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APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING IN GROUNWATER RECHARGE POTENTIAL OF ADO-EKITI, NIGERIA

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ABSTRACT

The increasing demand for freshwater has been on the increase as a result of geometric population growth, erratic climate change and urbanization has necessitated more attention and reliance on groundwater resources most especially in Ado-Ekiti, Nigeria. This necessitates the urgent need for judicious management of available groundwater resources to meet the freshwater requirements in the studied area. Geographical Information System (GIS) and Remote Sensing (RS) techniques were used to map out the groundwater recharge potential of the studied area. Google Earth and Land Satellite (LANDSAT) 7 sensor of Enhanced Thematic Mapper Plus (ETM+), path 191 and row 55 were used to acquire the satellite imageries of Ado-Ekiti. Using high resolution imageries, a Digital Elevation Model (DEM) was developed with Surfer 8 and ArcGIS 10.0 softwares to identify areas with high, medium and low groundwater recharge zones in the studied area. The elevation, slope, land use/ land cover, drainage density, lineament density, lithology, flow direction, flow length and flow accumulation maps of the study area were generated by using the DEM. The groundwater recharge potential was obtained by overlaying all the thematic maps that affected the groundwater distribution. Each thematic map was weighted according to its effect on groundwater infiltration. The results showed that areas with high lineament density, long flow length, high flow accumulation, high drainage pattern, low slope (lowland region) and vegetation have high groundwater recharge potential, and areas with medium lineament density, flow length, flow accumulation, drainage density, slope and sparse vegetation, respectively have moderate groundwater recharge potential while areas with low lineament density, short flow length, low flow accumulation, low drainage density, high slope (highland region) and sparse vegetation have low groundwater recharge potential. Better information on groundwater recharge potential of the studied area was provided via easily read and accessible maps generated from remotely sensed data and ArcGIS 10.0 software. The results also revealed that geology survey should be carried out to validate the results.

Keywords: Geographic Information System, remote sensing, groundwater recharge & potential.

1. INTRODUCTION

The increasing demands placed on the global water supply threaten biodiversity and the supply of water for agricultural, industrial and human needs has reduced drastically. Water shortages already exist in Nigeria, especially Ado-Ekiti with more than one billion people without adequate drinking water and other domestic activities. As water is connected to every forms of life on earth; an adequate, reliable, accessible and acceptable water supply has to be available for various users to carry out different purposes. This study will help in finding lasting solution to the growing need of water resources among users by bringing attention to the assessment of groundwater potential in the studied area. The research aimed at using remote sensing and Geographic Information System (GIS) to assess the groundwater recharge potential in Ado-Ekiti. Water is the most important natural resource and valuable natural asset which forms the major constituent of the ecosystem.

The major sources of clean water are tap, borehole, hand pumps, open wells, streams, and rivers. In the absence of available good water, people begin to use unsafe sources and encounter some health problems. (Pimentel 2008) states that about 90% of the diseases occurring in developing countries result from lack of clean water. It is also predicted that by the year 2025, many African countries will experience water scarcity (WMO, 2002 and 2008). United Nation Environmental Programme (2006) reports that degradation of groundwater is one of the most serious water resources problems in Africa and that is why its management is crucial.

Groundwater is a precious resource of limited extent. For the good use of it, proper prospecting, management, and assessment is required. Due to the increasing number of people living in cities and rural areas as a result of increase in world population; it becomes necessary to scout for other alternative sources of fresh water. One of these sources is groundwater which collects in aquifers that occurs above fresh rocks. In the Basement Complex terrain, groundwater occurs either in the weathered mantle or in the joints and fracture system in the unweathered rocks (Olorunfemi and Olorunmiwo 2006, Ako and Olorunfemi, 2004, Olayinka and Olorunfemi, 2003 in Oguntade and Ariyo, 2009). Successful assessment of groundwater requires in an environment a proper understanding of the areas hydrological and geological characteristics. Nature of hydrological characteristic of an area determines the groundwater quantity and quality of that area. These characteristics also determine the level of water in the aquifer. It is also stated that the water table is a function of topography and climate and the flow pattern of groundwater is a function of climate, topography,and geology. These three terms are called hydrological environment (Toth and Ophori, 2001).

