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Assessment of groundwater potential in Jos North Local Government Area of Plateau State, Nigeria

Ezekiel Ojei [1,*], Babalogbon Bowale Ayodeji [2], Jagila Jatinku [1], Epsar Philip Kopteer [1], Jibatswen Agbutsokwa Hosea [1], Moses Olorunfemi Areh [1], Anthony Chijioke Ukaefu [3], Abraham Ben-Obaje [1], James Adah John [1] and Sambo Abubakar Nasiru [1]

[1] *National Space Research and Development Agency (NASRDA), Abuja, Nigeria.*

[2] *African Regional Centre for Space Science and Technology Education- English (Arcsste-E), Ile-Ife, Osun State, Nigeria.*

[3] *No. 40 Graingers Mill, Muckamore, Antrim, Northern Ireland.*

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Abstract

This study addresses critical groundwater scarcity in Jos North, Nigeria (291 km^2, pop. 429,300), driven by rapid urbanization, population growth, and variable hydrogeology. Situated in basement complex terrain with limited primary porosity, the area faces acute water stress despite interventions like boreholes. Leveraging established methodologies, the research integrates Remote Sensing (RS), Geographic Information Systems (GIS), and Analytic Hierarchy Process (AHP) to delineate groundwater potential zones. Literature underscores the efficacy of lineament density (proxy for fracture-controlled porosity) and multi-criteria analysis (e.g., rainfall, geology, land use) in similar terrains. Core objectives included generating thematic maps of controlling factors and synthesizing a groundwater potential map for sustainable resource planning.

Seven thematic layers were developed: geology (18.7% weight), lineament density (18.2%), rainfall (21.4%), drainage density (11.6%), slope (2.2%), elevation (4.4%), and land use/land cover (1.7%). data from landsat 8, SRTM DEM, rainfall stations, and geological surveys were processed using ArcGIS 10.4.1, ERDAS IMAGINE, and PCI Geomatics. AHP pairwise comparisons assigned class weights (e.g., lineament density >1.5945/km^2 = "Very High" potential; slope <3.224° = optimal recharge). Integration via Weighted Overlay revealed four zones: Very High (12.8%, Northern sectors), High (35.1%), Slightly High (30.0%), and Low (22.1%, Eastern areas). Rainfall (32.2% priority) and lineaments (27.5%) were dominant factors. Urban expansion (0.53 km^2/year) reduced recharge areas (vegetation fell to 33%, settlements rose to 28%), intensifying water stress.

The study confirms RS-GIS-AHP as a robust framework for groundwater zonation in complex terrains, with 67.9% of Jos North having moderate-to-high potential. Key recommendations include: (1) Prioritizing exploration in Northern "Very High" zones (high lineament density, gentle slopes); (2) Implementing policies for equitable water access and recharge conservation; (3) Institutionalizing geospatial techniques in state water planning; and (4) Maintaining a dynamic groundwater database. These measures are vital for balancing resource use amid ongoing urban pressures.

Keywords: Groundwater Potential; Lineaments; Geospatial; Scarcity; Geology

1. Introduction

Urban regions are dynamic networks that are characterized by fast population increase, a scarcity of surface water, and a high demand for groundwater. A region's groundwater potential is determined by a variety of factors, and it fluctuates

* Corresponding author: Ezekiel Ojei

from place to place as conditions change. Groundwater potential has also been reported to vary within a short distance and within the same geological formation [1]; [2]. Hard rock terrain has a limited quantity compared to soft rock aquifers with high yield capacity, and is generally concentrated in the weathered zone and fractured zone. To avoid financial loss and the waste of time and effort in such a case, effective identification of potential zones is required. This type of accurate identification is feasible with geological and hydrogeological knowledge. In groundwater hydrology, evaluating potentiality is a critical domain in the planning and management of groundwater resources, both in terms of occurrences and accumulation [3]; [4].

There are a variety of methodologies and tools available for determining groundwater likely zones in a given location [5]; [6]; [7], with tools like remote sensing (RS) and geographic information system (GIS) being the most useful and cost-effective. GIS, RS, multi-criteria decision analysis (MCDA), and resistivity survey were used in the current study to classify groundwater likely zones in and around Raipur. Various studies have been carried out all over the world, including in Chattisharg, to identify prospective groundwater zones. Geospatial information systems (GIS) and mathematical models [8]; [9]; [10]; [11]; [12]; [13]; 14]; [15]; [16]. The successful application of geology, geomorphology, rainfall, land use, and land cover are emphasized in this research the groundwater potential model is created by combining the weighted index analytical hierarchy process (AHP) method with the drainage density, slope, groundwater level depth, soil texture, and lineament [17]; [18]; [19]; [9]; [10]; [20].

The hydrogeology of a region is influenced by a variety of geological and hydrological factors. Topography, structure, and stratigraphy are some geological features [21]. Because underground morphology is inaccessible, indirect methods have been developed to observe the underground morphology and processes that affect water movement and storage [22]. Estimation, modeling, and remote sensing are examples of such procedures. Remote sensing for data collection in difficult places and GIS for faster and less expensive processing is becoming more useful and needed [23].

Numerous terms have been used to describe lineament, geologic lineament, tectonic lineament, photo lineament, fracture traces and photo lines or geophysical lineament based on the assumed origin of the feature or sometimes the data source from which it has been derived [24]. [25] originally proposed the term lineament for significant lines of landscape caused by joints and fault revealing the architecture of the rock basement. The most widely used definition is by [26]. Lineament are structural line such as faults. They often represent zones of fracturing and increased secondary porosity and permeability and therefore of enhanced groundwater occurrence and movement [27]. Variations in size, shape, and orientation of these lineaments are mainly attributed to style, the nature of deformation and geological behaviour of the rocks [28].

MCDA is a technique with numerous applications in various fields. It is mostly used to solve complex issues by splitting them into portions and then solving and integrating each section to arrive at the final conclusion. It's employed in situations where making decisions is difficult and time-consuming. Because MCDA is seen as one of the more approachable techniques when compared to others, the AHP is highlighted as a key component. Thomas L. Saaty created and popularized the approach in 1977 [29]. For quantitative analysis, the AHP [30] is often used. It is a reliable decision-making tool for a variety of situations with varying criteria and natures, and it may also be used to assess the likely zones of groundwater occurrence considered in this study. Because of its ability to cope with difficult situations and make appropriate conclusions, the international scientific community has deemed AHP to be a very important instrument.

The concept of pairwise comparison was first presented via this method. In the lack of a quantitative rating, each controlling factor's rank can still be manipulated by properly assigning the rank of each parameter derived from the literature study and field observation according to its value. With the help of AHP, the pairwise comparison is turned into a collection of integers in this scenario. To classify it into different ranks based on its relative importance [30]; [31]. The pairwise comparison methodology is a theoretically based method for calculating weights that signify their relative importance. When all feasible pairs from the eigenvector of the square reciprocal matrix (normalized matrix) are compared, the best fit yields a set of weights that can be used to allocate weight to thematic layers.

[32] used Landsat imageries for landuse/landcover mapping and lineament analysis for groundwater prospecting in Ado-Ekiti, south-western Nigeria. Shuttle Radar Topographic Mission Digital Elevation Model was used for drainage network extraction, slope and geomorphological analysis. Thematic maps were generated, analyzed in terms of hydrogeological importance and reclassified for integration using appropriate software. The groundwater potential maps generated were validated against the existing groundwater yield data. This methodology provided improvements in the understanding of the hydrogeological characteristics of the basement terrain.

