GROUNDWATER POTENTIAL ASSESSMENT USING GIS AND AHP IN ANIOCHA SOUTH LGA, DELTA STATE.

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CERTIFICATION

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DEDICATION

This project work is dedicated to Almighty God, for his mercies and blessing shown on me during my school years. I also dedicate this to my friends, junior colleagues, and the residents of Aniocha South LGA

I will also like to dedicate this report to my parents who always stood by me and also supported me.

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I would like to thank God for protecting me and giving me the strength and resources I needed through these five years.

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ABSTRACT

In this study, Remote Sensing (RS), Land-sat 8 digital data, and digital elevation models (DEMs) from the Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER), Food and Agricultural Organization (FAO) along with other stereotypical data such as geology and rainfall were digitized and analyzed to create various thematic maps (geology, land use/cover, soil, drainage density, rainfall and slope maps) required for groundwater modelling in the study area.

These thematic maps were assigned well-chosen weights and different rankings to the individual categories within each thematic map using a manual Analytical Hierarchy Process (AHP). Parameters which had high influence on groundwater potential assessment were given higher percentages based on some criteria and others were which had low impact given low percentages. The groundwater potential zones are achieved by overlaying the thematic maps using the spatial analysis tool in Arc-GIS 10.8.

The result from the Groundwater potential map showed that A total of 5.51% of the 47km² area is classified as having excellent groundwater potential; 41.84% of the 360 km² area is classified as having good groundwater potential; 41.5% of the 352 km² area is classified as having moderate groundwater potential; 11.07% of the 95 km² area is classified as having fair groundwater potential; and 0.0165% of the 14 km² area is classified as having poor potential. This shows that there is a good groundwater potential in the LGA.

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ACRONYMS

GIS	Geographic Information System
AHP	Analytic Hierarchy Process
GPS	Global Positioning System
LULC	Land Use and Land Cover
USGS	United States Geological Survey
CHRS	Common Human Resources System
FAO	Food and Agriculture Organization
ESRI	Environmental Systems Research Institute

CHAPTER ONE
INTRODUCTION

1.1 Background of Study

An essential component of our existence is water. Being the only freshwater supply that has not yet been adversely affected by human activity, groundwater is an even more valuable natural resource. Since surface water development requires a lot more money and effort than groundwater development, more attention is placed on the groundwater utilization that can be established quickly. The importance of water as a natural resource to support human needs cannot be overemphasized, same can be said about the importance of groundwater as a source or major source of water based on purity and continuity compared to surface water.

The low chemical composition, low contamination, accessibility and wider distribution has made it a more desirable source of water. Although groundwater occurrence in various locations is not an independent or magical event as it occurs due to some factors such as the climate of the region, the hydrological and geological nature of the region also contributes to the availability of groundwater in a particular place. Groundwater can be widely used in homes for various domestic activities, in agriculture for irrigation and for various industrial purposes. The freshness, lower pollution coefficient, chemical compounds, constant temperature, cost effectiveness and high reliability level of groundwater has made it the major source for communities, industries and agricultural uses in the world. In both urban and rural areas, groundwater has been considered as a fundamental source of applying fresh water (Akeem, 2021).

The dependence of individuals on groundwater as a source of water calls for this research on the potential of various areas to have groundwater. The unavailability of groundwater to most people because of the specific location of their house, industries or farms has become a problem and has caused many to spend a lot of money on the search for groundwater. About 34% of the world resources belong to groundwater and is an important source of drinkable water (Zeinolbeotina and Esmaily., 2015). Due to the country's rapid economic growth, urbanization, and population increase, countries like Nigeria are becoming more and more in need of groundwater (Stanley, 2021).

Groundwater is termed to be accessible but some people still find it challenging to access ground water in their respective locations. Some methods such as the surface method which consists of techniques such as esoteric, geology, geomorphology, geophysics, hydrogeology or the ground survey methods, gravity method seismic method, some of these methods are done by trial by error (sub surface method using drilling technique) which cost a lot of money and time for individuals. Those who are unable to afford such process will not be able to have accessible water within their location, hence making them opt for other sources of water such as rain water harvesting or surface water which are neither potable nor reliable for some domestic use.

The availability of groundwater as a source of water depends largely on surface and sub-surface geology of well or climate. The porosity and permeability of a geologic formation controls its ability to hold and transmit water. Porosity is measured as a ratio of voids to total volume of rock material and is usually described in percentage (Vandas et al., 2002). Regional groundwater exploration campaigns in the Basement Complex terrains often target areas where there is considerable thick weathered residuum and densely fractured and jointed subsurface zones, (Chandra et al., 2019). The use of surface or sub surface method for groundwater assessment has been found to be expensive and unreliable leading to the use of a more reliable, cost effective and long term method for groundwater assessment such as GIS and AHP technology.. GIS (Geographic Information System) is a mighty instrument that can access a large number of spatial data and can be used to find groundwater of an area (Akeem, 2021). AHP (Analytical Hierarchy Process) is a method used of analyzing and organizing complex decisions, it is a structured means of modelling the problem at hand. Groundwater research employing this technology has exploded as a result of technological developments in the field of geospatial technologies and the associated rise in spatial precision. The flow and availability of groundwater are influenced by a variety of information, which may be managed and integrated using an integrated and goal-oriented platform provided by remote sensing and Geographic Information Systems (GIS). Often, this integration is carried out with the Multi-Criteria Decision Analysis (MCDA). The analytical hierarchy process (AHP) is a straightforward, trustworthy, efficient, and transparent method. By combining data from remote sensing (RS) and geographic information systems (GIS), the AHP approach may be easily and effectively identified. In a GIS framework, groundwater factors including precipitation, aquifers, land use, and soil type are readily described as geographical data. One of the most popular MCDA methods is the analytical hierarchy process (AHP). Recently, AHP has been used in a number of geological domains, but most significantly, it has been used to research pertaining to groundwater and has shown promising results, particularly in defining the groundwater potential zone, (Ejepu et al., 2022).

Using AHP, GIS, and RS together yields a far more dependable and suitable solution that may be applied to any other place, particularly in densely inhabited and developing regions, (Jhariya et al., 2021). Making maps that are useful for finding groundwater in this area is also beneficial.

1.2 Statement of the Problem

Groundwater exploration is the investigation of underground formations to understand the hydrologic cycles, know the groundwater quality and identify the nature, number and type of aquifer (Halle and Semir., 2016). An aquifer system is a collection of formations with enough saturated permeable material to supply boreholes and springs with a reasonable amount of water. Because they serve as the storage medium from which groundwater is extracted, aquifer systems are significant. Rainfall percolates through the soil and draws groundwater into an aquifer. Through wells and springs, it can resurface after travelling through the aquifer. A geologic material needs to be permeable and saturated, meaning that water fills the pore spaces in it, in order to be classified as a good aquifer. Some regions do not have good aquifers and are barely aware of the type pf aquifer available to them hence leading to the use of more expensive methods to explore groundwater. This study aims at identifying the aquifer of this zone and how to navigate.

The cost and time taken to search for groundwater using surface or subsurface methods cannot be afforded by all. Many people buy lands in the parts of an area that doesn't have easily accessible groundwater but cannot afford to search at lower depths for groundwater which leads them to use surface water or other sources of water that are not potable. With this study, maps will be generated in this region for groundwater potential. This map will serve as a reference on what lands should be sold for what purpose and to whom it should be sold to so as to aid those who intend migrating to that region and to ensure the maximization of lands with groundwater potential.

1.3 Aim and Objectives of the Study

This aim of this study is to access groundwater potential in basement formation using GIS and AHP.

The objectives of this study are to;

1. use the google earth application to study the study area.
2. identify the parameters which will be needed to determine groundwater potential.
3. obtain the various required base data or these parameters.
4. develop the thematic maps. This involves the preparation of a base map which shows the drainage density, slope density, lineament, land use/land cover (LULC), rainfall, soil type and soil structure amongst others.
5. analyze these parameters and how much effect they have on groundwater potential in this study area.
6. create the groundwater potential zone maps and identification of groundwater zones.

1.4 Scope of the Study

Groundwater occurrence and movement are primarily governed by underlying lithology, landform, soil characteristics, lineament and drainage densities, while recharge is regulated by precipitation, land use/land cover type, and rate of penetration (Shao et al., 2020). Groundwater potentiality modeling can be accomplished by looking at the elements that govern groundwater flow, storage, and occurrence (Yıldırım, 2021) (Ifediegwu et al., 2019)

In order to ascertain the groundwater potential of the research area, the scope of this project included gathering all pertinent data from previously published hydrological information, geological reports, hydro-geological studies, physical field measurements, data presentation, and data analysis.

The groundwater potential map was validated by weighting, rating, and overlaying the parameters (thematic maps) that contribute to groundwater potential in a GIS setting.

Numerous issues plague this effort, including the scarcity of available data, the high expense of data collection.

1.5 Justification

Urban regions are dynamic networks with high groundwater demand, rapid population increase, and a scarcity of surface water. A region's groundwater potential is dependent on various factors and fluctuates from location to location based on changes in that information (Jhariya et al., 2021).

The groundwater balance study of an area may serve the following purposes:

As a check on whether all flow components involved in the system have been quantitatively accounted for, and what components have the greatest bearing on the problem under study.

To calculate one unknown component of the groundwater balance equation, provided all other components are quantitatively known with sufficient accuracy.

As a model of the hydrological processes under study, which can be used to predict the effect that changes imposed on certain components will have on the other components of groundwater system. (Kumar., 2014).

With good and detailed studies on the groundwater potential in this region, resident can have a knowledge on the type of aquifer existing in the region and of good locations to build boreholes or wells. This can help them build water supply sites for those who are already situated in areas where groundwater is only assessable at lower depths and cannot afford it.

CHAPTER TWO
LITERATURE REVIEW

2.1. Introduction

Groundwater as a vital natural resource plays a crucial role in meeting the water needs of various sectors including agriculture industry and domestic usage. Water that exists beneath the surface of the earth in the voids left by soil or rock fragments, or in the fissures and fractures in rocks, is known as groundwater (Societe Generale de surveillance., 2011). Numerous substances, including gases, inorganic and organic compounds, and microbes, can be found in groundwater. A major source of groundwater contamination is agriculture and industry. These actions run the risk of contaminating municipal drinking water supplies, well water, and the surrounding ecosystem. Groundwater a vital component of the Earth's water cycle plays a crucial role in numerous engineering applications. This paper aims to explore the significance of groundwater in engineering practices highlighting its properties availability and challenges associated with its utilization. Understanding groundwater is essential for engineers to design sustainable infrastructure and manage water resources effectively.

Groundwater refers to the water present beneath the Earth's surface in saturated soil or rock formations. It exists in the pore spaces of soil or fractures in bedrock forming aquifers. Aquifers act as natural reservoirs storing and transmitting water. The properties of groundwater such as porosity and permeability influence its movement and availability.

Porosity refers to the percentage of void spaces in a material while permeability refers to the ability of a material to transmit fluids. These properties determine how easily groundwater can flow through an aquifer (Gleeson et al., 2012). Engineers must consider these characteristics to design efficient water supply systems groundwater extraction techniques and underground structures.

Groundwater represents a significant portion of the Earth's freshwater resources. It is estimated that approximately 30% of the world's freshwater is stored underground (Freeze & Cherry., 1979). However the availability of groundwater varies across regions due to factors such as climate geology and human activities.

In arid and semi-arid regions groundwater becomes even more critical as surface water supplies may be scarce. Engineers often rely on groundwater sources to meet the water demands of communities and industries in such areas. Proper monitoring and management of these resources are crucial to ensure their sustainability.

While groundwater is an invaluable resource its utilization poses certain challenges that engineers must address. Overexploitation often driven by excessive pumping can lead to groundwater depletion and land subsidence. Such issues have been observed in several parts of the world including the San Joaquin Valley in California and the North China Plain.

Contamination of groundwater is another significant concern. Pollutants from industrial activities agriculture and improper waste disposal can seep into aquifers rendering the water unfit for consumption (Todd & May., 2005). Preventing contamination and implementing proper remediation techniques are essential for preserving the quality of groundwater resources.

Groundwater plays a vital role in various engineering applications including:

1. Water Supply: Groundwater serves as a reliable source of drinking water for millions of people worldwide. Engineers design wells pumps and treatment systems to extract and distribute groundwater efficiently.

2. Geotechnical Engineering: Understanding groundwater conditions is crucial for designing foundations tunnels and underground structures. Groundwater pressure

affects soil stability and can significantly impact the safety and performance of engineering projects.

3. Environmental Engineering: Groundwater remediation techniques are employed to clean up contaminated sites. Engineers use technologies like pump-and-treat systems bioremediation and reactive barriers to restore groundwater quality.

4. Hydroelectric Power Generation: Groundwater resources contribute to the generation of hydroelectric power. Engineers design and operate systems that harness groundwater to generate electricity promoting sustainable energy production.

Groundwater is an invaluable resource for engineering practices providing essential water supplies and influencing the design of various infrastructure projects. Engineers must consider the properties availability and challenges associated with groundwater to ensure sustainable and efficient utilization. By implementing proper management strategies and innovative technologies engineers can harness the potential of groundwater while preserving its quality for future generations.

Understanding the potential of groundwater resources is essential for effective water resource management and sustainable development. In recent years the integration of Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) techniques has emerged as a powerful approach for assessing groundwater potential (Gupta & Nema., 2016). Groundwater Potential Assessment

Groundwater potential assessment refers to the estimation of the likelihood of finding water in a specific location or region. It involves the analysis of various factors that influence groundwater occurrence such as geology hydrogeology topography land use and climate. Traditional methods of groundwater potential assessment relied heavily on subjective judgment and experience-based approaches. However the integration of

GIS and AHP has revolutionized this field by providing a systematic and objective framework for groundwater potential analysis.

