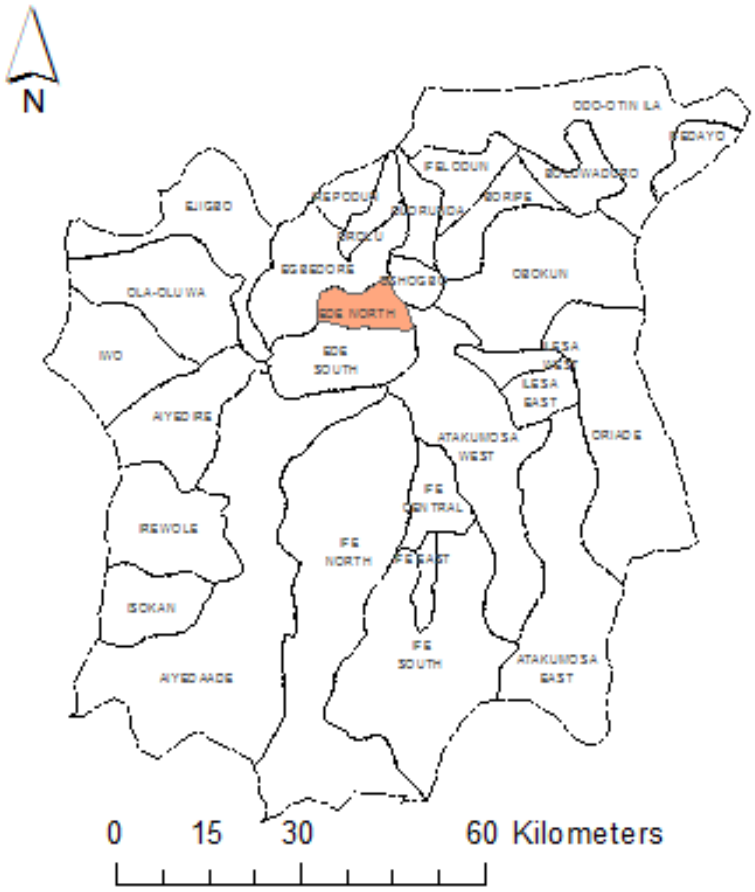


Figure 1.2 : Map of Osun State shown Ede North Local Government Area.

Ede Northhas its headquarters located in the town of Oja Timi (7.44'N 4.28'E). Ede North LGA has eleven (11) political ward (see Table 1.1)with a population of 83,831 at the 2006 census. It it situated on a vast flat agricultural land covering about 112.379 square kilometer of land. Commercial agriculture is the main occupation of the people and is rain-fed. Ede North is bounded in the North by Egbedore LGA, in the South by Ede South LGA, in the west by Atakumosa West LGA and East by Osogbo LGA. The nearby major towns include Awo, Iragberi and Osogbo. Ede is an important town in Yoruba land.

Table 1.1: Ede North Political Ward and Number

WARD NUMBER	NAME OF POLITICAL WARD
1	Oloba Atapara
2	Sagba Abopgunde
3	Ologun Agbaakin
4	Olusokun
5	Alusekere
6	Sabo Agbongbe 1
7	Sabo Agbongbe 2
8	Buhari Isola Isibo
9	Apaso
10	Asumo
11	Bara Ejemu

Source: Ede North LGA

Geology/Hydrogeology: Generally, the State is underlain by crystalline Basement Complex rocks of southwestern Nigeria, outcrop over many areas which comprises of: migmatite-gneiss-quartzite complex, slightly migmatised to non-migmatised meta-sedimentary and meta-igneous rocks, charnockitic, gabbroic and dioritic rocks, members of the older granite suite, metamorphosed to unmetamorphosed calc-alkaline volcanic and hyperbasal rocks and unmetamorphosed dolerite dykes, basic dykes and syenite dykes . The basement rocks are commonly considered as poor aquifers because of the crystalline nature, which lead to low porosity and permeability, appreciable porosity and permeability are developed through fracturing and weathering of the rocks. This makes an otherwise barren rock to function as a groundwater aquifer. Groundwater gets constant recharge from abundant rainfall, rivers, streams while the rivers and streams are also replenished by rainfall.

Relief and Drainage: The land surface is generally undulating.Many rivers, including the Osun River from which the state derives its name, have their source in the northern part of the state. Erinle River which is tributary to the Osun River flows across the Ede town.

Soil: The soils belong to the highly ferruginous tropical red soils associated with basement complex rocks. As a result of the dense humid forest cover in the area, the soils are generally deep and of two types, namely, deep clayey soils formed on low smooth hill crests and upper slopes; and the more sandy hill wash soils on the lower slopes.

The well drained clay soils of the hill crest and slopes are very important, because they provide the best soils for cocoa cultivation in the area. The lighter loams are more suitable for cultivating the local food crops, such as yam, cassava and maize. Soil degradation and soil erosion are generally not serious in the area, but considerable hill wash is recorded along the slopes of the hills.

Vegetation: The vegetation is the evergreen high forests which are composed of many varieties of hardwood timber such as proceraterminalia superb, meliciaexcelsa and others. Originally, virtually all parts of the state had natural lowland tropical rain forest vegetation; but this has since given way to secondary forest re-growths. Among the reasons for this are fuel wood production, road construction, clay and sand quarrying and traditional farming practices.

Human interference, by way of cocoa plantation, has also replaced the forest. Hence, the natural tree species have given way to oil palm (elacis guinniensis), gmelina and dense thickets.

Climate: The climate is of the lowland tropical rain forest type with distinct wet and dry seasons. Rainfall pattern of the area is generally characterized by long and short rainy season with short and long dry season. The long rainy season starts in March and lasts to the end of July, with a peak period in June over most parts of southern Nigeria. It is a period of thick clouds and is excessively wet. It is marked by humidity with values hardly below 85 per cent in most parts of the forested south. The short dry season is experienced in August for 3-4 weeks. However, the real dry period known as the "August break" is generally observed in the last two weeks of August in most parts of southern " Nigeria".

This brief wet period follows the "August break" from early September to Mid-October, with a peak period at the end of September. The rains are not usually as heavy as those in the long rainy season. The two periods of rainfall intensity give the double maxima phenomenon of the rainy season characteristic of southern Nigeria. The long dry season period starts from late October and lasts to early March with peak dry conditions between early December and late February. The period witnesses the prevailing influences of the dry and dusty north-east winds, as well as the 'harmattan' conditions.The mean annual rainfall for the region is about 1500 mm. The mean monthly temperature is about 28°C with a mean monthly range of 3°C. The mean relative humidity is over 75%. .

Wildlife: As in other parts of the country, hunting is an important traditional occupation in Ede North LGA. Because of this, the game population of the area has dwindled considerably. The fauna species found in the area include grass cutter, antelope and bus pig (warthog).

Water Supply: The main source of water supply in the area is boreholes fitted with pump power by generator or handpump. Most of the people depend on stream and rivers for sources of drinking water which are not protected in any way. There is one dam at Ede which serves as source of water to Ede Water Works and provides water for the inhabitants of the state mainly urban centre. The water works served less than 35% of the urban centre (FMWR, 2007).

CHAPTER TWO

LITERATURE REVIEW

2.1 **Preamble**

In 2002, the World Summit on Sustainable Development recognized that the scarcity of water information in many developing countries was one of the main obstacles in achieving sustainable development. The alarming low functionality of water supply facilities and unguided siting and distribution in developing countries necessitated additional new solutions to improve watergovernance based upon reliable and timely water information. Earth Observation technologies and modeling software can help fill these gaps.

Water is the most abundant substance on earth.It is very vital to the survival of all living things. The importanceof water in rural and urban settlementscannot be overemphasized. Human beings cannotlive for more than a few days without water. The quantity, quality andaccessibility determine the level of public health, food production, energy, and other aspects of life. It is essential for all social economicdevelopments in all parts of the world and it isdifficult to think of a resource more essential tothe health of human communities or their economies than water. The eradication of poverty andhunger in rural areas is closely related to a fairand equitable access for the most vulnerable peopleto basic livelihood assets (including land andwater) for most domestic and productive uses.

Water supply is threatened by increasing population growth and climate change. Since the last century, the population of the world has increased three times and industrial production

has increased 50 times. This means demand for water is increasing and resources with suitable quality are depleting because of urban, agricultural, and industrial uses (Karamouz *et al*.,2011).

The demand for water resources of sufficient quantity and quality for human consumption, sanitation, agriculture, and industrial uses will continue to intensify as the population increases and global urbanization, industrialization, and commercial development accelerate.

In Nigeria, water shortage is more serious than before because the needs for water resources development is increasing for irrigation, water supply and energy generation and so on with population growth and economic development (FMWR-JICA, 2014). In recent years, some rivers dry up completely and groundwater source also dry up more than ever before in dry season (FMWR-JICA, 2014). Therefore, adequate planning, management and development of water resources is now very crucial more than ever before in preventing environmental damage.Groundwater may be a reliable resource in many places today, but to keep the groundwater supply sustainable, risk assessments need to be conducted to keep groundwater a renewable resource (European Commission, 2006)

Groundwater which can be extracted by boreholes (Hand pump, Motorized-Solar/Mechanical) and hand-dug wells (protected and unprotected) occurs in permeable geological formations known as aquifers which have properties that allow storage and movement of water through them. There are about 57,600 boreholes for public water supply and with total pumping of 458m^3/day in Nigeria (Hisashi, 2011). Groundwater is used for wide purpose, such as water supply, private irrigation, livestock and aquaculture. Depth of boreholes is around 50m in average with yield from boreholes is 10 to 150m^3/day

in Basement Complex of the study area, where groundwater of weathered rock is pumped up and operation rate of boreholes is 63% due to breakdown of pumps (Hisashi, 2011).

Water resource planning and management is one of the most important challenges the world is facing today.In order to meet the demands of different users, efforts should be intensified on the efficient planning and use of all water resources (surface water, ground water, and rainfall) and also on water allocation plans that maximize the resultant economic returns to limited water resources and, at the same time, protect the fragile ecosystem. Therefore, availability of adequate data and information is crucial in the effective planning and management of fresh water resources, and generally, lack of adequate data pose major challenge in groundwater development. It is commonly reported thatorganizations that implement groundwater development keep borehole data 45zwithout unification and coordination with the other organizations. Many borehole data are scattered and lost without effective use during their custody (FMWR-JICA, 2014).The Nigeria government has made several efforts to address rural water supply challenges through development of Water Sector Roadmap, the Medium Term Goals and Strategy, provision of adequate policy such as water supply and sanitation policy, establishment of appropriate institutions, such as rural water supply and sanitation agency at the states level and WASH Department/Unit at Local Government Council level but the challenges in data management appear to be without end.

The effective planning and managing of the groundwater resources for utilization involve assessment of groundwater potential qualitatively and quantitatively vis-à-vis prevalent

climate changes, and facilities for abstraction to meet the demand of present and future population of the entire communities.

2.2 **Groundwater Potential**

Groundwater potential of an area can be successfully assessed through the use of various methods and procedures; some of these methods are based on the groundwater quantification while other are based on the determination of groundwater viable zone of an area. Kumar (2012),a hydrologist at the National Institute of Hydrology India,in his opinion, support the use of groundwater balance equation which he used to evaluate groundwater potential in Roorkee, India. According to Kumar(2012), the basicguiding concept of water balance is;

Input to the system - outflow from the system = change in storage of the system (over a period of time)

Therefore, the general methods of computations of water balance include: (i) identification of significant components, (ii) evaluating and quantifying individual components, and (iii) presentation in the form of water balance equation. Considering the various inflow and outflow components,the terms of the ground water balance equation can be written as:

$$\Delta s = \{(R_i + R_c + R_r + R_t + S_i + I_g) - (E_t + T_p + S_e + O_g)\} \quad (2.1)$$

Where:

R_i = recharge from rainfall;

R_c = recharge from canal seepage;

R_r = recharge from field irrigation;

R_t = recharge from tanks;

S_i = influent seepage from rivers;

I_g = inflow from other basins;

E_t = evapotranspiration;

T_p = draft from ground water;

S_e = effluent seepage to rivers;

O_g = outflow to other basins; and

ΔS = change in ground water storage.

Some of the shortcoming of the groundwater balance equation is that the equationconsiders only one aquifer system andthus does not account for the interflows between the aquifers ina multi-aquifer system (Kumar, 2012). Although, if sufficient data related towater table and piezometric head fluctuations and conductivity ofintervening layers are available, the additional terms for theseinterflows can be included in the governing equation.Computations ofwater balance elements always involve errors, due to shortcomingsin the techniques used for individual component. The water balance equation thereforeusually does not balance, even if all its components are computed by independent methods. The complexity of the computation of the water balancetends to increase with increase in area. This is due to a relatedincrease in the technical difficulty of accurately computing thenumerous important water balance components.

The GIS and RS technique has been successfully used to determine the groundwater potential zone of an area. Landsat Multispectral Scanner (MSS) satellite data was used to prepare drainage density, lineament, soil, geology, geomorphology land use/cover for the identification of groundwater zones(Anderson and Hardy, 1976). Also, ranks and

weightages were assigned to the individual thematic data and integrated using GIS overlay function and identified the groundwater potential zones(Krishnamurthyand Venkatesa,1996). Neelakantan and Yuvaraj (2012) bothfrom Tamil University, used Geospatial data to evaluate the groundwater potential zone of Salem Taluk, Tamil Nadu, India in which all the known factors that affect the groundwater potential were considered. The various terrain parameters were interpreted from LANDSAT MSS and SRTM data, different ranks and weightages were assigned to respective parameters, individual GIS layers were integrated, and the area has been divided into different groundwater potential zones.

Preliminary mapping of groundwater potential zone using GIS and remote sensing techniques in Ghana and applicable to other sub-saharan Africa (SSA) countries was carried out by Paul*et al.*,(2012) based on the spatial datasets; SRTM 90m DEM, Landsat ETM+, geology, soils and rainfall. Ratings and weightages were provided to the spatial data based on the expert knowledge and the spatial data layers were integrated to produced groundwater potential mapping.

In assessment of groundwater potential zone of basement complex aquifers part of southwestern Nigeria, Vertical Electric Sounding (VES) and field/physical data collectionwere employed in which Spatial and temporal distributions of saturated thickness of the available aquifers were successfully determined (Yinusa and Joy, 2013). However for any methods to be suitable for evaluation of groundwater potential, the method of

evaluation shall take into account not only hydro-geological conditions but also certain meteorological conditions of the area (FMWR-JICA, 2014).

2.2.1 **Groundwater recharge**

Part of the rain water that falls on the ground is infiltrated into the soil. This infiltrated water is utilized partly in filling the soil moisture deficiency and part of it percolates down reaching the water table. This water reaching the water table is known as the recharge from rainfall to the aquifer. Recharge due to rainfall depends on various hydro-meteorological and topographic factors, soil characteristics and depth to water table.

There are a wide range of methods of estimating groundwater recharge; these include field measurement, the use of properties of unsaturated soil, empirical relationship, groundwater estimation committee norms(Lerner *et al*.,1990).

Field methods are based on field studies such as the water table fluctuation method, lysimeter and tracer experiments. In the water table fluctuation method the rise in water table during the recharge season is multiplied by the specific yield to give a direct estimate of the recharge (Lerner *et al*, 1990). However, the method is only valid over short time periods of a few days. A further issue is the difficulty in obtaining realisticestimates of the specific yield(Lerner *et al*., 1990).

Groundwater estimates using properties of unsaturated soil is based on interaction between water and air in the pores of a permeable medium, though this is complex to determine. In saturated conditions, the flow can be estimated from Darcy's Law in terms of the head gradient and the saturated hydraulic conductivity. For unsaturated flow, Darcy's law still applies.

Different hydrologist/engineers developed and established groundwater model based on the relationship between recharge and rainfall for different regions. Notable among them are Chaturvedi model, Krishna Rao model, Amritsar model etc. Chaturvedi model was based on the water level fluctuations and rainfall amounts in Ganga-Yamuna doab, Chaturvedi in 1936, derived an empirical relationship to arrive at the recharge as a function of annual precipitation. This is expressed as

$$R = 2.0\ (P - 15)^{0.4} \qquad (2.2)$$

Where:

R=net recharge due to precipitation (inches);

P=Annual Precipitation (inches);

The formula was later modified as

$$R = 1.35\ (P - 14)^{0.5} \qquad (2.3)$$

Where:

P and *R*as defined in equation 2.2.

Amritsar formula used regression analysis for certain doabs in Punjab, Sehgal developed a formula in 1973 for Irrigation and Power Research Institute, Punjab.

$$R = 2.5\ (P - 16)^{0.5} \qquad (2.4)$$

Where:

R=net recharge due to precipitation (inches)

P=Annual Precipitation (inches).

Krishna Rao : Krishna Rao gave the following empirical relationship in 1970 to determine the ground water recharge in limited climatological homogeneous areas.

For areas where annual rainfall is <1000 mm/year,

$$R = 0.20\ (P - 400) \tag{2.5}$$

For areas where annual rainfall is between 1000-2000 mm/year

$$R = 0.25\ (P - 400) \tag{2.6}$$

For areas where annual rainfall is above 2000 mm/year

$$R = 0.35\ (P - 400) \tag{2.7}$$

Where:

R= net Recharge (mm),

P=Rainfall (mm)

Adelana *et al.,* (2006) argued that empirical methods, using simple mathematicalrelations, can give a quick recharge value for water resources decision making processes. Oke, *et.al.,* (2014) made a comparative analysis of groundwater recharge estimation value using empirical methods (Modified Chaturvedi, Krishna Rao, Kumar and Seethapathi) in Ogun-Osun River Basin and came to conclusion that any of the recharge methods can be used for estimation, although the Kumar and Seethapathi formula is preferred. The formulae were selected because of the similarities between the Indian monsoons climate where they were created and the humid sub-tropical climate of southwest Nigeria (Oke *et al*., 2014).

Also an initial calculation of annual recharge can be made using average values for rainfall and potential evapotranspiration(Rick, 2007). The estimate will be somewhat crude, but an

early idea of recharge values will be useful where a new groundwater development is proposed. If the estimated recharge is several times larger than the quantity of water required for supply then the scheme is likely to succeed. He also affirmed that in both sedimentary rocks and unconsolidated sediments, groundwater is contained in and moves through the pore spaces between individual grains. A groundwater system, therefore, consists of rainfall recharge percolating into the ground down to the water table, and then flowing through rocks of varying permeability towards natural discharge points. Therefore, information is needed on rainfall and potential evapotranspiration to estimate aquifer recharge.

Average annual recharge isindicationsof the groundwater potential in an area which can be obtained by multiply the potential recharge value (expressed as a depth of water in millimeters) by the area of the exposedaquifer. It is assumed that all the potential recharge will percolate into the outcropareas but a smaller amount will soak into the aquifer, where it is overlainby low-permeability materialand no recharge will take place where the aquifer is confined by thick clays. If the aquifer is not confined it is assumed that half the potential recharge will reach the aquifer by percolating through the clay or by running off the edge of the clay onto the outcrop. Recharge can occur throughvery low permeability materials provided that the vertical hydraulic gradientpermits it. This means that the groundwater head in the aquifer must be at alower level than that in the overlying rock. In urban areas according toRick (2007), recharge is reduced to about 25% because rainfall runs off buildings and roads into sewers.

2.2.2 Rainfall

The mean annual rainfall of the study area is about 1500 mm (Omotayo and Olarewaju, 2008). There is no functional rainguage in the entire Local Government Area. The only closest functional rainguage for rainfall measurement is situated in Osogboat 07.47'N 04.29"E and 302 meters height above sea level.

The arithmetic mean method is the simplest method of determining average rainfall. It involves averaging the rainfall depths recorded at a number of guages. The method is satisfactory if the gages are uniformily distributed over the area and individual guage measurement do not vary greatlyabout the mean.

