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Assessment of water shortage in underground aquifer in Abuja during dry season

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Abstract

Water shortage is a complex issue with severe implications for human well-being, agriculture, and ecosystems. Climate change, population growth, and inadequate water management practices contribute to this global problem. This study is to identify the causes of ground water scarcity and determine groundwater potential zones in the Abuja community. The research area's borehole coordinates, Landsat 8 satellite imagery, AsterDEM 30m resolution DEM data, and vertical electrical sounding (VES) data were all used to do this. Unsupervised classification of Landsat imagery was used to create a layer of land use and cover, image filtering techniques were used to improve the visualization of lineament extraction, and density analysis was used to quantify lineament density. AsterDEM data was subjected to surface analysis to acquire elevation data, while VES data were interpolated to produce spatial distributions of the resistivity and thickness parameters. To identify groundwater potential zones, multiple criterion analysis using the analytical hierarchical process (AHP) was utilized to reclassify variables such as land use, elevation, lineament density, resistivity, and thickness. To create the zones, these characteristics were weighted and layered. According to the findings, resistivity levels varied from 6.25 m to 676 m, and the geologic ground structure's thickness ranged from 0.27 m to 92.37 m. Elevation varied from 41 meters to 720 meters, while lineament density ranged from 0 to 0.04. 74% of the land was categorized as vegetated, 21% as built up, 2.7% as water bodies, and 2.3% as rock formations. Within Abuja, zones of groundwater potential were identified as being very low (5%), low (26.7%), marginally high (26.3%), moderately high (28.5%), and very high (13.4%)

Keywords: Groundwater Scarcity; Groundwater Potential; Lineament Density; AHP; DEM; VES Data

1. Introduction

Water availability is critical for ecosystem sustainability and human life, especially in terms of food security [1]. In contrast, water is a finite and non-renewable resource [2]. The hydrologic cycle is critical for the recycling of water through the atmosphere [2]. Only 2.8% of the world's freshwater reserve of 1.37×108 million hams are available, with the vast bulk in the oceans [3]. Groundwater supplies more than 34% of the world's freshwater resources, making it an important alternate water supply for urban and rural development [4]. Groundwater, also known as subterranean water, is water that exists beneath the Earth's surface and can be gathered using wells, tunnels, drainage systems, or pumping [5]. It is a part of the hydrological cycle and can be found in the pores of soil and rocks beneath the Earth's surface. Following precipitation, groundwater rapidly percolates down from bodies of water such as rivers, streams, and lakes. Groundwater occurrence, distribution, and flow are influenced by geological and hydro-geomorphologic

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factors specific to each location [6]. These factors include topography, geological formations, lithology, fracture density, connectivity, slope, groundwater potential, and climatic conditions. Groundwater's dynamic and renewing nature is assessed using groundwater recharge components for sustainable groundwater development and proper groundwater quality management [3]. Groundwater can be recharged through infiltration and percolation [5]. When the infiltration rate exceeds the infiltration power, infiltration occurs, and percolation occurs when the zone's porosity is optimally saturated with water. Water recharges when it runs past the groundwater level, which is an important aspect of the natural water cycle.

This study investigates the reason for the shortage in the accessibility of water in underground aquifers in Abuja. The specific objectives are to: Identify the various factors responsible for groundwater shortage in the study area; determine the groundwater potential zone in the study area; and determine the effect of water shortage in the study area.

1.1. Study Area Map

The study area consists of three local government areas Bwari, Abuja Municipal, and Gwagwalada in Abuja North Central, Nigeria. It lies between latitude 8o 40’ 0’’N and 9o 20’0’’ N and longitudes 7o0’0’’Eand 7o 40’0’’E (Figure 1).