GIS is a powerful tool for capturing storing analyzing and visualizing spatial data. It allows the integration of diverse data sources such as satellite imagery digital elevation models and soil maps to create comprehensive spatial databases (Kumar & Kaur., 2018). In the context of groundwater potential assessment GIS enables the identification and mapping of various thematic layers representing different factors affecting groundwater occurrence (Magesh et al., 2012). These layers are then combined using overlay analysis to generate a composite groundwater potential map.

AHP is a multi-criteria decision-making method that enables the prioritization and weighting of different factors based on their relative importance (Sener, et al., 2005). In groundwater potential assessment AHP is used to assign weights to the thematic layers generated in GIS analysis. The weights reflect the significance of each factor in influencing groundwater occurrence. By considering expert opinions and stakeholder preferences AHP ensures a comprehensive and objective assessment of groundwater potential.

This literature review aims to explore the application of GIS and AHP in groundwater potential assessment focusing on the key terminologies and methodologies utilized in this field.

2.2 Sources of Water

Water is a necessary resource for many engineering projects since it has life-sustaining qualities and is important for the growth of infrastructure. To guarantee the sustainability and success of their projects, engineers must locate trustworthy water sources. The various sources of water utilized includes.

2.2.1 Surface Water:

Surface water refers to water sources found above the ground such as rivers lakes and reservoirs. These sources are often used for engineering projects due to their accessibility and abundance. For instance rivers are frequently tapped into for irrigation hydroelectric power generation and water supply systems. However the availability and quality of surface water can be influenced by factors such as rainfall patterns and human activities which may impact the suitability of these sources for long-term use (Brown., 2012).

2.2 2 Groundwater:

Groundwater refers to water stored beneath the Earth's surface in aquifers. It is a significant source of water for engineering projects particularly in regions where surface water is scarce. Groundwater can be accessed through wells and its reliability often surpasses that of surface water as it is less susceptible to natural fluctuations. However over-extraction of groundwater can lead to depletion of aquifers causing land subsidence and long-term sustainability concerns (Gleeson et al., 2012).

2.2.3 Rainwater Harvesting:

Rainwater harvesting involves capturing and storing rainwater for various purposes. It is a sustainable approach to water management particularly in areas with limited access to surface or groundwater sources. Rainwater can be collected from rooftops stored in tanks and used for non-potable purposes such as irrigation toilet flushing and industrial processes. However the availability of rainwater is highly dependent on seasonal variations and geographical location making it less reliable for continuous water supply (Sharma et al., 2012).

2.2.4 Desalination:

Desalination is the process of removing salt and other impurities from seawater making it suitable for human consumption and irrigation. As the global population grows and freshwater sources become increasingly scarce desalination has gained prominence as a viable solution for water supply in coastal regions. However desalination is an energy-intensive process and can have environmental impacts such as brine discharge which requires careful management (. Shannon et al., 2008).

2.2.5 Recycled Water:

Recycled water also known as reclaimed or wastewater is treated sewage or greywater that can be reused for non-potable purposes. It is an alternative source of water that can be used for irrigation industrial processes and even indirect potable reuse through advanced treatment methods. Recycled water reduces the demand for freshwater sources and provides a sustainable solution for water-stressed regions. However public acceptance stringent treatment requirements and potential health concerns may limit its widespread use (Zhang & Qian., 2011).

Engineers must consider various factors when selecting water sources for their projects. Surface water groundwater rainwater harvesting desalination and recycled water each have their advantages and limitations. A comprehensive understanding of the available water sources their reliability and environmental impacts is crucial for sustainable engineering practices. By utilizing a combination of these sources and implementing efficient water management strategies engineers can ensure the long-term success and resilience of their projects.

2.3 Importance of Groundwater

Groundwater is a necessary natural resource that plays a crucial role in various engineering applications. The following are the importance of groundwater;

2.3.1 Sustainable Water Source:

Groundwater serves as a reliable and sustainable source of water for various engineering applications. It plays a critical role in meeting the water demands of communities industries and agriculture especially in regions where surface water is scarce or unreliable (Smith & Johnson., 2018). Groundwater resources can be accessed through wells and boreholes providing a consistent supply of water throughout the year. This accessibility ensures a stable water source for engineering projects that require a continuous water supply. Groundwater represents a vital component of the global water cycle. It serves as a natural reservoir and plays a vital role in maintaining streamflow wetlands and ecosystem balance. Sustainable management of groundwater resources is essential to prevent overexploitation and maintain ecological equilibrium. By conserving and replenishing groundwater engineers contribute to the preservation of natural habitats and the overall well-being of ecosystems.

2.3.2 Geotechnical Engineering:

Groundwater significantly influences geotechnical engineering practices. It affects soil stability foundation design and construction processes. By understanding the behavior of groundwater flow and its impact on soil properties engineers can make informed decisions regarding site selection excavation and soil stabilization techniques (Thompson & Todd., 2019). Groundwater conditions directly impact the stability and performance of infrastructure such as buildings bridges and roads. Groundwater affects soil properties such as permeability compressibility and shear strength. By analyzing groundwater characteristics engineers can accurately predict soil behavior and make informed decisions regarding soil stabilization slope stability and groundwater control measures (US Geological Survey., 2021).This knowledge is vital for the safe and efficient design of infrastructure projects such as dams tunnels and highways.

2.3.4 Environmental Sustainability:

Groundwater plays a crucial role in maintaining environmental sustainability. It helps in replenishing surface water bodies such as lakes rivers and wetlands by providing baseflow during dry periods. Groundwater also supports ecological habitats and sustains biodiversity by ensuring a constant water supply in ecosystems (Wilson & Simmons ., 2017). Moreover groundwater acts as a natural filter purifying water as it percolates through rocks and soils contributing to the overall water quality.

2.3.5 Construction and Foundation Engineering:

Groundwater conditions significantly impact construction projects especially those involving foundation design and excavation. Adequate knowledge of groundwater levels flow patterns and quality is essential for ensuring the stability and durability of structures. Excessive groundwater pressure can lead to soil erosion causing foundation failures. By conducting hydrogeological studies and implementing appropriate measures engineers can mitigate risks and design resilient structures.

2.3.6 Environmental Engineering:

Groundwater is closely linked to environmental engineering particularly in the areas of water supply and wastewater treatment. Many communities rely on groundwater as a primary source of drinking water. Understanding the hydrogeological properties and quality of groundwater is crucial for designing effective water supply systems and ensuring the provision of safe and clean drinking water (US Environmental Protection Agency., 2018). Moreover groundwater remediation techniques are employed to treat contaminated groundwater preventing adverse health effects and preserving the environment.

2.3.7 Agriculture and Irrigation:

Groundwater is crucial for agricultural practices providing a reliable water source for crop irrigation. In regions with limited rainfall or fluctuating weather conditions groundwater irrigation systems ensure consistent water supply enhancing agricultural productivity (US Geological Survey., (2021). Engineers play a pivotal role in designing and managing efficient irrigation systems that optimize water usage minimize wastage and promote sustainable agriculture.

2.3.8 Climate Change Resilience:

Groundwater acts as a buffer during periods of drought or reduced surface water availability caused by climate change. It serves as a dependable water source that can help mitigate the impacts of changing precipitation patterns. By implementing sustainable groundwater management practices engineers contribute to resilience-building efforts and ensure water availability during challenging times.

The importance of groundwater in engineering cannot be understated. It serves as a sustainable water source plays a crucial role in geotechnical engineering practices and contributes to environmental sustainability. By recognizing its significance engineers can make informed decisions to ensure the efficient and responsible use of this valuable resource.

2.4 Occurrence of Groundwater

It is important to understand the geological processes responsible for the formation of groundwater its distribution and its role in sustaining human activities. Additionally it is necessary to analyze the impact of human activities on groundwater resources and propose sustainable strategies for its management.

2.4.1 Formation of Groundwater

Groundwater primarily originates from precipitation in the form of rain or snow. As water infiltrates the ground it percolates through different layers of soil rock and sediment eventually reaching the water table (Birkle, et al., 2018). The water table represents the upper boundary of the saturated zone where the spaces between particles are filled with water. The characteristics of the underlying geology significantly influence the presence and movement of groundwater.

2.4.2 Distribution and Availability of Groundwater

The distribution of groundwater varies across different regions primarily influenced by geological formations. Porous formations such as sand and gravel provide ideal conditions for groundwater storage while impermeable layers like clay can hinder its movement. Aquifers which are underground layers containing significant amounts of water are crucial reservoirs of groundwater. They can be classified into confined and unconfined aquifers based on their interaction with surface water and the presence of overlying impermeable layers.

2.4.3 Factors Influencing Groundwater Occurrence

Several factors affect the occurrence of groundwater. Climate and precipitation patterns significantly impact the recharge rate of aquifers (Todd., 1980). Areas with high and consistent rainfall are more likely to have abundant groundwater resources. Geological characteristics such as the permeability and porosity of rocks and sediments control the movement and storage of groundwater. Additionally topography plays a crucial role as groundwater generally accumulates in low-lying areas.

2.4.4 Human Impact on Groundwater Resources

Human activities can have both positive and negative impacts on groundwater availability. Excessive pumping of groundwater for irrigation industrial use or domestic purposes can lead to overexploitation causing the depletion of aquifers (Ghasemizadeh, et al., 2017). Contamination of groundwater through improper waste disposal industrial pollutants or agricultural chemicals poses a significant threat to its quality and usability. These anthropogenic influences necessitate the adoption of sustainable management practices to ensure the long-term availability of groundwater.

2.4.5 Sustainable Groundwater Management Strategies

To mitigate the negative effects of human activities on groundwater resources sustainable management strategies must be implemented. These strategies include promoting water conservation practices adopting efficient irrigation techniques and implementing strict regulations to control groundwater extraction. Additionally the development of artificial recharge systems such as recharge ponds or infiltration basins can help replenish depleted aquifers. Regular monitoring of groundwater quality and quantity is essential to ensure effective management.

Groundwater occurrence is a complex phenomenon influenced by various geological climatic and human factors. Understanding the processes involved in its formation distribution and availability is crucial for sustainable water resource management. By implementing appropriate strategies and regulations we can ensure the long-term availability and quality of groundwater. As engineers it is our responsibility to prioritize the conservation and efficient utilization of this invaluable resource.

2.5 Rock Properties Affecting Groundwater

Groundwater is a valuable natural resource that plays a crucial role in maintaining ecosystems and supporting human activities. Understanding the properties of rocks that affect groundwater potential is essential for effective groundwater management and sustainable water supply. These properties include;

2.5.1 Rock Porosity

One of the fundamental rock properties that affect groundwater is porosity. Porosity refers to the volume percentage of void spaces within a rock or sediment. Rocks with high porosity can store and transmit large amounts of groundwater making them favorable aquifers. Conversely rocks with low porosity have limited water-holding capacity and act as aquitards or aquicludes impeding groundwater flow. The porosity of rocks is influenced by factors such as grain size sorting and cementation (Freeze and Cherry., 1979).

2.5.2 Permeability

Permeability is another critical rock property that determines the ease of groundwater flow through rocks. It refers to the ability of a rock to transmit fluids and is closely related to the interconnectedness of pore spaces. Highly permeable rocks known as aquifers allow water to flow easily ensuring a sustainable groundwater supply. On the other hand low-permeability rocks such as clays and shales act as barriers to groundwater flow reducing the potential for extraction. The permeability of rocks is influenced by factors such as grain size shape sorting and the presence of fractures or faults (Fetter., 2001).

2.5.3 Rock Heterogeneity

The heterogeneity of rocks including variations in mineral composition grain size and structure significantly impacts groundwater potential assessment. Heterogeneous rock formations often exhibit variations in porosity and permeability leading to the creation of preferential flow paths and localized groundwater accumulation. These variations can result from geological processes such as folding faulting or weathering. Assessing rock heterogeneity is crucial for identifying potential groundwater storage zones and understanding the distribution of groundwater resources within a given area (Fitts, 2012).

2.5.4 Rock Structure

The structural characteristics of rocks including bedding planes joints and fractures play a vital role in groundwater occurrence and movement. Bedding planes are horizontal layers of sedimentary rock that can act as barriers or conduits for groundwater flow depending on their permeability. Joints and fractures are natural fractures in rocks that enhance permeability and can serve as pathways for groundwater movement. These structural features significantly influence groundwater potential assessment by controlling the storage and flow of water within rock formations (Fetter, 2001).

2.5.5 Rock Saturation

Saturation refers to the percentage of pore spaces filled with water in a rock or sediment. Rocks with high saturation are likely to contain significant amounts of groundwater while rocks with low saturation may have limited water availability. The saturation of rocks is influenced by factors such as rainfall evaporation and interaction with surface water bodies. Understanding rock saturation is crucial for estimating groundwater reserves and predicting seasonal variations in groundwater levels (Freeze and Cherry., 1979).

2.5.6 Aquifer Heterogeneity

Aquifer heterogeneity refers to the variation in rock properties within an aquifer system. It can have a significant impact on groundwater flow patterns and storage. Heterogeneity can arise from variations in permeability porosity and the presence of geological structures such as faults or fractures. Understanding aquifer heterogeneity is crucial for accurate groundwater modeling and predicting flow behavior.

In summary rock properties have a significant impact on groundwater potential assessment and play a crucial role in engineering practices related to water resource management. The porosity and permeability of rocks determine the storage and flow of groundwater while rock heterogeneity and structure influence the distribution and movement of water within rock formations. Additionally rock saturation provides insights into the availability and variability of groundwater reserves. By considering these rock properties engineers and hydrogeologists can make informed decisions regarding groundwater exploration extraction and sustainable use.

2.6 Aquifer and Types of Aquifer

Aquifers play a crucial role in the field of engineering and are vital sources of water for various purposes. Understanding the concept of aquifers and their different types is essential for engineers to effectively manage and utilize groundwater resources (Custodio, 2002).

An aquifer can be defined as an underground geological formation that contains and transmits water. It serves as a natural reservoir and plays a significant role in groundwater replenishment and storage. Aquifers are characterized by their ability to store water in the pore spaces between sediment particles such as sand gravel or fractured rock.