The Thiessen method assumes that at any point in the watershed the rainfall is the same as that at the nearest guage so the depth recorded at a given guage is applied out to a distance halfway to the next station in any direction. If there are J gages, and the area within the watershed assigned to each is A_j, and P_j is the rainfall recorded at the j^{th} guage, the areal average precipitation for the watershed is given as;

$$P = 1/A \sum_{j=1}^{J} AjPj \qquad (2.8)$$

Where:

A=watershed area

2.2.3 Climate changesignal

Groundwater are susceptible to climate change Increases in evapotranspiration may offset precipitation increase and lead to reduction in groundwater rechage. Increase in temperature will result to increase in heating degree days and lead to increase in domestic use. In anticipating future climate change, there are main sources of uncertainty, we do not know future anthropogenic emission and resulting atmospheric concentrations of greenhouse gases and aerosols.

A number of climate and water balance models were developed to evaluateimpacts of climate change, but many of these models are not precise because of their coarse spatial and temporal resolution (Elgaali, 2005). In addition, the climate models use different initial boundary conditions and their results are quite different from each other. Howeverthe future tendency on climate condition in the World could bepredicted nowadays, the predictions by different climate models at local level are still widely scattering which makes it difficult to judge future conditions (Arun,*et al*.,1999 ; Fariborz , 2012). However, the possibility of changes in water resources by the climate change should not be ignored, because it is almost sure that some changes would occur in future.

According to Jamal and Morie,(2013) in theirresearch titled Toward Climate-Resilient Development in Nigeria supported by World Bank, said climate change is likely to make food, energy, and water security harder for Nigeria to achieve. Various climate modeling (CGCM, CMCC, RCM etc) that wereused underscore the severity of the challenge resulting from temperatures expected to rise at an average of 1–2°C by 2050.

Many of scientist researchers on Climate change based their research on statistical and trend analysis of historical climatic data, and analysis provides understanding of climate

variability. Climatic variability can be described as the annual difference in values of specific climatic variables within averaging periods such as a 30-year period(Murat and Huseyin, 2008). Air temperature and precipitation are principle element of weather systems, so examination of their behavior is important for understanding of climate variability because both are highly variable spatially and temporarily at different local, regional and global scales. For the prediction of future climate conditions, level of variability of these two weather elements must be examined and understood. Therefore, the focus on climate variability bases mostly on the detection of trends in instrumental records of precipitation and temperature. Several researches of climatic trends have been conducted on rainfall and temperature data at different periods of records throughout the world.There are many trend analysis methods and applications; Regression Analysis Based Methods, Triangular Episodic Presentation and Qualitative Scaling, Dynamic Time Warping, Wavelets, Qualitative temporal shape analysis etc The Linear regression, when applied to time-series data, fits the data to a model

$$y = mx + b \qquad (2.9)$$

Where:

m= the rate of change

b = y-intercept of the line.

Varioussoftwareare also available today for trend analysis this include Microsoft excel, ARIMA model.

2.2.4 **Potential evapotranspiration**

Various factors that influence evapotranspiration have been examined by different researchers and most of them have developed empirical formulae that make use of meteorological data which are readily available most time. Although these empirical formulae were developed under various climatic conditions which affect the accuracy when the equation are used outside the climatic environment in which it was derived. Apart from empirical methods of estimation, a pan and lysimeter can be used but none of these methods is perfect but all can provide reliable data. Among the scientist that developed empirical equation include Penman (1948), Doornbos and Pruitt (1997), Thornthwaite (1948) etc. Penman's formula is probably the most comprehensive approach to the estimation of potential evapotranspiration (PET) which has so far been devised and takes into account almost all factors which are known to influence it. However, it is established that modified Penman exaggerates the potential evapotranspiration value in less humid and Thornthwaite in more humid area. Modified Penmanalso requiredmore meteorological data which may not always be available.

Thornthwaite approach to the estimation of potential evapotranspiration has been used over a wide range of climatic conditions (Sibbons, 1956). Certain experimental and documentary evidence justified its application to the estimation of potential evapotranspiration in almost every climatic area in the world (Sibbons, 1956). Thornthwaite using the strong correlation between radiation and mean air temperature first proposed a model for estimating PET.

However, certain shortcomings are inherent in the method. Only day length and temperature are used as climatic inputs. Application of this method to short-time periods leads to significant errors.It was found that PET estimations based on short-term mean

temperatures by this method (Thornthwaite)are unreliable owing to the often excessive variation in mean temperatures (Cruff,1967). The failure of the Thornthwaite method over short time periods is attributed to the fact that short-term mean temperature is not a suitable measure of net radiation. Both PET and mean temperature are, however, correlated with net radiation over relatively long periods of time and hence, the Thornthwaite model has success on a long-term basis. According toCruff (1967),the use of the empirical method of Thornthwaite has declined in recent years as the availability of meteorological data required for more physically based methods (i.e. Penman, Priestly-Taylor) has increased, Certainly, for computer simulation models of soil moisture, irrigation scheduling, etc., which require PET estimations on a short-term basis, the Thornthwaite method is not recommended

2.3 **Rural Water Supply Schemes and Demography**

The main source of water supply in the area is boreholes fitted with pump powered by generator or handpump. These boreholes were sunk by Federal, State and Local Government. Development partners such as United Nation Development Programme (UNDP), United Nation's Children Fund (UNICEF), African Development Bank (AfDB) Assisted Programmes (FMWR, 2007). There are also open hand dug wells own by private individual as well as ponds, streams and rivers which are source of drinking water. The impounding dams which supply the water works is mainly for urban water supply and serving less than 35% of the urban inhabitants.

Ede North LGA is located within the Western Littoral or Hydrological Area-6 (HA). The HA-6 wasidentified to have highest municipal water demand of groundwater sources of 869MCM/year in 2010 and projected 1,372MCM/year by 2030 (FMWR-JICA, 2014).

In 2007, Ede North estimated water demand was put at 4,075.8m^3/day while the existing water supply facilities such as motorized and Handpump boreholes and other facilities were put at 26 numbers (FMWR, 2007).The National Rural Water Supply and Sanitation Programme sets consumption standards as 30litres/capital/day and 60litres/capital/day within 250m for rural and small town areasrespectively (FMWR 2004).

The Local Government Area has a population of 83, 831 and growth rate of 3.21% in 2006 census (NPC, 2006).The future population projection of Nigeria has not been officially disclosed by NPC until now. However,the long-term projection of population is indispensable for formulating the future socio-economic structure of any project areas. Generally there are many methods ofprojection a population. The common methods include Arithmetical and Geometrical methods.

2.4 **Groundwater Quality**

Monitoring of groundwater quality is essential for groundwater resources management.Historically, studies of the impact of groundwater quality started with the examination of the interaction of naturally occurring saline water and freshwater both at the coast and where saline water is present at depth. However, disturbances to the groundwater regime caused by man have led to the contamination of aquifers; typical examples include the impact of underground waste disposal or underground storage facilities. Contamination has also occurred due to agricultural practices such as the use of fertilizers and pesticides. An adequate understanding of the *quantity* of water passing through an aquifer system isa prerequisite of a study of *quality* issues..

Contamination of groundwater by chemicals is a problem in many countries, be they developed or not. Among the various chemicals, pesticides are some of the most dangerous ones, because even very small concentrations are sufficient to cause major health problems. In pollution studies even small groundwater flow rates may transport considerable amounts of contaminant over long periods of time. The research work done by Kerle,*et al* (1998) on the Site assessment for groundwater vulnerability to pesticide contamination describe soils, pesticide and their interactions to rate groundwater vulnerability. Soils having low and very low sensitivity tend to be slowly permeable and high organic matter. In these soils, leaching is limited and there is maximum retention of a chemical by adsorption onto organic matter. Soils having high and very high sensitivity tend to be rapidly permeable and low in organic matter. They transport chemicals very rapidly and have very little capacity to retain them in the soils. Chemicals that have low pesticide movement ratings tend to have relatively short half- life and pose very little risk of groundwater contamination. Chemicals rated high tend to have longer half-life increase the risk of their being transported to groundwater. Conversely, chemicals with high pesticide movement ratings applied on highly sensitive soils pose a real potential for transport through the soil to groundwater. Amy and Elizabeth (2012) affirmed that the combination of factors which would indicate the greatest vulnerability of groundwater includes a pesticide of high solubility, low adsorption, persistence; and a soil that is sandy, low in organic matter; and a site with shallow depth to groundwater, permeable layers and heavy rainfall. Asogwa and Dongo (2009) have reported overdose in pesticide usage and application in Nigeria cocoa production for the purpose of effecting rapid kill of crop pests among small scale farmers. It has also been

noticed that these farmers sometimes use these pesticides for purposes other than that for which they are manufactured.

Odebunmi*et al.,* (2014) reported that the drinking water sources in parts of Osun State contained trace metals (Fe, Mn, Zn, Cu, Cr and Ni) contents which were below or equal to the limits set by WHO for drinking and domestic water while the toxic metals (Pb, Hg, As, and Cd) recorded values higher than the safe limits set by WHO hence, the water sources are capable of constituting serious health hazards.The higher value for toxic metal was attributed to daily human activities, runoff addition, and aerial deposition and percolated related phenomena but the extent of the coverage of these contaminants in groundwater was not determined.

In assessing groundwater vulnerability to pollution, there are three traditional methods (Siham*et al.,* 2007). These include process-based, statistical, Overlay and Index. The overlay and index involve obtaining and combining maps of the parameters that affect the transport of contaminants from the surface to groundwater, then assigning an index value to these parameters.

The ArcGIS has been successfully use to determine the vulnerability of groundwater to contamination by pesticide in various locations such as the Vannetin watershed, located West of Paris (France). The use of GIS software is based on the following equation to arrive at the map of the pesticide concentration (C_a) in the aquifer.

Pesticides concentration (C_a) in the aquifer is given as;

$$Ca = \frac{Qa}{\mathrm{h}\phi} \qquad (2.10)$$

Where;

Ca= pesticide concentration

Q_a = mass of pesticide per unit area in the aquifer,

h= aquifer thickness,

ϕ= aquifer porosity.

The mass of pesticide per unit area in the aquifer is given as;

$$\mathrm{Qa} = \mathrm{Qp}.\mathrm{Exp}(-\lambda \mathrm{T}) \qquad (2.11)$$

Where;

Q_p = Pesticides application rate (Kg/ha),

λ = pesticide degradation rate

$$\lambda = \frac{\ln 2}{\mathrm{r}} \qquad (2.12)$$

r = pesticides half life,

T= Travel time

$$T = \frac{d}{V} \qquad (2.13)$$

d=distance from ground surface to water table.

The above parameters have been known to affect groundwater vulnerability.

The use of modeling with GIS contributes significantly to the delineation of vulnerable areas. The DRASTIC model, introduced by the U.S. Environmental Protection Agency (EPA),in 1987 studied several key hydro geologic characteristics that affect groundwater infiltration (Aller*et. al.*, 1987). DRASTIC is an acronym standing for Depth to water; net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone, and Conductivity. This model has been successfully used in Houston County, Minnesota, Barlad City and surrounding villages well, Dead sea area in Jordan, Jerash, Russeifa etc

The DRASTIC model accounts for the most significant hydro geologic factors that contribute to groundwater contamination and applies a series of ratings and weights based on how significantly they influenced pollution potential(Aller,*et a.*,1987). Each DRASTIC factor was assigned a DRASTIC weight ranging from 1 to 5. Each DRASTIC factor was further assigned a rating, typically from 1 to 10, based on a range of information within the parameter. Higher ratings and weights indicated higher risk of vulnerability. Pollution potential is also known as DRASTIC index (Aller, *et.al.*,1987). DRASTIC index is expressed as;

$$DRASTIC\ Index = D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W \qquad (2.14)$$

Where;

D_R= Rating of the depth to water(m)

D_W=Weight of the depth to water (m)

R_R=Rating of the net aquifer recharge (mm/year)

R_W=Weight of the net aquifer recharge (mm/year)

A_R=Rating of the aquifer media (Dimensionless)

A_W=Weight of the aquifer media (Dimensionless)

S_R=Rating of the soil media (Dimensionless)

S_W=Wight of the soil media (Dimensionless)

T_R=Rating of the topography (m)

T_W=Weight of the topography (m)

I_R=Rating of the impact of the vadose zone (Dimensionless)

I_W=Weight of the impact of the vadose zone (Dimensionless)

C_R=Rating of the hydraulic conductivity (m/d)

C_W=Weight of the hydraulic conductivity (m/d)

The higher the DRASTIC index means the higher the susceptibility

Pesticide DRASTIC model was developed based on the following assumptions (Aller,*et.al*1987). That:

a. the contaminant is introduced at the ground surface;

b. the contaminant is flushed into the groundwater by precipitation;

c. the contaminant has mobility of water; the area evaluated is 100 acres or larger

The DRASTIC model supplies a standard method to assess the risk of groundwater contamination. Combining the DRASTIC model with GIS creates a powerful tool; groundwater models integrated into GIS can visually represent the spatial aspects of groundwater data as well as execute spatial calculations on data enabling further inferences to be made about susceptible areas(Watkins *et al*., 1996).

2.5 **GIS and Remote Sensing**

The discovery of hydroinformatic science which coversapplication of information technology in water sector are now revolutionizing the trend in water data acquisition, processing and analyzing for decision making and prompt data retrieval. Advanced remote sensing technique and geographical information systems are useful for various groundwater applications such as identification of groundwater potential zone and artificial recharge zone, groundwater recharge etc. Effective management of water resources requires quantifying the interactions among the complex and uncertain processes in the hydrologic cycle. Groundwater recharge and discharge depend on the hydrological relationships among groundwater, climate, and surface water. It is not possible to directly measure fluxes into and out of groundwater system over large spatial scales hence indirect methods must be used(Yu-Feng*et al.*,2008) ArcGIS proves an ideal platform for the cross-analyzing approach to estimate groundwater recharge efficiently more than conventional methods.The use GIS which integrates computer hardware, software, data and human expertise for capturing, managing, analyzing, and displaying all forms of geographically referenced information as layers of processed geographic data has been commonly used to solve data management problems. ArcGIS was successfully used in making groundwater recharge

and discharge estimate Maps in one day using ArcGIS 9.2 for groundwater basin in Chicago (Yu-Feng,*et al*., 2008).

A remote sensing is the science of acquiring, processing and interpreting data or information about objects without being in physical contact with them. The characteristics of a particular object can be identified by analyzing the interaction between the electromagnetic (EM) energy and object. EM radiation which is reflected or emitted from an object is the usual source of remote sensing data and each object has a unique characteristic of reflection or emission. The unique characteristics of matter are called spectral characteristics. Reflectant with respect to wavelength is called the spectral reflectant. A basic assumption in remote sensing is that the spectral reflectant is unique and different from one object to another. Spectral reflectantis assumed to differ with respect to the types of land cover. This is the principle that in many cases allows the identification of land cover using remote sensing.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials and Data Collection

The materials and data used for this research work and their sources are shown in Table 3.1 below.

Table 3.1: Data Acquired, Materials and their Source

Data	**Source**	**Date**	**Relevance**
GROUNDWATER POTENTIAL ZONE/ GROUNDWATER POLLUTION POTENTIAL/ GROUNDWATER POTENTIAL QUANTIFICATION OR ESTIMATION AND CLIMATIC VARIATION			
Rainfall	NIMET, Lagos	1981-2010	Rainfall Map of the LGA,Groundwater recharge estimation & Trend analysis for Climatic variation
Soil map	State ministry of Agriculture (Osun State)	1997	Soil layer for the LGA
Geologic map	Nigerian geological Survey Agency	2008	Geologic (rock type)map, aquifer media
ASTER data (30m)	www.glcf.com www. terra.nasa.gov	2011	Digital Elevation and Drainage Density map of the area
Landsat 7 (ETM+) (30m)	USGS	2009	Land use/cover map of the area
Borehole Data	Osun Rural Water Supply and Sanitation Agency (RUWESA) and Field Data collection		Depth of water table, hydraulic conductivity, vadose zone
Air Temperature ^{o}C/month	NIMET,	1981-2010	Potential Evapotranspiration and trend analysis for Climate variability
EXISTING WATER SUPPLY FACILITIES AND DEMOGRAPHIC			
Water schemes location and Coordinates	Field/Facilities BaselineSurvey	April/June 2015	Determine gaps and future planning

	(appendix 1 contain Data Survey Tools)		
Population and Political Ward	NPC & Ede North LGA	June 2015	Planning
MATERIALS AND SOFTWARE			
The major equipment used is Geographic Position System (GPS) hand held germine receiver, Water level indicator. The software used are Arc GIS, Remote Sensing (ENVI) Software used for land use classification and Microsoft Excel for statistical trend and regression analysis			

3.2 Method for Groundwater Potential Zones and Groundwater pollution

Potential Zones

The methodology applied in this research is based on a set of parameters that describe the natural occurrence of groundwater accumulation. These include drainage density, geologic formations, rainfall, soil type, elevation and land cover. This involved the delineation of the study area and conducting remote sensing analysis for the extraction of these parameters. Field study which involved ground truthing was employed for verification. All the data sets were digitized in GIS environment, weightages were assigned based on their contributions to groundwater occurrence and their attributes were also ranked based on the modified DRASTIC Ratings for modeling using GIS. All the thematic layers were then overlaid by using GIS overlay function of ArcGIS and all the individual GIS layers were integrated i.e. the weightages of each parameters added to obtain different groundwater potential zones. The method based on the parameters used for the groundwater potential zones is summarized below and flow chart presented in Figure 3.1

Similar methodology was applied for groundwater pollution potentials, based on a set of parameters that describe groundwater pollution potentials. These include depth of water, net recharge, aquifer media, soil media, topography, impact of vadose zone and hydraulic conductivity. The flow chart describes the procedure presented in Figure 3.2.