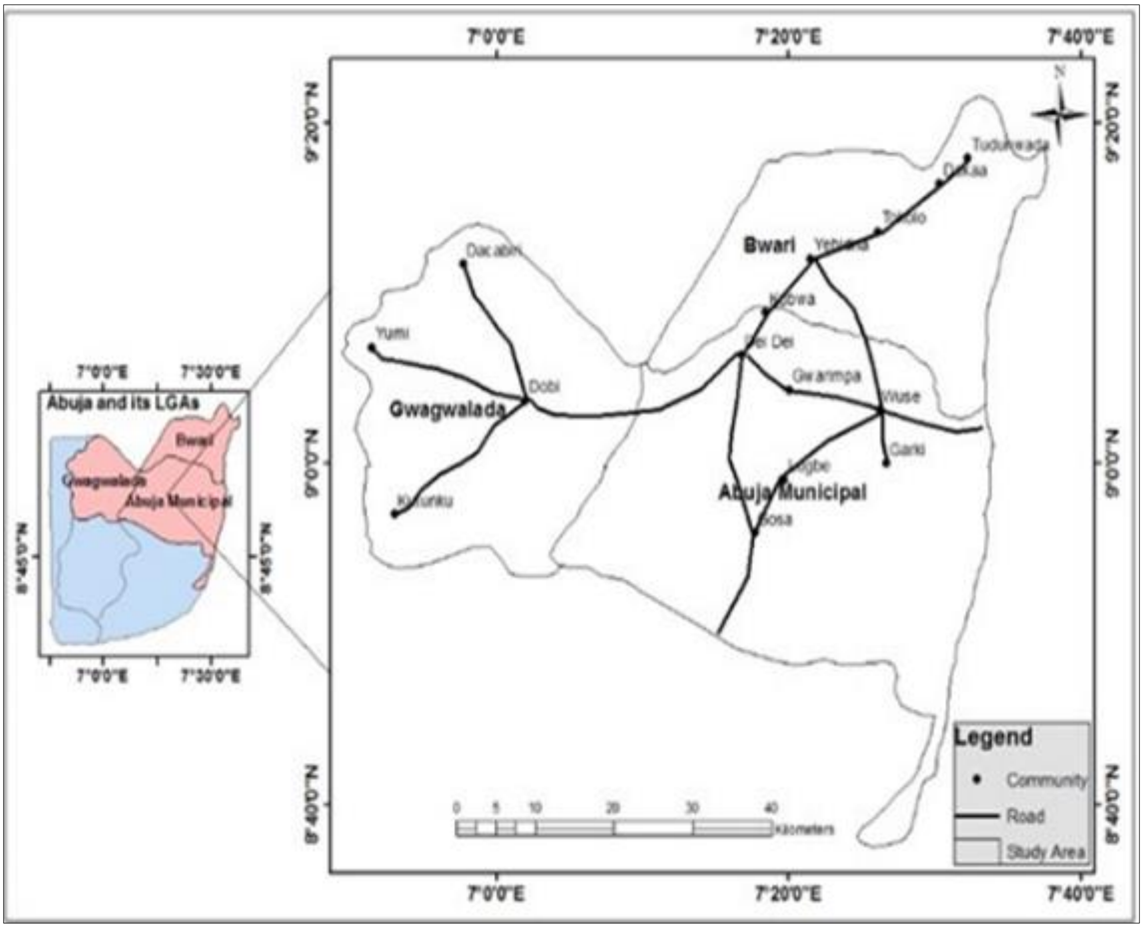

Figure 1 Map of the Study Area

2. Methodology

The data types used for this research consist of primary and secondary data collected for this study as the location information for boreholes within the study area. The secondary data used for this study are Landsat 8 imagery of the year 2021, AsterDEM, and VES.

Table 1 Data Source and Type

Data Acquisition	Data Type	Usage	Source	Date
Coordinates of the wells	Primary	borehole locations	Fieldwork	2021
Vertical electrical-sounding data	secondary	check the resistivity and overburden of the existing wells	Nigeria geological survey	2013
Landsat 8	Secondary	Creating Landuse and for easy identification of lineament extraction	Earth Explorer	14/04/2021
Amsterdam	Secondary	Elevation and Drainage	USGS Earth Explorer	26/11/2009