2.6.1 Types of Aquifers

Aquifers can be categorized into different types based on their geological characteristics hydrological properties and water flow dynamics. The following sections discuss some of the major types of aquifers.

1. Unconfined/Phreatic Aquifer

The unconfined aquifer also known as the phreatic aquifer is the most common type of aquifer. It is typically found near the surface and is not confined by an impermeable layer. Water in unconfined aquifers is in direct contact with the atmosphere making it vulnerable to contamination. These aquifers are often recharged by precipitation and surface water infiltration.

2. Confined/Artesian Aquifer

Confined aquifers also referred to as artesian aquifers are bounded by impermeable layers above and below. The water in these aquifers is under pressure due to the confinement allowing it to rise above the level of the aquifer. When a well is drilled into a confined aquifer the water may flow to the surface without the need for pumping. Confined aquifers are generally considered less susceptible to contamination compared to unconfined aquifers.

3. Leaky Aquifer

A leaky aquifer is characterized by the presence of both confined and unconfined conditions. It consists of alternating layers of permeable and semi-permeable materials resulting in varying water flow patterns. The confined portions of the aquifer are separated by less permeable layers allowing water movement between different zones. Leaky aquifers are common in regions with complex geological formations.

4. Karst Aquifer

Karst aquifers are formed in soluble rock formations such as limestone or dolomite. These aquifers exhibit distinctive features like sinkholes underground caverns and springs. The dissolution of rock by acidic groundwater creates voids and conduits resulting in rapid water movement and high permeability (Fetter, 2001). Karst aquifers are vulnerable to contamination due to the direct connection between surface and groundwater.

5. Fractured Rock Aquifer

Fractured rock aquifers are characterized by the presence of fractures or fissures in hard rock formations like granite basalt or shale. These fractures provide conduits for water flow and act as storage spaces. Fractured rock aquifers are often challenging to characterize due to the irregular distribution of fractures. Proper engineering techniques are required for efficient extraction of groundwater from such aquifers.

Aquifers are valuable resources that provide water for various engineering applications. Understanding the different types of aquifers is crucial for engineers to ensure sustainable water management practices. By considering the characteristics and classification of aquifers engineers can make informed decisions regarding groundwater utilization and protection (Foster & Chilton., 2003). It is essential to conduct thorough hydrogeological studies and implement appropriate engineering techniques to harness the potential of aquifers while safeguarding their quality.

2.7 The Concept of Groundwater Potential

GIS technology enables the collection storage analysis and visualization of spatial data related to groundwater resources. It provides a powerful platform for integrating various datasets such as geology hydrogeology land use and climate to create comprehensive groundwater potential maps. By overlaying and analyzing these datasets

GIS can identify favorable zones for groundwater occurrence facilitate decision-making processes and support sustainable water resource management.

One of the key advantages of GIS is its ability to handle large volumes of data from diverse sources. Through data integration and spatial analysis techniques GIS can identify areas with high groundwater potential based on factors such as groundwater recharge depth to water table and aquifer properties (Smith & Johnson., 2019). This information is crucial for policy makers water resource managers and engineers involved in groundwater exploration and management.

GIS also enables the creation of thematic maps that represent different aspects of groundwater potential such as groundwater vulnerability well locations and groundwater quality. These maps provide a visual representation of the spatial distribution of groundwater resources allowing stakeholders to identify areas of high potential or areas that require further investigation. Additionally GIS allows for the incorporation of temporal data enabling the monitoring and assessment of groundwater resources over time.

The Analytical Hierarchy Process (AHP) is a multi-criteria decision-making method that helps evaluate and prioritize different factors influencing groundwater potential. AHP allows decision-makers to assess the relative importance of various criteria and sub-criteria and derive a weighted ranking of different areas based on their groundwater potential. This method provides a systematic approach for decision-making considering both qualitative and quantitative factors.

AHP involves breaking down the assessment process into a hierarchy of criteria and sub-criteria assigning weights to each level based on their relative importance and comparing alternatives against these criteria. By using pairwise comparisons decision-makers can rate the criteria and sub-criteria based on their relative importance leading to a consistent and rational decision-making process.

The integration of GIS and AHP offers a powerful tool for assessing groundwater potential. GIS provides the spatial data infrastructure and analytical capabilities while AHP facilitates the decision-making process by assigning weights and priorities to different criteria (Park & Ha., 2018). Together they enable a comprehensive and objective evaluation of groundwater potential considering both spatial and non-spatial factors.

By incorporating AHP into GIS analysis decision-makers can consider multiple criteria such as hydrological parameters geological characteristics land use and socio-economic factors concurrently (Li et al., 2020). AHP allows decision-makers to systematically compare and rank different areas based on their groundwater potential considering the relative importance of each criterion. This integration promotes transparency enhances stakeholder participation and facilitates informed decision-making in groundwater management.

The integration of GIS and AHP provides a robust approach for assessing groundwater potential. By leveraging GIS technology and spatial analysis capabilities decision-makers can analyze various factors influencing groundwater resources. AHP complements GIS by providing a systematic decision-making framework considering the relative importance of different criteria. This integration enhances the accuracy and efficiency of groundwater potential assessment supporting sustainable water management practices. As water scarcity continues to be a global challenge the role of GIS and AHP in groundwater assessment becomes increasingly significant.

2.8 Application of GIS and AHP for Groundwater Potential Analysis

Groundwater exploration plays a vital role in the field of engineering as it involves the identification and assessment of underground water resources. The availability of groundwater is crucial for various purposes including drinking water supply irrigation and industrial use. Geographic Information Systems (GIS) have revolutionized the way engineers analyze and interpret spatial data. In the context of groundwater exploration GIS provides a powerful platform for integrating and visualizing diverse datasets such as geological hydrological and topographical information (Smith., 2019). By incorporating these datasets into a GIS environment engineers can generate comprehensive groundwater maps identify potential aquifers and analyze hydrological processes.

One of the key advantages of GIS in groundwater exploration is its ability to handle complex spatial relationships. Engineers can overlay different layers of data such as land use soil types and geological formations to identify areas with high groundwater potential. By analyzing the spatial patterns and characteristics of these layers engineers can make informed decisions regarding drilling locations and well placement. The spatial analysis capabilities of GIS enable engineers to optimize groundwater exploration efforts and minimize costs.

The Analytical Hierarchy Process (AHP) is a decision-making tool that enables engineers to prioritize and evaluate different criteria and alternatives. In the context of groundwater exploration AHP can be used to assess the suitability of potential drilling sites based on multiple factors such as water quality accessibility and proximity to demand areas. By quantifying and weighting these criteria engineers can rank potential sites and identify the most favorable options.

AHP involves a structured approach that requires engineers to establish a hierarchy of criteria and sub-criteria (Johnson., 2018). The criteria are then evaluated using pairwise comparisons where the relative importance of each criterion is determined. Engineers assign numerical values to indicate the relative importance or preference of one criterion over another. These values are then used to calculate priority weights and generate a final ranking of potential drilling sites.

The integration of GIS and AHP in groundwater exploration offers a comprehensive and efficient approach to decision-making (Wang & Chen., 2017). Engineers can utilize GIS to generate spatial datasets and identify potential drilling sites based on geological and hydrological factors. AHP can then be applied to evaluate and rank these sites based on multiple criteria providing a quantitative assessment of their suitability.

Case Study: Implementation of GIS and AHP in Groundwater Exploration

To illustrate the effectiveness of GIS and AHP in groundwater exploration a case study conducted in a region with limited water resources-Aniocha South LGA. The study aimed to identify potential drilling sites for a new drinking water supply project.

GIS was utilized to integrate various datasets including geological hydrological and land use information. The spatial analysis capabilities of GIS allowed to identify areas with favorable hydrogeological conditions such as permeable formations and proximity to surface water bodies. These areas were considered as potential drilling sites.

AHP was then applied to evaluate and rank the potential drilling sites based on criteria such as water quality accessibility and proximity to demand areas. The pairwise comparisons conducted by the engineers resulted in priority weights for each criterion. The final rankings provided valuable insights into the most suitable sites for drilling.

Groundwater exploration is a crucial aspect of engineering and the utilization of GIS and AHP can greatly enhance the efficiency and effectiveness of the exploration process. GIS enables engineers to analyze and visualize spatial data facilitating informed decision-making regarding potential drilling sites. AHP provides a structured approach to evaluate and rank these sites based on multiple criteria ensuring the selection of the most suitable options. By integrating GIS and AHP engineers can optimize groundwater exploration efforts and contribute to sustainable water resource management.

2.9 Analytic Hierarchy Process

An effective technique for making decisions is the Analytic Hierarchy Process (AHP), which may be used to rank the importance of different groundwater assessment-related criteria. This essay examines how AHP can be applied to groundwater evaluation and how it can help with well-informed decision-making. Analytic Hierarchy Analysis Developed by Thomas Saaty in the 1970s, the Analytic Hierarchy Process is a structured technique that offers a methodical framework for making decisions in difficult situations. AHP entails decomposing a complicated problem into a hierarchical structure of options, sub-criteria, and criteria. Each element is then given a numerical value according to its relative priority or importance. Decision-makers can now quantify their subjective assessments and conduct a thorough examination thanks to this (Cooke, 1991).

2.9.1 Application to Groundwater Assessment

In the context of groundwater assessment AHP can be employed to evaluate multiple criteria that influence the quality and quantity of groundwater resources. These criteria may include hydrogeological parameters water quality indicators socio-economic factors and environmental considerations. By structuring the assessment in a hierarchical manner decision-makers can systematically analyze and compare different factors enabling them to make informed decisions.

For instance in a groundwater assessment project the hierarchical structure may consist of criteria such as aquifer vulnerability recharge potential contamination risk and socio-economic impact. Each criterion can be further divided into sub-criteria such as geological characteristics land use patterns water quality monitoring and economic feasibility. Finally specific alternatives or management strategies can be evaluated within each sub-criterion.

2.9.2 Benefits of AHP in Groundwater Assessment

The application of AHP in groundwater assessment offers several benefits. Firstly it provides a transparent and systematic framework to evaluate and prioritize various criteria. This helps decision-makers to understand the relative importance of different factors and allocate resources accordingly. Furthermore AHP enables the incorporation of both qualitative and quantitative data allowing decision-makers to consider a wide range of information in their assessments.

AHP also facilitates stakeholder participation in the decision-making process. By structuring the assessment in a hierarchical manner stakeholders can provide their input at different levels of the hierarchy ensuring their perspectives are considered. This enhances the overall credibility and acceptance of the assessment outcomes.

Additionally AHP allows for sensitivity analysis which helps decision-makers understand the robustness of their decisions. By varying the weights assigned to different criteria decision-makers can assess the impact on the overall ranking of alternatives. This analysis helps identify critical factors and potential uncertainties in the decision-making process.

2.10 Multi-Criteria Decision Analysis

With increasing demands and potential threats to groundwater quality decision-making processes for groundwater assessment require a comprehensive and systematic approach. Multi-criteria decision analysis (MCDA) has emerged as a valuable tool for evaluating and prioritizing various criteria in decision-making processes. This paper explores the concept of MCDA and its application in groundwater assessment.

Understanding Multi Criteria Decision Analysis:

Multi-criteria decision analysis is a systematic approach that helps decision-makers evaluate multiple criteria simultaneously. It provides a structured framework to assess complex problems where several criteria need to be considered. The goal of MCDA is to identify the best alternative or decision based on a set of predetermined criteria.

The MCDA Process in Groundwater Assessment:

Groundwater assessment involves a range of criteria including water quality quantity accessibility and sustainability. MCDA offers a structured and transparent approach to evaluate these criteria and make informed decisions. The following steps outline the MCDA process in groundwater assessment:

1. Problem Identification: Clearly define the problem or decision to be made in groundwater assessment such as selecting the most suitable location for a well or determining the optimal water extraction strategy.

2. Criteria Selection: Identify and select the relevant criteria that influence the decision-making process. These criteria may include hydrogeological characteristics water quality parameters environmental impacts socio-economic factors and legal considerations.

3. Weighting of Criteria: Assign weights to each criterion to reflect its relative importance. The weights can be determined through expert opinions stakeholder consultations or quantitative methods such as the Analytic Hierarchy Process (AHP) or the Delphi method.

4. Alternatives Generation: Generate a set of alternative solutions or decisions that address the problem. These alternatives may include different well locations water management strategies or pollution control measures.

5. Criteria Evaluation: Assess each alternative against the selected criteria. This evaluation can involve qualitative or quantitative methods depending on the availability of data and the nature of the criteria.

6. Aggregation and Ranking: Combine the evaluations of each alternative and calculate an overall score or ranking. This step involves aggregating the individual criteria evaluations based on the assigned weights.

7. Sensitivity Analysis: Conduct sensitivity analysis to test the robustness of the results and identify the key factors influencing the decision. This analysis helps in understanding the potential impacts of uncertainties and variations in criteria weights.

8. Decision-Making: Based on the results of the MCDA process make an informed decision regarding groundwater assessment. The decision should be transparent and consider the trade-offs between conflicting objectives.

Application and Benefits of MCDA in Groundwater Assessment:

The application of MCDA in groundwater assessment provides several benefits. It enables the integration of various criteria considering their relative importance which leads to more informed and holistic decision-making. MCDA also promotes transparency as the process and criteria weights can be shared with stakeholders enhancing their understanding and acceptance of the decision. Additionally MCDA allows for sensitivity analysis which enhances the robustness of the decision by considering uncertainties and variations in criteria weights.

Multi-criteria decision analysis is a valuable approach for groundwater assessment as it provides a systematic and transparent framework for evaluating and prioritizing multiple criteria. By considering various factors MCDA assists decision-makers in making informed decisions that balance conflicting objectives. Its application in groundwater assessment promotes sustainable management of water resources and ensures the protection of this vital natural asset.