Flow Chart

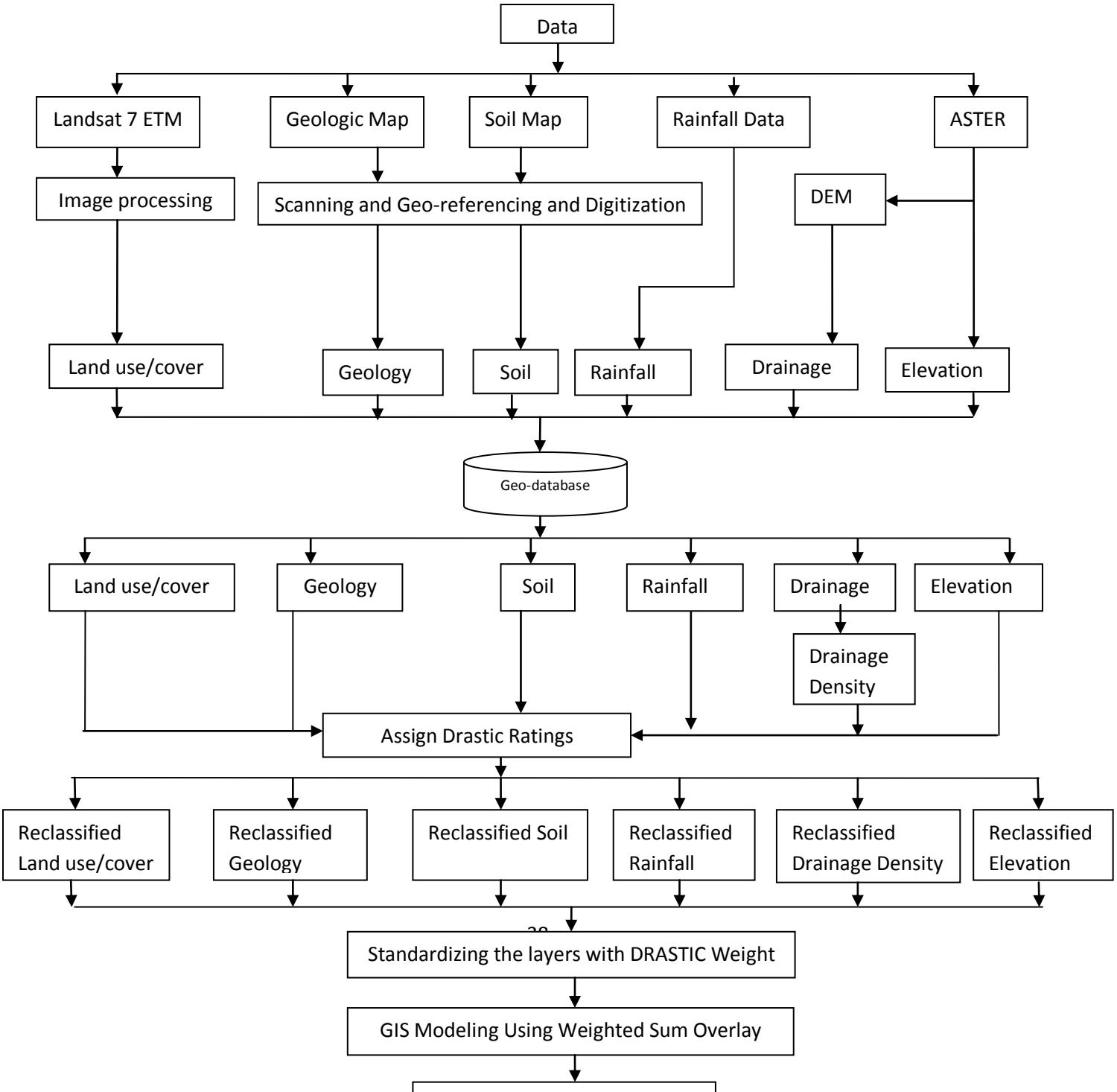

Data
Landsat 7 ETM
Geologic Map
Soil Map
Rainfall Data
ASTER
Image processing
Scanning and Geo-referencing and Digitization
DEM
Land use/cover
Geology
Soil
Rainfall
Drainage
Elevation
Geo-database
Land use/cover
Geology
Soil
Rainfall
Drainage
Elevation
Drainage Density
Assign Drastic Ratings
Reclassified Land use/cover
Reclassified Geology
Reclassified Soil
Reclassified Rainfall
Reclassified Drainage Density
Reclassified Elevation
Standardizing the layers with DRASTIC Weight
GIS Modeling Using Weighted Sum Overlay

Figure3.1 : Flow chart for Groundwater Potential Zone

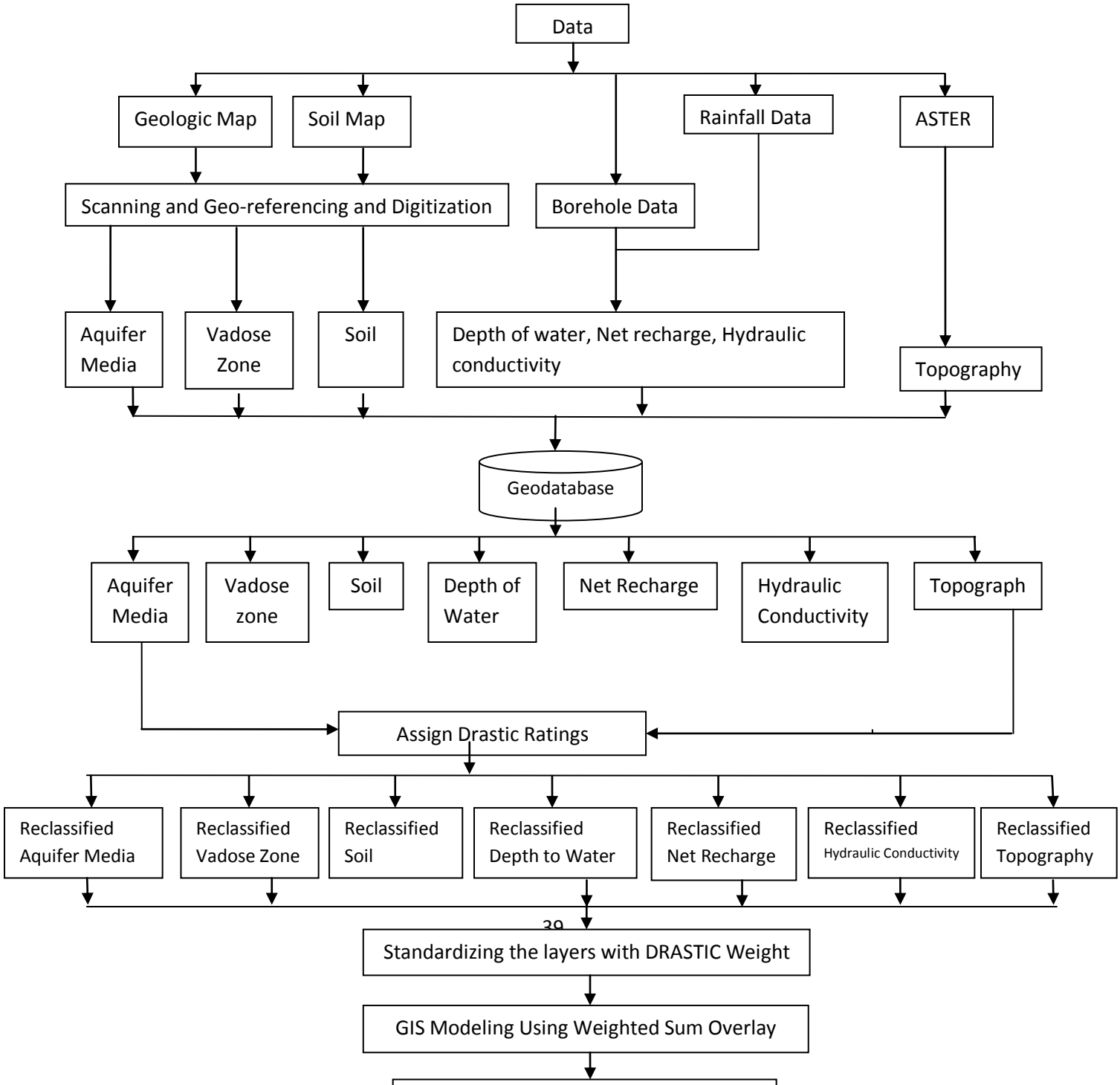


Figure3.2 : Flow chart for Groundwater Pollution Zone

3.2.1 **Data types, sources and analysis**

3.2.1.1 Elevation/topography and drainage

Advanced Spaceborne Thermal Emission and Reflection (ASTER) imagery of 30m resolution covering the study area was employed in the research to extract topography.

The elevation and drainage was obtained in meters from the contours that were generated from the sub-mapped ASTER data of Ede North. In the GIS environment, the contours were subjected to spatial analysis using the spatial analyst module in ArcGIS to generate the elevation. The elevation derived was further classified into appropriate classes. Global positioning System (GPS) receiver (Hand Held) was used for point data collection

3.2.1.2 Land cover

The land use/cover of Ede North was obtained from Landsat 7 imagery by subjecting it to unsupervised classification using ENVI 4.5 which gave a general idea of the land use/cover classes of the area. Bands 543 were combined to obtain a color composite that was used for the unsupervised classification. Information obtained from ground truthing was used to reaffirm land use/cover class before subjecting the imagery to supervised classification. The land use/cover of the study area was classified based on ground truthing.

3.2.1.3 Soil texture/media

The soil map of Ede North produced by the State Ministry of Agriculture, Osun State of scale 1:300,000 was scanned and imported into ArcGIS 10.0 environment where it was geo-referenced based on the map projection of Geographic Coordinate System.

3.2.1.4 Geology

The geologic map of Iwo produced by the Nigerian Geological Survey Agency Sheet 60, and scale of 1:250,000 all covering the study area was scanned and imported into ArcGIS environment where it was geo-referenced based on the map projection of Geographic Coordinate System and digitized to extract the rock type (aquifer media and impact of vadose zone).

3.2.1.5 Rainfall

The rainfall data was generated from the synoptic meteorology station in Osogbo and nearby stations using the same coordinate system to generate the pattern of rainfall occurring in Ede North.

3.2.1.6 Depth to water and hydraulic conductivity

The Depth to water and Hydraulic Conductivitydata was generated from the borehole data acquired from the field/RUWASA using the same coordinate system to generate the pattern occurring in Ede North.

3.2.1.7 Net recharge

Net Recharge was generated from rainfall data collected from NIMET observed at the synoptic stations around Ede North; using empirical method developed by Krishna (1970) net recharge was calculated and interpolated to obtain a representative net recharge value over the area.

3.2.2 Remote sensing analysis

The land use/cover map was prepared with the aid of satellite images. This is due to the fact that they provide a general overview of major landforms. Visual interpretation was key to achieving an efficient and effective interpretation of remote sensing images using basic interpretation elements such as size, shape, tone, texture pattern and color. The procedure in extracting basic information from digital remote sensing imagery involved digital image composition, manual interpretation and classification of various categories after conducting ground truthing, and lastly producing an output which facilitated interactive classification enabling capturing of information in a database.

3.2.3 GIS analysis

The hydrogeological resources of the study area was mapped and inputted into a GIS environment for proper analysis by creating a geo-database for proper data management of all dataset involved in the study. For groundwater potential the datasetused include; land cover, geology, soil, elevation and drainage from ASTER, and rainfall. For groundwater pollution potential,the input data required include; depth of water, net recharge, aquifer media, soil media, topography, impact of vadose zone and hydraulic conductivity so as to

aid modeling for groundwater pollution potential zones. All datasets were rasterized using uniform cell.

3.2.3.1 GIS modeling-groundwater potential map

All the hydrogeological factors were assigned weight (value) based on their groundwater prospects. The weight assigned also showed their importance to groundwater accumulation.

The values were assigned in terms of their importance with respect to groundwater occurrencesranges from 1 to 5 and each hydrologic factor attribute was further ranked and assigned a rating varies from 1 to 10 (Table 3.3). The resultant cell values were added to produce the final output raster that represented the potential groundwater zones. Finally, weighted overlay was done for all the factors in the GIS to generate groundwater producing zones suitable for exploration in the study area.

The equation for the modified DRASTIC Index isgiven by Khairul Anam *et al.*, (2000):

$$GP = G_r G_w + R_r R_w + E_r E_w + D_r D_w + S_r S_w + L_r L_w \quad (3.1)$$

Where;

r= ratings

w= weight

GP= Groundwater Potentials

G= Geology, R= Rainfall, E= Elevation D= Drainage density, S= Soil, L= Land cover

3.2.3.2 Groundwater pollution potential map

All the parameters were assigned DRASTIC Weight to show their importance to groundwater pollution occurring in the study area. Each parameter was ranged and rated according to their importance to groundwater pollution potentials areas.

The values were assigned in terms of their importance with respect to groundwater pollution (Table 3.2). The resultant cell values were added to produce the final output raster that represented the groundwater pollution potential areas. Finally, weighted overlay was done for all the factors in the GIS to generate groundwater pollution potential zones in the study area.

The equation for DRASTIC Index is given by Aller et al (1987) as expressed and defined in equation 2.14;

$$DRASTIC\ Index = D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W$$

Table 3.2: Parameters, Weightings, Attributes/Ranges and Ratings

RASTER	WEIGHT	ATTRIBUTES/RANGES	RATINGS
Geology	5	Schist	8
		Migmatite	6
		Pegmatite	4
Soil Texture/Media	3	Fluvisols	10
		Gleysols	7
		Luvisols	4
Drainage Density (m/m^2)	2	Very Low Drainage (0 - 101.7)	10
		Low Drainage (101.7-203.5)	8
		Moderate (203.5-305.3)	6
		High Drainage (305.3-407.0)	4
		Very High Drainage (407.0-508.8)	2

RASTER	WEIGHT	ATTRIBUTES/RANGES	RATINGS
Land cover/Use	1	Vegetation	10
		Water Body	6
		Settlement	3
Rainfall (mm/year)	3	1,466.1-1,691.8	10
		1,240.4-1,466.1	7
		1,014.7-1,240.4	4
Depth to Water (m)	5	4.0-10.3	10
		10.3-16.5	9
		16.5-22.8	8
		22.8-29.1	7
		29.1-35.4	5
		35.4-41.6	3
		41.6-47.9	1
Net Recharge (mm/year)	4	266.5-323.0	10
		210.1-266.5	8
		153.7-210.1	6
Aquifer Media	3	Sand and gravel	10
		Coarse Sand	9
		Migmatite	5
		Sandy Clay	3
Elevation/Topography (m)	1	274-291.3	10
		291.3-308.7	8
		308.7-326.0	7
		326.0-343.3	5
		343.3-360.7	3
		360.7-378.0	1
Impact of Vadose Zone	5	Sandy Clay	8
		Loamy Clay	6
		Clay	3
Hydraulic Conductivity (m/min)	3	0.83-0.96	10
		0.71-0.83	8
		0.58-0.71	6
		0.45-0.58	4
		0.33-0.45	2
		0.20-0.33	1

3.3 **Quantitative Estimation ofGroundwater Potential**

The collected thirty year record of monthly rainfall was processed into annual values. The groundwater recharge was determined using the empirical relationships established

between recharge and rainfall developed by Krishna Rao in 1970 and guiding principle of India Groundwater Estimation Committee norms.

The Krishna (1970) empirical equation is as expressed in equation 2.6

For areas where annual rainfall is between 1000-2000 mm/year

$$R = 0.25\ (P - 400)$$

Where;

R= Net Aquifer recharge due to rainfall

P= Precipitation/Rainfall

Also, the 30 years data on the monthly air temperature subjected into mean monthly. The annual mean monthly air temperature for each year as well as thirty year (1981-2010) mean air temperature utilized for the computation of potential evapotranspiration. Using the Thornthwaite Model of potential Evapotranspiration, the estimation of potential evapotranspiration was obtained for the area. The different between Rainfall and Potential Evapotranspiration was calculated in order to have an idea of how much rainfall available for recharge. This is to give picture of groundwater potential since Rainfall and Potential evapotranspiration are key components of hydrological water balance. Thornthwaite model was chosen due to availability of data required reliabilityand ranked nextto the modified Penman method.

Potential Evaporation is given by Thornthwaite (1948) as

$$PET = 16\left(\frac{10Ta}{J}\right)^{a}\frac{ND}{360} \qquad (3.2)$$

$$J = \sum_{i=1}^{12} \mathrm{j} \tag{3.3}$$

$$j = \left(\frac{Ta}{5}\right) 1.514 \tag{3.4}$$

$$a = 675(10)^{-9}J^3 - 771(10)^{-7}J^2 + 179(10)^{-4}J + 0.492 \tag{3.5}$$

Where;

PET =Potential Evapotranspiration(mm/month)

a= Coefficient,

J=Seasonal or annual heat Index,

N=Mean Hours between sunrise and sunset in the months (hours)

D=Numbers of days in the month

Ta=Mean Monthly Air temperature (^{0}C)

3.4 **Climate Variability**

The monthly rainfall and air temperature data observed at Osogbo synoptic (Lat 7.47N and Longitude 4.29E) station for 30 years (1981-2010) were collected via computer unit of NIMET and computed into annual and mean annual of rainfall and temperature respectively. Also monthly temperature and rainfall were averageover a period of 30 years (1981-2010) and in decades to give mean Monthly values.

The climatic variability was conducted by using Microsoft Excel statistical trend and least-square regression analysis function on the 30 years (1981-2010) data and projected to 2030.

Also, the difference of 30 years mean and each year mean were plotted on a chart for variation trend.

3.5 **Water Supply Schemes Mapping**

The field survey was carried out across the eleven wards of the LGA for the collection of the water facilities in line with the survey tools developed (appendix 1). The facilities parameters such as the facility location, facility types, Promoter/Responsible agency, functionality, depth, GPS coordinate, Altitude etc were obtained. The Garmin GPS receiver was used to acquire Coordinates and altitude.

The scan map of Osun state was imported into ArcGIS .Geo-processing function carried out by clipping Ede North out of the Osun State map and the scan map was geo-referenced appropriately in Arc Map.Import the text file containing the GPS longitude and latitude coordinates and altitude in Microsoft Excel. The GPS coordinates imported to ArcGIS, convert to raster (shape file) and projection carried out appropriately.

Different layer creation such as Road, boundary and town layer were now created in Arcmap before it was digitized and XY data of the borehole points was now plotted on the map.

3.6 **Water Supply Schemes Investment Plan**

Domestic water demand of the area was carried out using 2006 population census figures and projected population up to 2030 along with the relevance water supply policy and other relevance document which specified consumption standard in various settlement types; Rural, Semi-Urban and Urban. However, the margin of agricultural related economic

activities and loss at 15% and 5% respectively were added to the standard specified in the policy. See Appendix 2 and 3. The existing facilities strength in term of supply was also evaluated. The gaps created as a result of balance between water demand and existing supply vis-à-vis projected population figure of 2006 census was determined and projected to year 2030 which is set aside for Sustainable Development Goal. The 2006 population figure with growth rate of 3.21% was projected using Geometrical method.

The percentage of water supply coverage is calculated as follow;

$$WC=\left[\left\{\left(\sum(MBH)*(X)\right)+\left(\sum(HPBH)*(X)\right)+\left(\sum(HDW)*(X)\right)\right\}\div(N)\right]*100 \quad (3.6)$$

Where:

WC=Water Coverage in Percent

MBH=Motorized Borehole

HPBH=Handpump Borehole

HDW=Hand dug well

X=Average No of people per point

N=Total population of ward or LGA

The facility plan both for new construction and rehabilitation of existing dysfunctional water facilities for communities and public institutions was computed in each five year plan up to year 2030. The cost implication for each of the five-year plan was estimated based on the average contractual price of construction and rehabilitation in the area.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Groundwater Potential

Geology: The analysis of geology of the study area indicated three major types:Schist, pegmatite, and migmatite. Schist has wider spatial spread of the study area follow by Migmatite. Pegmatite has little spatial spread and can be found in South East corner of Ede North LGA as illustrated in figure 4.1.The groundwater aquifer is directly related to the rock especially when fractured. Therefore, based on the DRASTIC model, the weight of 5 was assigned to geology due to its relevant to groundwater occurrence. Each attributes of the geology were appropriately reclassified and also rated based on their affinity for groundwater storage and transmission capacity.