Geology influences groundwater movement, storage and subsequently, potential [33]. In a study on three sites, it was noted that geology is also a major theme in groundwater analysis [34]. A study by [35], assigned the second highest weight to the geology of all the themes used for groundwater potential in Puruliya district, West Bengal, India. Geology significantly influences groundwater fluxes, both on the surface and subsurface [36]. In typical basement complex areas such as the study area, the occurrence of groundwater in recoverable quantity as well as its circulation is controlled by geological factors i.e. faults, joints and fracture zones [37]. The role of Land use/ Land cover (LU/LC) on groundwater potential is obvious and wide. Types of land cover/ land use are forest plantations, crop farms, and open denuded soils surfaces, water bodies like lakes and rivers and settlements. Each LU/LC has a certain influence on groundwater potential indirectly through infiltration, runoff and evaporation [38]. Vegetation cover minimizes evaporation and runoff while it increases infiltration. Hence vegetation increases chances of groundwater recharge and can be a good indication of high groundwater potential [39]. Forest plantations require large amounts of water, which they abstract from the vadose zone and in other cases from beneath the water table hence forest plantations indicate high groundwater potential. In settlements and built-up areas, infiltration is low because of roads, pavements and buildings covering the soil surface and consequently, low groundwater potentials are expected.

Jos North has been an area faced with challenges of water unavailability in most of the resident area. The area has been experiencing rapid increase in population and infrastructural development, which resulted to increased scarcity of water to meet the demand of the population in the area. Government efforts have yielded little success in increasing groundwater availability through boreholes and artisan wells, hence, the need to employ the use of Remote Sensing and Geographic information system (GIS) to analyse these areas and estimate its groundwater potential in Jos North local government of plateau state, Nigeria.

The study aims to assess the groundwater potential in Jos North local government area of plateau state, Nigeria with the specific objectives is to: develop thematic maps of factors influencing groundwater potentials in the study area and produce the groundwater potential zones of the study area.

1.1. Study area

1.1.1. Location, Extent and Population

Figure 1 Study area map

The study area is located in Jos North Local Government Area, plateau State, Nigeria. It has an area of 291 km^2 and a population of 429,300 at the 2006 census [40]. Jos is a semi city located between latitude 7° E 9.5179" N to 7° E9.2182 N and longitude 6° E9.8965" E to 6° E8.8583" E. (See Plate 1). The LGA shares boundaries with Bauchi State.

1.1.2. Climate

Nigeria as a country has a tropical climate with variable rainy and dry seasons depending on the location. Jos plateau forest savannah, montane grassland, mosaic ecoregion the climatic condition of Jos North in plateau State with an altitude of 1,217m (3,993ft) above sea level, Jos climate is closer to temperate than that of the vast majority of Nigeria. The average monthly temperature ranges from 21-25^{o}C (70-77^{o}f) at this time the environment is very hot then from mid-November to late January the temperature drop as low as 7^{o}C(45^{o}F).

1.1.3. Vegetation

With long grasses and a few scant trees, the vegetation of Jos North local government of plateau state, the area, and its environs falls under the Tropical Guinea Savannah Belt. The vegetation here is dominated by thinly spaced trees, plants, shrubs, and tall grasses. During the rainy season, the terrain is lush with fresh leaves and tall grasses, but during the dry season, the ground is barren, which shows charred trees and grasses that have been burned. The trees, which grow in clusters, can reach a height of six metres and are mixed with grasses that reach a height of three metres. The majority of the trees in this area are found in fracture zones within plutonic bodies and on pegmatite ridges. There is appropriate soil cover and groundwater retention as a result. The locust bean, she butters, and isoberlinia trees are among these trees. However, due to constant human usage of the forest and the resulting deciduous and savannah vegetation, the many types of vegetation are not in their native luxuriant state. The vegetation in this area therefore includes both primary and secondary. The secondary vegetation implies that the natural vegetation is being altered and as such agricultural crops such as yam, cocoa, maize, sweet potato, and some fruit crops are cultivated. The most widely grown crops are, cocoa yam.

1.1.4. Geologgy and Geomorphology

The regional and local geology were ascertained from literature review obtained from the Federal Survey Department (FSD) Lagos, on the geology and landform in Nigeria as well as from the plateau state master plan. Several rock outcrops are found all over the place extrusion of the basement complex. These outcrops fall into the Jos sand stone formation which consist of siltstone and imbedded clays all of cretaceous age. Laterite is well developed in some places. The weather in the area has resulted in a gentle, rolling, almost flat topography, with mostly sandy fertile soil. The other Precambrian units of metamorphic and sedimentary rocks are the types found around this place. Along streams that cut through the rock outcrops, gradients are steeper. Where the valley bottom is approached, there is a general convex steeping of hill slopes with ironstones frequently occurring at the break in the slope of the place.

1.1.5. Socio-Economic Activities

The Study examines the socio-economic impact of colonial Tin mining on Jos plateau State. Tin mining is said to be one of the oldest industries known to mankind. It has been in existence long before the coming into contact with the European. From the Nok culture that tin had been worked in Jos areas several centuries before the 19th century. The thesis examines the activities of colonial Tin mining and socio-economic effect on the Jos plateau. The imposition of the British colonial rule on the Jos Plateau State area as from 1902 onwards had serious socio-economic implication for the people of that area. The colonial rule, there were few foreigners who had established contact with the people of Jos plateau. These people were mainly the neighbouring ethnic groups like the Hausa Fulani, jukun, among other, however the imposition of clonial rule led to the massive influx of immigrant both within and outside Nigeria to the area. These include Europeans, Lebanese, Indians, chadians, Cameroonians and some part of Nigeria such as the Hausa Fulani, igbo, Yoruba, Urhobo *et* cetera. It makes the increase in population led to the growth of Jos which later become both the administrative and commercial capital of plateau state.

2. Materials and method

This part discusses data types and sources, data analysis procedure, and analytical techniques employed in the study, all of which will aid in achieving the thesis's defined objectives. The figure below shows steps involved in mapping groundwater potential for Jos North.

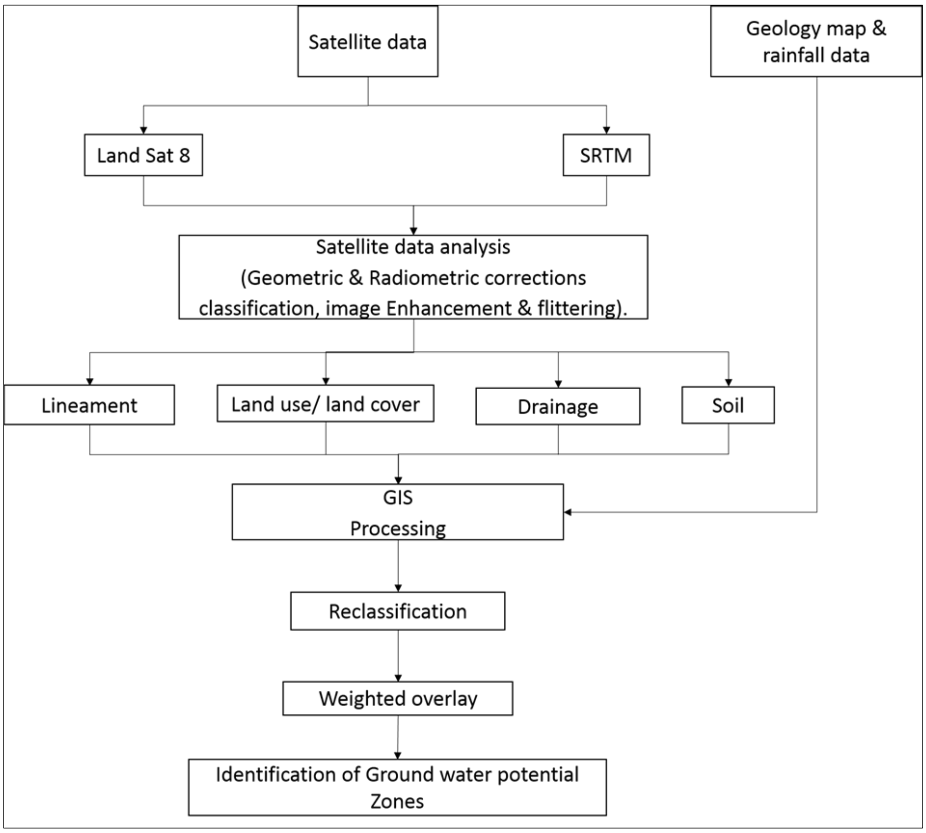

Figure 2 Methodology workflow

2.1. Data Types and Sources

The data used for this study include geology map, rainfall data and satellite imagery. The data and their sources are given in the table below.

