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Geospatial Assessment of Groundwater Potential in Jos South Local Government Area of Plateau State, Nigeria

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***Abstract* - Groundwater occurrence in the Jos-Bukuru Younger Granite Complex of Jos South LGA. is regulated by permeabilities of the crystalline basement complex induced through weathering processes in which aquifers are usually discontinuous and could worsen the issue of water scarcity in addition to an improper sighting of water wells. This study identified the features for determining groundwater potential zones, examine the spatial pattern and relationship between the results obtained from geospatial and geophysical techniques. The study used geospatial techniques to construct and integrate thematic maps based on multi-criteria assessment using Saaty's Analytical Hierarchy method, and geophysical techniques such as Vertical Electrical Sounding (VES) using electrical resistivity method. The findings revealed very high groundwater potential in the northern part of the area characterized by high rainfall, low slope and dominated by cambisols with high relative water retention capacity. Also, moderate to low groundwater potential areas are scattered all over the study area, while the very low is found within the central areas. However, geophysical results overlaid on groundwater potential map coincides with the expected values. Areas with higher value of aquifer thickness such as Vom, Bukuru, and Barakin Columbai have high groundwater potential and areas with low aquifer thickness such as Dutsen Kato, Gyel and Du have low groundwater potential. Generally, from this study, it can be deduced that geospatial techniques such as Remote Sensing and GIS are faster, cost-effective and accurate in assessing groundwater potential zones. This study suggests that the government, decision-makers, and stakeholders in water resources should consider deploying geospatial techniques when conducting groundwater exploration.**

Keywords: Remote Sensing, GIS, Aquifer, Vertical Electrical Sounding, Electrical Resistivity, Basement Complex.

INTRODUCTION

Groundwater is a vital and valuable natural resource that plays a vital role in sustaining life and the ecosystem [1], [2]. This natural resource is found within the earth’s geological formation and its presence depends mainly on the permeability of the formation. Surface water sources serve as recharge zones to enhance any community's groundwater resource [3], [4]. The occurrence and movement of groundwater within the earth's crust are governed by several interrelated factors: land use, geological structures, slope, drainage pattern, soil, and lineament features [5].

The negligence of groundwater to supply an ever-increasing demand contributes to water shortages and pollution. Excessive demand for water, especially for household use, has led to a widespread and intensified quest for water resource, particularly in crystalline basement complex regions where the existence of groundwater is dependent on the types and extent of rock fractures, and degree of weathering [6]. Several conventional methods exist for the exploration and development of groundwater potential map of an area. These methods include; geological, geospatial, geophysical, and hydrogeological. However, geospatial amongst these methods are considered more favorable as it is less expensive and applicable even in inaccessible areas. Integrating advanced geospatial techniques is essential for the continuous assessment and monitoring of groundwater status periodically. Therefore, the possible groundwater zones for successful groundwater exploration need to be evaluated to meet the population's demand [7], [8].

Severe water scarcity has been one problem citizens of Jos South Local Government Area had to contend with, and only those in Jos, the capital city, could boast of access to water supply. Water projects constructed about 40 years ago when the state was created is insufficient for providing enough water for the growing population. This has subjected people of the state to extreme exploration of groundwater. Wells dug by private individuals and public authorities within the region yield insufficient water supply which would eventually dry up in dry seasons due to lack of knowledge on the groundwater potential zones [9].

Several researchers, including Abiola, Enikanselu and Oladapo [10], Alabi, Bello, Ogungbe and Oyerinde [11], Abel and Moshood [12], Alkali and Yusuf [13], Anudu *et al.*, [14], Mbiimbe, Olasehinde and Bute [15], Dasho *et al.*, [6], Layade, Adegoke and Oladewa [16], and Adeoti *et al.*, [17] explored groundwater potential in various parts of Nigeria. They employed geophysical methods such as vertical electrical sounding (VES) and Lineaments technique, while others used geospatial methods such as Geographic Information Systems and Remote Sensing techniques.

Literatures reviewed indicate that there are no known study of groundwater potential of the study area deploying geospatial techniques and comparing results with that of geophysical. Consequently, this research will

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dwell on deploying geospatial techniques (Remote Sensing and GIS) in assessing groundwater potential zones by identifying the characteristics for the determination of groundwater potential, establishing the spatial pattern of the groundwater potential zones, and the relationship between the results obtained from geospatial and geophysical techniques.

MATERIALS AND METHODS

Study Area

The study area is located between Latitude 8°45'00" and 9°50'00" North of the Equator and Longitude 8°41'00" and 8°58'00" East of the Greenwich Meridian (See Figure 1). Jos South Local Government Area consists of three main districts; Du, Kuru and Vwang, and has approximately 510km^{2}, making it the second-largest in Plateau State with a population of about 306,716 persons as of 2006 census.

The high population concentration in this region can be attributed to the attraction of industrial, commercial, and mining activities, which has adversely affected the morphology of the environment with numerous mine pits and heaps of overburden leading to contamination of the ecosystem [18], [19].

The geology of the area belongs to the Jos-Bukuru Younger Granite Complex and consist mostly of biotite granite. Some sections are intruded by the Precambrian to late Paleozoic Pan-African granite (Old Granite), diorite, charnockite, etc. The region's peculiar physical attributes are its high relief, especially in the north with undulations dominating the area and ranges between 915 meters to 1,300 meters with an average of about 1,250 meters, which are source points for many rivers in northern Nigeria. The formation of its high relief makes Plateau State one of the country's mineral-rich states [20], [18] [19].