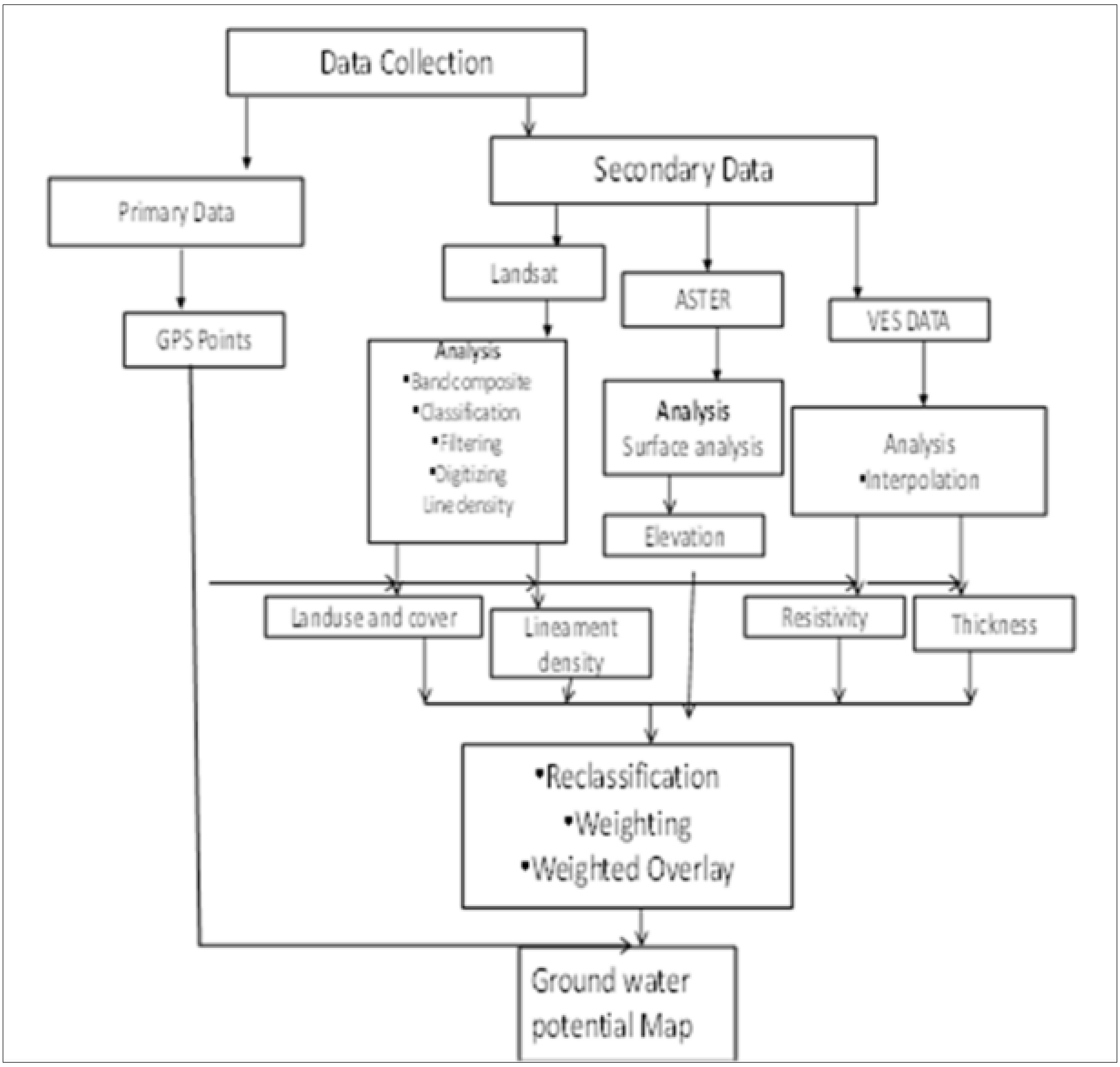

Figure 2 Methodology Flowcharts of the study Area

3. Result and discussion

This chapter shows the presentation of results, their interpretations, and a discussion of the study's specific objectives, such as; identifying the existing boreholes, identifying various factors responsible for groundwater shortage in the study area, and determining the groundwater potential zone in the study area.

3.1. Identifying the Existing Boreholes

Figure 3 and Table 2 shows seventeen existing vertical electrical sounding (VES) spots were found from the study region using the tetrameter model 500 at 23.4 m deep in the cracked basement. The current borehole coordinates obtained from the Nigeria Geological Agency were validated using a global positioning system (GPS).