Table 1 Data Types and sources

S/n	Type	Scale/ Resolution	Date	Source
1	Land sat8	30m	2020	Earth Explorer
2	Soil	1:1,300,000	2018	Wageningen Netherlands
	SRTM DEM	30m	2019	Earth Explorer
3	Geology	1:500,000	2006	(NGS) Nigerian Geological Survey of Nigerian.
4	Rainfall		2018	Nigerian Metrological Agency (NIMET)

2.2. Software Framework

The assessment utilized a dedicated geospatial software suite. ESRI ArcGIS 10.4.1 served as the primary platform for spatial analysis, interpolation, and integration. ERDAS IMAGINE 2014 was employed for critical remote sensing tasks, specifically Landsat 8 image processing, layer stacking (bands 5, 6, 4), sub-setting the study area, and supervised land use/land cover (LULC) classification. PCI Geomatics 2018 was applied for the extraction of lineament features from satellite imagery, a key indicator of subsurface structures influencing groundwater.

2.3. Core Data Processing

Landsat 8 imagery (2018) underwent pre-processing and supervised classification in ERDAS IMAGINE to generate the essential LULC map, categorizing pixels into Built-up, Vegetation, Bare Ground, Agricultural Area, and Water Bodies. Multiple thematic layers were systematically constructed within ArcGIS. The annual rainfall map was derived using the

Inverse Distance Weighting (IDW) interpolation method within the Spatial Analyst toolbox, processing point data (locations and mean annual rainfall) from NIMET meteorology stations imported via a .csv file. A slope map (% gradient) was calculated from SRTM elevation data and classified into Near Level (0-1%), Very Gentle (1-3%), and Gentle (3-5%) slopes, critical for understanding infiltration versus runoff dynamics.

2.4. Thematic Map Processing for Hydrogeomorphic Parameters

Further hydro-geomorphic parameters were developed. Drainage density, a measure of stream length per unit area, was calculated, with stream ordering performed according to Strahler's method to understand network development and its inverse relationship with percolation potential. The LULC map generated in ERDAS was finalized as a key thematic input, representing surface conditions impacting recharge. Lineaments, identified as tectonic linear features (faults, fractures) crucial for secondary porosity, were extracted using PCI Geomatics. Their influence zones were defined using multi-ring buffers (50m, 100m, 150m, 200m), with intersecting buffers flagged as high-potential indicators.

2.5. Thematic Map Processing for Geological Control

The underlying geological framework, a fundamental control on groundwater occurrence, flow, and storage capacity (porosity/permeability), was established through a detailed geology map. This integrated field verification, literature review [41]; [42], and visual interpretation of satellite data. The lithology of the study area, dominated by calcareous and argillaceous sedimentary rocks of the Raipur group, was classified into five distinct units: Alluvium, Stromatolite Dolomitic Limestone, Laterite, Stromatolitic Dolomitic Limestone with Sandstone, and Shale.

2.6. Integrated Analysis and Zoning

The final groundwater potential zoning employed the Analytic Hierarchy Process (AHP) following [43] for multi-criteria decision analysis. Prior to integration, individual classes within each thematic map (Lineament buffer zones, LULC classes, Drainage density classes, Geology units, Rainfall zones) were comparatively evaluated. Eight pairwise comparison matrices were constructed to objectively assign relative weights to each class based on its contribution to groundwater potential. These weighted thematic layers were then integrated within the GIS environment to synthesize and classify the study area into five distinct groundwater potential zones: Very Good, Good, Moderate, Low, and Very Low.

Table 2 Procedure of Assigning Weightages in Analytical Hierarchy Process

Process Scale	Degree of preference	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judge slightly favour one element over another
5	Strong or essential importance	Experience and judgment strongly favour one element another
7	Very strong importance	One element is favoured very strongly over. Its dominance is demonstrated in practice
9	Extreme importance	The evidence favouring one element over another is of the highest possible order of affirmation
2, 4, 6, 8	Values for inverse comparison	Can be used to express intermediate values

Source: [43]

The final groundwater potential zone map was generated in ArcGIS 10.4.1 using the Weighted Overlay tool (Spatial Analyst module). This integrated the processed thematic layers through a GIS-based multi-criteria evaluation framework. Saaty's Analytical Hierarchy Process (AHP) was applied to derive the critical input parameters: class ranks within each thematic layer and the relative weights assigned to the layers themselves based on their contribution to groundwater potential.

3. Results and analysis

3.1. Introduction

Groundwater prospective zones were analysed on the basis of lineament density, drainage density, geology, land use/land cover, rainfall, slope and elevation. The parameters in each factor were given weight and were related to groundwater potential as adopted from [44].

The groundwater potentiality of Jos north was carried out by analysing the surface features as mentioned above. The weights of the surface features contributing to groundwater prospects in the study area were synthesized by pair-wise comparison using Analytical Hierarchy Process (AHP). The thematic maps of the surface features contributing to groundwater were produced in ArcGIS 10.1 environment and the results are presented in Figures 3 to 10 while the weights of the factors are represented in Tables 3 to 9

3.2. Elevation

The Digital Elevation Model (DEM) was generated from the Shuttle Radar Topographic mission (SRTM-90) data. Figure 3 shows the Digital Elevation Model (DEM) used to build the topographic elevation factor values and Table 4 represents the weight of elevation and potentiality for groundwater prospects in the area of study.

The result shows that areas with low elevation (123m - 274m) values have very good groundwater potential and places on high elevation have low water potential. This is because places on low elevation will give more chance for groundwater accumulation [45]. Topographic data is a vital element in determining the water table elevations [46]. The combination of fractures with topographically low ground can also serve as the best aquifer horizon [47].

Table 3 Weight assigned to Elevation

RASTER LAYER	%INFLUENCE	FIELD VALUE	RANK	SCALE VALUE
ELEVATION	4.4%	0-23	VERY LOW	1
		23.0001-68	LOW	2
		68.0001-111	MEDIUM	3
		111.0001-151	HIGH	4
		151.0001-180	VERY HIGH	5

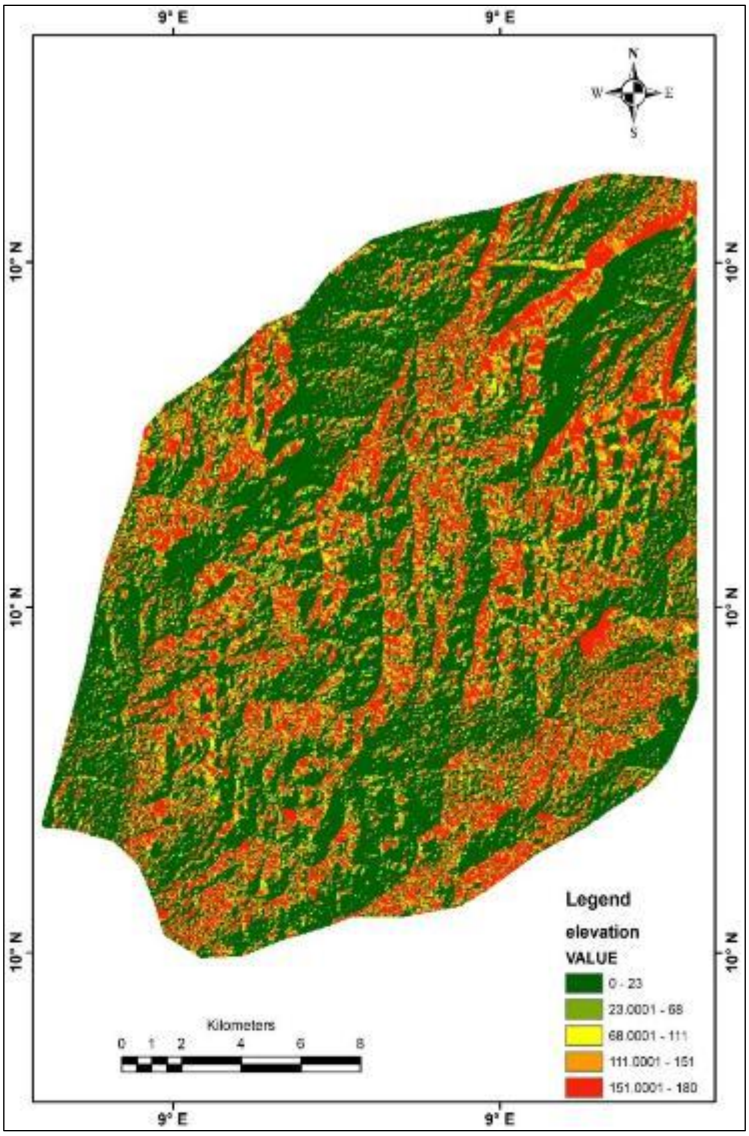

Figure 3 Digital Elevation Model of Jos North L.G.A.