Remotely sensed data and GIS are playing increasing role in the field of hydrology, groundwater resource development, and management. Remote sensing provides multi-spectral, multi-temporal and multi-sensor data of the earth‟s surface (Choudhury, 2009). These tools are very effective in delineating groundwater potential zones and recharge zones. Modern tools of GIS, Remote sensing and Multicriteria analysis using AHP and ground truthing can provide efficient method for delineating groundwater prospect zones in an area and can establish relationship between geological characteristics and yield data in an area (Kavidha and Elangovan, 2013. The increasing demand for drinking water in rural areas of Ado-Ekiti resulting from exponential population growth rate primed the need for increased water supply. Many efforts have been made by governments to make water available in the rural areas through construction of dams and reservoirs, and water treatment plants. The purpose of this is to reduce water shortage in the rural areas of Ado-Ekiti. Despite these efforts, water supply is still in short supply in virtually all rural areas of Ado-Ekiti. Some of the borehole projects have failed due to inappropriate techniques used for their siting. Supply of drinking water in the rural areas of Ado is focused mostly on harnessing and exploiting surface water. This is because the area is mostly underlain by the Basement Complex rocks with probably low permeability and thus poor aquifers due to inadequate information on groundwater condition. This resulted into shortage of water which resulted into taking water from improved water source. Water supply in Ado-Ekiti depends mainly on reservoirs, ponds and hand dug wells. Prior to various borehole projects, several

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government agencies shared the responsibility for the development of domestic water supplies in the state (Wardrop, 2000). Despite these efforts drinking water is still inadequate. This is due to increasing number of population and agricultural expansion in the rural areas of the state. This resulted into taking raw surface water from dams and ponds.

In hard rock terrains composite aquifers of the weathered basement zone and fractured basement are known to give the highest groundwater yield. Olorunfemi et al (1999) reported that the groundwater potential of a basement complex area is determined by a complex inter-relationship between the geology, post emplacement tectonic history, weathering processes and depth, nature of the weathered layer, groundwater flow pattern, recharge and discharge processes. Assessment of groundwater recharge potential using remote sensing and GIS in complement with geophysical method will be of great importance in solving water shortage problem and provides useful data for groundwater prospecting and drilling. A study of this nature is expected to assist in selecting promising areas for further groundwater exploration. Integrated study of this nature can be cost-effective for well sites selection. The aim of this research is to assess the groundwater potential of Ado-Ekiti, Ekiti State using remote sensing (RS) and Geographic Information System (GIS). The specific objectives are to assess the hydrology of the study area; lineament pattern of the study area; and flow pattern of runoff in the study area.

2.MATERIALS AND METHODS

Description of the Study Area

Ado Ekiti is a city in southwest Nigeria, the state capital and headquarters of the Ekiti State. The population in 2006 was 308,621. The Coordinates: 7°37′16″N 5°13′17″E and 7.62111°N 5.22139°E. The tropical climate of the area is characterized by uniformly high temperature and seasonal distribution of bimodal rainfall. The mean daily temperature is usually 320 throughout the year, while mean daily minimum temperature does not usually fall. Generally, there is a long wet season from April to July, followed by a short dry season in August (August break) then another short wet season from November to March. The total annual rainfall increases from a value of 1500mm to a value exceeding 2000mm. The rainfall in this area which is characteristic of tropical rainfall is generally high (Oredipe, and Bakare 2009).

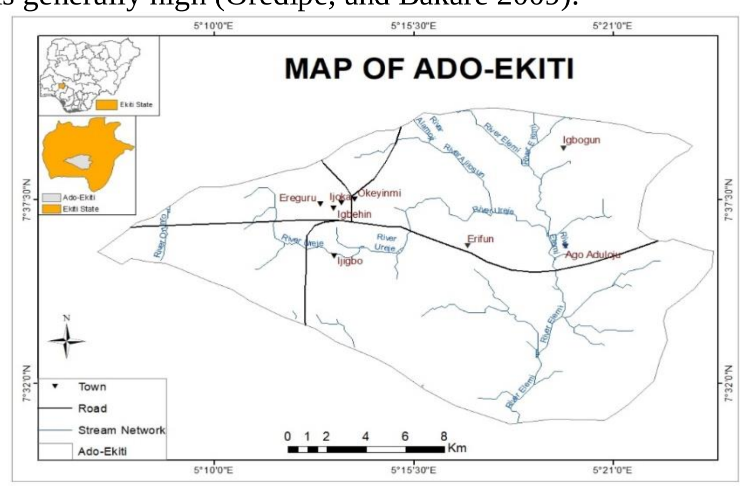

Figure 1: Map of Ado-Ekiti

Data Collection
LANDSAT ETM+ and Google Earth were used to acquire the satellite imageries of the studied area. The map of Ado-Ekiti was scanned and geo-referenced in GIS.