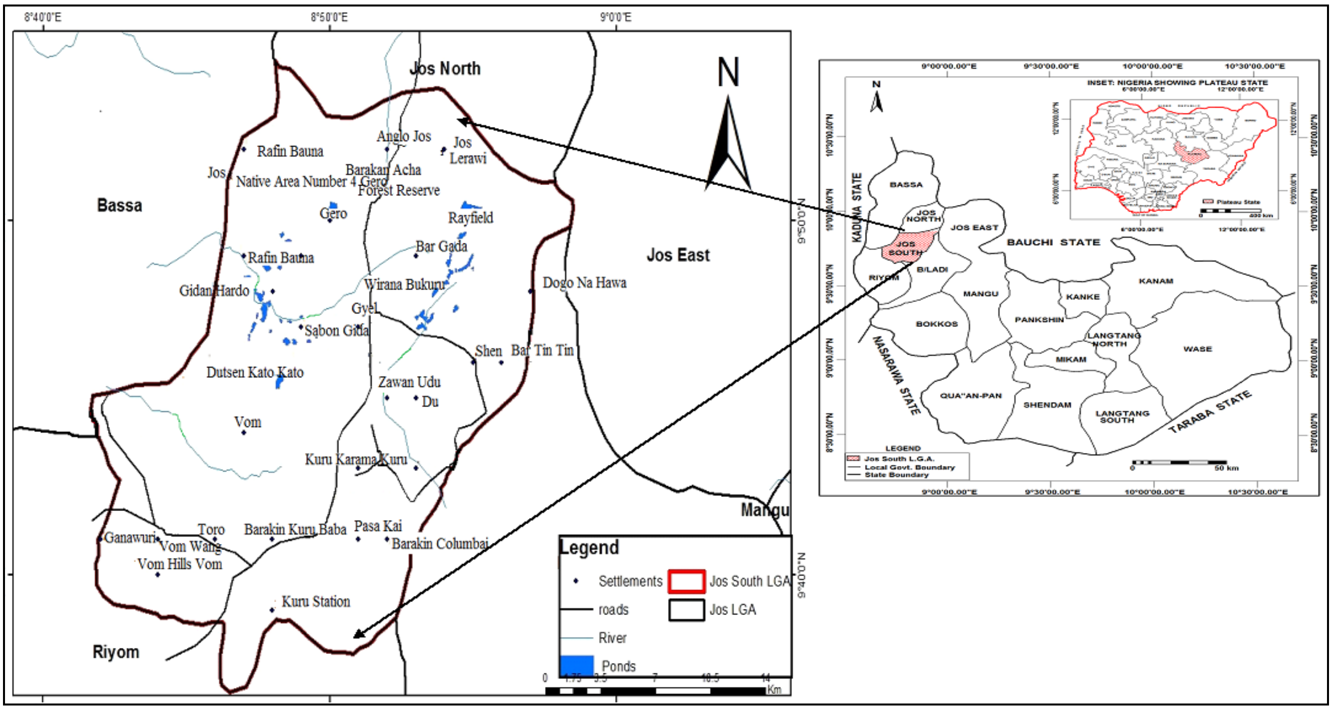

Fig 1: Jos South L.G.A (Study area)

Source: Adopted from Administrative Map of Plateau State

The high altitudes largely control the region's climatic conditions, with temperatures averaging between 18^{0}C and 22^{0}C. The wet season falls between April and October, with annual rainfall ranging from 131.75cm in the south to 146cm on the peaks [20], [21]. The soils are ferruginous and loamy in nature found around the Plateau. Past mining activities have disrupted the soil profile reducing its porosity and permeability, causing a major environmental problem such as soil erosion and reduced groundwater [18].

Types and Sources of Data

The data used for this study include; The Shuttle Radar Topographical Mission/DEM (SRTM Version 3) with a spatial resolution of 90m, and LANDSAT 8 (2015) with a spatial resolution of 30m from National Institute of Remote Sensing, Bukuru, Jos. Rainfall data (2004-2014) were collected from the Nigeria Metrological Agency, geologic and soil data were collected from the Department of Geology, University of Jos. Latitude/Longitude coordinates from Global Positioning System (GPS) were used to verify features on the imageries.

Software

ArcGIS 10.5 was used for digitizing and Groundwater analysis.

ERDAS Imagine 9.2 was used for image processing and classification.

PCI Geomatica v10.0 was used for lineament extraction.

Microsoft Excel was used for the graphical representation of charts.

Image Classification

The different band layers for LANDSAT 8 image were stacked and processed using ERDAS imagine

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software. The maximum likelihood algorithm under the supervised classification method was deployed and entails training the image data into various themes or classes such as vegetation, built-up, bare land, agricultural area, and water bodies. The classification was done based on the study area's prior knowledge and adopting Anderson classification scheme [22].

Data Analysis

The features for determining groundwater potential zones in the study area was assessed by creating thematic maps such as elevation, average annual rainfall, slope, soil, landuse/landcover, drainage network and drainage density, lineament density, geology. Class weights and scores were assigned to each thematic data set based on Saaty and Vargas Analytic Hierarchy Process (AHP) [23] and used to characterize each thematic map into very high, high, moderate, low, and very low. Each class's relative importance within the same map was compared to each other pair-wise, and eight essential matrices were prepared for assigning weight to each class.

A combination of thematic maps using the weighted overlay spatial analysis tool in ArcGIS was used to determine groundwater potential zones' spatial distribution following the equation below. Multi-criteria evaluation based on AHP was used to compute ranks and weights, which was then reclassified into five groundwater potential zones (very high, high, moderate, low, and very low).

