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Research Article

Delineation of Groundwater Potential Zones Using a Modified DRASTIC–GIS Approach in a Crystalline Basement Terrain, Northwestern Nigeria

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Abstract

In northern Nigeria's crystalline basement terrains, where surface water resources are seasonal and poorly distributed, groundwater is the primary source of drinkable water. In order to identify groundwater potential zones in the Lere Local Government Area of Kaduna State, Nigeria, this study used an integrated Remote Sensing and Geographic Information System (GIS) approach. Landsat-8 OLI images, the ASTER Digital Elevation Model (30 m resolution), and pre-existing geological and soil maps were used to determine six groundwater-influencing parameters: geology, lineament density, slope, soil texture, drainage density, and land use/land cover (LULC). The studied area's drainage density ranges from 0 to 2.172 km/km², and its slope extends from 0° to 72.86°. Bare terrain makes up the majority of the region (84.57%), followed by settlements (8.44%), hills (6.16%), water bodies (0.82%), and vegetation (0.001%), according to LULC research. Thematic layers were given weights using a modified DRASTIC-based multi-criteria evaluation technique, including geology (5), lineament density (4), slope (4), soil texture (3), drainage density (2), and land use/land cover (1). A Groundwater Potential Index (GPI) map that divided the region into high, moderate, and low groundwater potential zones was created using weighted overlay analysis in a GIS context. Fractured granite gneiss and migmatite, high lineament density (0.656–1.365 km/km^2), mild slopes (0–9.429°), permeable soils, and low drainage density (0–0.564 km/km^2) are all associated with high potential zones, while steep slopes and severely dissected terrains are associated with low potential areas. The findings show that lithology and structural characteristics play a major role in the occurrence of groundwater and show that integrated remote sensing and GIS techniques offer a dependable and affordable tool for sustainable borehole siting and groundwater exploration in basement complex terrains.

Keywords

Basement Complex, GIS, Groundwater Potential, Kaduna State, Modified DRASTIC Model, Nigeria, Remote Sensing

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1. Introduction

Particularly in crystalline basement terrains where surface water bodies are seasonal, transient, and irregularly distributed, groundwater is an essential freshwater resource [1]. Groundwater development is crucial to reliable availability to drinkable water in many northern Nigerian regions [2]. However, the presence of groundwater in complex basement environments varies greatly and is influenced by the degree of weathering, lithology, and structural discontinuities like lineaments and fractures [3]. Therefore, before conducting in-depth field research and borehole drilling, locations with high groundwater potential must be identified using methodical and economical techniques. The geographical, spectral, and temporal data coverage of remote sensing has made it a useful tool for groundwater assessment, allowing for the quick mapping of vast and difficult-to-reach areas [4].

Surface indicators like geology, geomorphology, soil properties, drainage patterns, and land use/land cover can be taken from satellite data and used as stand-ins for groundwater occurrence even though satellite sensors cannot directly detect groundwater [5]. Important details on the variables affecting groundwater entry, storage, and movement within subsurface formations are provided by these theme levels [6]. By offering a strong platform for storing, organizing, evaluating, and combining vast amounts of spatial and attribute data, geographic information systems (GIS) enhance remote sensing [7]. GIS makes it easier to combine groundwater-influencing factors in order to discover and rank possible zones through spatial modeling and multi-criteria evaluation procedures [4].

The cost, time, and uncertainty associated with traditional hydrogeological exploration techniques are greatly decreased by this integrated remote sensing–GIS strategy, which also aids in identifying target locations for in-depth geophysical investigations and drill siting [5]. In order to identify groundwater potential zones in the Lere Local Government Area of Kaduna State, Nigeria, this study uses geospatial modeling approaches. Geology, soil properties, land use/cover, topography (slope), and drainage density are some of the important hydrogeological elements that affect groundwater accumulation and are taken into account in this research. Each thematic layer is given a relative relevance using a modified DRASTIC-based weighting and rating scheme developed by Aller *et al*. [8]. A groundwater potential index map is then produced using weighted overlay analysis.

In order to confirm model outputs, field verification and GPS measurements were carried out. In Lere LGA and other basement complex terrains, the final groundwater potential map and the resulting thematic maps are meant to be used as decision-support aids for sustainable groundwater research and development.

2. Study Area and Geological Setting

In Kaduna State, northwest Nigeria, the Lere Local Government Area (LGA) lies between latitudes 10°23′N and 10°43′N and longitudes 7°17′E and 7°37′E (Figure 1). The region is in Nigeria's sub-humid ecological zone, which is defined by Guinea savannah flora [9, 10], and is situated on a gently sloping plain on the outskirts of the Jos Plateau [11]. With an average yearly rainfall of more than 1600 mm, the climate is characterized by a clear wet and dry season [12]. Rain-fed agriculture benefits from the favorable conditions of the rainy season, which normally lasts from May to October [13]. The majority of the population is agrarian, growing basic crops such rice, millet, and maize that rely heavily on seasonal rainfall and additional groundwater supplies [14].