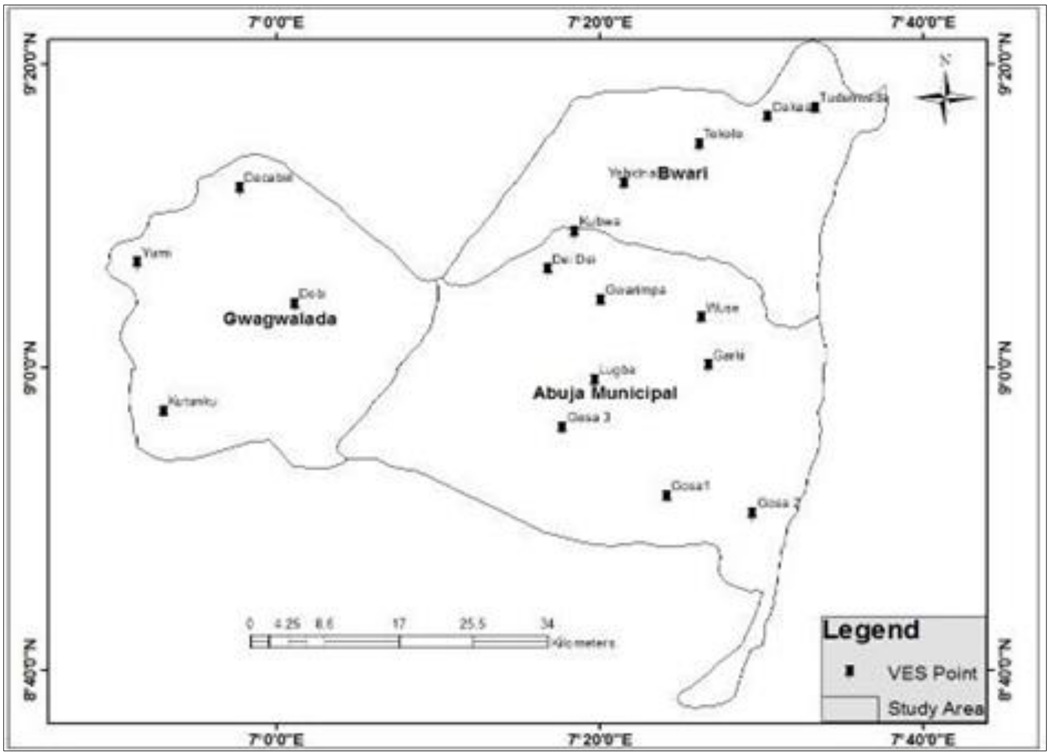

Figure 3 Vertical Electrical Sounding of the study Area

Table 2 Location of the Vertical Electrical Sounding

s/n	Location	X _Coordinate (m)	Y_Coordinate (m)
1	Kubwa	313966.9	1011629.6
2	Gwarimpa	316893.8	1003284.8
3	Wuse	328227.7	1001105.2
4	Garki	329099.6	995313.7
5	Lugbe	316208.8	993570.1
6	Dei Dei	310899.8	1007110.4
7	Yumi	264491.9	1008167.3
8	Tokolo	328132.5	1022248.8

9	Dakaa	335888.4	1025521.1
10	Gosa1	324320.6	979423.2
11	Gosa 2	333973.2	977325.3
12	Gosa 3	312487.3	987822.2
13	Dobi	282260.2	1003029.9
14	Kutunku	267295.8	990030.7
15	Dacabiri	276068.4	1017138.0
16	Yehidna	319635.7	1017494.0
17	Tudunwada	341280.8	1026543.2

3.2. Identifying Various Factors Responsible Groundwater Shortage in the Study Area

The groundwater potential factors identified for this study are resistivity, thickness, lineament density, digital elevation model, and land use of the study area.

3.2.1. Resistivity

The study's vertical electrical sounding method sampled the fractured basement, revealing that the area is dominated by a weathered/fractured aquifer layer. The presence of these fractures supports the groundwater potentials of distinct zones in the research area, and resistivity measurements are dependent on water saturation and subsurface pore space connectivity. The research area's fractured bedrock resistivity ranges from 6.25m to 676.05m (Table 2 and Figure 4).