Groundwater Potential Zones =
GL+RF+LD+DD+SL+LU+TP ………….. (1)
Where:
GL= Geological map
RF= Rainfall map
LD= lineament density map
DD= Drainage Density map
SL= Slope map
LU= Landuse Map
TP= Topographic Elevation map

Finally, the study deployed the resistivity method, which comprises Vertical Electrical Sounding (VES) at various selected areas under survey. Vertical electrical sounding investigates how the subsurface resistivity varies with depth and is often related to the formation's strength and conductivity and has proved useful in groundwater studies. Groundwater potential investigations using this method were conducted in nine (9) locations: Vom, Shen, Rayfield, Kuru, Gyel, Dutsen Kato, Du, Bukuru Barakin Columbai. The relationship between geospatial and geophysical techniques in groundwater potential investigation was used to validate this study's result. An overlay of both results was used to produce a map that depicts the relationship between both methods.

RESULTS AND DISCUSSION

Features for Determining Groundwater Potential Zones

Features contributing to groundwater potentiality were analyzed and developed into thematic maps, as shown in figures and tables below.

Elevation

Topographic data is vital in determining the water table elevations [24]. Shuttle radar topographic mission (SRTM-90) was used to develop the Digital Elevation Model (DEM), which was then interpolated using the kriging algorithm and slope function to produce elevation map shown in Figure 2. The result from the elevation map was used to generate the topographic elevation factor values, weights of elevation, and potentiality for groundwater prospects in the study area. High elevation values are found around the northern (Bukuru And Rayfield) and western (Shen, Du, Kuru and Barakin Columbai) sections, with patches around the south (Vom).

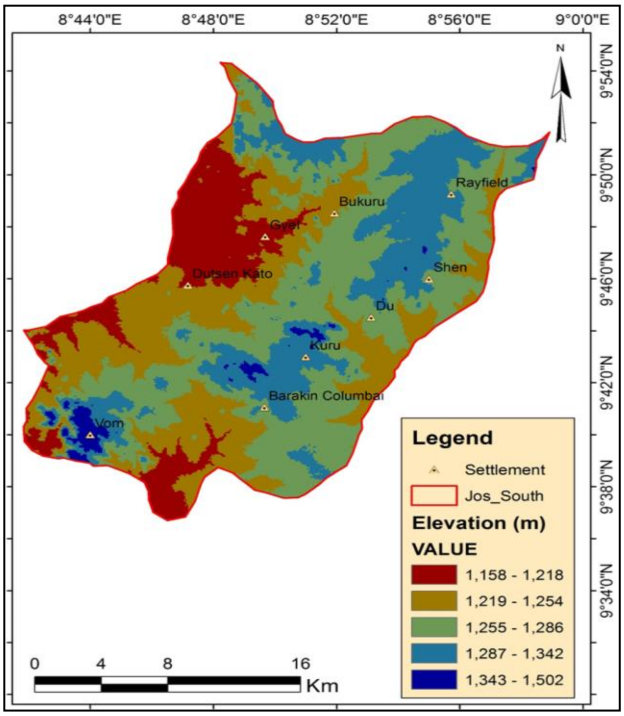

Figure 2: Elevation of the Study Area

Table 1: Groundwater Potential for Topography

Elevation	1158-1218	1219-1254	1255-1286	1287-1342	1342-1502	Weightage	Potential
1158-1218	1	3	4	5	7	0.49	Very High
1219-1254	1/3	1	1	3	5	0.20	High
1255-1286	¼	1	1	3	5	0.19	Moderate
1287-1342	1/5	1/3	1/3	1	3	0.08	Low
1342-1502	1/7	1/5	1/5	1/3	1	0.04	Very Low

Consistency Ratio=0.04

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The result from Table 1 shows that areas with low elevation values (1158m-1218m) have very high groundwater potential and high elevation areas have low water potential. This is because sites on low elevation will increase groundwater accumulation [25].

Average Annual Rainfall

Rainfall is one of the major contributing factors responsible for groundwater recharge. Figure 3 shows a low amount of annual rainfall (940-974mm) around the mid-western area in Bukuru, Gyel, Du, and Kuru where the elevation is high. Rainfall appears to be high (1,112 – 1,180mm) in parts of the northern areas around Rayfield where the elevation is low. A pair-wise comparison and reclassification were carried for the mean annual precipitation of the study area using AHP, and the result is presented in Table 2.

These precipitation values were weighted to reflect the influence of perception on groundwater. More water will be available for surface runoff and infiltrations will naturally recharge the groundwater as we have more precipitation. Table 2 shows that the high rainfall amounts imply the possibility of high groundwater recharge and vice versa. The area characterized by high rainfall amounts shows high groundwater potential zones.

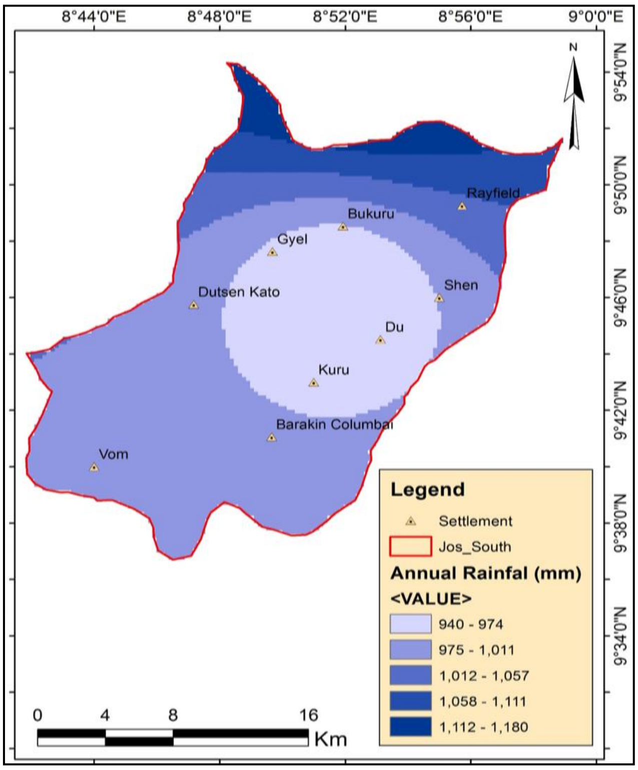

Figure 3: Average Annual Rainfall of the Study Area

Table 2: Groundwater Potential for Rainfall

Rainfall	940-974	975-1011	1012-1057	1058-1111	1112-1180	Weightage	Potential
940-974	1	2	2	2	2	0.11	Very Low
975-1011	½	1	2	2	2	0.14	Low
1012-1057	½	1/2	1	2	2	0.19	Moderate
1058-1111	½	1/2	1/2	1	2	0.24	High
1112-1180	½	1/2	1/2	½	1	0.32	Very High