The Nigerian Basement Complex's Precambrian rocks form the geological foundation of the research region [15, 16]. Because of the extended weathering of these crystalline rocks in tropical climates, a variable layer of unconsolidated regolith has developed on top of the newly formed bedrock [17, 18].

The majority of the migmatite–gneiss complexes, Pan-African granitoids, metasedimentary and metavolcanic rocks (including schists, quartzites, amphibolites, and banded iron formations), calc-alkaline granites, and minor Jurassic volcanic rocks make up the Basement Complex in the area [17, 18]. The presence of groundwater in this basement terrain is mostly regulated by secondary permeability and porosity that are created by weathering and structural deformation. In such cases, the primary determinants of groundwater storage and transmissivity are the thickness of the weathered overburden and the size, density, and connectedness of fractures and other structural discontinuities within the bedrock [15, 16]. Although groundwater is important for residential and agricultural use, it is still underdeveloped in Lere LGA, and there is a lack of thorough hydrogeological data on its potential and dynamics. Given the hydroclimatic and geological features of the region, a comprehensive assessment of the groundwater potential is necessary.

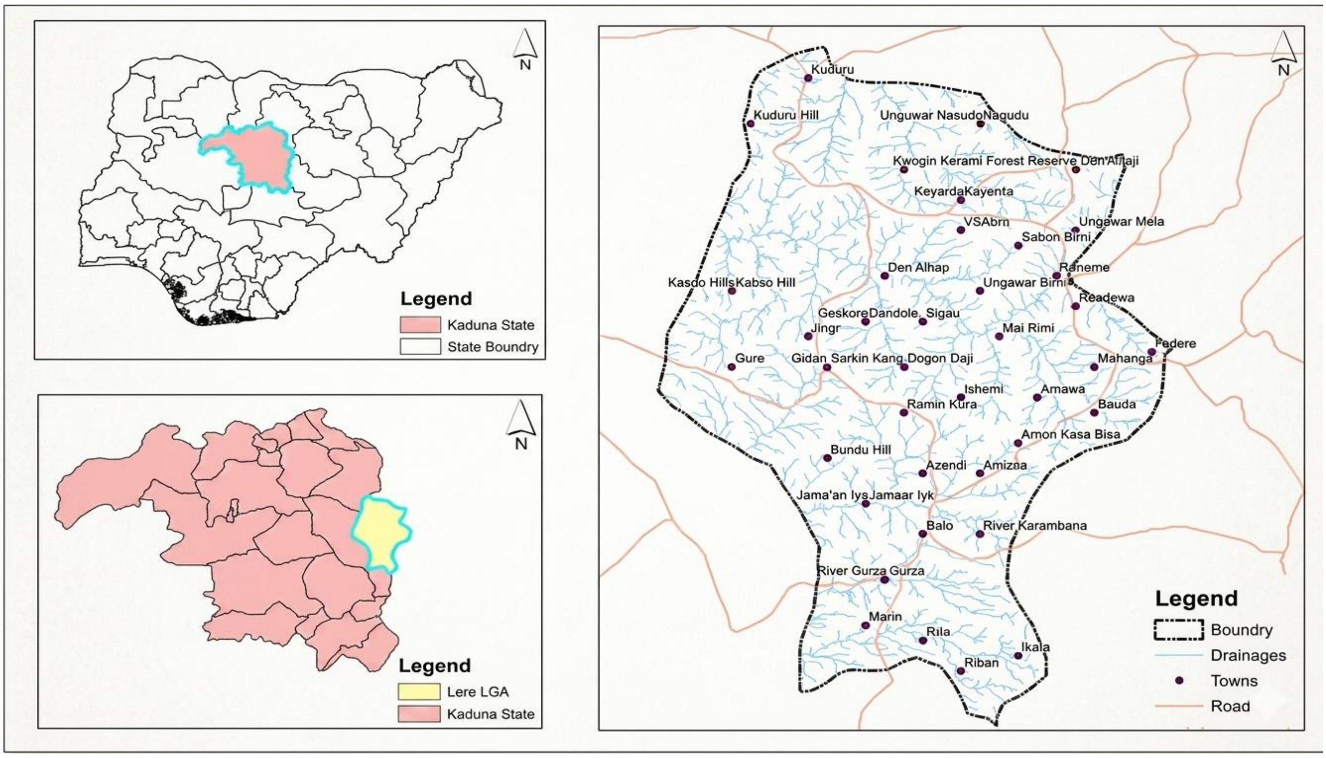

Figure 1. Location map of the Study Area.