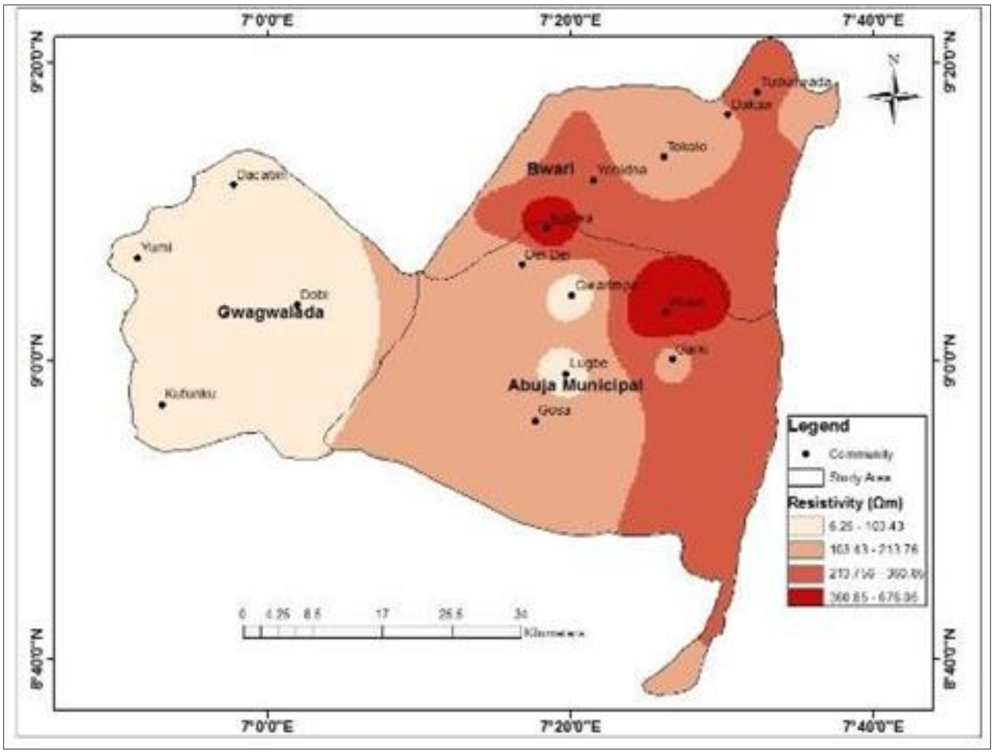

Figure 4 Resistivity of the study Area

3.2.2. Thickness (overburden)

The thickness of the geologic ground structure in the study area ranges from 0.27m – 92.37 m (Figure 5 and Table 3). Thickness value was classed into four classes such as; 0.27m – 11.83m, 11.83m – 27.36m, 27.36m – 49.75m, and 49.75m - 92.37m.