3.3. Geology

Geology is the main control on the primary porosity and permeability of rock. Higher porosity contributes to higher groundwater storage, and higher permeability contributes to higher groundwater yields. Figure 4 is characterized with migmatite rock type, thickness of weathering, fracture density etc. The rock has a sympathetic character for groundwater accumulation owing to their primary porosities and permeability. The cretaceous rocks formation was assumed to have better groundwater accumulation than other rock type due to secondary structures, joint, and secondary porosity.

Table 4 Weight assigned to geology

Raster Layer	%Influence	Field Value	Rank	Scale Value
Geology	18.7%	Basement Complex	Low	1
		Younger Granites	Midium	2
		Tertiary To Recent Volcanics	High	3

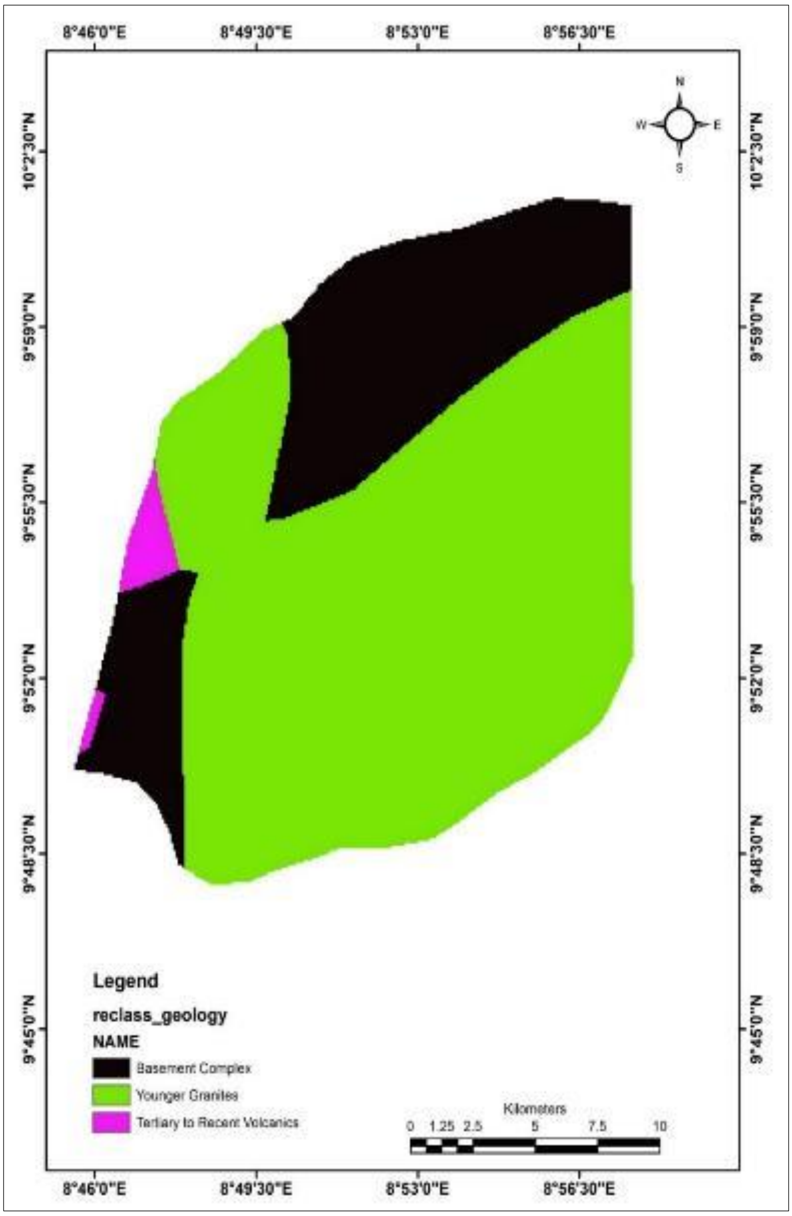

Figure 4 Geology of Jos North L.G.A.

3.4. Drainage Network and Drainage Density

The drainage density was calculated directly in ArcMap using the line density in the spatial analyst extension. In the study area, mainly three (3) drainage density classes were identified and mapped. The drainage network is presented in Figure 5, Figure 6 represents the drainage density of the study area, and also the weightage is shown in Table 5.

Very high drainage density is found in the North Eastern part of the study area whereas high drainage density is found scattered in all parts of the area. Table 5 shows that higher drainage density relates to low groundwater potential and vice versa.

[48], drainage density with respect to groundwater potential is determined by analyzing the drainage density calculated using the stream length within the study area. The higher the drainage density, the lesser the infiltration capacity of the terrain, which in turn means the lesser the groundwater potentiality. This is because much of water coming as rainfall goes as run off.

Table 5 Showing weight assigned to drainage density

Raster Layer	% Influence	Field Value	Rank	Scale Value
Drainage Density	11.6%	1	VERY LOW	1
		2	LOW	2
		3	MEDIUM	3
		4	HIGH	4
		5	VERY HIGH	5

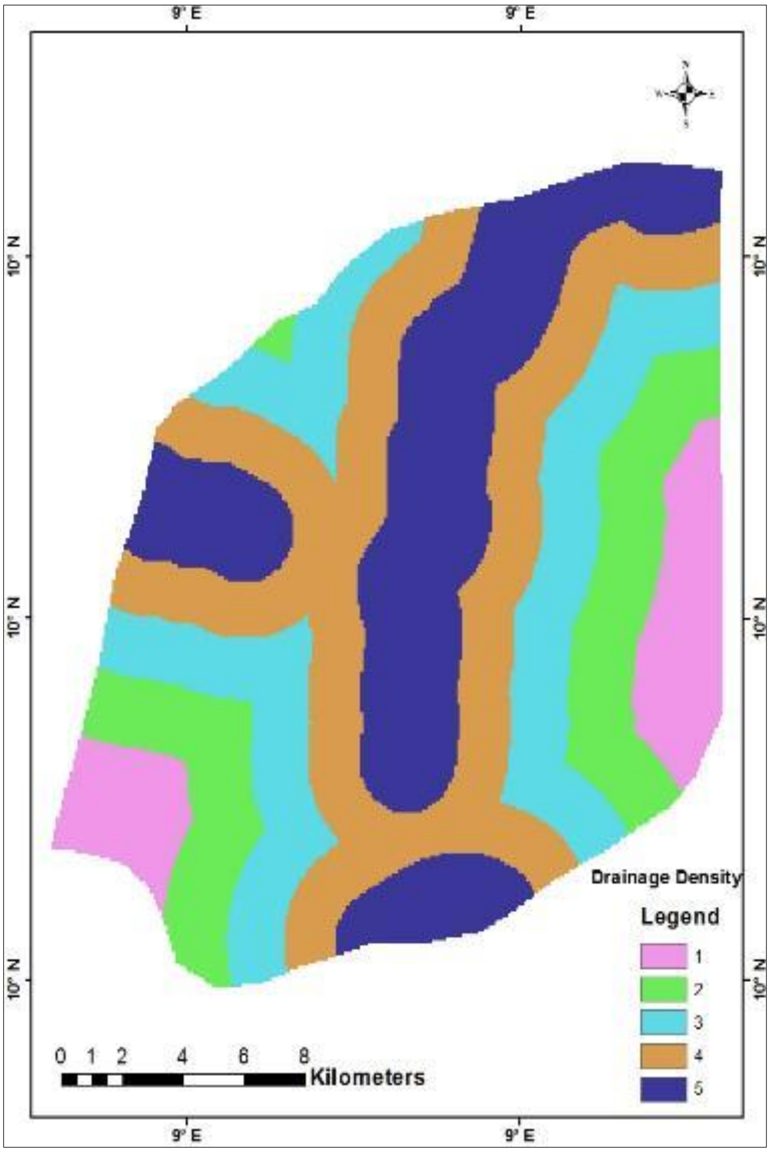

Figure 5 Drainage Density of Jos North L.G.A.