Consistency Ratio=0.01

Slope Steepness

Slope is one of the major factors that influence groundwater potentials and it was generated from the Digital Elevation Model as shown in Figure 4. It shows that Vom is highly sloppy while Bukuru, Barkin Columbai and Dutsen Kato are on low elevation.

Result from Table 3 shows that areas with the value of slope ranging from 0-1.3percent have very good groundwater potential and those areas with high slope ranging from 10.8-23.4 percent have very low water potential. Areas with low slope amount can hold rain water and enable recharge, unlike areas with high slope amount with characteristics such as high run-offs and low permeation rate.

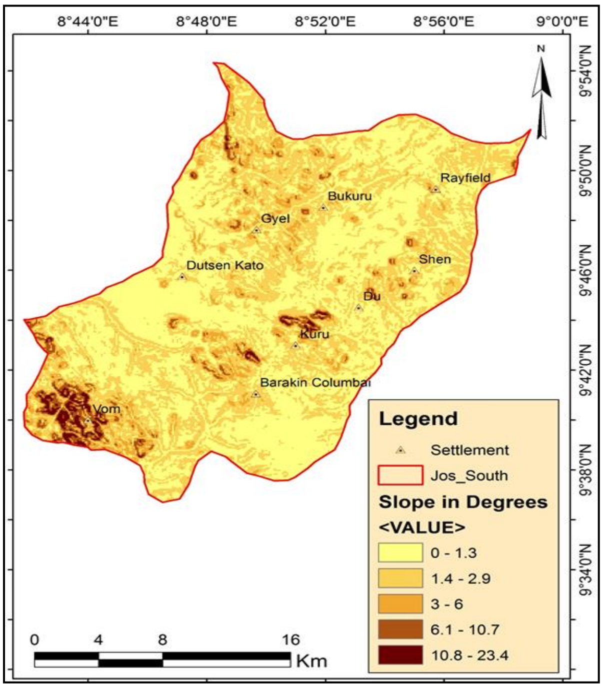

Figure 4: Slope Steepness of the Study Area

Table 3: Groundwater Potential for Slope

Slope (%)	0-1.3	1.4-2.9	3-6	6.1-10.7	10.8-23.4	Weightage	Potential
0-1.3	1	2	5	7	9	0.47	Very High
1.4-2.9	1/2	1	3	5	9	0.3	High
3-6	1/5	1/3	1	3	7	0.14	Moderate
6.1-10.7	1/7	1/5	1/3	1	5	0.07	Low
10.8-23.4	1/9	1/9	1/7	1/5	1	0.03	Very Low

Consistency Ratio=0.06

Drainage Density

Digital elevation model was used to extract the drainage network of the study area, which was used in developing drainage density classes and was map as presented in Figure 5.

Result from Table 4 shows the weights where areas with very high drainage density (0-19) were found in the western, eastern and southern part of the study area, while moderate and low drainage density concentrates in the northern and central part of the area. This implies that areas with higher drainage density relate to low groundwater potential and vice versa. The higher the drainage density, the lesser the infiltration capacity, that is, the low void ratio of the terrain, which in turn, reduces groundwater potentiality. This is because a considerable amount of water coming as rainfall goes as runoff [26]. In general, drainage density is an important parameter that controls groundwater occurrence and distribution.

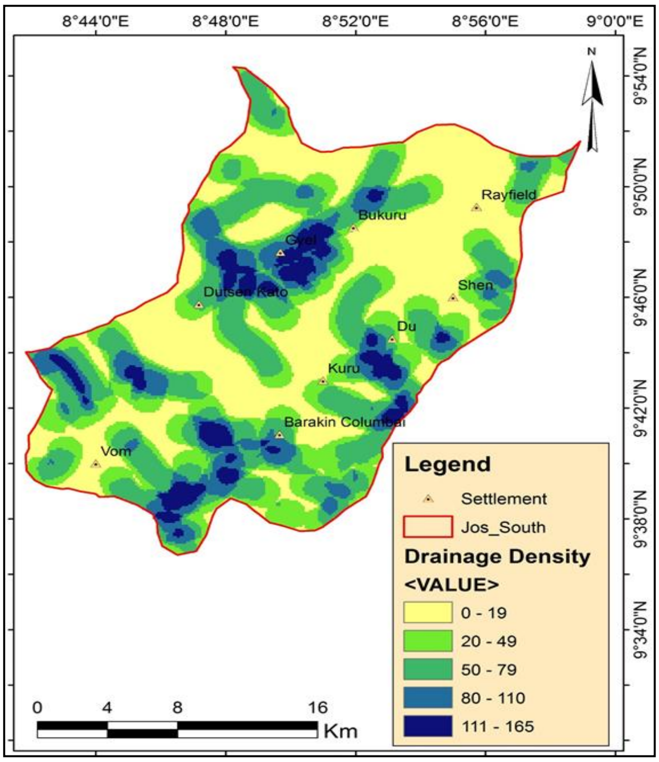

Figure 5: Drainage Density of the Study Area

Table 4: Groundwater Potential for Drainage Density (DD)