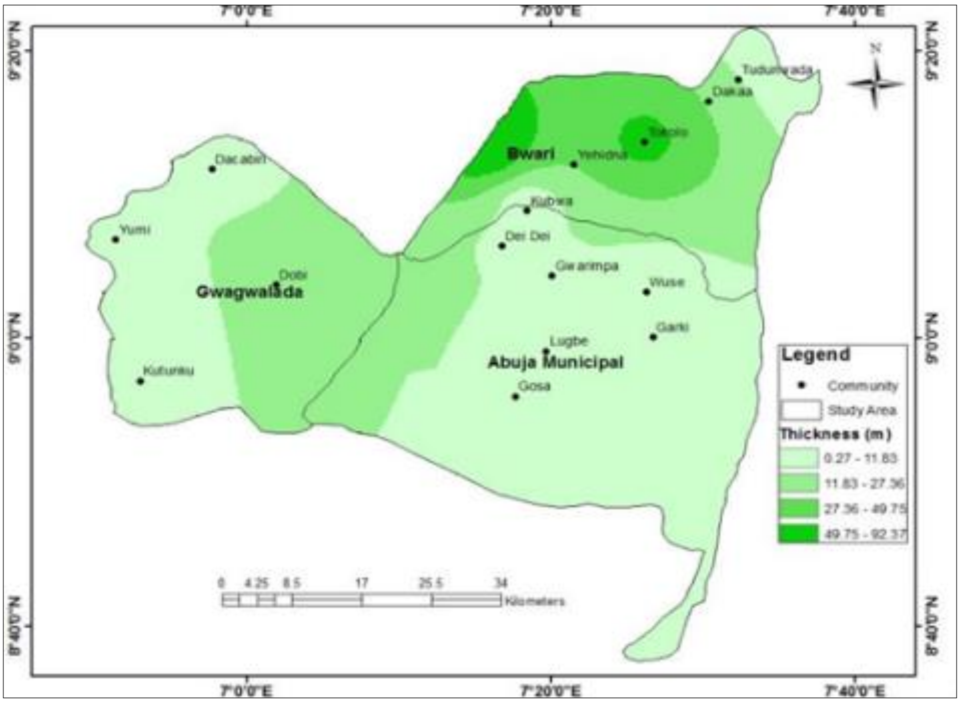

Figure 5 Thickness of the study Area

Table 3 Resistivity and Thickness of the study Area

S/N	Location	Over burden	Resistivity	X coordinate (m)	Y coordinate (m)
1	Kubwa	527	0.8	313966.9	1011629.6
2	Gwarimpa	27	9.8	316893.8	1003284.8
3	Wuse	677	2.8	328227.7	1001105.2
4	Garki	171	2.8	329099.6	995313.7
5	Lugbe	59	2.4	316208.8	993570.1
6	Dei Dei	100	9.7	310899.8	1007110.4
7	Yumi	24.9	1.94	264491.9	1008167.3
8	Tokolo	145	56.6	328132.5	1022248.8
9	Dakaa	250	5.04	335888.4	1025521.0
10	Gosa1	184.3	0.22	324320.6	979423.2
11	Gosa 2	332.8	1.33	333973.2	977325.3
12	Gosa 3	130.5	9.8	312487.3	987822.2
13	Dobi	15.8	24.9	282260.2	1003029.9

14	Kutunku	6.24	2.55	267295.8	990030.7
15	Dacabiri	30	1.1	276068.4	1017138.0
16	Yehidna	152	92.5	319635.7	1017494.0
17	Tudunwada	178	1.5	341280.8	1026543.2