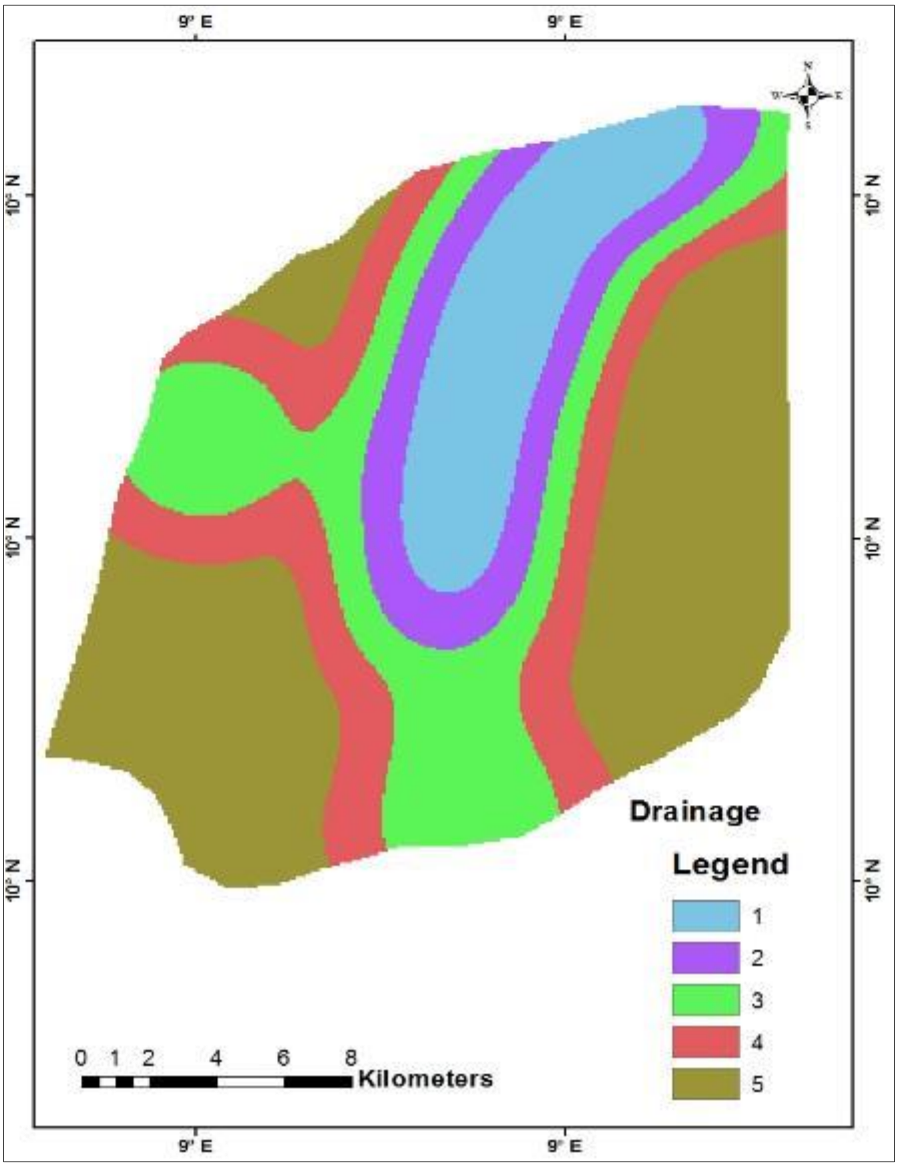

Figure 6 Drainage of Jos North L.G.A

3.5. Lineament and Lineament Density

Lineaments are important in rocks where secondary permeability and porosity dominate the intergranular characteristics. This combines in secondary openings influencing weathering, soil water and ground water movements. The fracture zones form an interlaced network of high transmission and act as ground water conduits in massive rocks in inter-fractured areas. The areas with higher lineament density and topographically low elevated grounds are considered to be the best aquifer zones.

Mapping of lineaments in this study was done by visual interpretation of various digitally enhanced single band and multi band images that involves standard band combinations, principal component analysis and directional filtering. The bands combined for the purpose of this study was band 5, band 3 and band 1 as RGB from Landsat 8. Directional filtering applied was the histogram equalization on the spectral tool bar of ERDAS imagine.

Lineaments are structural lines such as faults. They often represent zones of fracturing and increased secondary porosity and permeability and therefore enhanced groundwater occurrence and movement but from the lineament density map, it shows that around the metropolis (Jos North), groundwater potential is moderate while it was high in the eastern corner of the metropolis and the south west corner on the map. This could be attributed to the higher concentration of this lineament in that region where more of them crisscross, thus areas with higher lineament density are regarded as good for groundwater development as represented in figure 8.

The pair-wise comparison was done based on the fact that areas closer to lineaments are the highest zone of increased porosity and permeability which in turn have greater chance of accumulating groundwater. Figure 7 shows that lineament features are distributed in all parts of the study area and Table 6 reveals that lineament density ranging between 7 and 20 have very high groundwater potential while the range between 0 and 2 have very low potential.

Table 6 Weight assigned to lineament density

Raster Layer	%Influence	Field Value	Rank	Scale Value
Lineaments Density	18.2%	0.0 -1679	Very Low	1
		0.1679-0.5035	Low	2
		0.5036-0.9351	Medium	3
		0.9352-15944	High	4
		1.5945-3.0569	Very High	5

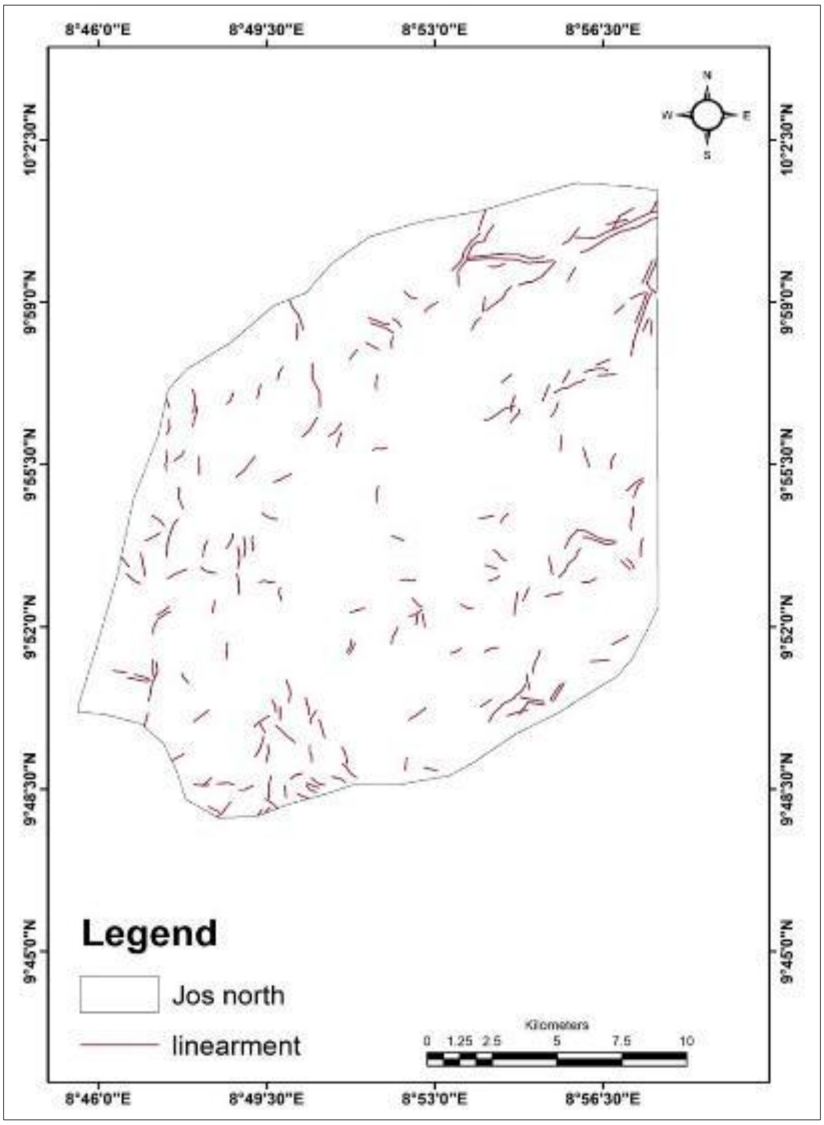

Figure 7 Lineaments of Jos North L.G.A.