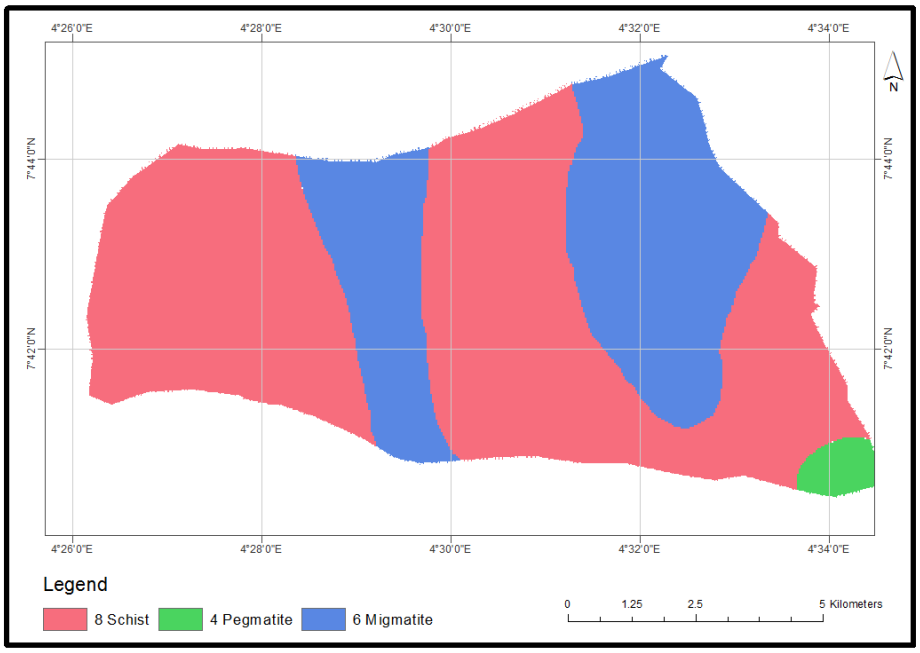


Figure 4.1: Geology Parameter thematic Map

Rainfall: Groundwater gets its supply from rainfall. It assumedthat the higher the amount of rainfall, the moreis the water available for infiltration and percolation. Rainfall varies from 1,469.6mm/year to 1304.2mm/year across the study area and decrease from East to West of the Ede North LGA. Rainfall thematic map is presented in figure 4.2.Based on the importance of rainfall to groundwater formation, the area that received highest rainfall was rated highand assigned a value of 10.Avalue of 5 was assigned to least area in term of rainfall amount considering theshort interval between the amounts of rainfall. The weight of 3 was also assigned to rainfall in line with modified DRASTIC model.

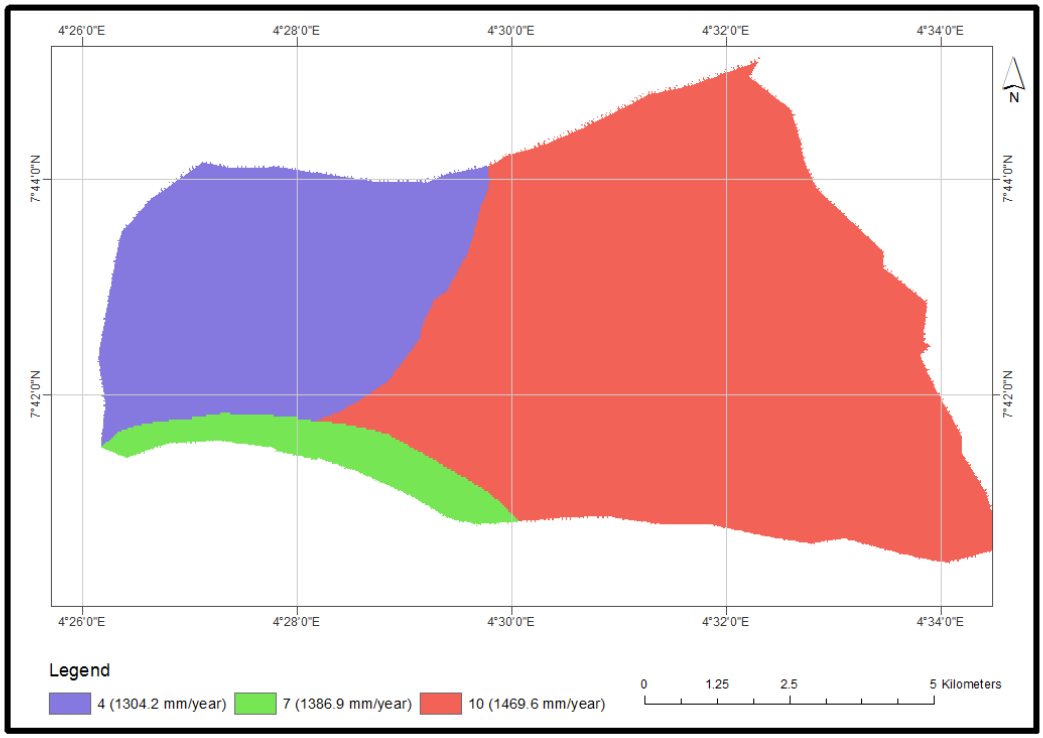


Figure 4.2: Rainfall Parameter /thematic Map

Elevation/Topography: Elevation affect the rate of movement and quantity of runoff that can infilterate, this form the basis for rating. The result indicated that the elevation of the study area varies from 274m to 378m. The highest point is located at the central part while the lowest point were found at South West area of Ede North LGA. Figure 4.3 illustrated the raster view of the study area elevation.The elevation values were ranges at varying interval.The class of highest values was assigned a value of 1 while the class of lowest values was assinged 10. Topography or elevation was assinged the weight of 1 based on the relative importance to groundwter formation and in line with the model.

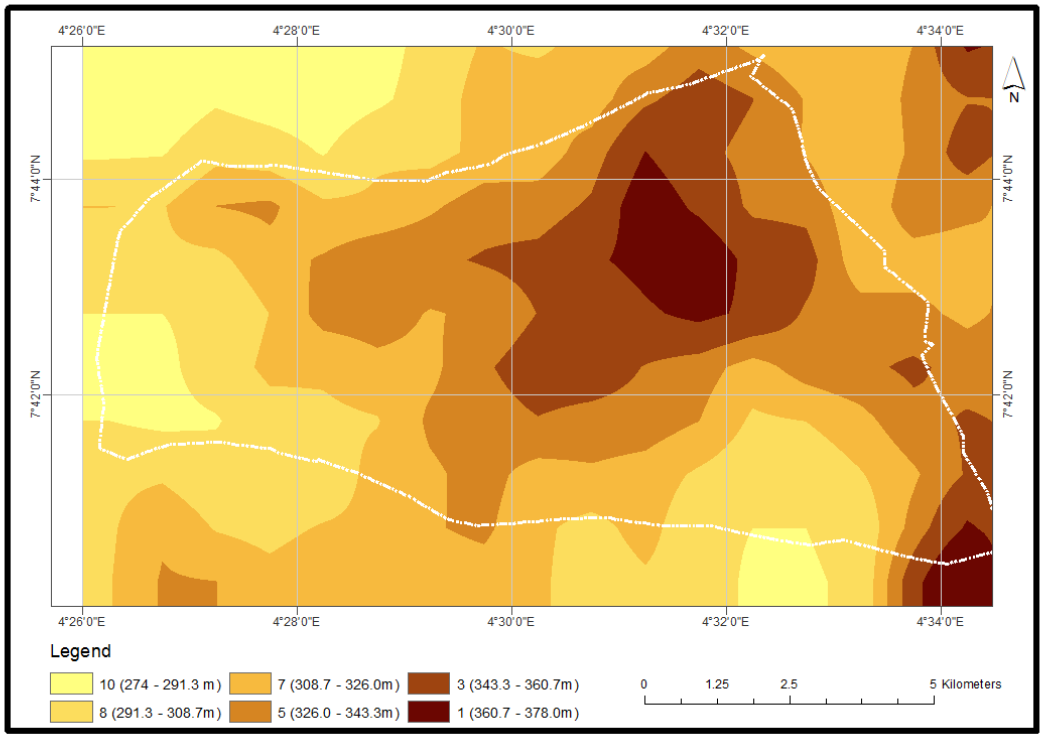


Figure 4.3: Elevation Parameter /thematic Map

Drainage Density: It is a measure of how well or how poorly a watershed is drained by stream channels. The drainage density pattern result indicated that an extensive part of study area is poorly drained as presented in figure 4.4. Based on the result obtained from the analysis, the study area was demarcated into five sections for drainage density: Very high; high; moderate; low and very low drainage densities.Very high and high demarcated areas were wide spread and occupied larger part of study area while low and very low areas scattered across the study area. Very low drainage areas retain water for long period thereby encourage infiltrations more than high drainage area, this form the basis for rating. Very low drainage density is ranked high while very drainage is ranked low. Drainage

density was assigned weight of 2 based on its relative importance to groundwater formation and in line with modified DRASTIC model.

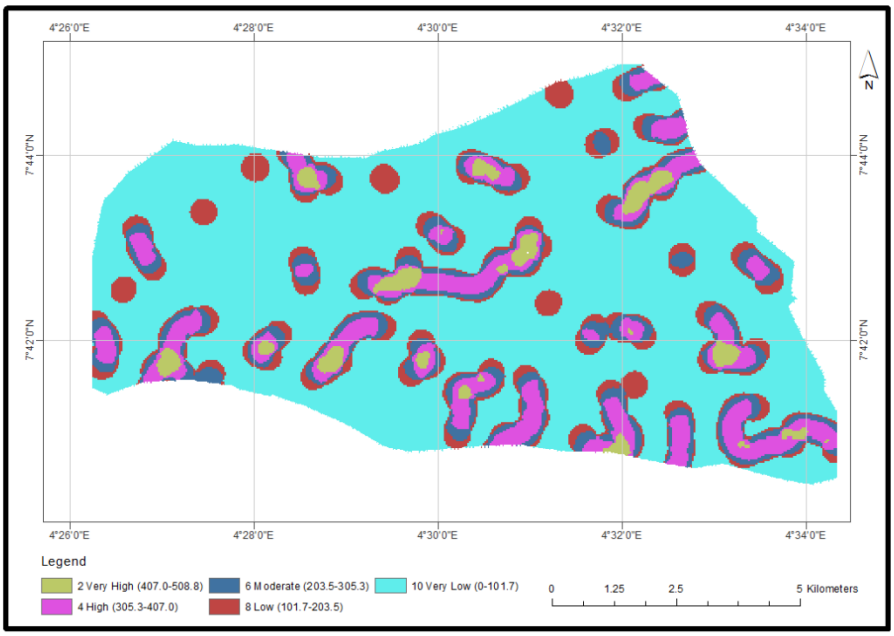


Figure 4.4: Drainage Density Parameter /thematic Map

Soil media: The types and size of the soil media directly affects the rate of infiltration. The result indicated three major types of the soil as presented in figure 4.5. They are luvisols, gleysols and fluvisols. The luvisols occupied more than 70% of the total area. Luvisols was rated low value because itcontain appreciable clay which retain water and hinder its passage. Fluvisols are synonymous with alluvium or river levees, this attribute made it to be ranked high. Fluvisols is found at the Southern part of study area.Gleysolsis developed wherethere is poor drainage because the water table (phreatic surface) is high based on this attribute it was rated next to fluvisols. . Based on the relative importance of soil to

groundwater occurrence, the weight of 3 was assigned to soil media in line with DRASTIC model.

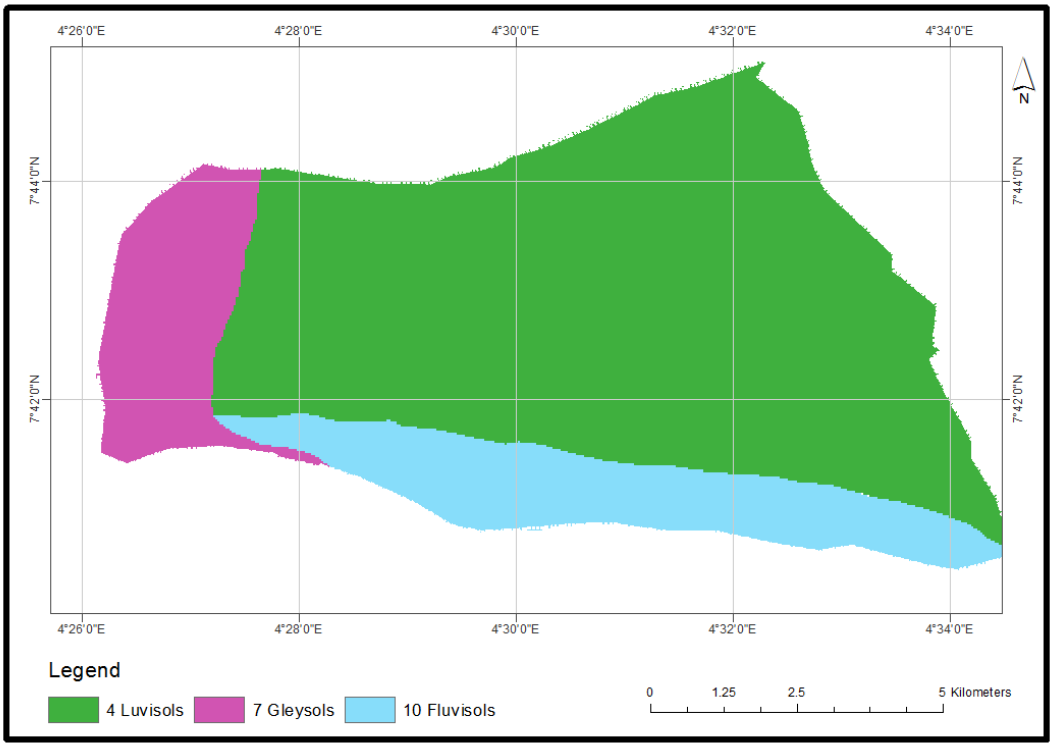


Figure 4.5: Soil Parameter /thematic Map

Land cover: The result of land cover revealed three major types: Vegetation, settlement and water body. The land cover of the study area is presented in figure 4.6. Vegetation covered more than 40km^2 while settlement covered more than 50km^2. The vegetation encourage water infiltration thereby contribute to the formation of groundwater. Based on this attributes, vegetation was ranked high while settlement area was ranked next. Land cover is not as important as vadose zone or geology in relation to the thickness for the passage of the water thereby it was assigned the weight of 1 in line with the DRASTIC model.

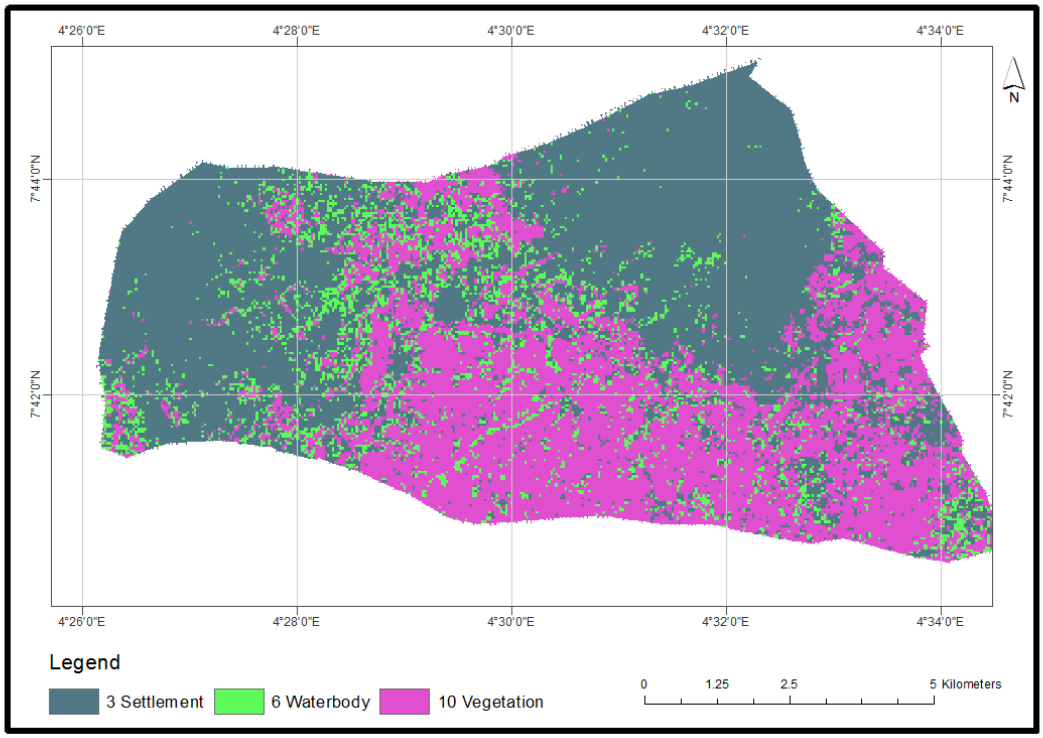


Figure 4.6: Land Used Parameter /thematic Map

4.2 **Groundwater Potential Zone**

The result of the groundwater potential zone indicated that Ede North is viable for groundwater development. The maps produced show three classes of groundwater potential zones on a blue colourscale. The Navy blue colour shows high potential zone while Turquoise blue and baby Bluer show moderate and low groundwater potential zones respectively. Out of the LGA total land mass,31.9% of the area translate to 35.85km^2 rated highly as groundwater potential zone, 41% of the area which equal to 46.104km^2 are moderately rated groundwater potential zone and 27.1% of the area equal to 30.415km^2 are

identified as low potential zone. The highly potential zones fall on the South East and very small area at the central part of Ede north. The area consists of communities / villages such as Pegba, Aduloju, Oloyin Ogangan, Elere, Oniyere, Kajola, Olodo, Aworo, Gbangba. The moderately groundwater potential zone scattered and widely spread across the entire LGA. The communities or village around these areas includes Abere, Atapara, Aworo, Pere, Onigba, Aperire etc. Groundwater development is not viable in Sikako, Oloba communities and villages as much as others areas in the LGA due to low Groundwater potential. The low groundwater potential zones fall at the central and North West of Ede North area. The highly and moderately rated communities/villages/areas for the groundwater potential zone offer the best productive and suitable for groundwater development. Groundwater potential zone for the Ede North area is presented in the map below(Fig 4.7) while the thematic database are described in figures4.1 to 4.6

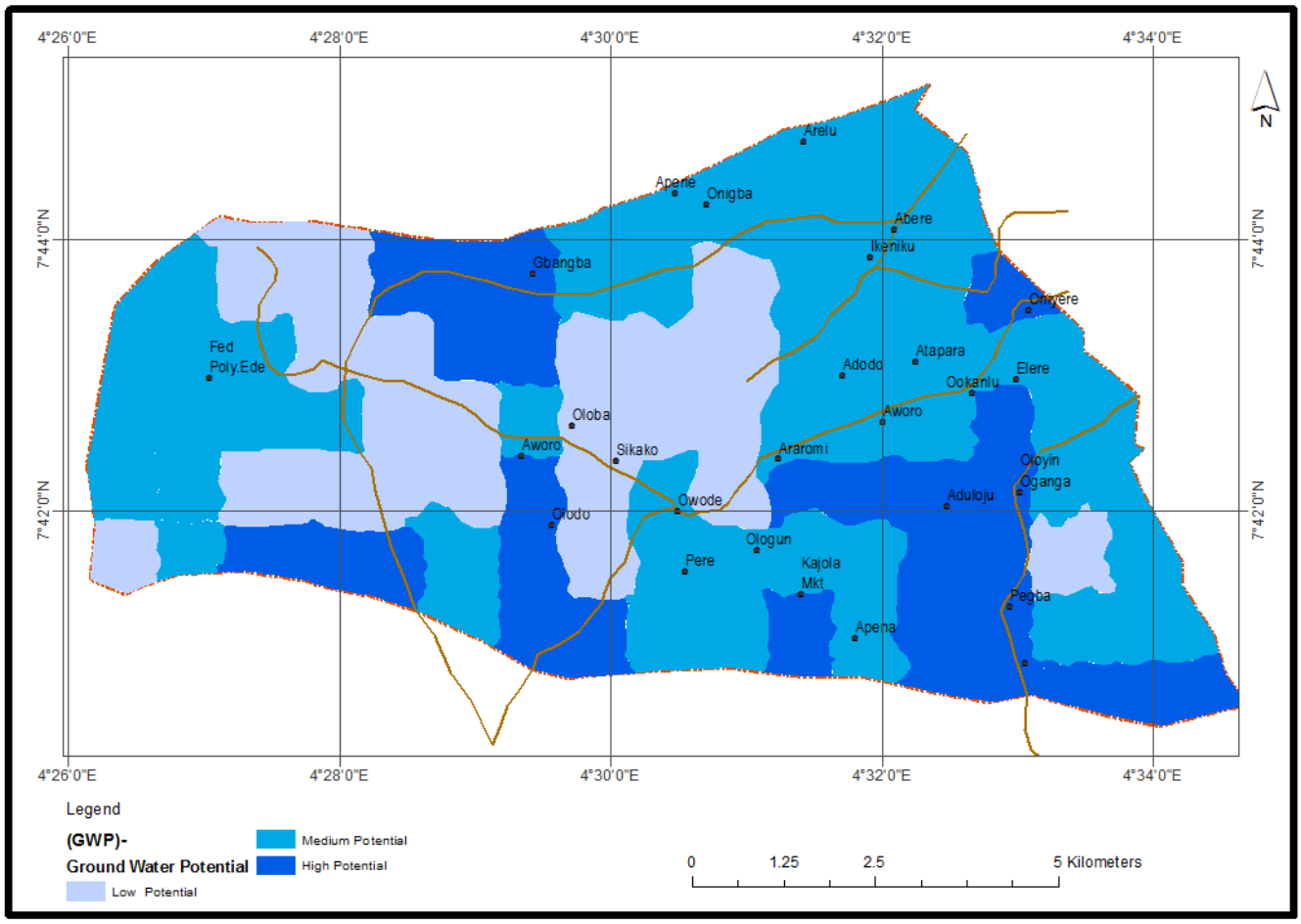


Figure 4.7: GROUNDWATER POTENTIAL ZONES

4.3 Groundwater Pollution Potential

Depth to water: The depth to water is important because it determines the thickness of material that a contaminant would have to pass through to reach the aquifer. Generally, the thicker the material between the surface and the water table, the higher is chance of the contaminant breaking down before it can reach the aquifer. This is what forms the basis of ranking the seven classes of the depth to water. The depth to water in the study area varies from 4meters to 47.9meters and group into seven classes for ranking purpose. These values for water depth were ranges and ranked with high value for the shallow water depth and

low value to deeper water level. Each colour represented each of the classfor the depth to water on the thematic map. The thematic map is presented in figure 4.8.