Data Processing
Pre-processing of the data was carried out to eliminate any discrepancies of mismatching during overlaying of the images because georeferencing image was needed. This was achieved with the aid of topographic map and images. Image enhancement was done in order to increase the details of the image by assigning maximum and minimum brightness values to maximum and minimum display values, and it was done on pixels values. This makes visual interpretation easier and assists in data analysis. Image classification was not only done to convert image data into thematic data but also to improve the visual quality and to classify the image into different land use type. The band combination was done through the analyses of reflectance properties of features, correlation matrix of the bands and spectral reflectance curve of known features in all bands. Spectral profile was generated from the image and the different band combinations were made for the analysis.

Data Analyses
Data were analyzed in Surfer 8 and ArcGIS to generate Digital Elevation Model, lineament map, lineament density map, drainage map, soil map, study area map, slope map, land use map, flow accumulation, and flow direction for this project.

Development of digital elevation model (DEM)
The Ado-Ekiti was delineated in Google Earth and several points within the study area were marked within Google Earth and their coordinates and elevations were recorded in a Microsoft Excel spreadsheet. The X, Y and Z point data was exported to surfer 8 software where the data were re-sampled to a grid interval of 10m. The re-sample data was blanked from the blank file and then the digital elevation model of the study area was generated using surfer 8.0.
Development of slope, lineament, drainage and geology maps
The slope, lineament, drainage and geology maps were generated by using the slope, lineament, drainage and geology functions in the 3D hydrology spatial toolbox in ArcGIS 10.0.
Development of flow direction, flow accumulation, and lineament density maps
The flow direction, flow accumulation, and lineament density maps were generated by using the flow direction, flow accumulation, and lineament density functions in the 3D hydrology spatial toolbox in ArcGIS.

3.RESULTS AND DISCUSSION
Digital elevation model (DEM)
The digital elevation model in Figure 2 revealed that Ado-Ekiti consists of areas with low, medium and high elevation within the terrain. Figure 4.1 represents the DEM which ranges between 1the areas with low elevation are likely to have high groundwater potential. The areas with very high elevation are likely to have very low or poor groundwater potential. This involves the interpolating 176 – 190 m. Values from 171-176 m, 177-183m and 184-190m are areas with high, moderate and high groundwater potential.

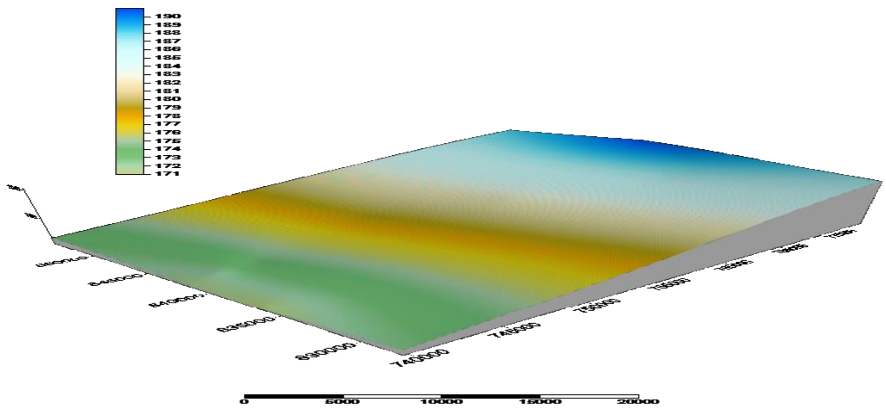

Figure 2: Digital elevation model (DEM)

Slope map of the study area

Lowland region has the tendency to retain water. This implies that it has high groundwater potential, unlike plain region and highland region. Lowland region can retain water. Water flows from the region of highland to plain land and then to lowland. Water retained in highland is less compared to pain land and lowland. Lowland region has high groundwater recharge potential because of the ability to retain water while the highland region is usually dry land. The best region for agriculture and construction purpose is the plain land because it has normal groundwater potential. Plain region is more vulnerable to pollution than the lowland region and highland region because human activities often take place in this region. Industrial and households chemicals and garbage landfills, excessive fertilizers and pesticides used in agriculture, industrial, waste lagoons, tailings and septic system.