3.2.3. Lineament and Lineament Density

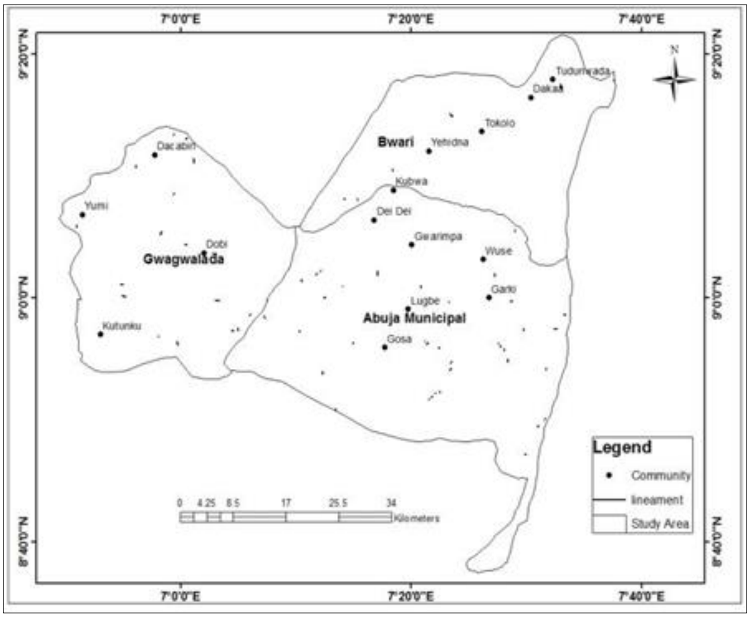

Figure 6A Lineament of the study Area

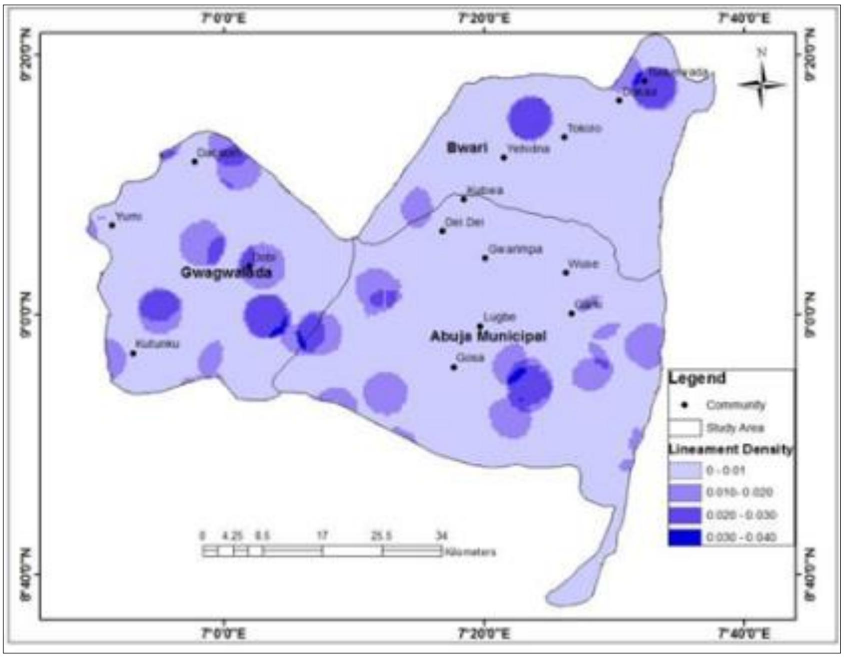

Figure 6B Lineament Density of the study Area

Lineament is a simple or composite linear feature of the earth's surface in which the parts are aligned in rectilinear or slightly curvilinear coherent structures characterized by distinct patterns from adjacent features. However, Lineament density is the frequency distribution of intersections lineaments that occur in a unit area which is purposed to estimate the areas of diverse lineament orientation.

3.2.4. The Elevation

The lowest elevated area with 41 – 249 (m) has high potential zones for groundwater and the aquifer water level for this area recharged fast the area includes; Kutunku, Dobi, Yumi, and Dacabin in Gwagwalada local government. Abuja municipal falls under the gentle elevation and the groundwater recharge is moderate while the larger part of Bwari local government has the highest elevation in the study area such area has low groundwater recharge and the area includes; Dakaa and Tudunwada.

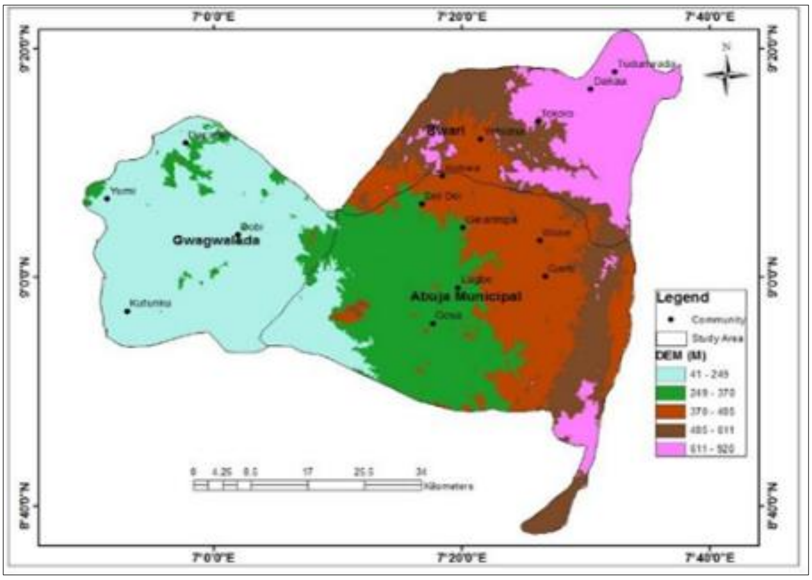

Figure 7 Digital Elevation Model of the study Area

3.2.5. Landuse and Cover (LULC)

The land use and land cover of the study area which was computed using unsupervised classification and the identified features are; vegetation, built-up, water body, and rock (Figure8).