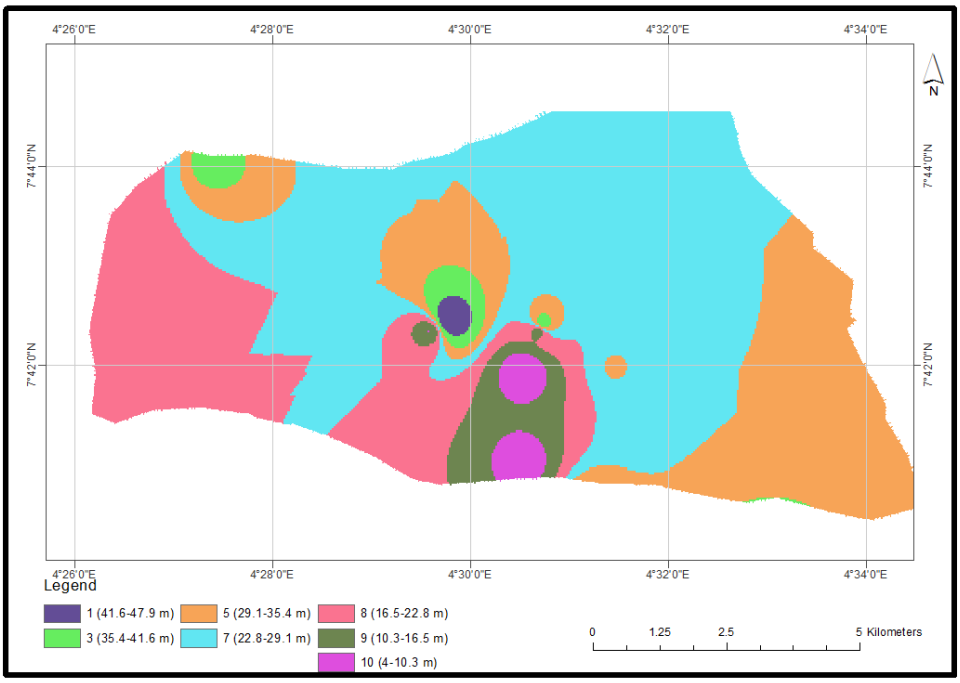


Figure 4.8: Depth to Water thematic map

Net recharge :The net recharge varies from 323mm/year to 153.7mm/year. The net recharge decreased from East to West. This is represented by the three colour scale. Since net recharge represents the amount of water per unit area of land which penetrate the ground surface and reaches the aquifer, the area that have high net recharge was rated high while low net recharge area were rated low. Because of the relevance of the net recharge to groundwater occurrence, net recharge was assigned a weightage of 4.

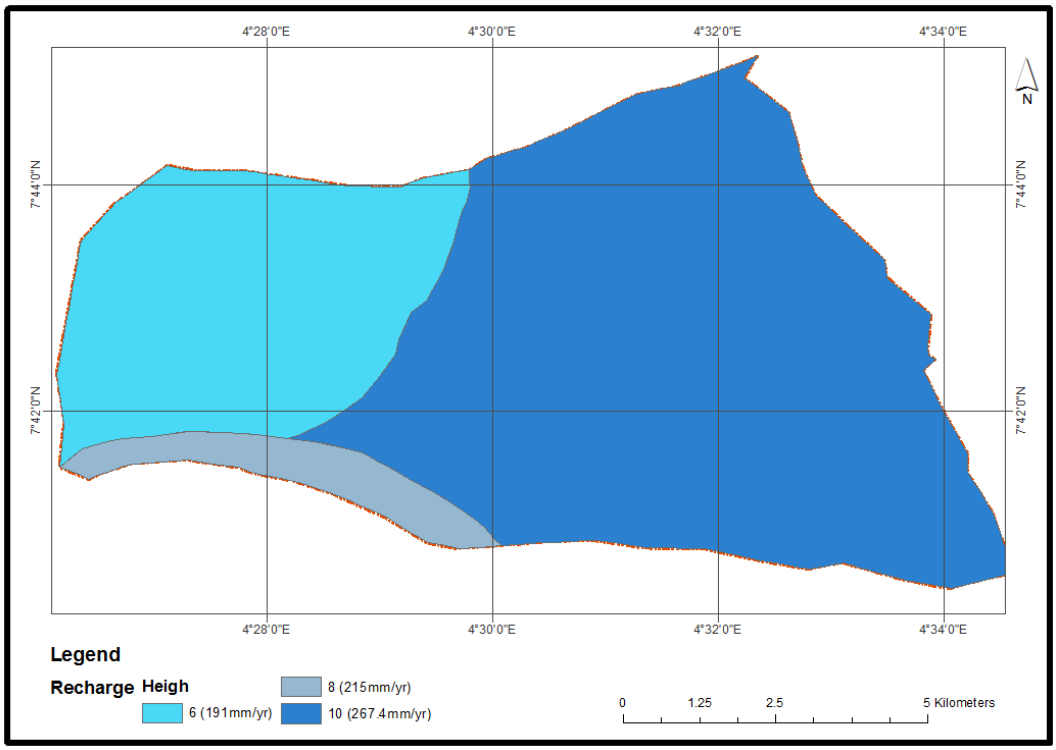


Figure 4.9: Net Recharge thematic maps

Aquifer media: The analysis of aquifer media indicated that the study area has different types of media. The map produced show four classes of media using four different colour scales to represent each of the aquifer media. The aquifer media is presented in figure4.10. Sand and gravel media were concentrated at a point as compare to the other media which were found at more than one location. Sand and gravel offered the best media and found towards the boundary of the study area with Ede South LGA. Migmatite overlapped other media and spread from North to the South of Study area. Sand and gravel aquifer media was ranked high because of high affinity with the groundwater while migmatite ranked low. The weightage for aquifer media is 3 inline with the DRASTIC model.

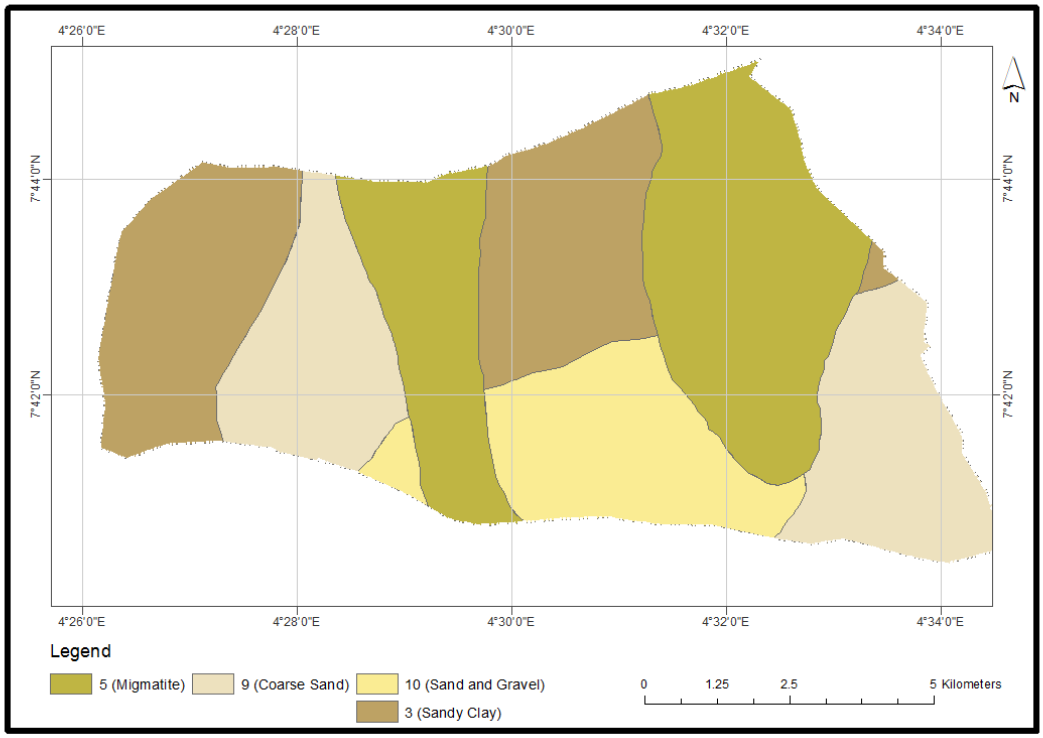


Figure 4.10: Aquifer media thematic maps

Impact of Vadose Zone: The unsaturated zone above the water tablein the study area revealed three classes. Based on the map produced in figure 4.11, loamy with clay content is occupied large area and spread from North East corner to South West of the study area. The clay types can be found at the West part of study area while sandy clay at the South East corner. The ratings were assigned based on the influence of the least impervious material, taking into account all types of material toward the surface. In line with the DRASTIC model and its importance to groundwater accumulation, the weight of 5 was assigned to this parameter.

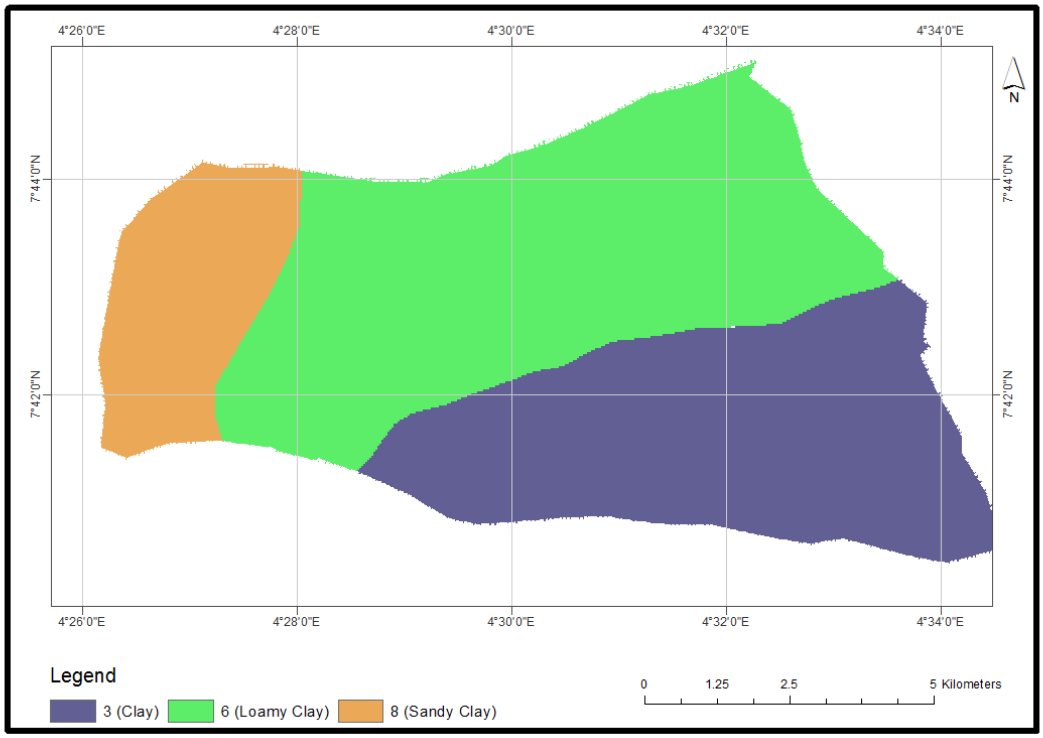


Figure 4.11: Vadose thematic maps

Hydraulic Conductivity: The hydraulic conductivity (k) of the aquifer of the study area indicated that the value varies from 0.20m/min to 0.96m/min. The map produced in figure 4.12 indicated six classes on different colour scales. The class with the highest hydraulic conductivity occupied small area and was found at the central part of study area. The least class of hydraulic conductivity was found majorly at the South East corner of the Study area although this class was also found at other two points with a little spatial spread. The highest class of the k was rated high with 10 value while the lowest class of k was rated low with 1 because the higher the k, the higher the rate it transmit water and vice versa. The weight value of 3 was assigned to the k due to the importance to water accumulation and in line with the model.

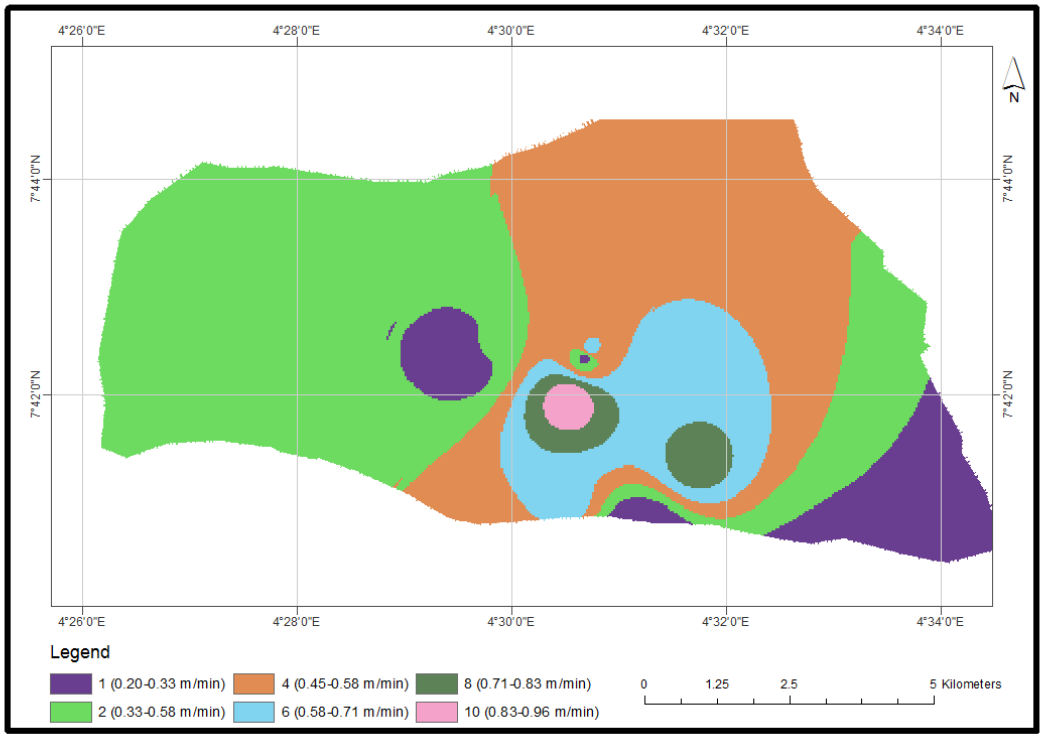


Figure 4.12: Hydraulic Conductivity thematic maps

4.4 GroundwaterPollution Potential/Vulnerability to Pollution Zone

The result of the groundwater potential pollution zone indicated that Ede North is susceptible to pollution from agro-allied contaminants with more than 27% of the entire land area of the LGA is being threatened. The map produced show a variety of relative susceptibility over the study area, using red, yellow and green colour scale. The red colour represents higher susceptibility, yellow colour moderately and green colour represents lower susceptibility (Figure 4:13). Out of entire LGA land mass, 32% of the areas which is an equivalent of 36km^2 are not vulnerable to pollution from agricultural activities. About 40.4% which equal to 45km^2 are moderately prone to groundwater contamination while only 27.6% of the areas which translate to 31km^2 are currently at risk to Groundwater

pollution. The highly groundwater pollution potential zone fall within the central part of the LGA around Owode, Pere, Ologun, Apena villages as well as South West of the LGA; along the boundary with Atakunmosa West LGA and villages share boundary with Ede South. The moderately groundwater pollution potential zone take the central spread and are widely dispersed and interwoven with the low risk area. The low risk area can be found at the Eastern and central part of the study area. The low risk area as well as moderately rated area offer best suitable area for groundwater development. The highly risk area need to be avoided and further detained assessment to be conducted for pollutants identification and if confirmed appropriates remediation measures will be carried out. Groundwater pollution potential zone for the LGA area is presented in the map in Figure 4.13

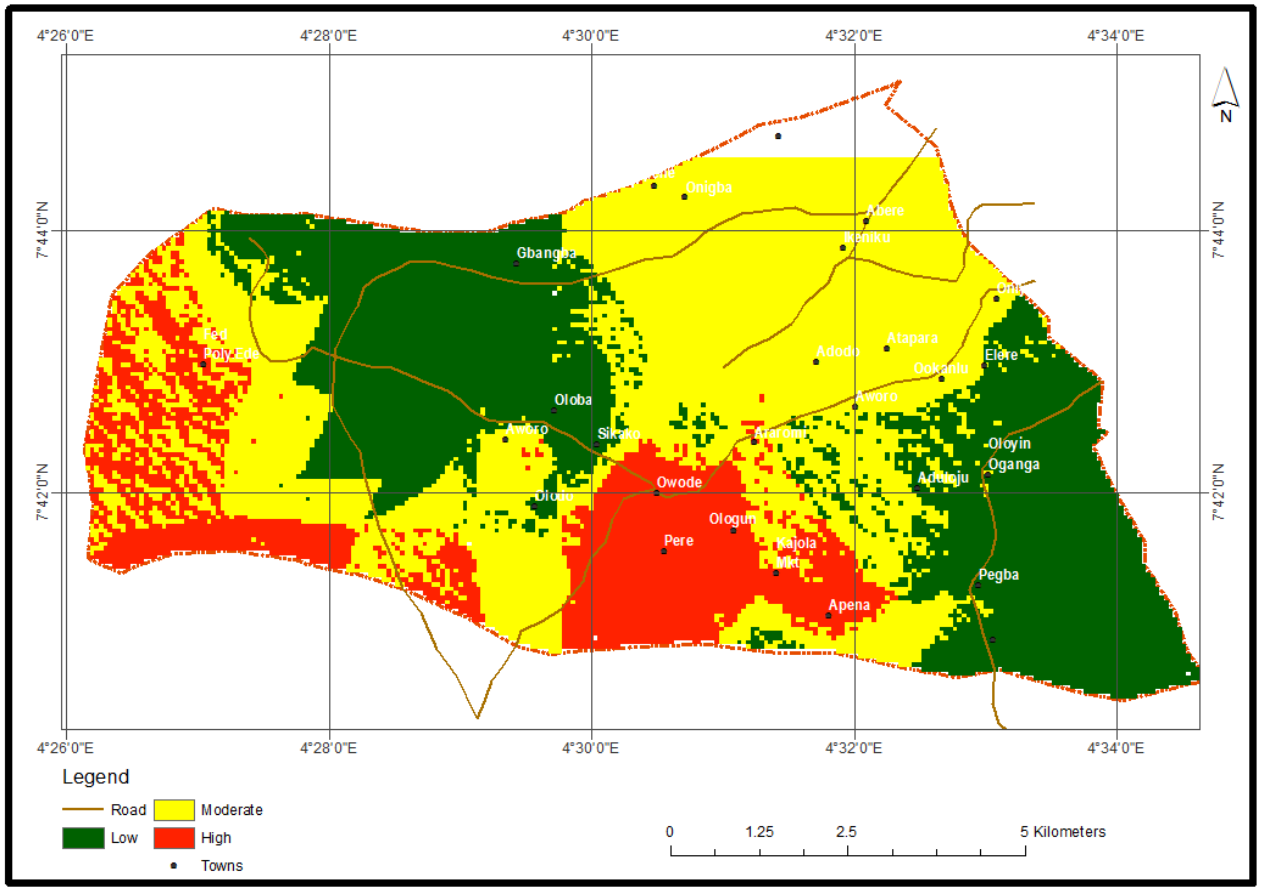


Figure 4.13 GROUNDWATER POLLUTION POTENTIAL ZONES

4.5 **Groundwater Potential Estimation**

The groundwater potential available annually in the area was estimated to26,781,320m^3/year. Table 4.1 presented the summary of the analysis and detail presented in appendix 6. This value is enough to meet the domestic needs of the population within the area.