DD	0-19	20-49	50-79	80-110	110-165	Weightage	Potential
0-19	1	6	4	6	6	0.49	Very High
20-49	1/6	1	2	1	2	0.26	High
50-79	1/5	1/3	1	2	4	0.12	Moderate
80-110	1/3	1/6	1/2	1	6	0.07	Low
110-165	1	¼	1/4	1/6	1	0.05	Very Low

Consistency Ratio=0.06

Lineament Density Analysis

Lineament analysis is guided by some geomorphological structures characterized by faults and fissures, which increases porosity within the formations and significantly affects the occurrence of groundwater recharge and discharge zones within the aquifer. Visual interpretation of the study area's multispectral band image was used to derive lineaments based on other contributing factors such as drainage, soil, slope, and vegetation.

The lineament density map in Figure 6 indicates a low of less than 12 and a high of above 127 in lineament numbers. Table 5 shows the pair-wise comparison of groundwater potential for lineament density, which was analyzed based on the fact that areas around lineaments have increased porosity and a higher chance of groundwater accumulation. The result revealed that areas with lineament density between 82 and 127 have very high groundwater potential, while areas between 0 and 12 have very low groundwater potential. Areas with higher lineament density are zones with high degree of rock fracturing and are regarded as a criterion for groundwater channel development in an area [27].

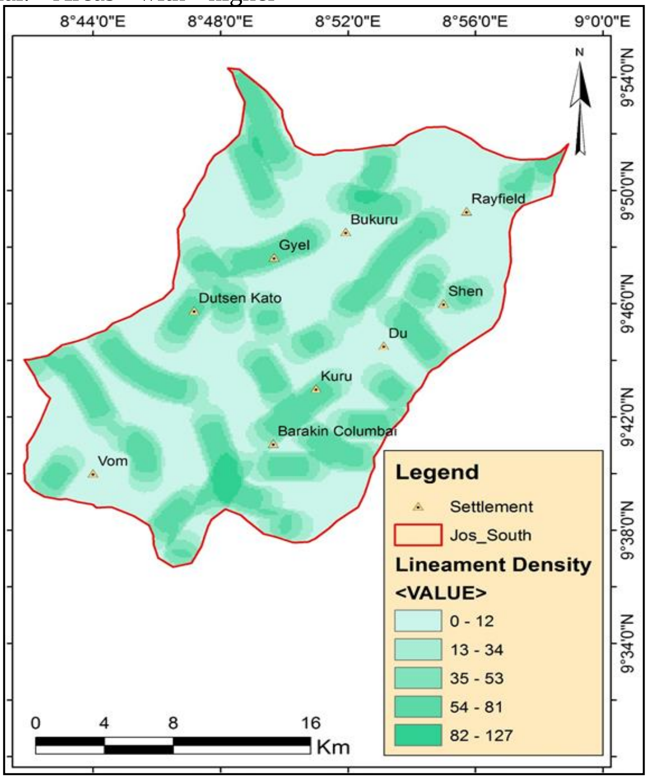

Figure 6: Lineament Density of the Study Area

Table 5: Groundwater Potential for Lineament Density (LD)

LD	0-12	13-34	35-53	54-81	82-127	Weightage	Potential
0-12	1/9	1/7	1/5	1/3	1	0.03	Very Low
13-34	1/7	1/5	1/3	1	3	0.06	Low
35-53	1/5	1/3	1	3	5	0.13	Moderate
54-81	1/3	1	3	5	7	0.26	High
82-127	1	3	5	7	9	0.51	Very High

Consistency Ratio=0.08

Landuse and Landcover

The landuse and landcover of an area is an important parameter that influences the occurrence of groundwater in an area. The landuse and landcover map (Figure 7) was generated from the Landsat imagery using supervised classification and the areal coverage was presented in Table 2.

The result shows that Jos-South occupies 493.95 sq. km of which Farmland occupies the highest with 257.45 sq. km (52.1%). Built-up areas 105.72 sq. km (21.4%), vegetation cover 101.86 sq. km (20.6%), bare land and water body occupies the least 25.56sq. km (5.2%) and 3.54sq. km (0.7%) respectively.

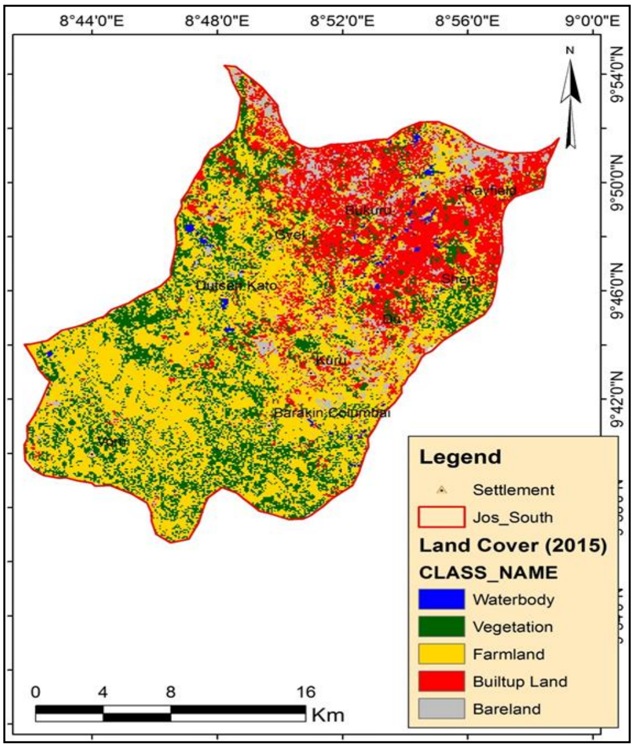

Figure 7: Landuse/Landcover of the Study Area

Table 6: Areal Coverage of LULC in the Study Area

No.	LULC	Areal Extent	
		(Km^2)	(%)
1	Vegetation	101.68	20.6
2	Farmland	257.45	52.1
3	Bare Land	25.56	5.2
4	Build-up Areas	105.72	21.4
5	Water body	3.54	0.7
	Total	**493.95**	**100**

Table 7 shows that area around the water body has very good groundwater potential, followed by vegetated areas with good water potential. The bare land was weighed moderate while cultivated land and built-up land had low and very low groundwater potential respectively.