2.11 Terminologies in Groundwater Potential Assessment

Terminologies in Groundwater Potential Assessment

1. Aquifer: A geological formation capable of storing and transmitting groundwater.

2. Recharge: The process of water infiltrating into the ground to replenish groundwater reserves.

3. Permeability: The ability of a material to allow the flow of water through it.

4. Transmissivity: A measure of the ability of an aquifer to transmit water horizontally.

5. Vulnerability: The susceptibility of an aquifer to contamination or depletion.

6. Infiltration: The process by which water penetrates the soil surface and enters the groundwater system.

7. Delineation: The process of defining the boundaries of a specific area or region.

Methodology

The methodology for groundwater potential assessment using GIS and AHP typically involves the following steps:

1. Data Collection: Gathering relevant spatial and attribute data including geological maps hydrological data and land use information.

2. Data Preparation: Preprocessing the data to ensure compatibility and consistency.

3. Weight Assignment: Determining the weights of different factors using the AHP method.

4. Data Integration: Overlaying the thematic layers in GIS to generate a composite groundwater potential map.

5. Validation: Validating the results through field surveys and comparison with existing well data.

6. Interpretation: Interpreting the groundwater potential map and identifying areas of high or low potential.

The integration of GIS and AHP has significantly enhanced the accuracy and efficiency of groundwater potential assessment. By considering multiple factors and their spatial relationships this approach provides valuable insights for decision-makers in water resource management. However it is essential to acknowledge the limitations and uncertainties associated with data quality parameter selection and model assumptions. Further research is needed to refine and validate the methodologies employed in groundwater potential assessment using GIS and AHP.

2.12 Review of Previous Related Literature

In this study by Akeem Alabiagboola in 2021 on Assessment of groundwater potential zones in Oke-Ero LGA of kwara state Nigeria. The author used remote sensing and other GIS based integrated approaches to obtain the thematic maps required for groundwater modelling in the area. AHP was used in ranking the different categories in each map. Results obtained showed the the Oke-Ero LGA of Kwara State has three groundwater potential zones namely; high zone (covering 30.27% and 132.5km^2 of the area), moderate zone (covering 62.35% and 273.1km^2) and low zone (covering 7.38% and 32.32km^2) with the total area being 438km^2. This research shows that with the daily water demand there will be a 3.2% annual increase in the demand for water in this area.

In this study done by Owolabi et al in 2022 on groundwater potential assessment of the sedimentary and basement complex rocks. In this study the authors carried out their research on seventy boreholes to assess the groundwater resources of the sedimentary and basement complex rock terrains. This study shows that the basement complexes have deeper aquifers, thicker groundwater storage and more efficient boreholes than the sedimentary rocks. The ground water obtained from both complex rocks are good for domestic, industrial and agricultural purposes but are not potable due to their weak acidity.

This study done by Anifowose and Aladejana in 2015 on A preliminary assessment for groundwater in a par of north central Nigeria shows that the authors used remote sensing and GIS as the major tool for obtaining thematic maps for this area. This study showed correlation in lineaments and development of new lineaments in some places, it also showed that the linear of curvilinear alignment of healthy vegetation can be a major indicator of groundwater zones that cannot be seen on the surface.

In this study by Oluwagbemi et al in 2022 on delineation of groundwater potential zones indicates the authors use of GIS, remote sensing and hydro-geophysics to carry out this research and to obtain necessary data while AHP and MIF were used in assigning weights to the thematic layers and internal features. This study shows that the area has good aquiferous zones and five different classes namely; very high, high, moderate, low, very low.

A study by Ejepu et al done in 2015 on integration of geology, remote sensing and geographic information system in assessing groundwater potential shows that the topic clearly highlights the method employed by the authors while normalize weights were gotten using the AHP. This method was used in obtaining groundwater potential maps for this region. Results obtained shows four different potential zone which can be very good, good, moderate or poor zones. This study proves that the integration of GIS and good knowledge in geology is effective in easily locating groundwater zones.

In a study done by Rowland et al in 2023 on Investigating groundwater potential in northeastern Nigeria basement complexes using geospatial and electrical technique for mapping and assessing ground water in this region. The Analytical Hierarchy Process (AHP) was used in GIS software to incorporate five maps of components impacting the suitability of groundwater and movement using weighted layering. Results showed that hydraulic conductivity and longitudinal conductance are greatest towards the west of the region while Transverse resistance and transmissivity are greatest in the east. The region has enormous groundwater development potential for sustainable and profitable extractions.

In a study done by Stanley in 2021 on assessment of groundwater potential zones. In this study the author used AHP and GIS technique. Result obtained shows that the maps gotten has been divided into four zones (good, moderate, poor and very poor), each of which represents 19.3, 12.9, 57.8, and 10% of the study area. This procedure produces highly reliable results that can aid in long-term development and strategic use of groundwater resources in this area.

In this study by Akinlalu et al in 2017 on application of multi-criteria decision analysis in prediction of groundwater resources potential. The author used the GIS and AHP technique. Results obtained shows classification of the area into, low, medium and high groundwater potential zones. Validation of the model from well information and two aborted boreholes suggest 70% agreement.

In a study by Olubukola et al in 2021 on a combined GIS, remote sensing and geophysical methods for groundwater potential assessment. The authors used a combination of GIS, Remote sensing and geophysical methods for groundwater potential investigation. Evaluation of thematic layers was done using AHP. The groundwater potential of the area of study was qualitatively classified into five classes, namely; very high, high, moderate, low, and very low which account for 0.3%, 7.8%, 54.8%, 35.6%, and 1.5% of the total area respectively. The groundwater potential map generated in this research could be used as a basic reference in selecting suitable sites for groundwater resource exploitation in the area in order to ameliorate the current scarcity of water in this region.

In study by Jude et al in 2022 on groundwater exploration using multi criteria decision analysis and analytic hierarchy process. The authors employed the use of remote sensing, Geographic Information System (GIS), and Multi-Criteria Decision Analysis (MCDA) techniques and freely open datasets in mapping groundwater potential zones. Analytic Hierarchy Process (AHP) was used to assign normalized weights to the thematic maps. The resulting Groundwater Potential Zones (GPZ) of the area gave rise to Five classes: Very good, Good, Moderate, Poor and Very Poor. The research shows that the maps obtained can be used for selecting sites for groundwater exploitation.

In a study by Jerjera et al in 2022 on groundwater potential zone assessment using integrated analytical hierarchy process-geospatial driven in a GIS environment. The authors used GIS and AHP techniques in this study. The result shows that the distribution of groundwater potential zones was spatially varied in that a high groundwater recharge zone covers 2.4 % of the watershed, a moderate (93.7 %) and a low (3.9 %). The results are reliable and enable water users and decision-makers to sustainably utilize the available groundwater in the study area.

In a study by Watcharin and Bantita in 2022 on assessment of groundwater potential zones and mapping using GIS/RS techniques and analytic hierarchy process. The authors employed the use of GIS and AHP technique. The ground water potential zones are divided into; very high potential, high potential, moderate potential, poor potential, and very poor potential. The mostly groundwater quality distribution represented a moderate potential of about 1,101 km2 (46.01%) to a poor potential of about 1,114 km2 (46.57%) from the 2,390 km2 of the study area. This shows that the GWPZ maps should be used when selecting a land or area as groundwater resources are not readily available in this area..

In a study by Pazhuparambil et al in GIS and AHP based groundwater potential zones delineation. The authors used the GIS and AHP technique in this study to identify or assess groundwater potential zones. The result obtained pointed out the following five classes: very poor, poor, moderate, good, and very good. The results were comparable to the actual specific yield data from the field and accuracy was 78.43%.

In study by Ally in 2023 on assessment of groundwater potential zones using remote sensing and GIS-based fuzzy analytical hierarchy process (F-AHP). The resulting GWPZ map shows that 19%, 31%, 28% and 22% of the area are classified as very good, good, moderate, poor and very poor zones.

In this study by Mustapha et al in 2023 on delineation of groundwater potential area using an AHP, remote sensing, and GIS techniques. In this study the GIS and AHP technique was employed for the classification and weighting of various factors based on their impact on groundwater. The result showed four classes of potentiality: very high, high, moderate, and low, occupying 15.22%, 20.17%, 30.96%, and 33.65%, respectively, of the basin’s area. The AUC (area under the curve) was calculated at 80%, indicating the good predictive accuracy of the AHP method. These results will enable water operators to select favorable sites with a high groundwater potential.

In a study by Cherif et al in 2021 on delineation of groundwater potential zones. The authors employed the use of remote sensing, GIS, AHP and geostatistical analysis to evaluate ground water potential and to validate results to ensure accuracy. Result shows that the southern part of the study area has higher groundwater potentials. This helps to identify groundwater ones so as to ensure proper management of these zones.

In a study by Jhariya et al in 2021 on assessment of groundwater potential zone using GIS-based multi-influencing factor (MIF), multi-criteria decision analysis (MCDA) and electrical resistivity survey techniques. The author involved the use of remote sensing, geographic informatic system (GIS), electrical resistivity, MCDA, to assess the potential zones of groundwater occurrence. While normalization was done using the AHP method. The resulting groundwater potential areas that are delineated applying these methods have been categorized into five zones, low, medium, medium-high, high, and very high potential. The groundwater potential zones demarcated show that high potential zones are present in the west and north-eastern portion, while low to medium groundwater potential is located in the central and eastern portion.

In a study by Neelam and Nema in 2022 on a review on groundwater potential zones. The authors employed the use of GIS and remote sensing to identify groundwater potential zones. This study basically highlights the need to demarcate groundwater zones as surface water is no longer a reliable source of water as it is greatly influenced by pollution and weather conditions.

In a study by Sabri and Argjend in 2023 on identification of groundwater potential zones using remote sensing, geographical information system, and analytic hierarchy process techniques. The above topic highlights the method used by the author used to determine the potential areas for groundwater resources. The results obtained through statistical analysis with software were compared with the data collected in the field, a comparison which resulted in an accuracy of approximately 95%. The results are reflected in table form and using maps also prepared with ArcGIS software.

In this study by Fatima et al in 2022 on application of analytical hierarchy process and geophysical method for groundwater potential mapping. The authors used the GIS and AHP. The results showed Five categories of potential zones were determined: very low (8.67%), low (17.74%), moderate (46.77%), high (19.95%), and very high (6.87%) which revealed a good correlation between the high potential groundwater zones and the spatial distribution of high flow wells. This has helped in the proposal of new well sites in this area.

In most of these researches the authors did not include identification of soil type or strata of the respective areas they worked on. This is a very important factor in groundwater potential assessment as varying soil types and strata in varying parts of an area can influence its availability and access groundwater. I will introduce a brief study on the type of soil in that location as one of the factors and as necessary thematic map.

CHAPTER THREE
METHODOLOGY

3.1 Study Area

Aniocha South is a local government area of delta state Nigeria. Its headquarters is Ogwashi-uku. It has an area of 868 square kilometers (335 sq mi) and a population of 140,604 according to the 2006 census. Major occupation of the citizens are farming, and fishing. The major crops grown in the area are cassava, yam, maize, plantain, and vegetables. The people also engage in fishing, trading, and petty businesses.

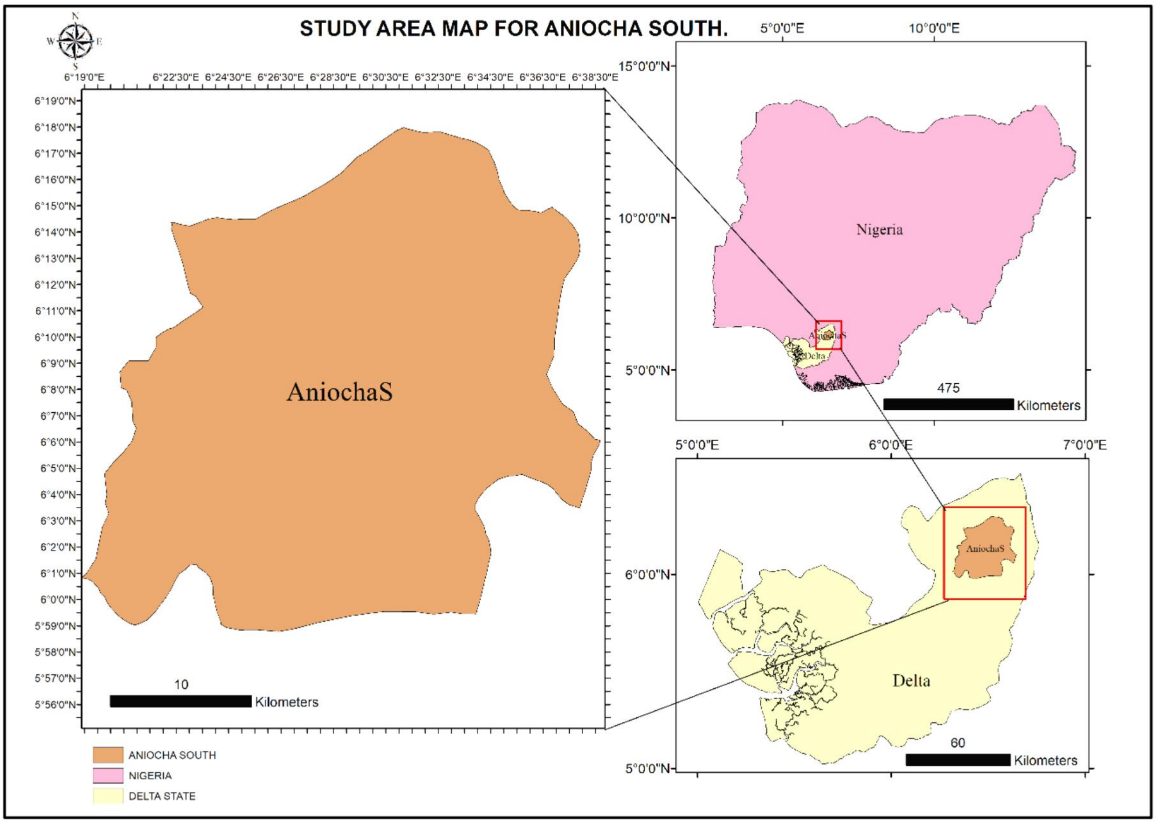

Fig 3.1 Boundary Map Showing Aniocha South LGA

3.2 Materials

The following are but not limited to the materials used in carrying out this project work;

- ARCGIS/ARCMAP 10.8
- Google earth
- GPS

3.3 Data Collection

Using google earth the local government was studied in details with its communities, after which various parameters where used to zone groundwater potential of the local government.