The slope map characterizes the percent of terrain slope. It shows the steepness and direction of slope of study area in the descending order of the percent, indicating the directing of flow of water. According to the first level with green colour indicates the low degree of hazard or instability while the second level with yellow colour indicates the high degree of hazard or instability which may lead to loss of arable land and soils and the third level with red colour indicates the higher degree of hazard or instability which may endanger human life and property. The areas with low, medium and high slope have more, moderate and low groundwater potential.

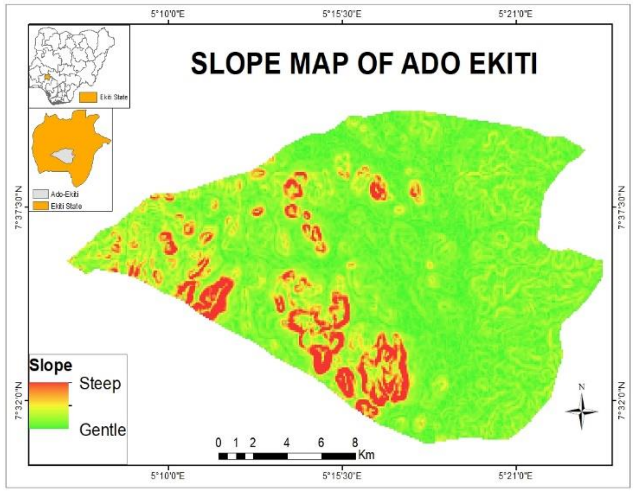

Figure 2: Slope Map Ado-Ekiti

Lineament map of the study area

Figure 3 shows the lineament map. The map was prepared by removing all lineaments that fall on hills, ridges and those on streams and river channels which are presumed not to be structurally controlled in the study area.

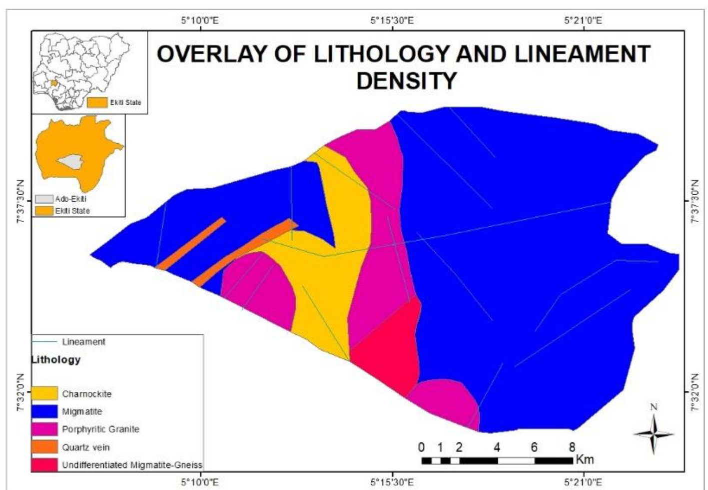

Figure 3: Lineament Map of the Study Area

Lineament density map of the study area

Lineament density map is one of the important thematic maps prepared from the lineaments, which are critically used in groundwater studies related to hard rock terrain ((Subba 1992)), (Krishnamurthy, 1996)). Figure 4 presents the lineament density map of the study area which is a measure of cluster of linear features in a particular area. The peaks in the lineament density contour maps are the places of interest for groundwater resource development. Areas with high lineament density excluding (the residual hill environment) are good for groundwater development (Haridas, 1994).

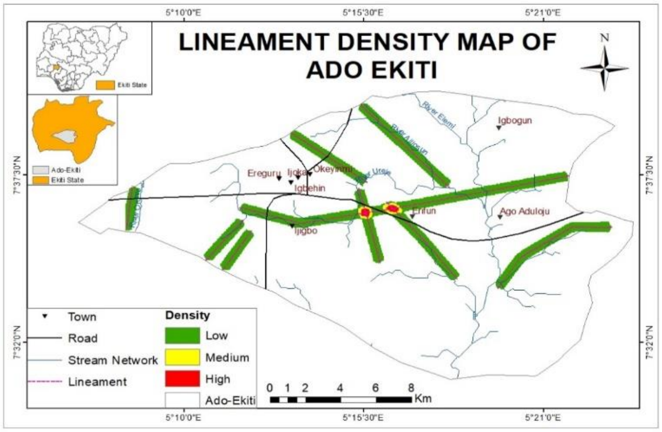

Figure 4: Lineament Density

Flow direction of the Study Area

Figure 5 shows the flow direction of the study area. The areas with long flow length are likely to have high ground water potential, while the areas with medium flow length are likely to have medium ground water potential and areas with short flow length are likely to have low ground water potential.