Table 4.1: Summary of Groundwater Potential Evaluation

Total Area (Km^2)	112.379
Average Annual Rainfall (mm/year)	1,353
Average GW recharge (mm/year)	238
Rainfall- recharge (%)	17.5
GW Potential (m^3/year)	**26,781,320.44**

However, this result of groundwater potential estimation is less than that of the mean value estimated in the JICA, 2014 master plan for the entire western littoral (HA-6) which was put at 23.4 BCM/year while average groundwater recharge used by JICA was put at 236mm/year which is similar to the result obtained in this research work.

The key parameter in estimation of groundwater potential is rainfall net recharge. Thenet recharge result obtained from the chosen model for each year from 1981 to 2010 varies from 153.7 mm/year to 323mm/year. The lowest and highest occurred in 2001 and 2010 years respectively. The mean value of the rainfall-groundwater recharge used for groundwater potential estimation calculated is 238mm/year. This result of rainfall net recharge shows that the minimum and highest occurred in the last ten year of the data considered. By implication, the highest and lowest rainfall over the thirty years records

(1981-2010) occurred during the last ten years of the records. The average annual rainfall estimated is 1,353mm/year.

Due to the importance of Evapotranspiration as a key process inhydrologic balance, this led to the estimation of potential Evapotranspiration (PET) in order to have a vivid understanding of net rainfall recharge available for the replenishment of groundwater. The potential Evapotranspiration (PET) is calculated using Thornthwaite model and the calculated PET values (monthly and annual) were deducted from rainfall values (monthly/annual), the results indicated that there are deficit in most of the months/years.Although the obtained PET values are similar to the values from Nomograph for solution of Thornthwaite's general equation (Thornthwaite 1948).

However, the annual PET values resultvaries from 1,475.1mm/year in 1992 to 1,655.1mm/year in 1987 while annual rainfall varies from 1,014.7mm/year in 2001 to 1,6910mm/year in 2010. Figure 4.14 shows the distribution pattern of PET and rainfall over the thirty year period while Figure 4.15 show PET variability over the thirty years period considered. The distribution pattern of rainfall is more erratic. The PET mean monthly value between 1981-2010 obtained using mean air temperature value show that the lowest PET occurred in August (115.1mm/month) and highest in March (156.1mm/month).

The balance between rainfall and PET which yielded water deficit for lengthy part of the period of 30years is of concern. Although there is tendency for aquifer to be recharged from main river that transverse part of the study area. This could not be verified because theriver is un-gauge.

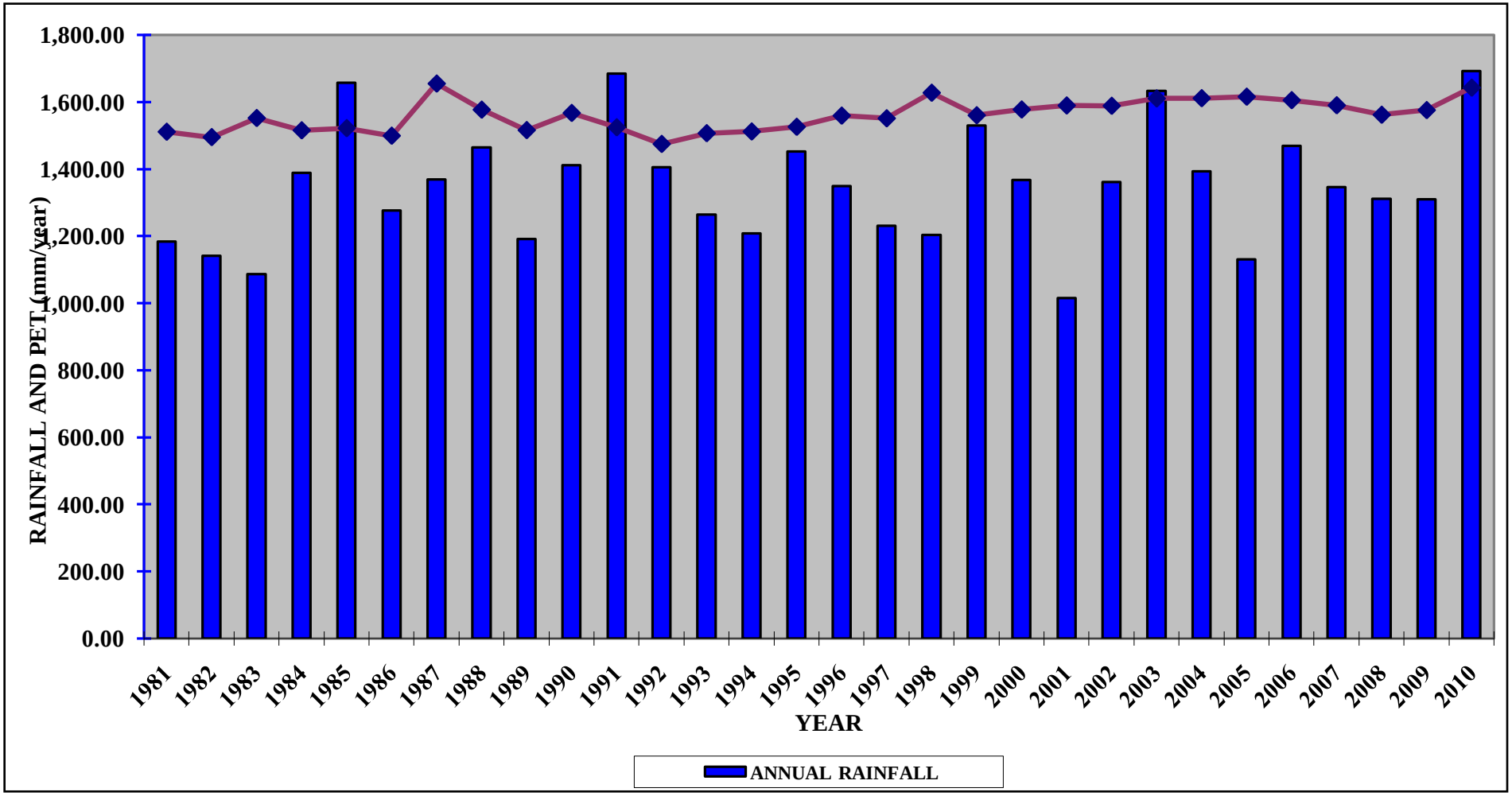


Figure 4.14: Distribution of Rainfall and Potential Evapotranspiration

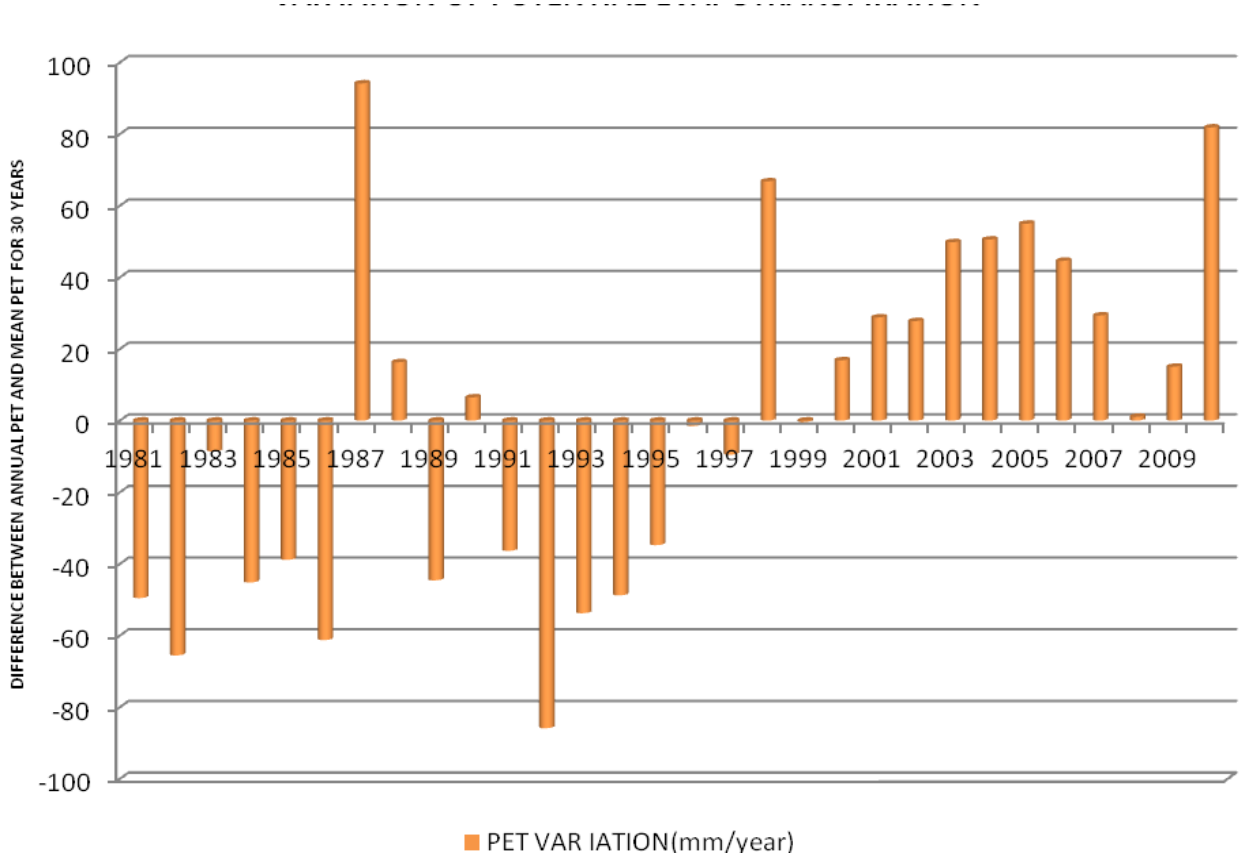
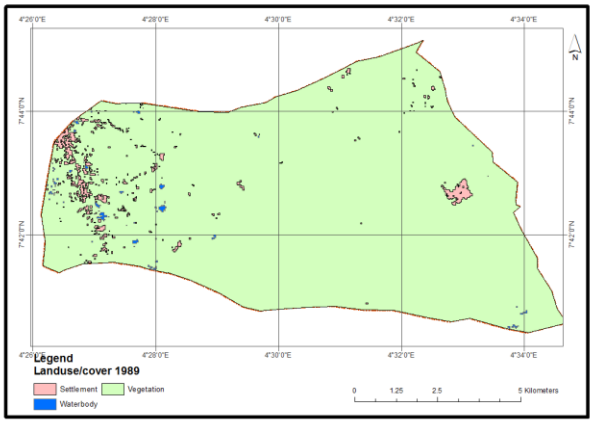
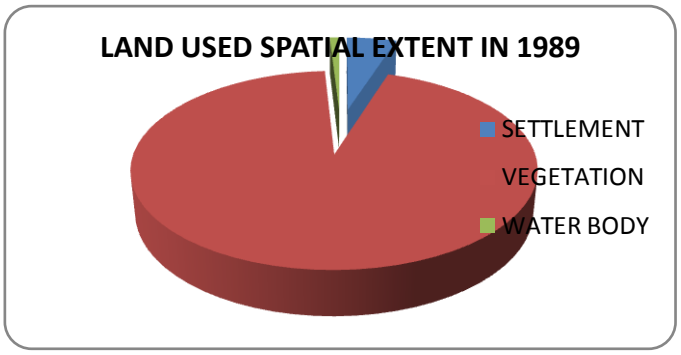


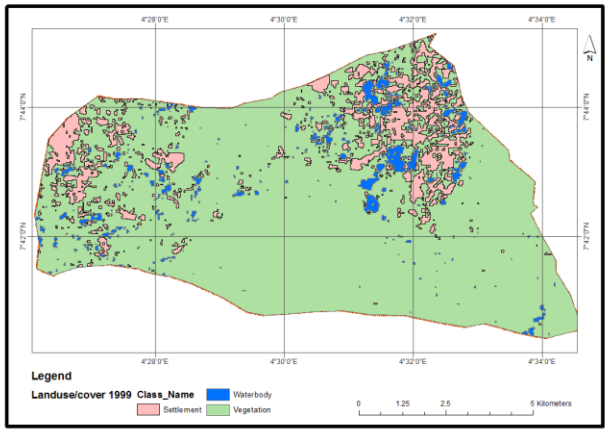
Figure 4.15: Variation of Potential Evapotranspiration

The change in land use pattern is another factor that may deplete the rainfall net recharge of the area. The depletion of the vegetation and resulted increase in settlement within the area will reduce rainfall percolation rate and consequently reduction in groundwater recharge. Settlement area increases from 4.9% in 1989 to 51% in 2009 while the vegetation area decrease from 94% in 1989 to 37.471% in 2009. The figure 4.16 shows the spatial changespattern in land cover of the area and Landsat imageries for 1989, 1999 and 2009 are presented in appendix 4.

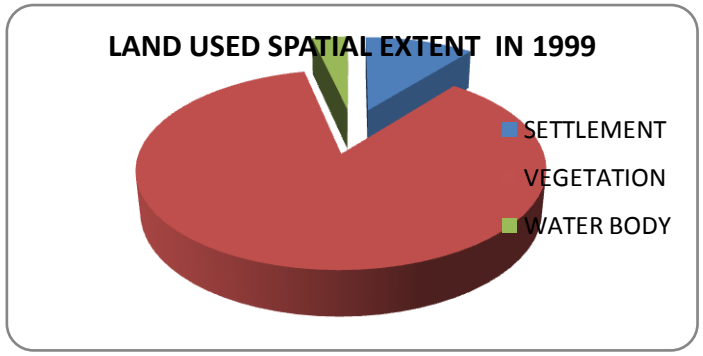


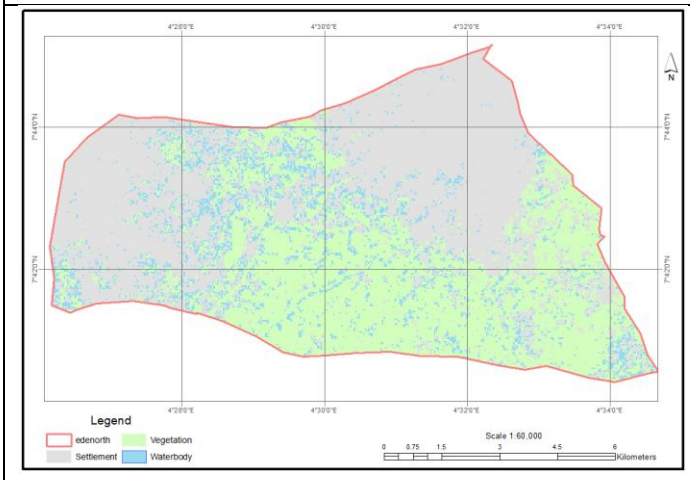
LAND USE CLASSIFICATION-1989





LAND USE CLASSIFICATION 1999





LAND USE CLASSIFICATION – 2009

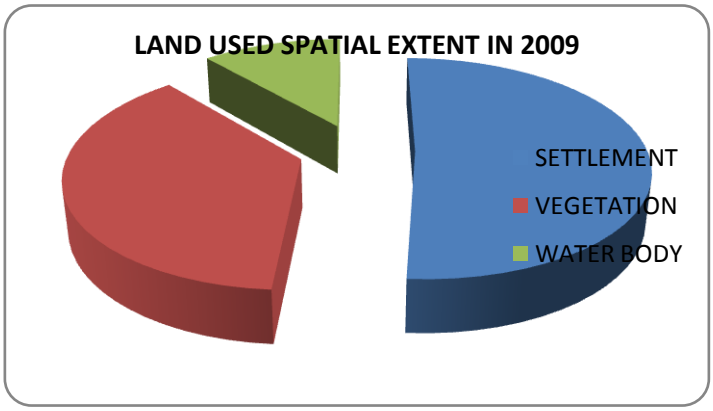


Figure 4.16 Land Cover/Use Changes and Spatial Distribution Pattern 1989-2009

4.6 Climatic Variation

Generally, the rainfall and temperature data suggest that rainfall trends are more spatially heterogeneous than temperature trends.The trend analysis result shows that temperature and rainfall increase but not proportionately and the percentage variation of temperature and rainfall are 36.6% and 3.1% respectively. The linear regression model in which the rate of change is defined by the slope of regression line, for this study, rainfall is 0.031mm/30years and air temperature is about $0.36.6^0$C/30years during the period of 1981-2010. This trend of air temperature is not similar to global warming rate with an estimation mean values of 0.6 ^{0}C or 1.5 ^{0}C recently reviewed by UN general assembly on Climate change.However, this trend is similar to result obtained by Obasi and Ikubuwaje (2012) on Analytical Study of Rainfall and Temperature Trend in Benin-Owena River Basin, which shows that as air temperature increases there is corresponding increase in rainfall.

However, expected rainfall increase will be override by increase in potential evapotranspiration occasion by expected temperature increase which would deplete the rainfall-groundwater net recharge of the area over the time. Although the temperature and rainfall variation show increase in trend but for this area no strong correlation exist between the two parameters. The regression equation for temperature y=0.0269x + 25.293 and R^2=0.3656 while that of rainfall is y=0.2911x+ 108.06 and R^2=0.031. The result of least-square regression and trend analysis of the climatic parameters for the study area is presented in Figure 4.17.