The LULC of an area provides essential indications for the extent of groundwater requirement and utilization. Land use/cover may also affect groundwater negatively by evapotranspiration, assuming interception to be constant. This was affirmed by Todd and Mays [1] that farmlands with vegetation are an excellent site for groundwater exploration. Chowdary *et al.*, stated that vegetation and water body areas are favorable for groundwater potential [28].

Table 7: Groundwater Potential for Landuse/Landcover

LULC	Water body	Vegetation	Bare Land	Farm Land	Build-up	Weightage	Potential
Water body	1	5	7	6	9	0.56	Very High
Vegetation	1/5	1	3	4	9	0.23	High
Bare Land	1/7	1/3	1	2	7	0.11	Moderate
Farmland	1/6	1/4	½	1	4	0.07	Low
Build-up	1/9	1/9	1/7	¼	1	0.03	Very Low

Consistency Ratio=0.12

Soil Types

The soil influences groundwater recharge depending on the texture, grain size, and porosity. Soil can go a long way in influencing the infiltration of water. The Food and Agricultural Organization standard was used to classify and develop the soil map of the area [29].

The different soil types from the study area includes leptosols, cambisols, and acrisols, as shown in Figure 8, while Table 8 represents the weight of groundwater potentiality of the study area. Figure 8 shows that cambisols dominate a large portion of the study area from north to south. Leptosols dominate few portions to the southwest, and acrisols dominate some portion of the south.

The pair-wise comparisons from Table 8 show that cambisols soil type have high groundwater potential due to their high infiltration rate. The acrisols have moderate potentiality, while leptosols have low groundwater potential.

According to Tewodros most cambisols soils are characterized by medium-texture, high porosity, good water holding capacity, and good internal drainage [26]. Cambisols also contain at least some weatherable minerals in the silt and sand fractions. Based on these characteristics, cambisols have an excellent infiltration capacity to recharge groundwater.

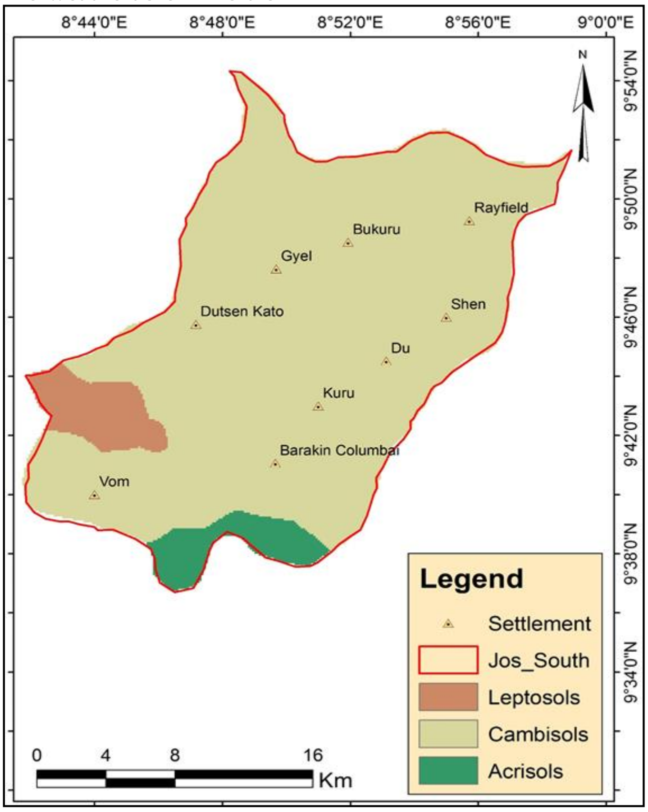

Figure 8: Soil Types of the Study Area

Table 8: Groundwater Potential for Soil

Soil Type	Cambisols	Acrisols	Leptosols	Weightage	Potential
Cambisols	1	3	5	0.64	High
Acrisols	1/3	1	3	0.26	Moderate
Leptosols	1/5	1/3	1	0.1	Low

Consistency Ratio=0.04

Geologic Profile

The geology of an area plays a vital role in the distribution and occurrence of groundwater. Geological mapping was carried out by digitizing the existing geological map of the study area.

Figure 9 shows the study area's geologic profile, where rock exposures such as alluvium, basalt, older basalt, granite, and migmatite were identified. The result revealed that the north and eastern parts were dominated mainly by granite, basalt, and older basalt to the southeast, migmatite to the east, and alluvium to the southwestern part of the study area.

It is evident from Table 9 that areas with alluvium formations have very high groundwater potential, the basalt has high while the older basalt has a moderate groundwater potential. The granite and migmatite have low and very low groundwater potential respectively.