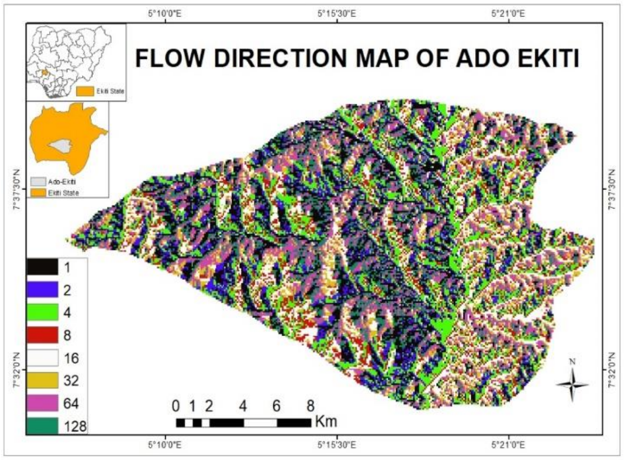

Figure 5: Flow Direction of Map

Flow Accumulation of the study area

The flow accumulation which represents the cell within the study area where water accumulates as it flows downwards was developed by using the flow accumulation function in the spatial analyst tool box and flow length which represents the distance at which water flows in the study area was generated by using the flow length function. In figure 6, the area with high accumulation has high groundwater potential that is the infiltration rate is high in region with high accumulation. The area with low accumulation has low groundwater potential which implies that the infiltration rate is low.

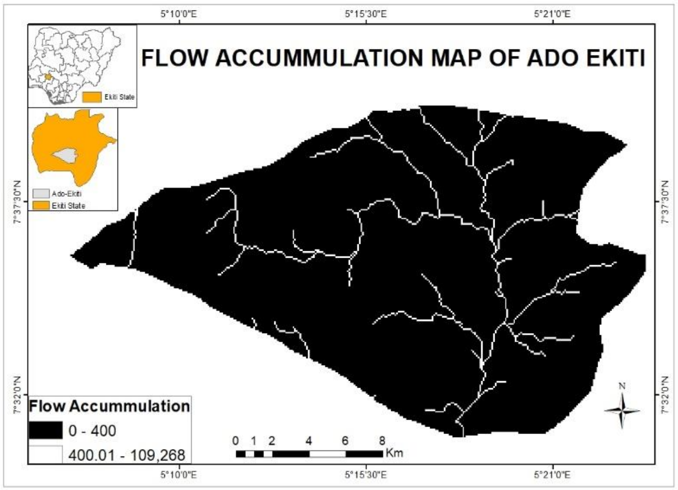

Figure 6: Flow Accumulation

Drainage map of the study area

In Figure 7 areas with high drainage have high groundwater potential while the areas with low drainage have low groundwater potential.