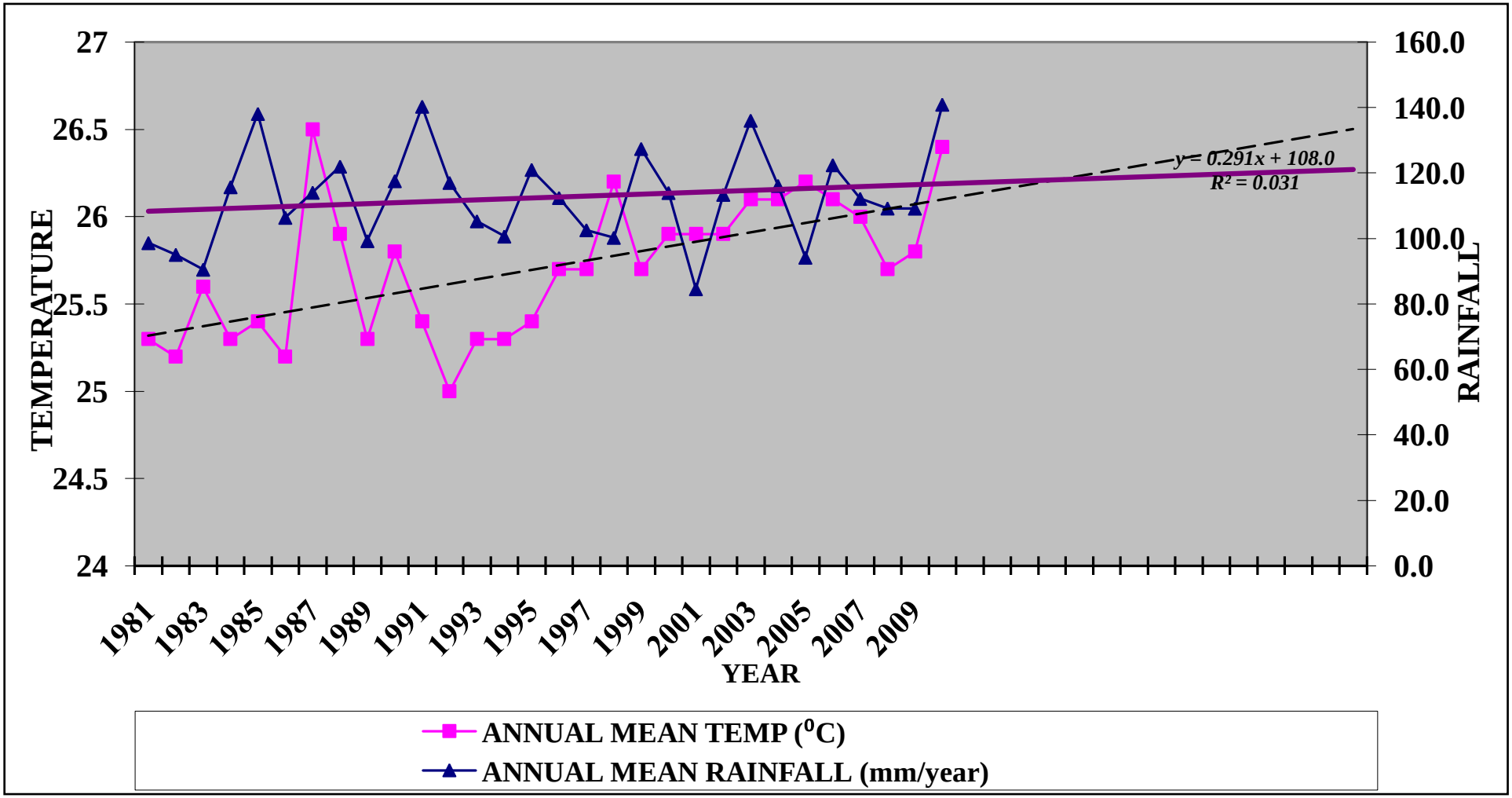


Figure 4.17: Rainfall and Temperature Trend Analysis

Evidently from the charts presented in Figures 4.18 and 4.19, that shows the pattern of air temperature variation, it can be deduced that the marked changes in air temperature commenced in year 1997 and continue increasing, but the pattern of rainfall variation in the charts presented in Figures 4.20 and 4.21 was completely different.

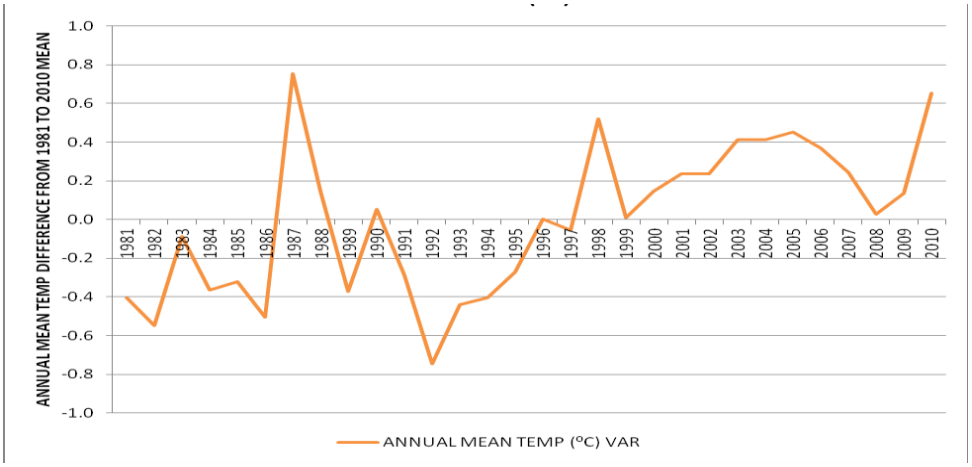


Figure 4.18: Pattern of Mean annual Air Temperature Variation

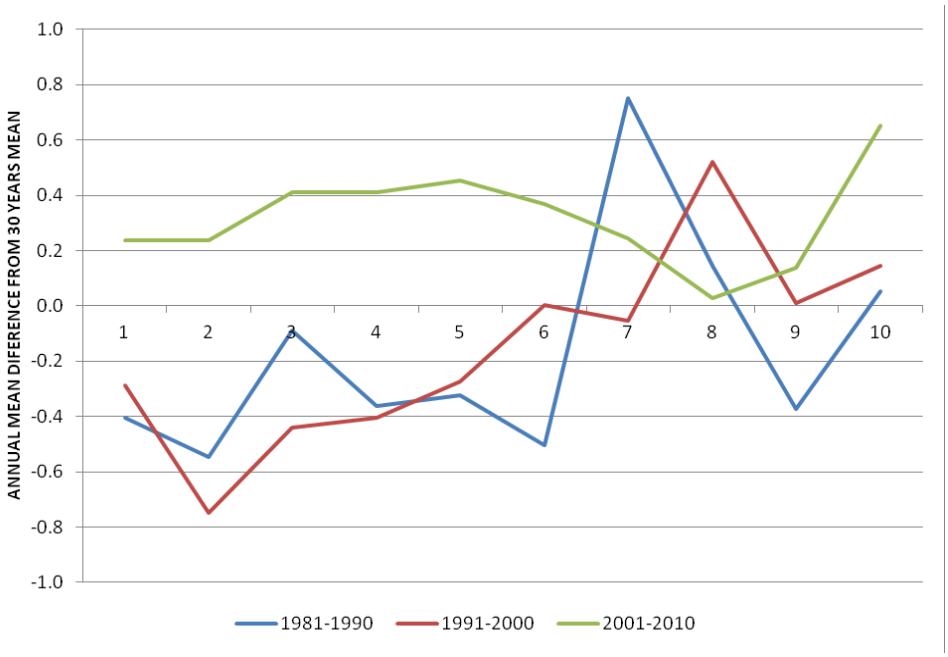


Figure 4.19: Pattern of Mean annual Air Temperature variation in decades

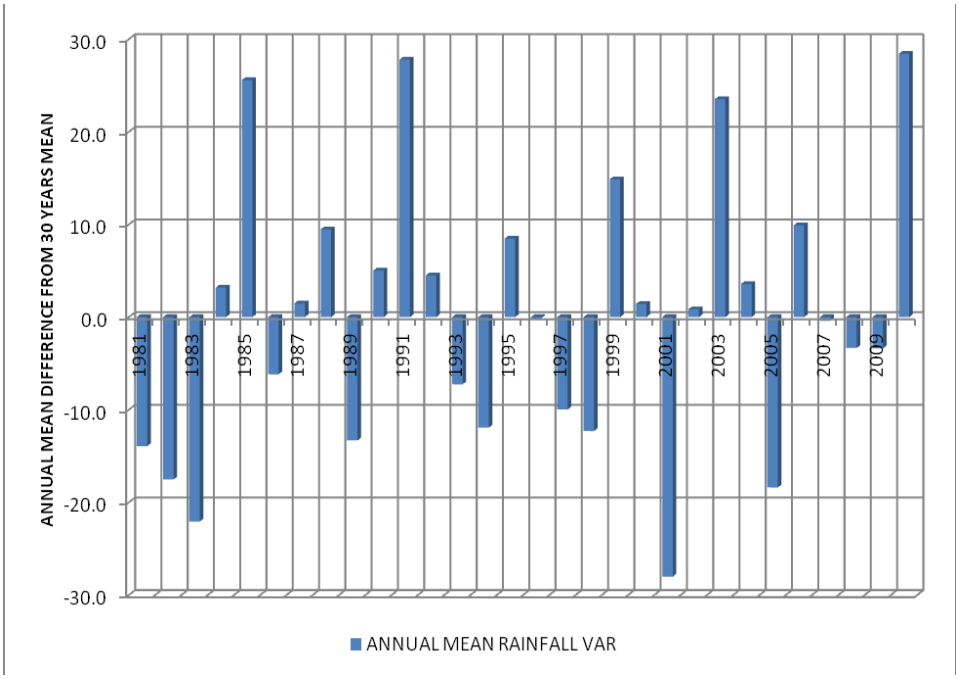


Figure 4.20: Pattern of Mean Annual Rainfall variation

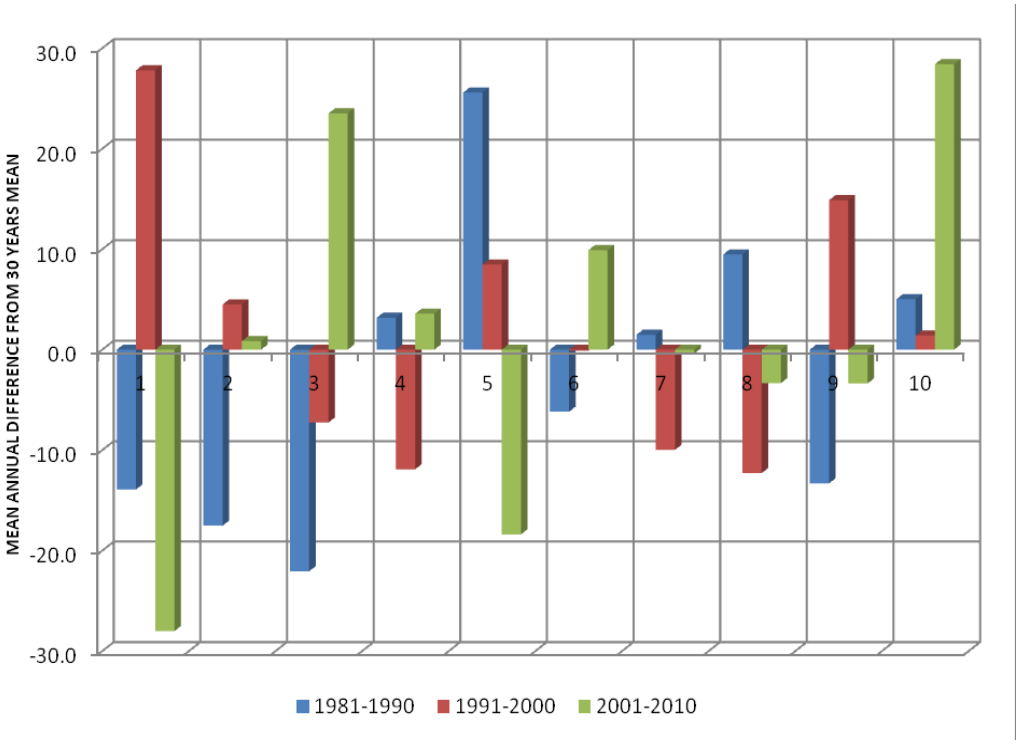


Figure 4.21: Pattern of Mean Annual Rainfall variation in decade

4.7 Water Supply Schemes Mapping

The public water schemes locations within the study area are represented with the dot on the facility map presented in Figure 4.22. From the map it is evident that the distribution of water facilities among the communities is bad.

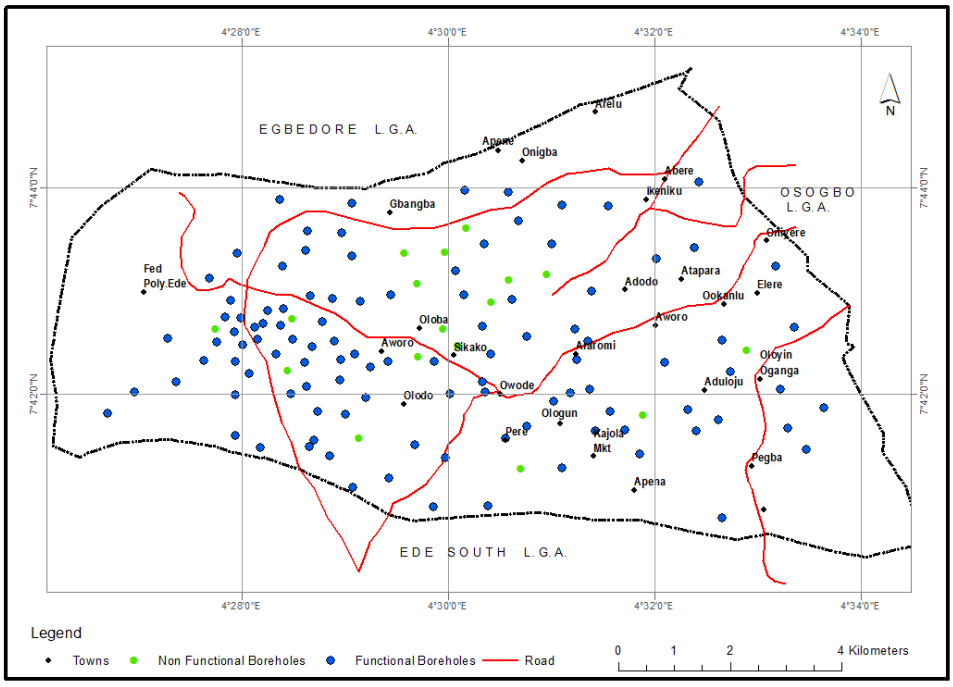


Figure 4.22: Water Point Mapping of all Water Scheme

Some part in the study area has no public water facilities at all, for instance North West of Ede North. From this distribution it can be inferred that sitting of water facilities is not prioritize based on the needs of the community but on the human interference or influence which may be political.

Figure 4.23 and Figure 4.24 show the spatial distribution of functional and non-functional boreholes respectively. Very few water points that are not functional are located almost the same area. The water point functionality is above 85%. The concentration of water facilities

within the same area does not hold best in addressing the water access and total coverage of water supply services, therefore priority must be given to all those area with little or no public water facilities.

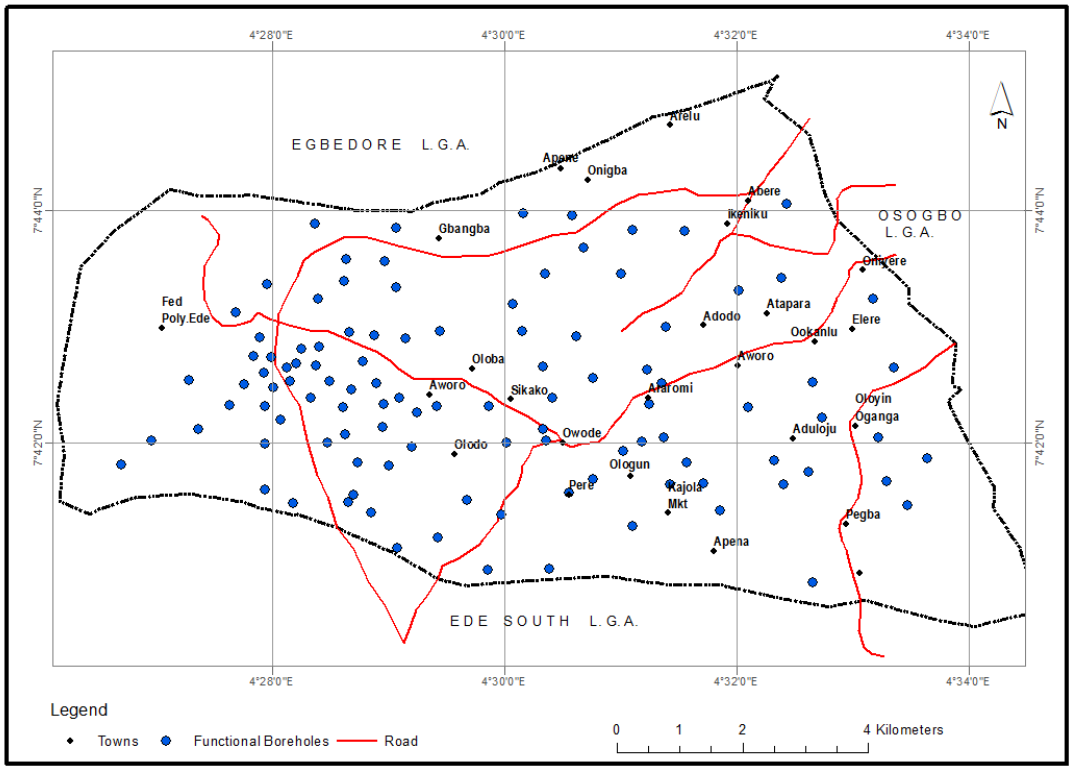


Figure 4.23: Water Point Mapping of functional boreholes

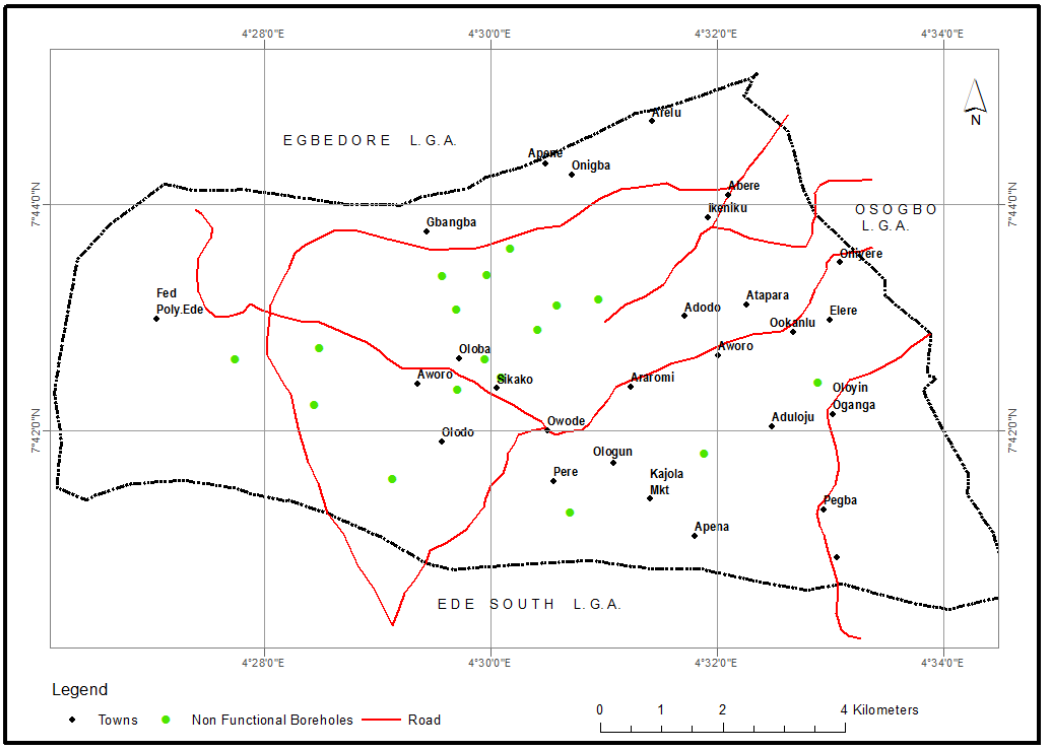


Figure 4.24: Water Point Mapping of Non- functional boreholes

4.8 Water SupplySchemes Capital Investment Plan

4.8.1 Existing water supply schemes

The existing public water facilities within the study area are mainly boreholes. The total public water points in the entire LGA are 126 numbers and fully completed. Majority or 69% of the boreholes power with Handpumps, 21% boreholes are powered with motor either generator or connected to national grid or both and very few, about 9.5% are hand dug well. Over 13% of all the water points are not functional due to technical or management issues. Out of the total water facilities, 50% are constructed by various government institutions (Federal, State and LGA), 46.8% are constructed by developments partners while the remaining 3.2% are constructed by philanthropic or religious bodies.