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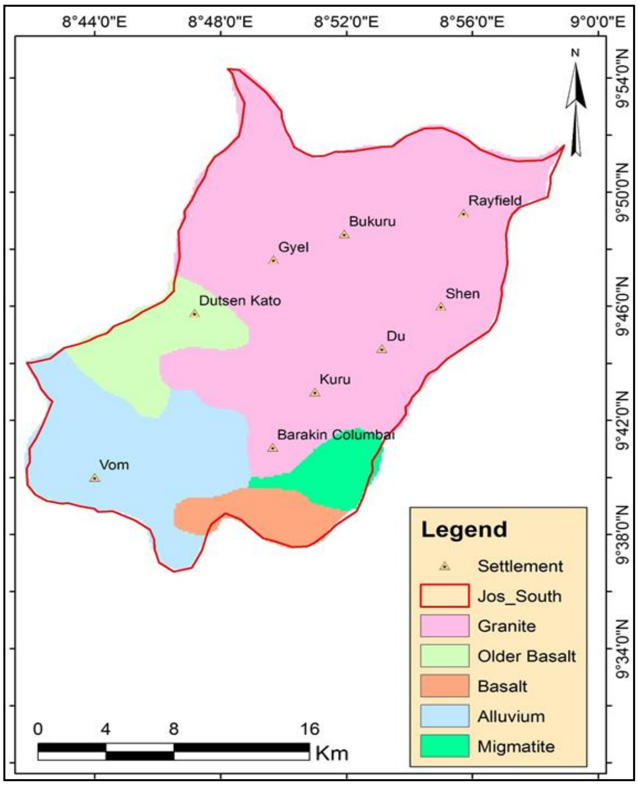

Figure 9: Geology of Jos-South L.G.A.

Table 9: Groundwater Potential for Geology

LULC	Alluvium	Basalt	Older Basalt	Granite	Migmatite	Weightage	Potential
Alluvium	1	2	3	5	7	0.41	Very High
Basalt	½	1	3	5	7	0.31	High
Older Basalt	1/3	1/3	1	3	5	0.16	Moderate
Granite	1/5	1/5	1/3	1	4	0.07	Low
Migmatite	1/7	1/7	1/5	1/3	1	0.04	Very Low

Consistency Ratio=0.04

Spatial Distribution of Groundwater Potential Zones

Groundwater potential zones in Jos South L.G.A. were determined by integrating all the thematic maps of groundwater recharge's contributing surface features.

The weights of the surface features were analyzed using the Analytical Hierarchy process according to Saraf and Choudary [30]. The result from Table 10 shows that rainfall weighed the highest (34%) followed by lineament density (24%), geology (14%), while Landuse/landcover with (2%) represents the least groundwater contributor in the study area. Hence rainfall, lineament, and geology of the area were seen as the major features contributing to Groundwater Potential.

Table 10: Weights of the Surface features of Groundwater Potential

Rainfall	1	3	3	4	5	6	7	9	0.34	34
Lineament	1/3	1	2	3	5	6	7	9	0.24	24
Geology	1/3	½	1	2	2	3	4	7	0.14	14
Slope	1/4	1/3	1/2	1	2	3	4	5	0.1	10
Elevation	1/5	1/5	1/2	1/2	1	3	4	5	0.08	8
Soil	1/6	1/6	1/3	1/3	1/3	1	3	5	0.05	5
Drainage	1/7	1/7	1/4	1/4	1/4	1/3	1	3	0.03	3
LULC	1/9	1/9	1/7	1/5	1/5	1/5	1/3	1	0.02	2

Consistency Ratio=0.05

Figure 10 shows the various groundwater potential zones within the study area with very high groundwater

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potential zones covering about 14.1% of the land area, High potential 22.4%, moderate occupies 15.0%, while low and very low occupying 23.9% and 24.6% respectively.

It also shows that the northern area has a very high groundwater potential and is characterized by high rainfall, low slope, and dominant cambisols with relatively high-water retention capacity. The central area within the map shows very low groundwater potential which are characterized by low rainfall, moderate slope, low lineament density, high drainage density, and granite with low groundwater potential. This implies that rainfall, soil types, and slopes are the main factors contributing to the groundwater resource's spatial distribution in the study area. The distribution pattern also shows that areas with high groundwater potential are located within the northern and southern parts. In contrast, areas with moderate and low groundwater potential are scattered all over the study area.

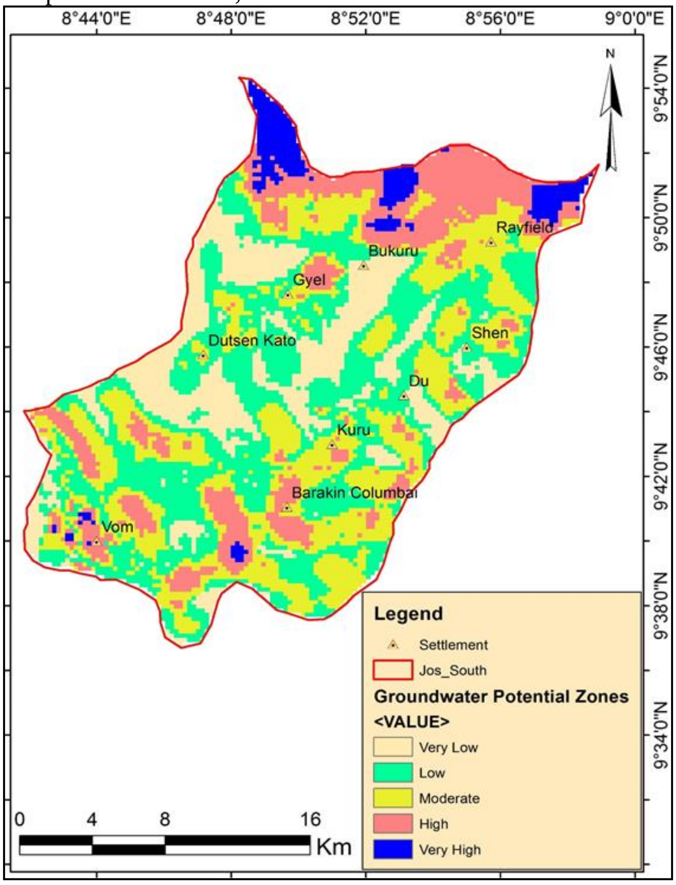

Figure 10: Groundwater Prospect Zones

Relationship Between GIS and Geophysical Technique

The relationship between the result obtained from the geospatial technique was compared with that of geophysical involving electrical resistivity method. Vertical Electrical Sounding result acquired across the community (Vom, Rayfield, Dutsen Kato, Barkin Columbai, Bukuru, Gyel, Kuru, Du and Shen) were overlaid on the groundwater potential map generated from the integration of the various thematic maps. Figure 11 and Table 11 shows the overlay of the electrical resistivity points on the groundwater potential zones.