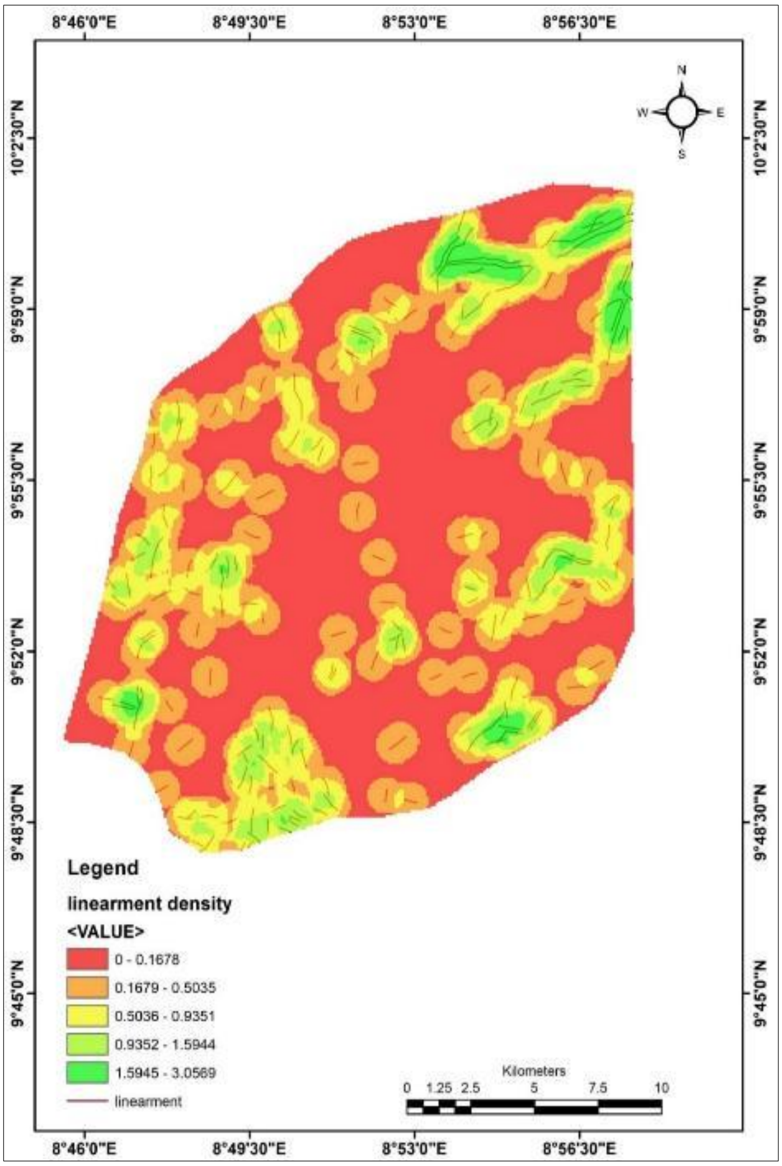

Figure 8 Lineament Density of Jos North L.G.A.

3.6. Slope

Slope which is one of the factors that influence groundwater in the study was generated from the DEM and is shown in Figure 9 and the weight of the slope map was reclassified and is represented in Table 7.

In Table 7 areas that have the value of slope ranging from the field value 3.224 is very low, 3.235-7.164 low, 7.165-13.432 medium, 13.433-22566 high, 22.567-45.669 very high. In relation to groundwater, flat areas where the slope amount is low are capable of holding rainfall, which in turn facilitates recharge whereas in elevated areas where the slope amount is high, there will be high run-off and low infiltration.

Table 7 Weight assigned to slope

RASTER LAYER	% INFLUENCE	FIELD VALUE	RANK	SCALE VALUE
SLOPE	2.2%	0 -3.224	Very Low	1
		3.235 -7.164	Low	2
		7.165 -13.432	Medium	3

		13.433 -22566	High	4
		22.567 -45.669	Very High	5

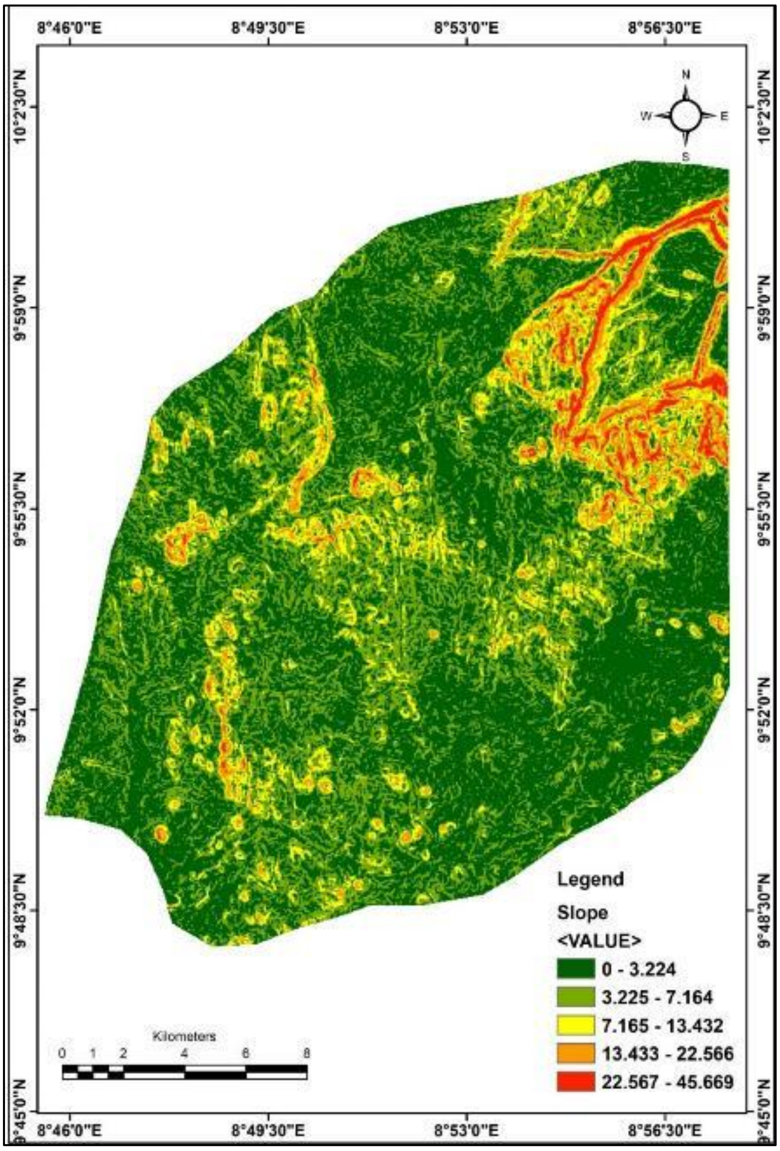

Figure 9 Slope Steepness of Jos North L.G.A

3.7. Average annual rainfall

The amount of rainfall is one of the major factors that contribute to groundwater recharge. In Figure 10, rainfall appears to be high ranging between 1,257 – 1,275 mm. The study area can be seen to have a relatively good rainfall supply. A pair wise comparison was carried for the mean annual precipitation of the study area using AHP and the result is presented in Table 8 and figure 10.