3.3.1 Parameters

Groundwater occurrence and movement are primarily governed by underlying lithology, landform, soil characteristics, lineament and drainage densities, while recharge is regulated by precipitation, land use/land cover type, and rate of penetration (Shao et al. 2020). Groundwater potentiality modeling can be accomplished by looking at the elements that govern groundwater flow, storage, and occurrence. Various parameters such as geology, slope, soil, drainage density, land use/ land cover and rainfall were used to determine the groundwater potential of the local government. Database for these various parameters were collected and these database was used to create the maps for these parameters.The table below shows summary of data sources and its purpose.

Table 3.1a Data and Sources

Data Category	**Data**	**Source**	**Relevance**
Geological map	Geology	USGS	Rock type of the LGA
Land cover map	LULC	ESRI, Sentinel 2	Land use/cover map
Metrological data	Rainfall	CHRS	Net recharge determination

Table 3.1b Data and Sources contd.

Geological data	Soil	FAO	Soil layer of LGA
SRTM DEM	Slope	Open topography	Slope map of LGA
SRTM DEM	Drainage density	Open topography	Drainage density and watershed

3.4 Datatype, Analysis and Sources

3.4.1 Geology map

The geology map for Africa was downloaded from USGS, the boundary map for Nigeria was the downloaded from geo boundaries website. The files were imported to ARCGIS 10.8 and the boundary map for Nigeria was clipped to the shape file for Africa to obtain the shape file for Nigeria. The shape file of the LGA was obtained by clipping the boundary map of Nigeria containing states and then local governments. I was able to identify the map of the local government due to previous studies done using google earth.

The map obtained contained the rock type particular to Aniocha South. Symbology and other features where added to the map to distinguish the various rock types properly. Obtaining this map is very important in GWP as it is one of the most important factors affecting GWP. Geology completely determines the penetration and percolation of groundwater. As a result, it is a crucial criterion for assessing groundwater potential (Aju et al, 2021).

3.4.2 Slope

This map was created by obtaining Digital Elevation Modelling (SRTM DEM) from Open topography website. The file was opened in ARCGIS10.8, using the boundary map for Aniocha South, the DEM for the LGA alone was obtained by clipping and the slope map was first created and then the drainage density map was created. In the arc toolbox, the spatial analysis tool- hydrology-fill, 3D analyst-conversion, were all used in the creation of these maps. Slope is an important geomorphological feature that affects the groundwater potential of a region and an important parameter in identifying groundwater recharge prospects. Groundwater potential is greater in gentle slopes, as more infiltration occurs due to the increased residence time. On the other hand, the increased runoff rate for steep slopes makes them less suitable for groundwater recharge.

3.4.3 Soil

Soil database for the world was gotten from FAO website and the SWAT file which contains the soil description and information was also downloaded. The file was imported to ARCGIS 10.8 and the boundary map of the LGA was clipped to obtain the soil data for the LGA. The SWAT file was then used to find the soil type using the grid code from the attribute table. Soils play an important role in groundwater potential and its characteristics are varied, with respect to grain size and types

3.4.4 Land use/ Land cover (LULC)

Sentinel-2 Land cover map was obtained from ESRI website. The map is a 10m map. The file was imported to ARCGIS 10.8 and the existing boundary map of the LGA was clipped to obtain the LULC data particular to the LGA. Reclassification was done and areas in SQKM and percentile were calculated and added to the attribute table. The map features were added and the map was created showing the use of land in the LGA. Land use id an important factor that determines the water holding capacity of soils. Recharge is largely controlled by the land use. Hence, a proper understanding of land use is necessary for sustainable groundwater development.

3.4.5 Drainage Density

This map was created by obtaining Digital Elevation Modelling (SRTM DEM) from Open topography website. The file was opened in ARCGIS10.8, using the boundary map for Aniocha South, the DEM for the LGA alone was obtained by clipping and the slope map was first created and then the drainage density map was created. In the arc toolbox, the spatial analysis tool- hydrology-fill, 3D analyst-conversion, were all used in the creation of these maps. DEM was used to obtain the streamflow and watershed which was used to create the drainage density map. Drainage, and its density, is a key factor in groundwater potential. The higher the drainage density, the lower the permeability and infiltration

3.4.6 Rainfall

The rainfall data for Nigeria was downloaded CHRS data portal and was imported into ARCGIS 10.8. the LGA boundary file was clipped to obtain rainfall data for Aniocha south. Availability of rainfall improves groundwater recharge possibility. Rainfall data for the year 2021 was used as rainfall varies temporarily.

3.5 Method

With the aid of conversion tools and ArcGIS software, the thematic layers were converted to raster format. Prior to being brought into weighted overlay within the Spatial Analyst Tools in ArcGIS, which was utilized to conduct overlay analysis, each of the theme raster maps had an identical square grid size. Weights were assigned to each class of that specific feature based on its influence on the occurrence, movement, and storage of groundwater using the spatial analysis tool in ArcGIS 10.8. The ranking method was applied to individual parameters of each theme map during weighting overlay analysis. Data such as drainage density, slope, rainfall, soil type, land use, and geology were assigned appropriate weights using expert choice software. In order to produce distinct groundwater potential zones, rates of the corresponding thematic unit were applied along with relative weights to each topic. The groundwater potential zones were produced by using the GIS add function to further integrate all of these thematic raster maps over one another after they had been superimposed using ArcGIS's overlay and union tool. To evaluate both the accuracy and reliability of the results of the research, field data on well water levels and borehole yields as well as gathered data were compared to the study's outcome. Three prospect zones—high potential, moderate potential, and low potential—were identified from the resulting map.

3.5.1 Rank and Weight

In order to map groundwater potential, several thematic layers must be analysed, including geology, drainage density, land use/cover, rainfall, soil, and slope. When identifying the probable zones, each topic is differently necessary. The AHP approach was used to assign weights to each parameter, and the ranks were determined by taking into account previous research projects conducted by the researchers. Weight values ranging from 1 to 100% were allocated to each theme layer, signifying the relative significance of each parameter concerning the impact of infiltration characteristics and events involving groundwater. The Analytic Hierarchy Process (AHP) is used by Expert Choice. According to Saaty (1994), the higher the score, the more closely the choice complies with the standard under consideration. When it comes to weighting the choices, geology was given a higher weight than land use, drainage density and rainfall. Following the assignment of weights to various parameters, the sub-variable's individual ranks were specified. Therefore, the GIS layer on geology, drainage density, land use/cover, rainfall, soil, and slope was carefully examined, and ranks were assigned to each sub-variable; the lowest prospect feature was assigned the smallest figure, and the highest groundwater prospectively was assigned the maximum figure. When taking slope into account, almost level received the greatest value, while higher slope received low rank valence. The shortened drainage density area received higher rank factors owing to its conduciveness to infiltration rather than runoff, whereas higher drainage density areas were assigned a lower score. A lower rank value was given to other regions with low rainfall, while the area with the highest rainfall class was given a higher rank value because this class has more water to recharge the groundwater.

The weight calculation was done manually by first ranking the various factors based on their order of importance in obtaining groundwater. The most important factor was given the highest value and the least important was given the lowest value. The weight calculation was done as follows;

Summing all the values on the first column :6+(6/2)+(6/3)+(6/4)+(6/5)+(6/6)

: 6+3+2+1.5+1.2+1= Y

Dividing each value by 14.7 we have;

6 ÷ Y= A
(6/2) ÷ Y = B
(6/3) ÷ Y= C
(6/4) ÷ Y= D
(6/5) ÷ Y= E
(6/6) ÷ Y= F. The sum of all weights must be equal to 1.

Table 3.2 Weight calculation table

Factors	Geology	Slope	Soil	LULC	Drainage Density	Rainfall	Weight
Geology	6	5	4	3	2	1	A
Slope	6/2	5/2	4/2	3/2	2/2	1/2	B

Soil	6/3	5/3	4/3	3/3	2/3	1/3	C
LULC	6/4	5/4	4/4	¾	2/4	¼	D
Drainage Density	6/5	5/5	4/5	3/5	2/5	1/5	E
Rainfall	6/6	5/6	4/6	3/6	2/6	1/6	F
Total							1

Table 3.3a Factors and Method for calculating Weight and Rank

Raster	Factor	Weight Method	Rank Method
Geology	Pleistocene	Multiply A by 100	Using the map the rank for each factor was given.
	Holocene		
	Cenezoic		
	Tertiary		
Slope	Low	Multiply B by 100	Very low slope was given the highest rank
	Moderate		
	High		
Soil	Sandy-loam(Nd-17)	Multiply C by	The soil type was the same hence
	Sandy-Loam(Nd-18)		

Table 3.3b Factors and Methods for Calculating Weight and Rank contd.

	Sandy-Loam(Nd-21)	100	same rank.
	Water bodies		

LULC	Trees	Multiply D by 100	Rank was given according to how the factors help or contribute to the groundwater assessment potential.
	Grasses		
	Flooded vegetation		
	Crops		
	Scrub/Shrub		
	Built up area		
	Bare-ground		
Drainage Density	Very Low	Multiply E by 100	Very high density the lowest rank
	Low		
	Moderate		
	High		
	Very High		
Rainfall	Very Low	Multiply F by 100	Low rainfall has the lowest rank
	Low		
	Moderate		
	High		
	Very High		

3.5.2 GIS Analysis and Modelling of Ground Water Potential Zones

The parameters of the study area were mapped and inputted into a GIS environment for a proper analysis for the hydrological parameters of the study area was done, mapped and inputted in ArcGIS environment. This was done by creating a geo-database for apt data management which involves all dataset used for groundwater potential, namely as rainfall, slope, soil type, geology, drainage density, land use/ cover layers and borehole dept. These parameters were rasterized using same cell and resolution (Akeem, 2021).

After deciding on the grid raster data structure, the hydro-geological parameters that were focused on each raster cell's groundwater potential were scored summaries, and each raster cell weight was assigned accordingly. Each of the five factors—which range from 1 to 5—was given a weight that varied according to its significance for the groundwater prospect. The results are shown in Table 3.2. The importance of each parameter to the groundwater prospect was taken into account while allocating weight and rate. Lastly, to determine the area's groundwater potential zones, all the variables were superimposed using the spatial analysis feature of ArcGIS 10.8 software.

$GP=GrGw+RrRw+ErEw+DrDw+SrSw+LrLw$

where; r= rank, w= weight, GP= groundwater potential

G=Geology, R=rainfall, E=slope, D=Drainage Density S=Soil, L=Land cover

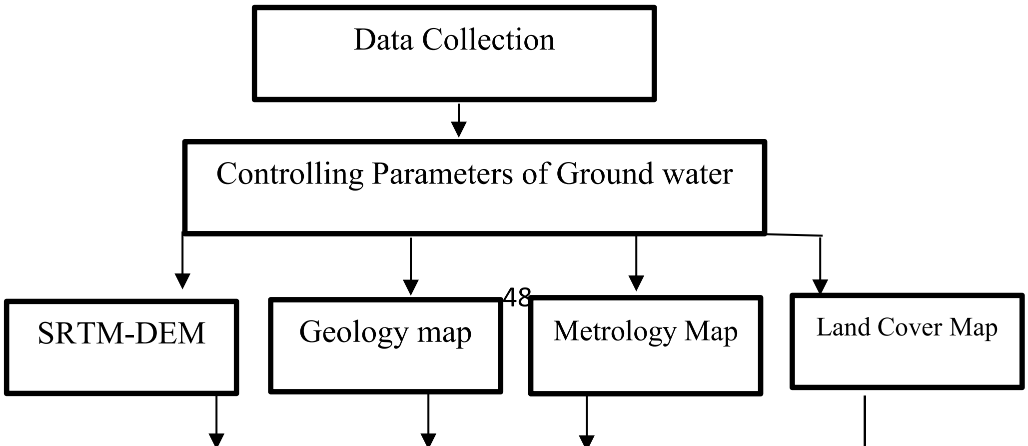

Fig 3.2 Methodology Flow Chart

CHAPTER FOUR
RESULTS AND DISCUSSION

The above mentioned geological parameters such as; rainfall, geology, drainage density, slope, soil and land use/land cover were analysed using GIS and their respective maps were drawn, ranking was done manually. The analysis of each parameter and of results obtained is shown below.

4.1 Ranking and Weightage

The ranking and weightage of parameters was done as follows with the results obtained being shown. Ranking shows the order of importance of one parameter in comparison to another or to others, it shows areas with high potential. Weights are being assigned based on previous evaluations and as seen below, those with higher ranks have higher weights and vice versa. The calculation was done manually using this table below.

Table 4.1 Weight calculation

Factors	**Geology**	**Slope**	**Soil**	**LULC**	**Drainage Density**	**Rainfall**	**Weight**
Geology	6	5	4	3	2	1	0.41
Slope	6/2	5/2	4/2	3/2	2/2	½	0.20
Soil	6/3	5/3	4/3	3/3	2/3	1/3	0.14
LULC	6/4	5/4	4/4	¾	2/4	¼	0.10
Drainage Density	6/5	5/5	4/5	3/5	2/5	1/5	0.082
Rainfall	6/6	5/6	4/6	3/6	2/6	1/6	0.068
Total							1

Table 4.2a Factors, Weight and Rank

Raster	**Factor**	**Weight %**	**Rank**
	Pleistocene		1

Geology	Holocene	41	2
	Cenezoic		3
	Tertiary		4
Slope	Low	20	3
	Moderate		2
	High		1
Soil	Sandy-loam(Nd-17)	14	3
	Sandy-Loam(Nd-18)		3
	Sandy-Loam(Nd-21)		3
LULC	Water bodies	10	5
	Trees		4
	Grasses		5
	Flooded vegetation		5
	Crops		5
	Scrub/Shrub		2
	Built up area		1
	Bare-ground		3

Table 4.2b Factors, Weight and Rank contd

Drainage Density	Very Low		5
	Low		4

	Moderate	8	3
	High		2
	Very High		1
Rainfall	Very Low	7	1
	Low		2
	Average		3
	High		4
	Very High		5

4.2 Estimation of Overall Groundwater Potential Values

The estimation and analysis below helps to assign weights to each sub-parameter and showing the effect these sub=parameters have on groundwater potential. Higher overall Groundwater Potential (GP) value shows higher overall potential of the parameter, a whole parameter can have its effects on the availability of groundwater but that parameter is also made up of individual factors which are more important and which makes up the parameter. These individual factors or sub-parameters are as important as they show regions of high and low concentration and availability of groundwater. For example; in LULC regions that are water related are more likely to have groundwater compared to bareground. The below tables and result shows how the parameters influence the availability of groundwater in Aniocha South local government.