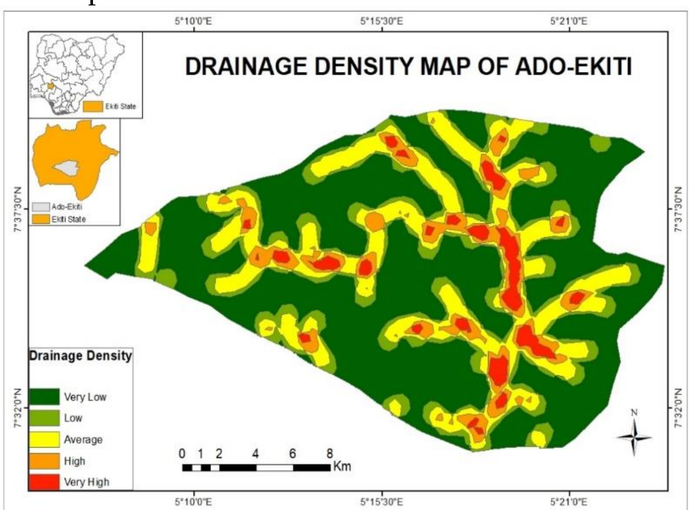

Figure 7: Drainage Map

Geology of the Study Area

In a typical Basement Complex area, groundwater occurs in the weathered mantle or in the joints and fractured basement column and buried stream channels. The rocks are mechanically competent (granites more so than gneisses) and therefore respond to imposed strains by brittle fracture. Surface water percolates down through the fractures and the process of chemical weathering proceeds. Those rocks that have cracks have high groundwater potential while those rocks that have no cracks have low groundwater potential. The area is underlain by the Precambrian Metamorphic and igneous rocks.

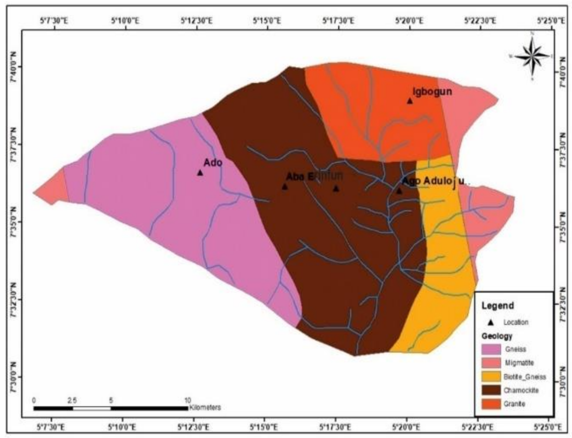

Figure 8: Geology Map

Groundwater Recharge Potential Map

Figure 9 shows the groundwater potential map shows a regional view of the groundwater potential of the basement complex area of Ado-Ekiti. The areas in red colour are with very low groundwater recharge potential and areas in green colour are with average groundwater recharge potential while the areas in green colour are with very high groundwater recharge potential.

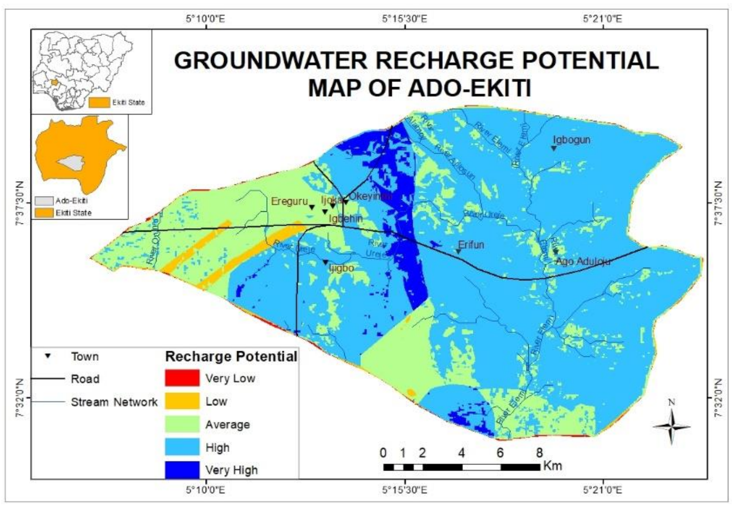

Figure 9: Groundwater Potential Map

4. CONCLUSION

The study area is characterized with three groundwater potential zones which includes low, medium and high. The three groundwater potential zones are directly controlled by some factors which are lineament, lineament density, drainage pattern, geology, flow direction, flow accumulation, slope and elevation. Areas with high lineament lines density, high drainage density, low slope, older granite basement complex, alluvial, hydromorphic and ferruginous soils and high vegetation are areas with high groundwater recharge potential. Some of the areas that have high groundwater are; NTA satellite, Olujoda (Ajilosun), and Omisanjana. Areas with low groundwater potential are areas with low lineament density, low drainage, high slope, high granite basement complex, low flow accumulation, and high elevations; Some of the areas that have low groundwater potential include; Basiri, Adebayo, and Afao. Areas with medium groundwater potential are; Odo Ado and some areas in Ajilosun (Alafia, Akinbami). It is therefore recommended that the use of GIS and RS for the assessment of groundwater potential is very efficient, time and cost effective tools for identification and delineation of groundwater potential zones for rural water supply

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