These precipitation values were weighed to reflect the influence on groundwater. More precipitation, more water will be available for surface runoff and infiltrations will naturally recharge the groundwater. The area characterized by high rainfall amount shows high groundwater potential zones (See figure 10).

Table 8 Weight assigned to Average Annual Rainfall

Raster layer	% infuence	Field value	Rank	Scale value
RAIN FALL	21.4%	1, 198 – 1,216	Very Low	1
		1,216.0001- 1,230	Low	2
		1,230.0001- 1,243	Medium	3
		1,243.0001-1,257	High	4
		1,257.0001-1275	Very High	5

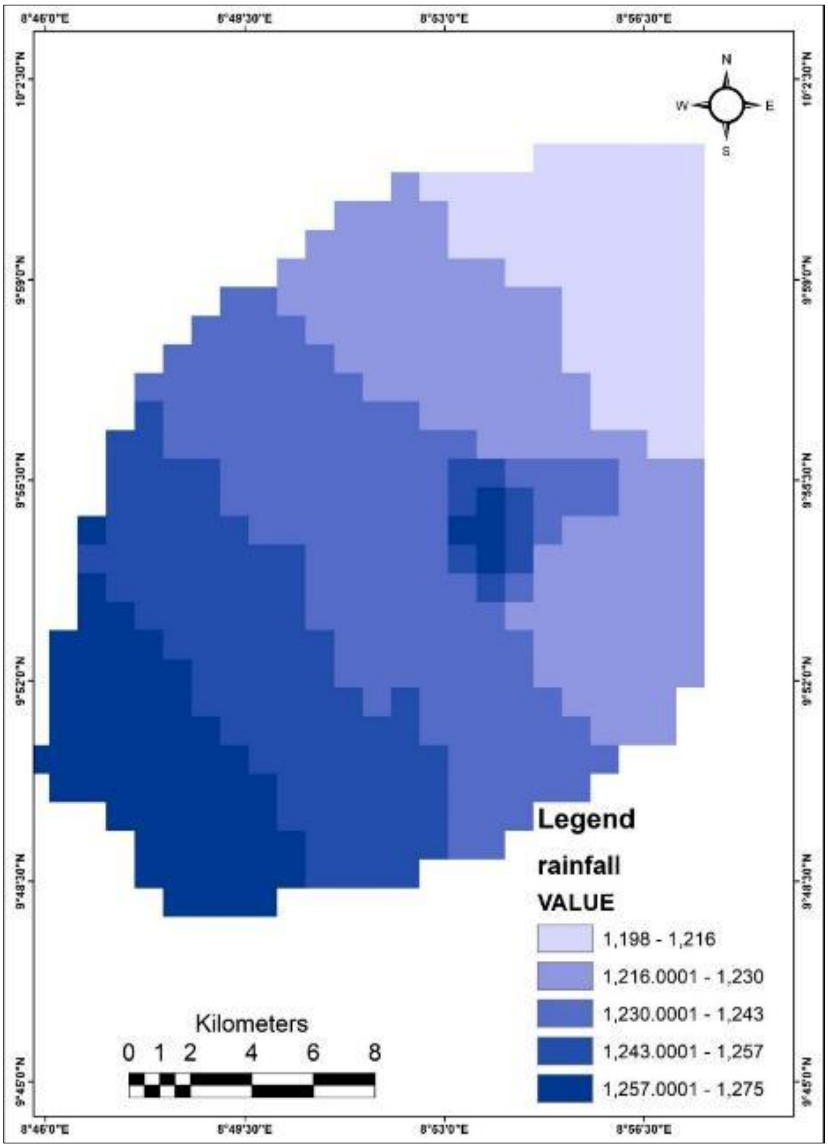

Figure 10 Average Annual Rainfall of Jos North L.G.A.

3.8. Landuse/Landover

One of the parameters that influence the occurrence of groundwater is the land cover and land use of the area. The land use and land cover map were generated from the Landsat imagery by supervised classification and shown in Figure 11 and the weight is shown in Table 9.

The result shows that Jos North occupies an area of 29,100 Hectares, of which vegetation occupies the highest with 9344 Hectares (33%). This is followed by settlement with 8217 Hectares (28%), cultivation covers 699 Hectares (24%), and bare surface occupies 421 (14%) while the water body coverage is about 330 (1%) Hectares (14%).

The LU/LC of an area provides important indications of the extent of groundwater requirement and utilization. The effect of land use/cover is demonstrated either by reducing runoff and facilitating, or by trapping water on their leaf. Vegetation is an excellent site for groundwater exploration [49]. The area with built-up land is poor for it.

Table 9 Weight assigned to land use/ land cover

Raster layer	% influence	Field value	Rank	Scale value
LULC	1.7%	Vegetation	Very High	5
		Settlement	High	4
		Cultivation	Medium	3
		Bare Land	Low	2
		Water Body	Very low	1

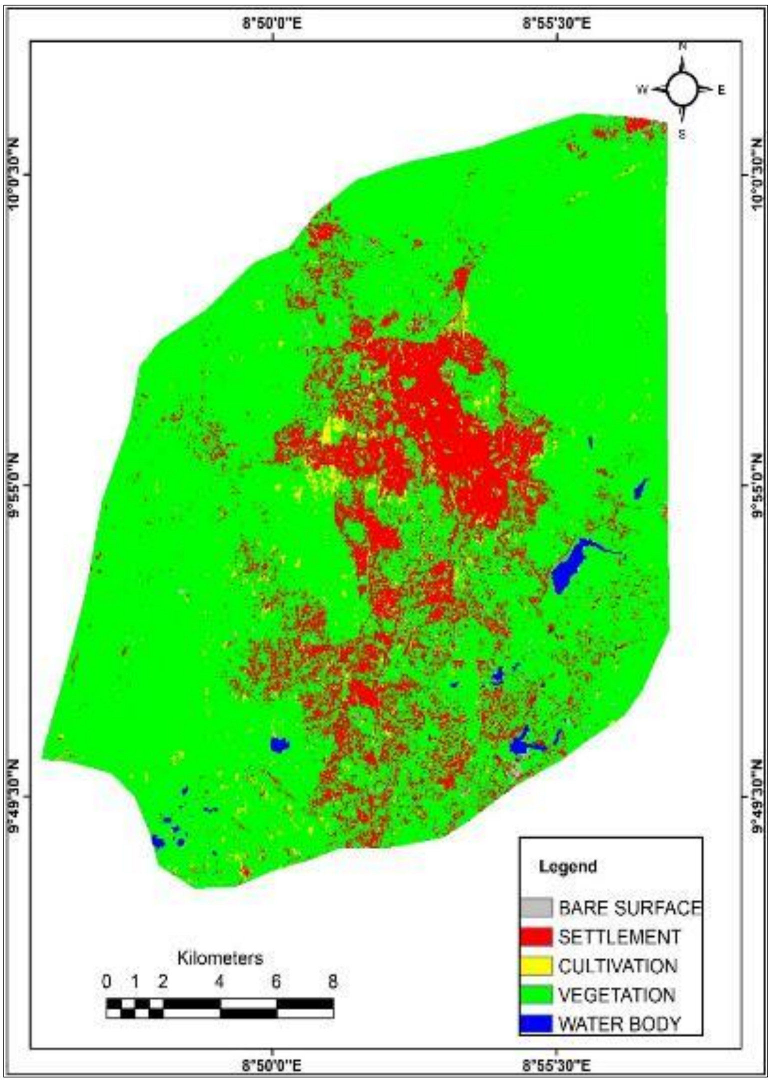

Figure 11 Landuse/Landover of Jos North

3.9. Identification of the ground water prospect zones from the thematic maps

In an attempt to show the groundwater prospects zones in Jos North L.G.A., all the thematic maps of the factors influencing the groundwater recharge in the area were weighed and integrated in the order suggested by [44].