Table 4.3a Overall Ground Water Potential Values

Raster	**Factor**	**Weight %**	**Rank**	**Overall (GP)**

Geology	Pleistocene	41	1	41
	Holocene		2	82
	Cenezoic		3	123
	Tertiary		4	164
Slope	Low		3	60
	Moderate	20	2	40
	High		1	20
Soil	Sandy-loam(Nd-17)	14	3	42
	Sandy-loam(Nd-18)		3	42
	Sandy Loam(Nd-21)		3	50
LULC	Trees	10	4	40
	Grasses		5	50
	Flooded vegetation		5	50
	Crops		5	50
	Scrub/Shrub		2	20
	Built up area		1	10
	Bare-ground		3	30
	Water bodies		5	

Table 4.3b Overall Ground Water Potential Values contd

Drainage Density	Very Low	8	5	41
	Low		4	32
	Moderate		3	24
	High		2	16
	Very High		1	8
Rainfall	Very Low	7	1	7
	Low		2	14
	Average		3	21
	High		4	28
	Very High		5	35

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4.3 Generated Groundwater Potential Factor Maps

Since parameter maps offer crucial input data for modelling groundwater flow and storage, it is customary in groundwater studies to generate parameter maps prior to producing a groundwater potential map. It's crucial to calibrate and validate a groundwater flow model to make sure it's accurate and reliable before utilising it to create a groundwater potential map. In order to match observed groundwater levels or other field data, modellers can modify parameters using parameter maps, which form the foundation for model calibration. It would be difficult to calibrate the model successfully without precise parameter mappings. To effectively estimate groundwater flow and evaluate uncertainty, parameter maps must be created before groundwater potential maps can be created. These maps give us useful input data that improves our ability to model and comprehend groundwater system behavior. Below are the vaious parameter or factor maps and how they influence groundwater potential.

4.3.1 Rainfall Map

The rainfall map is presented in Figure 4.1

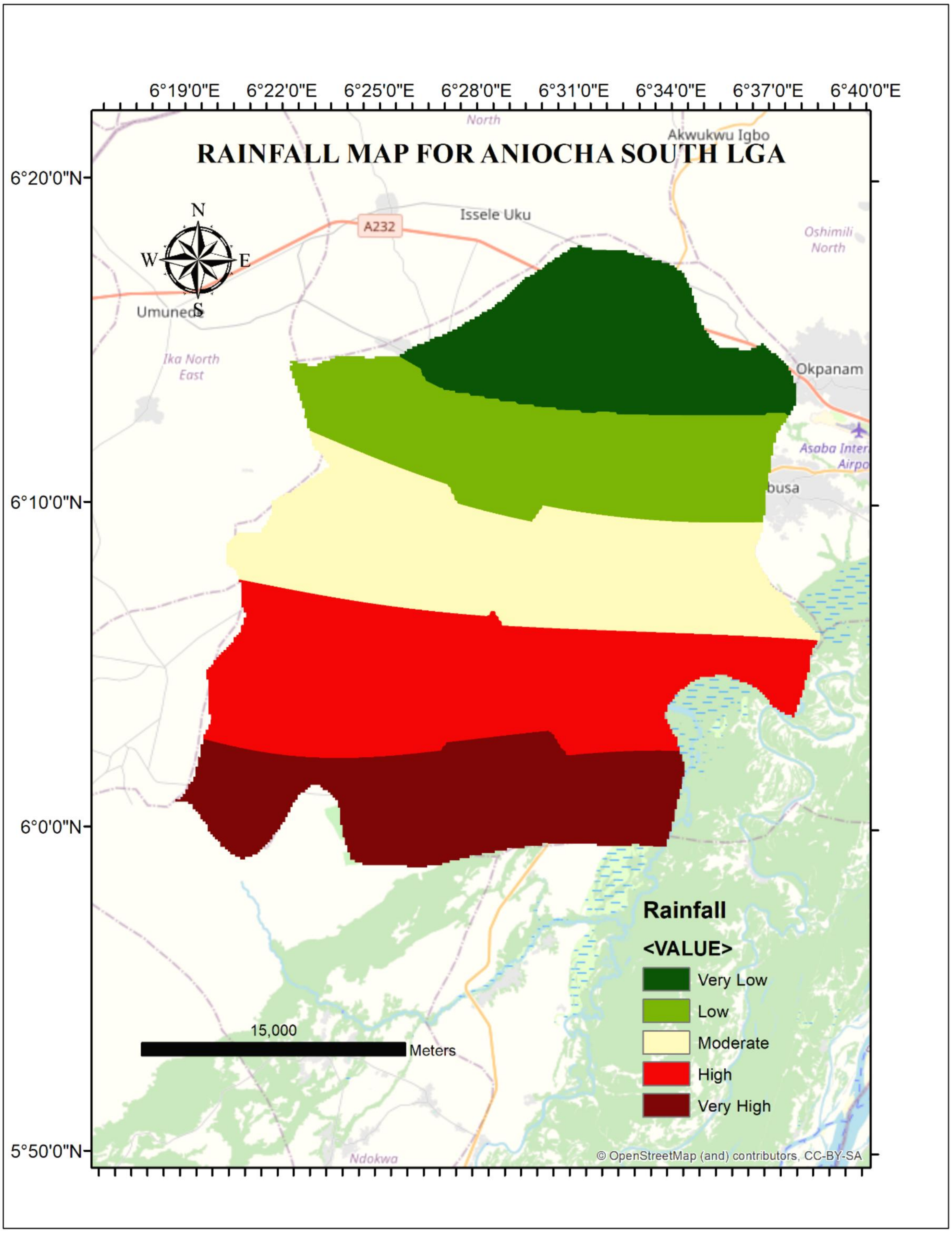

Figure 4.1. Rainfall map for Aniocha South LGA

Rainfall recharge aids in replenishing groundwater storage, which in turn maintains base flow in rivers and streams, nourishes ecosystems that rely on groundwater, and supplies a steady supply of water for industrial, agricultural, and human uses. In order to simulate recharge processes and predict groundwater levels under various climatic conditions and water management scenarios, groundwater potential maps frequently incorporate rainfall data. This understanding of the relationship between rainfall and groundwater recharge is essential for sustainable groundwater management.

Since rainfall is the primary source of groundwater and also naturally regulates groundwater recharge, it is expected that areas with high rainfall availability will have higher levels of infiltration and percolation, while areas with low rainfall availability will have lower levels of infiltration. Figure 4.1 shows the thematic map of the average annual rainfall. Following the discovery of the spatial distribution of rainfall, the entire local government area was divided into five regions (Table 4.3b) using equal intervals. Appropriate weighting was then assigned to each class, taking into account the significance of rainfall for groundwater prospects. The area with the highest rainfall amount was assigned a value of 5, and the area with the lowest amount was assigned a value of 1, taking into account the short interval between the amounts of rainfall.

4.3.2 Drainage Density Map

The Drainage Density map is presented in Figure 4.2

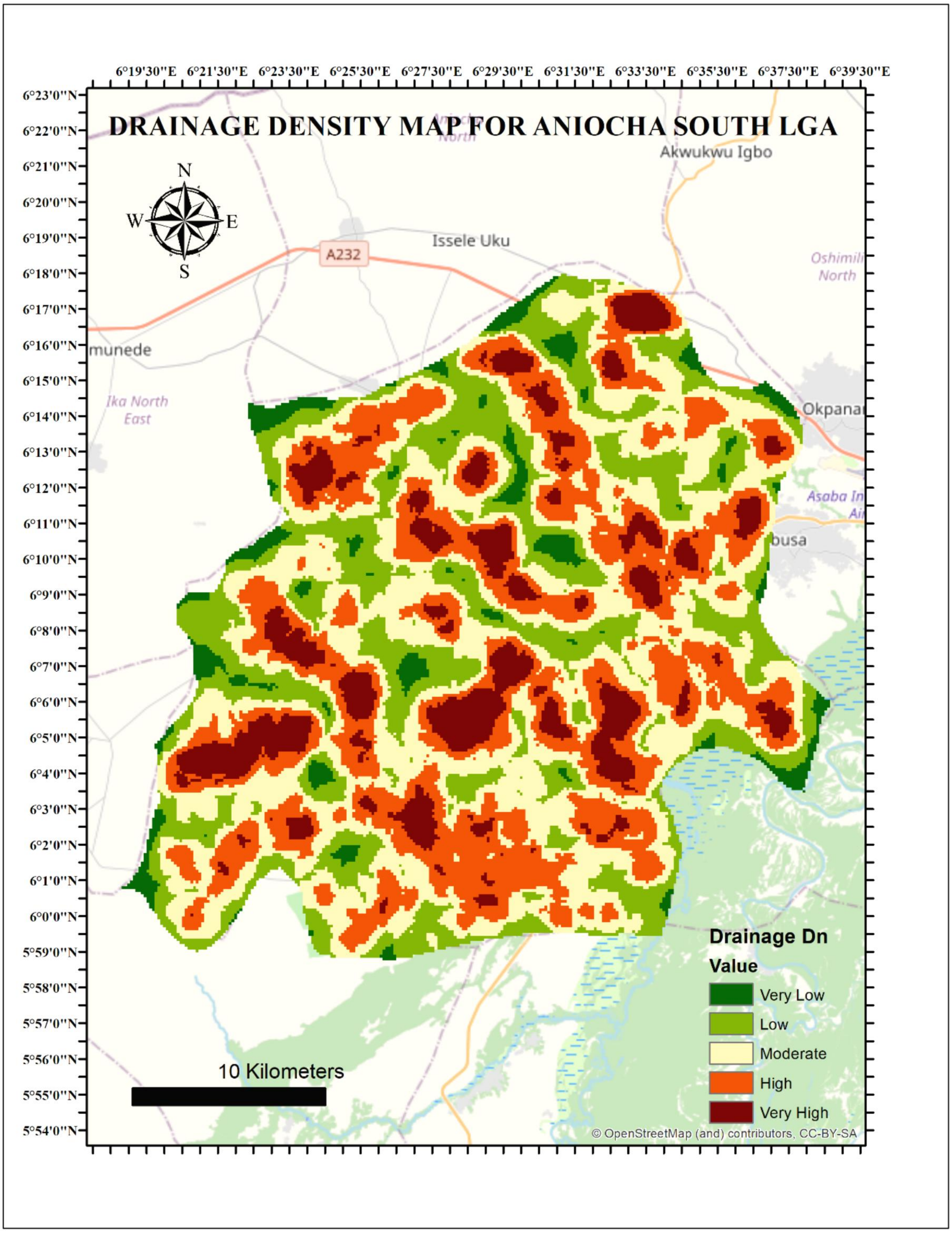

Figure 4.2. Drainage Density Map for Aniocha South LGA

The frequency and abundance of natural or man-made drainage features, such as rivers, streams, and channels, within a landscape is referred to as drainage density. The amount and distribution of groundwater recharge are determined by the drainage density of an area. Surface water runoff is more common in high drainage density regions, which limits the amount of rainfall that can penetrate the soil and replenish the groundwater system. On the other hand, less surface water runoff is more common in low drainage density regions, like semi-arid or arid regions, which permits more rainfall to penetrate the soil and replenish the groundwater system.

Since it determines how well or poorly a watershed drains, drainage density is a significant factor in Potential Groundwater Zones. Figure 4.2. All of the drainage areas are dispersed throughout the study area, as can be seen from the map following analysis of the results, and the drainage densities were divided into five categories (Table 4.3a/b): very low, low, moderate, high, and very high. The study area's low delineated areas were distributed and located near its edge, whereas the moderate and high delineated areas are uniformly distributed throughout the study area. Low drainage areas are rated based on how long they hold onto water, which encourages infiltrations more than high drainage areas. It is ranked low for high drainage and high for low drainage density.

4.3.3 Land Use/ Land Cover (LULC) Map

The LULC map is presented in Figure 4.3.