Figure 11 shows that areas with higher aquifer thickness values have high groundwater potential, and areas with low aquifer thickness have low groundwater potential. Table 11 indicates that Vom settlement with aquifer thickness of 45m has high groundwater potential using electrical resistivity but has very high groundwater potential using GIS technique. On the other hand, Dutsen Kato and Du settlements, both with an aquifer thickness of 25m each, have low groundwater potential using the electrical resistivity technique and very low using the GIS technique. The result obtained from this study is similar to the findings of Oyedele and Olayinka, who were of the opinion that areas characterized by aquifer thickness greater than 30m generally indicates good Groundwater Potential [31].

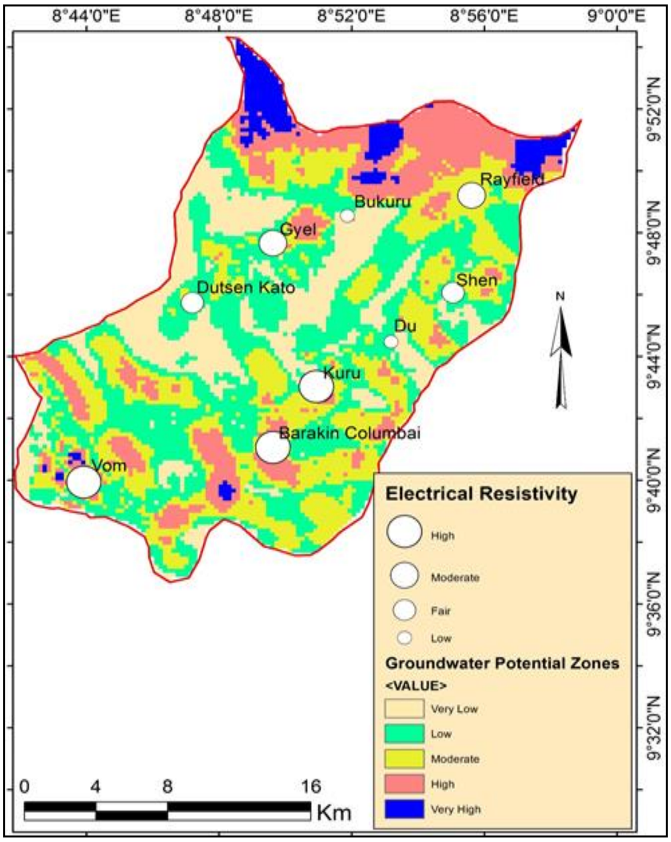

Figure 11: Overlay of Electrical Resistivity on Groundwater Prospecting Zones

Table 11: Groundwater Potentiality of Geophysical against Geospatial Technique

Lat	Long	Location	Electrical Resistivity		GIS
			Aquifer Thickness (m)	Groundwater Potential	Groundwater Potential
9.666667	8.733333	Vom	45	High	Very High
9.766667	8.916667	Shen	35	Moderate	Fair
9.833333	8.900000	Rayfield	35	Moderate	Moderate
9.716667	8.850000	Kuru	40	High	Moderate
9.783333	8.850000	Gyel	30	Fair	Low
9.750000	8.783333	Dutsen Kato	25	Low	Very Low
9.750000	8.883333	Du	25	Low	Very Low
9.800000	8.866667	Bukuru	40	High	High
9.684505	8.828122	Barakin Columbai	40	High	High

CONCLUSION

Geospatial techniques such as GIS and remote sensing has proved efficient and cost-effective for determining groundwater potential. This study deployed geospatial techniques such as GIS and remote sensing to detect probable sites for groundwater exploration. Thematic maps were developed and weights of each important variables controlling groundwater potentials such as annual rainfall, geology, lineament density, soil, elevation, slope, land cover, and drainage density were assigned using Analytical Hierarchy Process (AHP) model based on their characteristics and was overlaid and integrated for groundwater potential zone. The final map for groundwater potential zones was obtained by algebraic summation of these useful parameters multiplied by their effective weights. The result showed a distribution pattern for areas classified as very high potential zones located within the Northern areas around Bukuru and Northeastern areas around Rayfield while areas with the high potential lie in the North-central and Southern part around Gyel and Barakin Colombai respectively. The moderate and low groundwater potential areas are scattered all over the study area, while very low groundwater potential areas are found in central areas around Dutsen Kato. Finally, the groundwater potential zone was corroborated by determining the relationship between the results obtained using geospatial technique with geophysical surveys using some selected points within the study area. Given the results obtained from this study, it can be deduced that geospatial techniques such as Remote Sensing and GIS are faster, cost-effective, and accurate in assessing groundwater potential zones. Hence, it is recommended that the government, decision-makers, and stakeholders in water resources consider deploying geospatial techniques for effective groundwater exploration. Such explorations should be concentrated within and around the northern and southern parts of the study area. More studies should also be conducted on groundwater recharge and pollution to protect groundwater resources in these zones sustainably.

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