5.6% of total water facilities are located within the public institutions like school, hospitals, and market places. The detail statistic of existing water supply facilities is presented in Table 4.2.

Table 4.2: Summary of Existing Water Supply Schemes

WARD NO	TOTAL WF	TYPES			OPERATION STATUS		PROMOTER			NON FUNCTIONAL			PPWF
		MBH	HPBH	HDW	F	N	GOVT	DONOR	PHIL	MBH	HPBH	HDW	
1	1	0	1	0	1			1					
2	21	9	10	2	14	7	13	7	1	1	4	2	1
3	14	5	9	0	14	0	5	9	0				
4	5	2	3	0	4	1	3	2	0	1			3
5	48	2	40	6	47	1	15	30	3	1			1
6	5	2	3	0	4	1	5	0	0	1			1
7	6	1	5	0	5	1	3	3	0	1			1
8	15	2	10	3	10	5	14	1	0	1	4		
9	4	0	4	0	4	0	0	4	0				
10	4	1	2	1	3	1	2	2	0	1			
11	3	3	0	0	3	0	3	0	0				
	126	27	87	12	109	17	63	59	4	7	8	2	7

NOTE: MBH=Motorized Borehole, HPBH = Hand pump Borehole HDW =Hand dug well. PPWF =Public Places Water Facilities, WF = Water facilities. GOVT=Government PHIL=Philanthropic

4.8.2. Water supply demand for Ede North LGA

The population of Ede North LGA was 83,818 in 2006 census figures and 2015 and 2030projected population estimate based on the geometric population projection method

and growth rate of 3.21% is put at 111,387 and 178,920 people respectively. Figure 4.25 and Table 4.3 provide the detail.

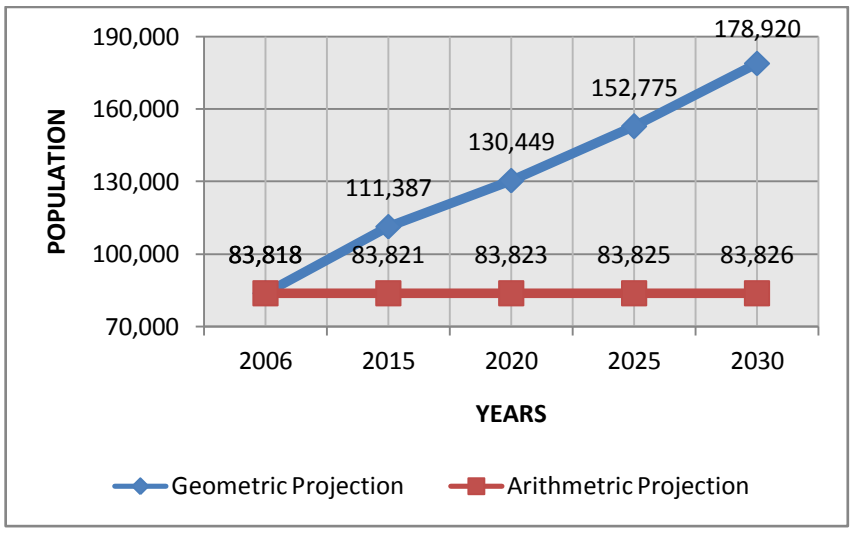


Figure 4.25: Population Projection

Table 4.3: Population Projection

S/N	NAME OF POLITICAL WARD	WARD NUMBER	2006 CENSUS	PROJECTED POPULATION			
				2015	2020	2025	2030
1	Oloba Atapara	1	11,271	14,978	17,542	20,544	24,059
2	Sagba Abopgunde	2	10,872	14,448	16,921	19,816	23,208
3	Ologun Agbaakin	3	8,757	11,637	13,629	15,961	18,693
4	Olusokun	4	7,024	9,334	10,932	12,803	14,994
5	Alusekere	5	10,540	14,007	16,404	19,211	22,499
6	Sabo Agbongbe 1	6	5,902	7,843	9,186	10,758	12,599
7	Sabo Agbongbe 2	7	6,502	8,641	10,119	11,851	13,879
8	Buhari Isola Isibo	8	5,783	7,685	9,000	10,541	12,345
9	Apaso	9	5,759	7,653	8,963	10,497	12,293
10	Asumo	10	5,851	7,775	9,106	10,665	12,490
11	Bara Ejemu	11	5,557	7,385	8,649	10,129	11,862
	Total		**83,818**	**111,387**	**130,449**	**152,775**	**178,920**

The existing total water supply demands across the eleven political ward based on 2015 population estimate is 2.0MCM/year. It is expected to increase to 3.21MCM/year by 2030. The expected water demand increase rate is 3.42% annually. The groundwater public water use rates are7.48% and 12.0% for 2015 and 2030 respectively. Table 4.4 provided the LGA water demand.

Table 4.4: Water Supply Demand

POLITICAL WARD NUMBER	WATER DEMAND (Litres/capital/day)			
	2015	2020	2025	2030
1	1,078,427	1,262,990	1,479,138	1,732,278
2	1,040,251	1,218,279	1,426,776	1,670,954
3	837,884	981,280	1,149,216	1,345,893
4	336,034	393,543	460,894	539,771
5	504,242	590,538	691,603	809,964
6	282,356	330,679	387,271	453,549
7	311,061	364,296	426,642	499,657
8	276,663	324,012	379,463	444,404
9	275,515	322,667	377,888	442,560
10	279,917	327,822	383,925	449,630
11	265,851	311,349	364,634	427,037
Total	5,488,202	6,427,454	7,527,450	8,815,699

Note: 72l/c/d was used for wards 1to 3 because of small town nature while 36l/c/d for wards 4 to 11.

The total number of functional improved public water pointslocated across the communities is put at 109numbers or otherwisehas 86.5% functionality and assumed to be serving 61.5% of the entire LGA population leaving closeto 38.5% population unserved. Political Ward 2,3 and 11 have more than enough water facilities required to meet the water demand up to 2015. The number of people unserved in 2015 is put at 47,756 which will required new

water points construction; 134 numbers Hand pump and 6 numbers Motorized schemes to fill the gaps in communities excluding people that are being serve with pipe water system. When deducted the proportion of people located within the urban centre and assumed to be served with the existing pipe water system of estimated 35% operational status, the future water demand in line with expected population growth were computed according to ratio 30:70 (MBH:HPBH) for 2020, 2025 and 2030. The expected new water point facilities to be constructed in communities (Table 4.5) within the LGA in order to meet the coverage and sustainable access varies from 46 to 64 numbers of Handpumps and 2 to 7numbersof motorized boreholes between 2016 to 2030 while 15 numbers of dysfunctional borehole will be rehabilitated within the first year.

Table 4.5: IMPROVED WATER SUPPLY POINTS AND FIFTEEN YEARS PLAN FOR WATER SUPPLY SCHEMES

POLITICAL WARD NUMBER	MBH	HPBH	HDW	POPULATION SERVED BY 2015	WATER SERVICES %	UNSERVED POPULATION 2015	WS F GAPS (2015)		EXPECTED WS F 2020		EXPECTED WS F 2025		EXPECTED WS F 2030	
							HPBH	MBH	HPBH	MBH	HPBH	MBH	HPBH	MBH
1		1		250	1.7	9,573	27	1	5	1	5	0	6	0
2	8	5		21,250	147.1		0	0	5	0	5	1	6	0
3	5	9		14,750	126.7		0	0	4	0	4	0	5	1
4	1			2,500	26.8	6,834	19	1	4	0	5	1	6	0
5	1	39	6	12,356	88.2	1,651	5	0	7	1	8	0	9	0
6	1	2		3,000	38.2	4,843	14	1	4	0	4	0	5	1
7		4		1,000	11.6	7,641	21	1	4	0	5	0	6	1
8	1	6	3	4,300	56.0	3,385	9	0	4	0	4	0	5	1
9		4		1,000	13.1	6,653	19	1	4	0	4	0	5	1
10		2	1	600	7.7	7,175	20	1	4	0	4	0	5	1
11	3			7,500	101.6		0	0	4	0	4	0	5	1
Total	20	72	10	68,506	61.5	47,756	134	6	46	2	54	2	64	7

The new water points construction and rehabilitation will requireNGN940,332,124 to meet the existing gaps and future water demand. The detail financial breakdown for each of five year period is presented in Table 4:6 while average cost of rehabilitation and new construction is presented in Appendix E.

Table 4.6: COSTING/ESTIMATE FOR THE SCHEMES

	WS F GAPS (2015)		EXPECTED WS F 2020		EXPECTED WS F 2025		EXPECTED WS F 2030		
Water facility required	HPBH	MBH	HPBH	MBH	HPBH	MBH	HPBH	MBH	Total
Communities	134	6	46	2	54	2	64	7	315
Public Institutions	23	15							38
Rehabilitation	8	7							15
Sub-Total	165	28	46	2	54	2	64	7	368
Cost (NGN)	315,432,889	193,576,343	92,977,269	17,931,330	108,889,417	21,000,102	127,524,774	63,000,000	431,322,892
Total									940,332,124

CHAPTER FIVE

5.1 Conclusion

This research work has been able to confirm the use of Geographic Information System and Remote Sensing for determination and evaluation of the viable and safe areas for rural water supply scheme siting within Ede North Local Government of Osun State by demarcating the study area into groundwater potential and pollution zones.

It is established that Ede North has high groundwater potential which can sufficiently take care of the domestic water supply of its rural populace, for more than 82$km^2$of the total land area equivalent to 73% of the study area is adjudged as productive areas for groundwater development.

Also, this study established that Ede North LGA has 26.8million cubic meter groundwater potential annually. This is sufficient to meet immediate domestic water demand of 2.0MCM/year and remotely domestic water demand of 3.21MCM/year by 2030 with3.42% annual increase rate in domestic water demand.The groundwater public water use rates are 7.48% and 12.0% for 2015 and 2030 respectively.

In order to meet SDG goals-6on universal coverage for water supply, Ede North LGA will require353 numbers of boreholes scheme (new construction)as well as rehabilitation of 15 numbers of dysfunctional existing schemes with financial total cost of NGN940,332,124.

Ede North LGA has 27% of the entire land area vulnerable to pollution from agricultural practices.The study found that vegetation is fast decreasingfrom94% in 1989 to 37% in 2009.

The temperature and rainfall variationshow increase in trendof 36.6% and 3.1%respectively in other word, rainfall and air temperature is 0.031mmand 0.36.6^{0}C respectivelyper the period of 30 years.

It could therefore be concluded that the use of GIS and RS can providenecessary data based/water information that can guide the practitioners in the field of water supply inschemes siting and distribution which shall aid the effective planning and managing of rural water supply.

5.2 Recommendation

Based on this research work it can be recommended that;

I. Motorized scheme and hand pump scheme should be situated in an area demarcated as high groundwater potential and moderately potential area respectively.

II. The demarcated high risk area “flash point” need to be avoided for well siting,

III. Periodic monitoring and further detailed assessment need to be conducted for pollutants identification and remediation measures.

IV. Advocacy and sensitization with Information Education Communication (IEC) material on the safe handling of contaminants.

V. Alternative water sources need to be exploited for the designated flash point.Rainwater Harvesting through Roof Top is recommended dueabundances of untapped rainfall.

APPENDICES

Appendix A: Survey Data Collection Form

DATA COLLECTION FORM USED FOR EDE NORTH RURAL WATER SUPPLY

	State	Osun		LGA	Ede North
1.1	Ward No		1.2	Village	
1.3	Location/Community		1.4	Code No	
2.1	GPS- Lati References		2.2	GPS- Long References	
2.3	GPS- Altitude				
3.1	No. of Households-Users		3.2	Population	
4.1	Scheme Types		4.2	Year of Installation/ Completion	
Note:	**Protected Hand Dug Well=1; Hand pump on Hand dug well=2; Hand pump on Borehole=3; Borehole (Motor/Solar)=4; Rain Water Harvesting=5; Protected Spring=6; Pipe Water=7; Others=8**				
4.3	Responsible Agency/Owner		4.4	Depth of Installation (m)	
Note	**Good=1; Minor=2; Severe=3**		4.5	Water Quality	
Note	**If Motorized state No of Stand pipe (Tap)**		5.1	No of Taps	
Note	**If hand pump state the Types: Ru=Ruwatsan; IM=Indian Mark ;Ru1(Indian Mark 3);Ru2 (Afridev): Ru1=1; Ru2=2; IM2=3; Tara=4; Other=5**		6.1	Types of Hand pump* Ru1/ Ru2/ IM2/ Tara/ Other	
Note	**Seasonality: Perenial=1; Seasonal =2**		6.2	Perenial or Seasonal	
Note	**Workability: Yes=1; No=2**		6.3	Working ?	
Note	**Usage: Use=1; Not Use=2**		6.4	Usage	
Note	**Condition: Good=1; Bad=2**		6.5	Condition	

Appendix B: Rural Water Supply Facilities and Services Level

TECHNOLOGY OPTION	NATIONAL RWSS STRATEGIC FRAMEWORK	STATE OWN POLICY
	SERVICES POPULATION/FACILITY	SERVICES POPULATION/FACILITY
Motorised/solar scheme	3000	2500
Handpump Borehole	300	250
Handpump Dugwell	100	100
Protected Hand-dug well	100	100

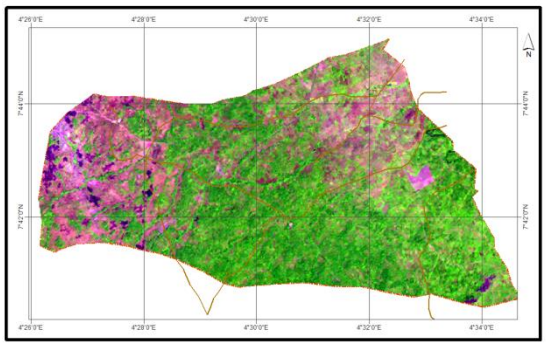
Source: National RWSS Frame Work

Appendix C: Settlement Classification and Services Level

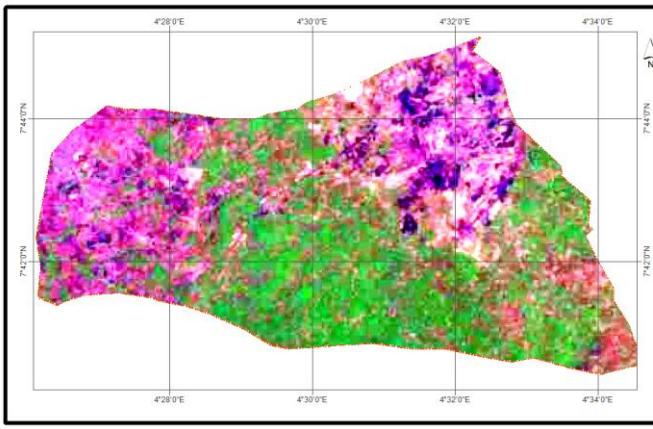
CONSUMPTION STANDARD			
CLASSIFICATION	**DESCRIPTION**	**PER CAPITAL CONSUMPTION PER DAY**	**MODIFIED TO INCLUDES ECONOMIC ACTIVITIES AND LOSS AT 15% and 5% RESPECTIVELY**
RURAL AREAS	Settlement with population of less than 5,000	30 litres/capital/day within 250m radius	36 l/c/d
SMALL TOWN	Settlement with population between 5,000 to 20,000	60 litres/capital/day within 250m radius	72 l/c/d

Source: The National Policy on Water Supply and Sanitation (Jan 2000)

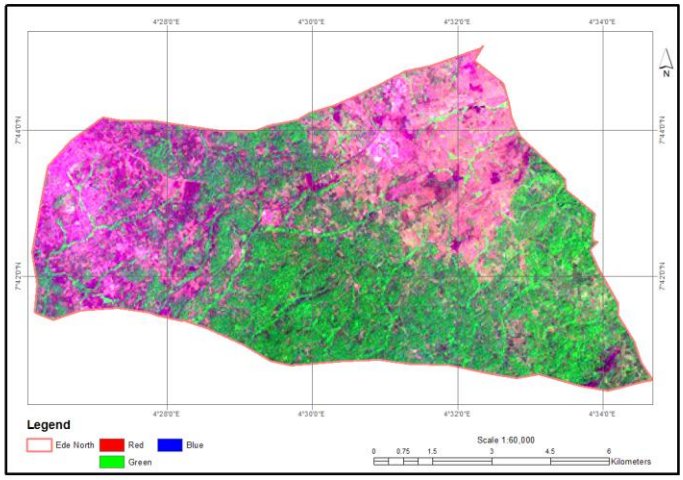
Appendix D: Landsat Imageries



LANDSAT 1989 IMAGERIES



LANDSAT 1999 IMAGERIES



LANDSAT 2009 IMAGERIES

Appendix E: Average Rate for Water Supply Scheme/facilities Construction and Rehabilitation

Description	Average Rate
New HPBH	2,000,000.00
New MBH	9,000,000.00
Rehab HPBH	250,000.00
Rehab MBH	1,000,000.00

Appendix F: Net Recharge from Rainfall Data

i

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Annual Rainfall (mm/year)	1,183.7	1,140.6	1,086.2	1,388.9	1,657.9	1,276.7	1,368.6	1,464.5	1,191.1	1,411.1
Recharge (mm/year)	195.925	185.15	171.55	247.23	314.475	219.18	242.15	266.13	197.78	252.78
% of Annual Rainfall	16.6%	16.2%	15.8%	17.8%	19.0%	17.2%	17.7%	18.2%	16.6%	17.9%

ii

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Annual Rainfall (mm/year)	1,684.4	1,404.8	1,263.8	1,207.8	1,452.5	1,349.4	1,231.1	1,203.3	1,529.3	1,367.8
Recharge (mm/year)	321.1	251.2	215.95	201.95	263.13	237.35	207.78	200.83	282.33	241.95
% of Annual Rainfall	19.1%	17.9%	17.1%	16.7%	18.1%	17.6%	16.9%	16.7%	18.5%	17.7%

iii

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Annual Rainfall (mm/year)	1,014.7	1,361.0	1,633.0	1,393.7	1,130.2	1,469.7	1,346.1	1,310.8	1,310.4	1,691.8
Recharge (mm/year)	153.68	240.25	308.25	248.43	182.55	267.43	236.53	227.7	227.6	322.95
% of Annual Rainfall	15.1%	17.7%	18.9%	17.8%	16.2%	18.2%	17.6%	17.4%	17.4%	19.1%

iv

YEARS	MIN	MAX	AVERAGE
1981-1990	171.7	314.5	243.1
1991-2000	321.1	200.8	261.0
2000-2010	153.7	323.0	238.3
1981-2010	153.7	323.0	238.3

FIELD SURVEY



Plate i: HPBH Water Supply Scheme GPS Coordinate taken



Plate ii: MBH Water Supply Scheme GPS Coordinate taken

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