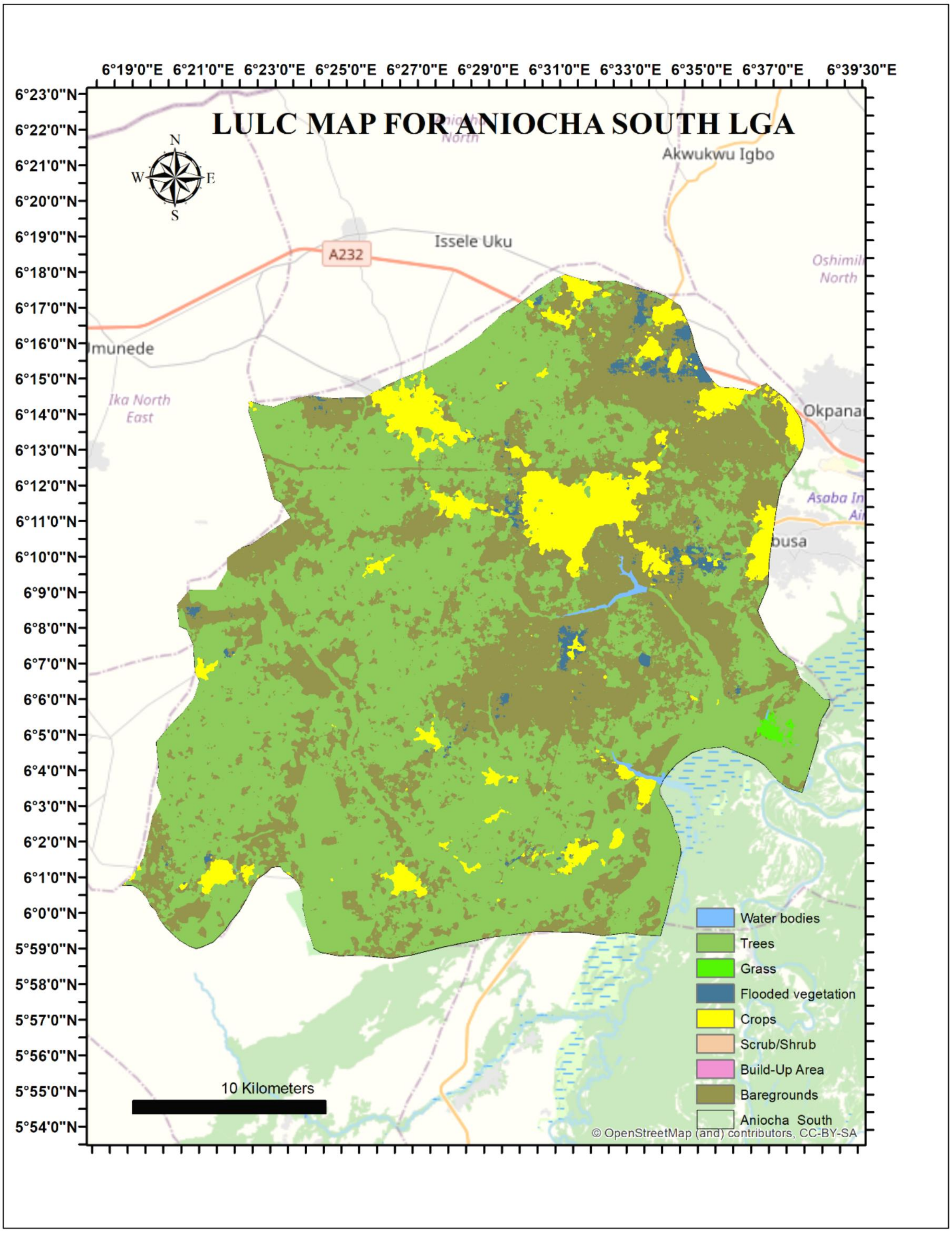

Figure 4.3. LULC Map For Aniocha South LGA

Various land components have their own impact on groundwater potential and on how well they allow rainwater penetrate the ground to encourage groundwater recharge. Urban regions having tarred roads and so many buildings do not have the likelihood of encouraging groundwater recharge as the tarred roads and building encourage runoff but does not permit infiltration. Whereas areas having vegetation, crops, water bodies etc encourage the penetration of water and encourages groundwater recharge, presence of trees and crops covers the ground surface and reduces the rate of evaporation of water from the ground surface. Activities such as mining, deforestation and urbanization causes groundwater depletion, these activities do not encourage groundwater recharge which makes the depth at which water is increase. By changing infiltration rates, recharge rates, and groundwater storage dynamics, land use and land cover have a direct impact on the availability of groundwater.

Figure 4.3 displays the land use/cover map of the research area, which is divided into four primary categories: flooded vegetation, trees, crops, and barren ground. Bare land has the least influence on penetration, whereas vegetation encourages it the greatest. The factors such as trees, crops, flooded vegetation encourage infiltration of water into the soil and are indicators of the presence of groundwater in a particular area, bur bare ground shows low or no groundwater present.

4.3.4 Slope Map

The slope map is presented in Figure 4.4

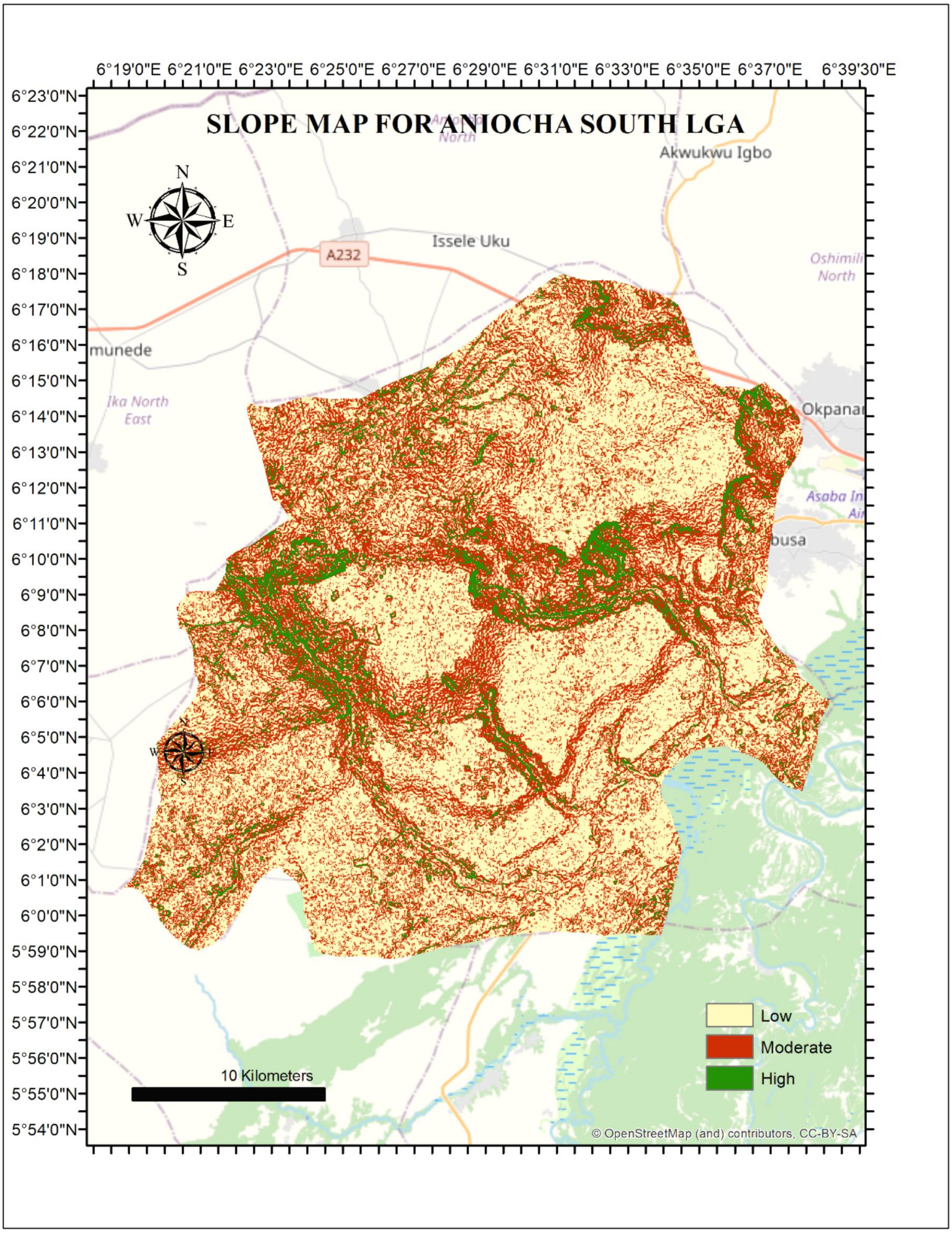

Figure 4.4. Slope Map for Aniocha South LGA

Because of its impacts on groundwater recharge, the land's slope has a major impact on groundwater availability. Surface water runoff is frequently accelerated by sloping topography as opposed to level or slightly sloping regions. However, sloped regions can also encourage rainfall infiltration into the soil, contingent upon soil properties and vegetation cover. Slopes have the ability to capture and focus groundwater flow, particularly in areas where the subsurface contains impermeable or low-permeability layers. These layers may serve as impediments to the flow of groundwater, allowing it to build up and release at the slope's base in the form of seeps or springs. The water table's depth can be affected by the land's slope. In sloping terrain, the water table may be nearer the surface at the slope's base than it is at the ridge or hilltop. Because groundwater discharge increases at lower elevations and recharging occurs more quickly on steeper slopes, the water table may be shallower. The thickness and properties of subterranean aquifers can be influenced by slope. Slope affects sediment movement and erosion processes, which might have an effect on the rate of groundwater recharge. Soil can be removed by erosion, revealing underlying geological formations.

The study area's slope map, which is seen in Figure 4.4, was created. The slope was graded for each of the three groups (low, moderate, high) (Table 4.3a). A nearly level area has the best groundwater potential accumulation zone when it rains because runoff is slow and takes longer to percolate. Conversely, a very high slope area encourages high runoff, which reduces the amount of time it has to accommodate rainwater. As a result, infiltration is less in strong, sloppy areas, which leads to poor groundwater potential.

4.3.5 Soil Map

The soil map of the study area is presented in Figure 4.5

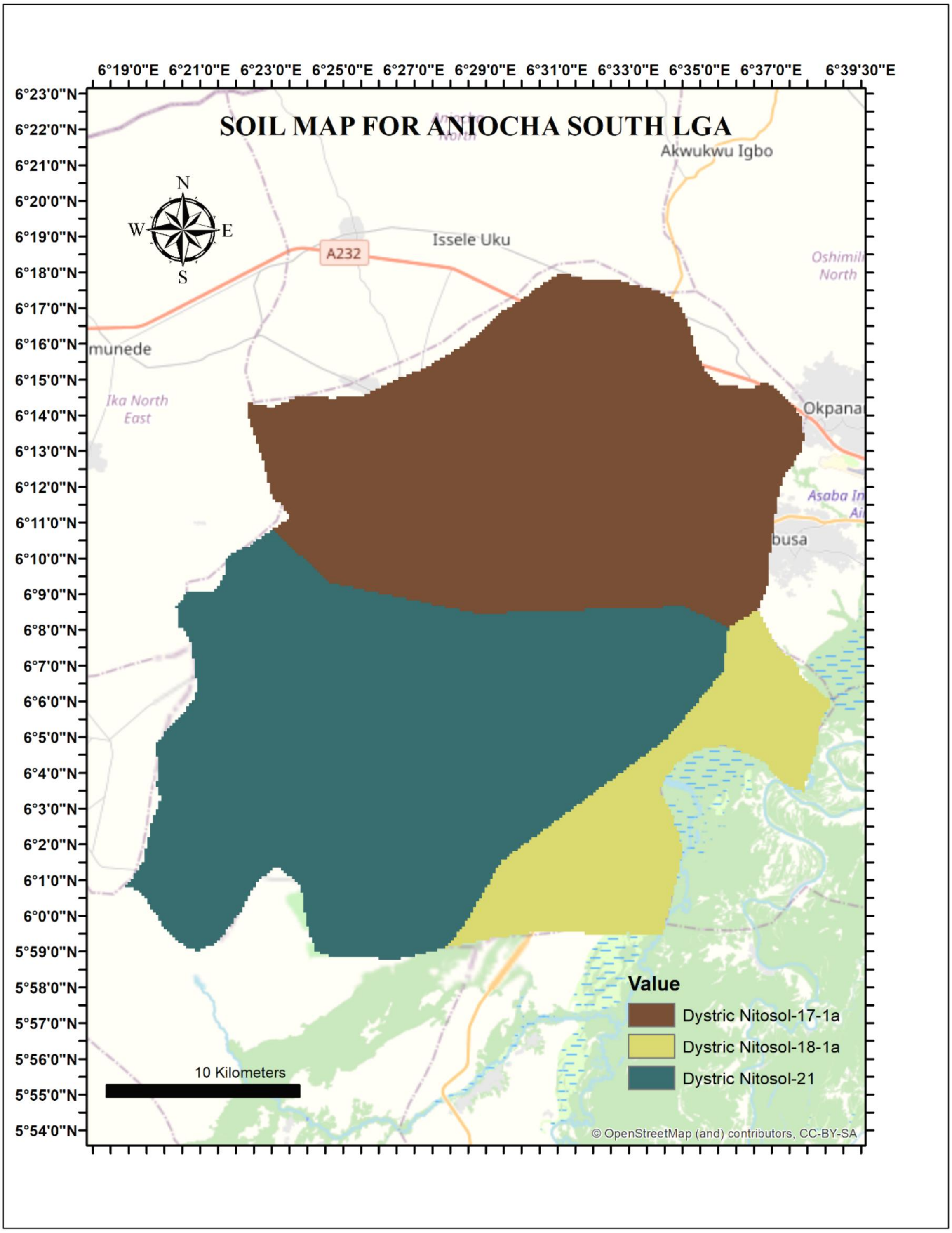

Figure 4.5. Soil Map for Aniocha South LGA

For surface water and precipitation, soil serves as a natural filter and storage area. When precipitation happens, water seeps into the soil through infiltration and percolates into the earth's deeper layers. Numerous characteristics of the soil, including its porosity, structure, texture, and hydraulic conductivity, affect the infiltration rate. Depending on the kind of soil and moisture level, the amount of water that is stored in the pore spaces of the soil might vary. The moisture in the soil is necessary for plant growth, controlling surface runoff, and replenishing groundwater. This stored water helps to maintain soil moisture. In times of drought, soil moisture helps maintain groundwater levels by acting as a buffer against them. Water moves from the surface of the land to subterranean aquifers through the soil. Under the influence of capillary forces and gravity, water can descend vertically once it has penetrated the soil. By recharging aquifers with precipitation and surface runoff, this process—also referred to as percolation or vertical drainage—contributes to the recharge of groundwater. Because they absorb surplus surface water and lower peak runoff rates, soils can help lessen the effects of flooding. The soil type in the study area was studied and created using FAO soil data and soil type details were obtained. It was found that the soil type in this area is the same- Dystric Nitosol (Nd)-which are sandy loams in texture, but are in varying concentrations. Dystric Nitisols are typically sandy loam soils and have quite good water retaining characteristics, Because of the clay and organic matter content of these nitisols, they frequently have a high water-holding capacity. Seasons can affect how Dystic Nitisols behave with groundwater. Saturation of these soils during the rainy season may result in decreased infiltration and possible surface discharge. As soil moisture gradually decreases during the dry season, on the other hand, they might show greater potential for groundwater recharge. The soils were given the same rating as they are all of the same type and influence groundwater potential in the same way.