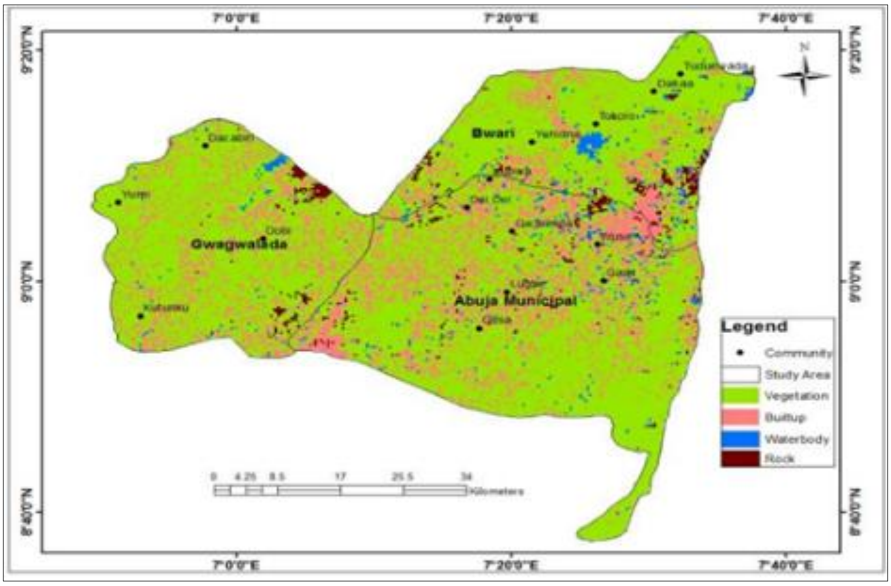

Figure 8 Land-Use/Land-Cover of the study Area

3.3. Identifying the Existing Borehole

The groundwater potential was computed using five weighted thematic parameters layers integrated. The rating reclassification and weight were assigned to different thematic layers using an analytical hierarchical process (AHP). The parameters used were resistivity, thickness, digital elevation model, lineament, and land use/cover (Figure9).

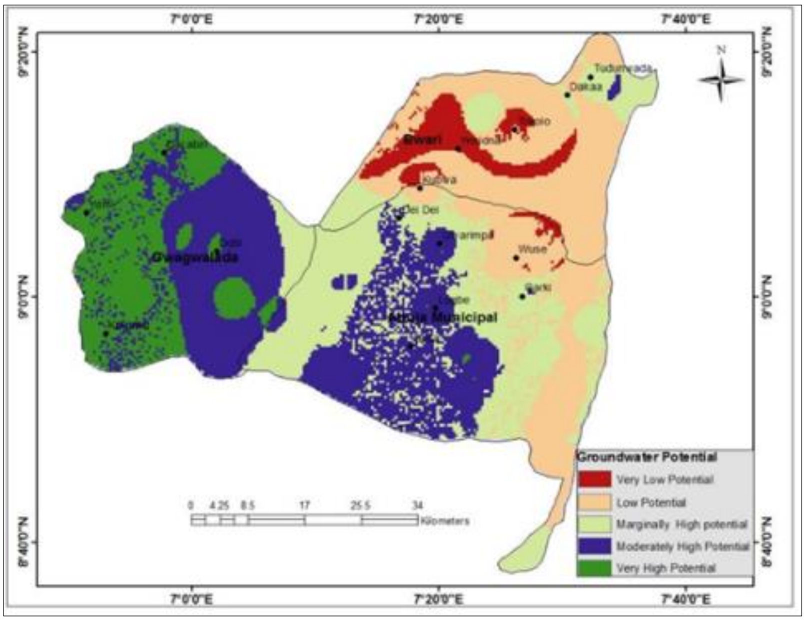

Figure 9 Groundwater Potential of the study Area

4. Conclusion

The Integration of remote Sensing, GIS, and Hydro-geophysics for the delineation of groundwaterpotential zones has proven to be very efficient and effective. This study considered factors such as; lineament density, Landuse/cover, digital elevation resistivity, and thickness for the factors responsible for groundwater potential. These identified parameters were weighted and overlaid toform the groundwater potential map of the study area. They classified it into very low (5%), low (26.7%), marginally high (26.3%), moderately high (28.5%), and very high (13.4%). The very high-water potential is found more prominent in Gwagwalada, and moderately water groundwaterpotential is found in some parts of Gwagwalada and a larger part of Abuja municipal. Wuse and Kubwa experienced low groundwater potential which also spread towards the northeast and very low water potential is found in Bwari local government. The low and very low groundwater potential zones may experience a shortage of water during the dry season.

Recommendation

For productive boreholes in basement complex environments like in the study area, a robust assessment of the weathered basement and fractured basement aquifer parameters should be carried out. This will create opportunities for efficient resource management and reduce the risk of sinking unproductive boreholes. An integrated approach to groundwater potential assessment using remote sensing and GIS is highly recommended.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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