Preparing the groundwater (potential) map the following procedure was followed. This was prepared by integrating the information from the geology, drainage density, lineament density, land use land cover, rainfall, elevation and slope map in ArcGIS.

Groundwater potential zones were delineated by reclassifying into different potential zones; low potential, slight high potential, high potential, more potential and most potential (See Figure 12). The map produced showed that the groundwater potential of the study area is related mainly to rainfall, lineaments, geology, slope, elevation, drainage and landuse/landcover. It can also be seen from the map that the areas with very good groundwater potential are within the Northern part of the map while the areas by low potential are towards the Eastern area. It can be observed from the thematic maps generated that the areas with very good groundwater potential in the Northern area were characterized by high lineament density and are of flats areas or gentle slope.

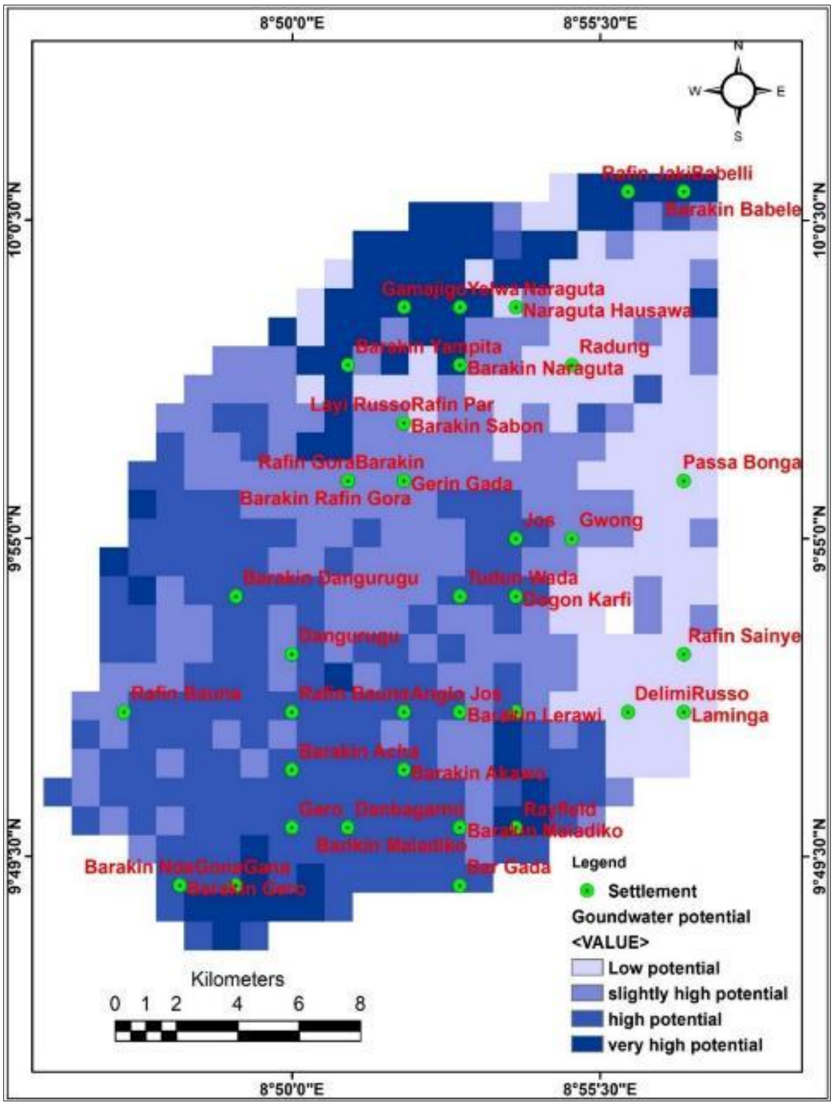

Figure 12 Map showing groundwater potential zones in Jos North L.G.A

3.10. Estimation of the area coverage of the ground water potential zones

The area coverage occupied by the groundwater potential zones was estimated in ArcGIS by converting the potential sites to vector format and using the calculate geometry tool in the attributes table to calculate the area of each of the potential zones. Table 10 represents the estimated area coverage of the groundwater potential zones in square kilometre and in percentage. Table 11 shows the resulting weight for criteria based on the overall pairwise comparison while Table 12 shows Principal Eigen Value of the Analysis.

Table 10 Area coverage of groundwater potential zone

Ground Water Potential Zones	Area in Hectares	Percentage (%)
LOW POTENTIAL	86.700171	22.092
SLIGHTLY HIGH	117.686743	29.987
HIGH	137.890192	35.135
VERY HIGH	50.179697	12.786

Table 11 Overall pairwise comparison for all criteria

Category		Priority	Rank	(+)	(-)
1.	Rainfall	32.2%	1	9.1%	9.1%
2	Lineament density	27.5%	2	8.7%	8.7%
3	Geology	17.7%	3	6.0%	6.0%
4	Drainage density	11.6%	4	4.4%	4.4%
5	Elevation	6.1%	5	2.4%	2.4%
6	Slope	2.8%	6	1.1%	1.1%
7	Land use/ Land cover	2.1%	7	0.9%	0.9%

Number of Comparison = 21, Consistency Ratio CR =8.9

Table 12 Principal Eigen Value

	1	2	3	4	5	6	7
1	1	2.00	3.00	4.00	5.00	6.00	7.00
2	0.50	1	3.00	4.00	5.00	6.00	9.00
3	0.30	0.33	1	2.00	6.00	7.00	9.00
4	0.25	0.25	0.50	1	2.00	8.00	9.00
5	0.20	0.20	0.17	0.50	1	5.00	3.00
6	0.17	0.14	0.14	0.12	0.2O	1	2.00
7	0.14	0.11	0.11	0.11	0.33	0.50	1

Principal Eigen Value = 7.714

4. Conclusion

This study employed an integrated GIS and remote sensing approach to delineate groundwater potential zones in Jos North metropolis. A key finding highlights the significant negative impact of urbanization on cultivated land and natural vegetation, with an observed urban growth rate of 0.53 km^2/year driving increased water demand. Furthermore, the analysis revealed that a larger percentage of the study area falls within the moderate groundwater potential classification.

Rapid urban expansion in Jos North, driven by rural-urban migration, educational and residential development, economic growth, and transportation network evolution, has resulted in the encroachment of urban areas onto rural lands. This growth underscores the need for balanced distribution of infrastructural facilities to achieve sustainable urban development. To assess groundwater potential objectively, a weighted overlay model within the GIS framework was implemented, utilizing seven key thematic parameters derived from spatial analysis: average annual rainfall, geology, lineament density, elevation, slope, land use/land cover, and drainage density. The relative weights for these parameters were systematically assigned based on their influence on groundwater occurrence using established multi-criteria decision analysis (MCDA) principles.

The final groundwater potential zonation map demonstrates a distinct spatial pattern. Areas classified as having high groundwater potential are predominantly clustered within the northern sectors of the study area. Conversely, zones designated as moderate and low groundwater potential are distributed across the wider Jos North metropolis.

Recommendation

- Investigate Urbanization Impacts: Conduct targeted studies on population growth and urban expansion to quantify their impacts on water demand, land cover, and groundwater recharge, enabling evidence-based mitigation strategies.
- Target Exploration in High-Potential Zones: Prioritize groundwater exploration and development efforts in the identified "Very Good" potential zones located in the Northern part of the study area.
- Ensure Equitable Water Access: Implement policies and infrastructure to guarantee sufficient, safe, acceptable, physically accessible, and affordable potable water for all residents.
- Integrate Geospatial Technologies: Mandate the systematic integration of remote sensing and GIS techniques into groundwater exploration and monitoring protocols for enhanced terrain analysis and feature mapping.
- Maintain a Dynamic Spatial Database: Establish a dedicated platform for regularly updating the groundwater potential map and thematic layers with new hydrogeological data to support informed decision-making.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest is to be disclosed

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