4.3.6 Geology Map

The geology map is presented in Figure 4.6

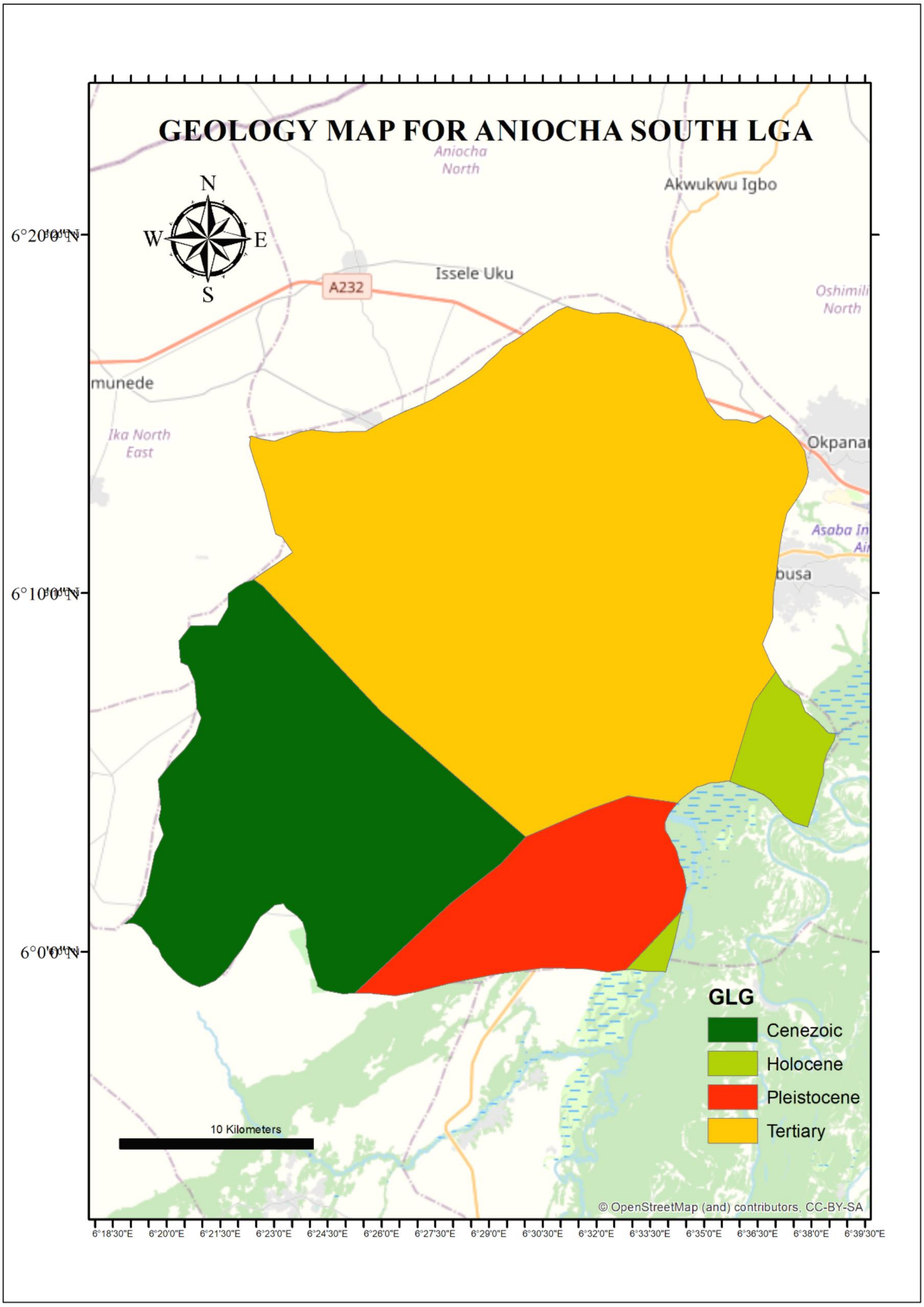

Figure 4.6. Geology Map for Aniocha South.

Aquifers are subterranean layers of rock or sediment that have the ability to store and transfer water. Geology affects how aquifers originate and what their properties are. The geological composition and structure of aquifers determine their porosity, permeability, and storage capacity. Different geological materials have different hydraulic qualities, which affect the amount of groundwater that flows and may be stored. For instance, although impermeable formations like clay or shale limit the movement and storage of groundwater, porous and permeable formations like sandstone or gravel permit water to flow more freely and can store large amounts of groundwater. Groundwater recharge zones are places where surface water seeps into the subsurface to resupply aquifers. Geology defines these zones' locations and features. In geological formations where water can easily percolate through the ground and replenish aquifers, such as karst landscapes, cracked rock, or alluvial deposits, recharge zones are frequently linked. Water interacts with geological materials as it passes through the subsurface, which is how geology affects the quality of groundwater. The chemical makeup of groundwater can be altered by the dissolution of minerals or other pollutants found in some geological formations. Additionally, toxins may migrate into aquifers through geological features like faults or fractures. The state of confined or unconfined aquifers is determined by geology. Unconfined aquifers are not restricted by impermeable formations above them, but confined aquifers are tucked between impermeable layers. The degree of confinement is determined by the geological setting, which also influences groundwater storage, pressure, and contamination susceptibility. The geologic map was created from USGS data base and the rock type distribution is as displayed in figure 4.6.

4.4 GROUNDWATER POTENTIAL ZONES

Figure 4.7. Map showing villages in Aniocha South and surrounding villages and LGA's (sourced from Google)

The above map shows Aniocha South local government map and most of the various villages in it. The map also shows the villages and local government areas surrounding it. The above map will be used to identify the specific villages that have poor, fair, moderate, good and excellent groundwater potentials using the groundwater potential map.

With the aid of this map exact analysis can be made about the groundwater potential of Aniocha South LGA and can directly identify the villages that have good groundwater potential. The groundwater potential map is presented in Figure 8.

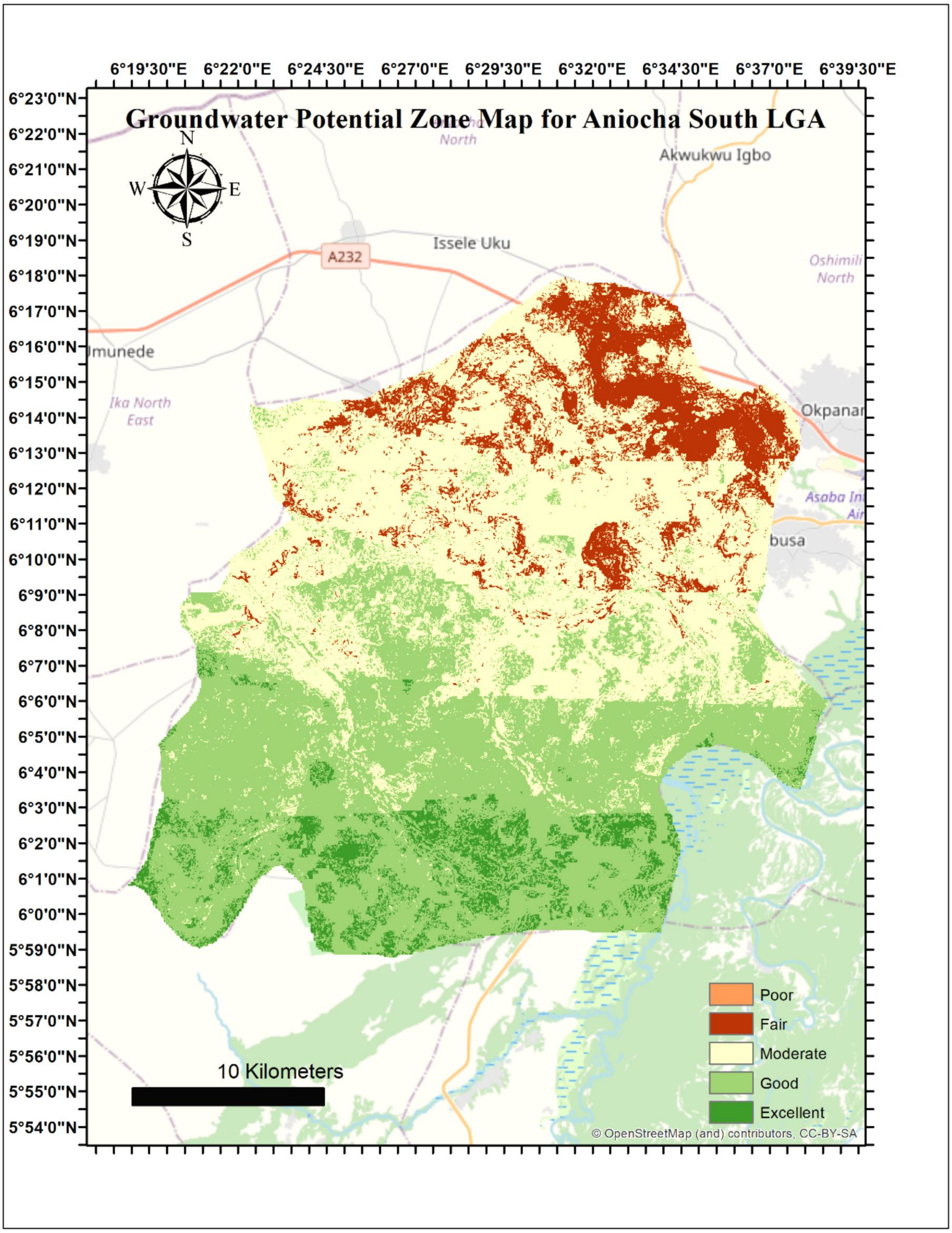

Figure 4.8. Groundwater Potential Map for Aniocha South LGA

Figure 4.8 shows the delineation and depiction of the groundwater potential zones with poor, fair, moderate, good, and outstanding occurrences over the whole region. The groundwater potential zones are color-coded based on the map. The groundwater potential map's results indicate that the high potential zones are located in the south, the low potential zones are in the north, and the moderate potential zones are dispersed throughout the entire study area. The poor potential zone is hardly visible, and the high potential zones are located in the south as small to scattered patches. The overall analysis reveals that a larger portion of the research region is occupied by the good potential zone. The research area's good and moderate groundwater potential zones are suitable for irrigation and groundwater expansion, and they may be used safely to supply water to all sectors of the development there.

Of the total land area, the result from the Groundwater potential map showed that A total of 5.51% of the 47km² area is classified as having excellent groundwater potential; 41.84% of the 360 km² area is classified as having good groundwater potential; 41.5% of the 352 km² area is classified as having moderate groundwater potential; 11.07% of the 95 km² area is classified as having fair groundwater potential; and 0.0165% of the 14 km² area is classified as having poor potential. From the analysis of the maps above areas such as Ubulu-Uku, Ofeogbeje, Ogwashi-Uku have fair and moderate groundwater potential, while Ashama has moderate groundwater potential and areas like Egbudu, Adonte, Olodu, Alidima, Umute etc have good and excellent groundwater potentials.

The overall analysis reveals that a greater area of the research region is occupied by the good potential zone. The study area's moderate potential zones and good groundwater potential zones, are suitable for irrigation and groundwater expansion, and they can be used safely to supply water to all sectors of the development there.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

GIS techniques were used to prepare the thematic layers of six hydrologic and hydrogeologic parameters, namely land slope, soil and geology formation, drainage density, rainfall, and land use/cover, which mainly controlled the groundwater potential as revealed by GIS analysis. This study was conducted to demarcate groundwater potential zones in Aniocha South LGA using a multi-parametric method. Weighted and rank overlay analysis was used in conjunction with a spatial analysis tool in the ArcGIS environment to incorporate the characteristics influencing groundwater accumulation and demarcate groundwater potential zones within the study area. the result from the Groundwater potential map showed that A total of 5.51% of the 47km² area is classified as having excellent groundwater potential; 41.84% of the 360 km² area is classified as having good groundwater potential; 41.5% of the 352 km² area is classified as having moderate groundwater potential; 11.07% of the 95 km² area is classified as having fair groundwater potential; and 0.0165% of the 14 km² area is classified as having poor potential.

In summary, areas such as Ubulu-Uku, Ofeogbeje, Ogwashi-Uku have fair and moderate groundwater potential, while Ashama has moderate groundwater potential and areas like Egbudu, Adonte, Olodu, Alidima, Umute etc have good and excellent groundwater potentials.

This study's findings demonstrate that GIS technology is a powerful tool for evaluating groundwater potential across a wider area, allowing for the more accurate identification of suitable places for groundwater withdrawals. This is suitable for usage as normative Process for long-term planning and management of this vital resource to guarantee groundwater use that is sustainable and the area's impending drinking water and irrigation expansion. Additionally, the current methodology is noted to be able to act as a guide for future study.

5.2 RECOMMENDATION

The following should be done based on the conclusions made;

1. Geology, soil, slope, drainage density, land use, and rainfall are the main elements influencing the occurrence of groundwater in the research region, thus additional high-resolution topography data, such as radar scans, should be used to assist the analysis of these parameters.
2. The general potential map and other maps created as a result are sources of significant information and databases that may be updated at any moment by adding new data for continued growth.
3. Periodically, additional identification and measures of other detail assessment should be carried out for monitoring.

5.3 AREA FOR FURTHER RESEARCH

With so much being done to discover the groundwater potential zones in the area using GIS and AHP method, further confirmation of result can be carried out by well testing, site research on these areas to ascertain the availability and depth of wells present in these areas.

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