3. Materials and Methods

3.1. Data Types and Sources

In order to identify groundwater potential zones in Lere LGA, Kaduna State, this study integrated field data, thematic maps, and remotely sensed imagery within a GIS environment. The dataset employed in this study are summarized in Table 1. Landsat 8 Operational Land Imager (OLI) (30 m resolution, Path/Row 189/53, acquired in 2019) was used to extract Land use/land cover (LULC) and lineament features. The Seven bands make up the imagery: one panchromatic band at 15 m resolution and six multispectral bands at 30 m resolution. Advanced Spaceborne Thermal Emission and Reflection (ASTER) images (30 m resolution, obtained 2015) were used to extract slope and drainage extraction. Geological map (1: 250,000 scale) 2008 obtained from the Nigerian Geological Survey Agency (NGSA), 2008 was scanned in order to identify lithological units. Soil map (1: 100,000 scale, 2010) obtained from the Kaduna State Ministry of Agriculture was digitally altered to identify soil types that are important for groundwater infiltration and storage. Data obtained from the Global Positioning System (GPS) was used for land use ground trothing and lithology.

Table 1. Summary of data types and sources.

Data	Source	Year	Relevance
Soil map	Kaduna State Ministry of Agriculture	2010	Soil characteristics
Geologic map	NGSA	2008	Lithology/rock types
ASTER DEM	Earth Explorer	2015	Slope and drainage
Landsat 8 OLI	USGS	2019	Land use/cover and Lineaments

3.2. Methods

The methodology combines remote sensing, GIS, and a modified DRASTIC-based multi-criteria evaluation to map groundwater potential. Six theme parameters—geology, lineament density, slope, soil texture, drainage density, and land use/cover—were chosen because of their impact on the occurrence of groundwater.

Land Use/Land Cover (LULC): The Maximum Likelihood approach was used to classify Landsat 8 imagery after it had been reprocessed (radiometric correction, layer stacking, sub-setting). GPS ground truthing was used to confirm the classification.

Lineaments: Converted into lineament density maps using GIS tools after being extracted visually with the aid of edge enhancement and directional filtering.

Slope and Drainage: were extracted from the ASTER DEM using the spatial analyst toolkit. The ratio of total stream length to drainage basin area was used to compute drainage density. Five categories were used to classify slope based on the possibility of infiltration.

Geology and Soil: Permeability and groundwater storage properties were used to scan, georeference, digitize, and re-classify maps.

3.3. Conceptual Framework: DRASTIC and Modified DRASTIC Models

A standardized method for assessing groundwater vulnerability is the DRASTIC model [8] (Aller *et al*., 1987), which makes use of seven hydrogeological factors:

D = Depth of water;

R = net recharge;

A = Aquifer media;

S = Soil media;

T = Topography/Slope;

I = Impact of vadose zone;

C = Hydraulic conductivity.

The traditional DRASTIC index is calculated as follows:

$$GPP = D_r D_w + R_r R_w + A_r A_w + S_r S_w + T_r T_w + I_r I_w + C_r C_w \quad (1)$$

Where:

GPP = Groundwater Pollution Potential

r = rating of each parameter

w = assigned weight

A modified DRASTIC model was used for mapping groundwater potential [8], substituting hydrogeological variables that govern groundwater occurrence for vulnerability factors:

$$GP = G + L + SL + S + D + Lu \quad (2)$$

Where:

GP = Groundwater Potential

G = Geology, L = Lineament density, SL = Slope, S = Soil, D = Drainage density, and Lu = Land use/cover

The weighted form of the modified DRASTIC index is as follows:

$$GP = G_r G_w + L_r L_w + SL_r SL_w + S_r S_w + D_r D_w + Lu_r Lu_w \quad (3)$$

Where:

r = rating for each class within the thematic layer and

w = weight given to each parameter according to its proportional importance in groundwater occurrence

This method is frequently used to combine several hydrogeological factors into a single index in GIS-based groundwater assessment. Using easily accessible hydrogeological data to assess groundwater potential, identifying target zones for groundwater exploration at a reasonable cost, and effectively adapting to regional-scale mapping in complex basement terrains are some of the benefits of the Modified DRASTIC approach.

3.4. GIS-based Weighted Overlay Analyisis

The Raster Calculator in ArcGIS 10.7 was used to multiply each theme layer by the weight that was provided to it [19, 20]. A composite raster depicting groundwater potential was created by adding up all of the weighted layers. Whereas lower values indicate poor groundwater prospects, higher values indicate regions with substantial groundwater potential [4]. Using the natural breaks (Jenks) categorization approach, the resulting groundwater potential map was divided into three zones: high, moderate, and low potential [21, 22]. The flowchart of the Modified DRASTIC model is shown in Figure 2. In profoundly complex terrains, this integrated technique guarantees a methodical, repeatable, and economical approach to assessing regional groundwater potential [4, 21].

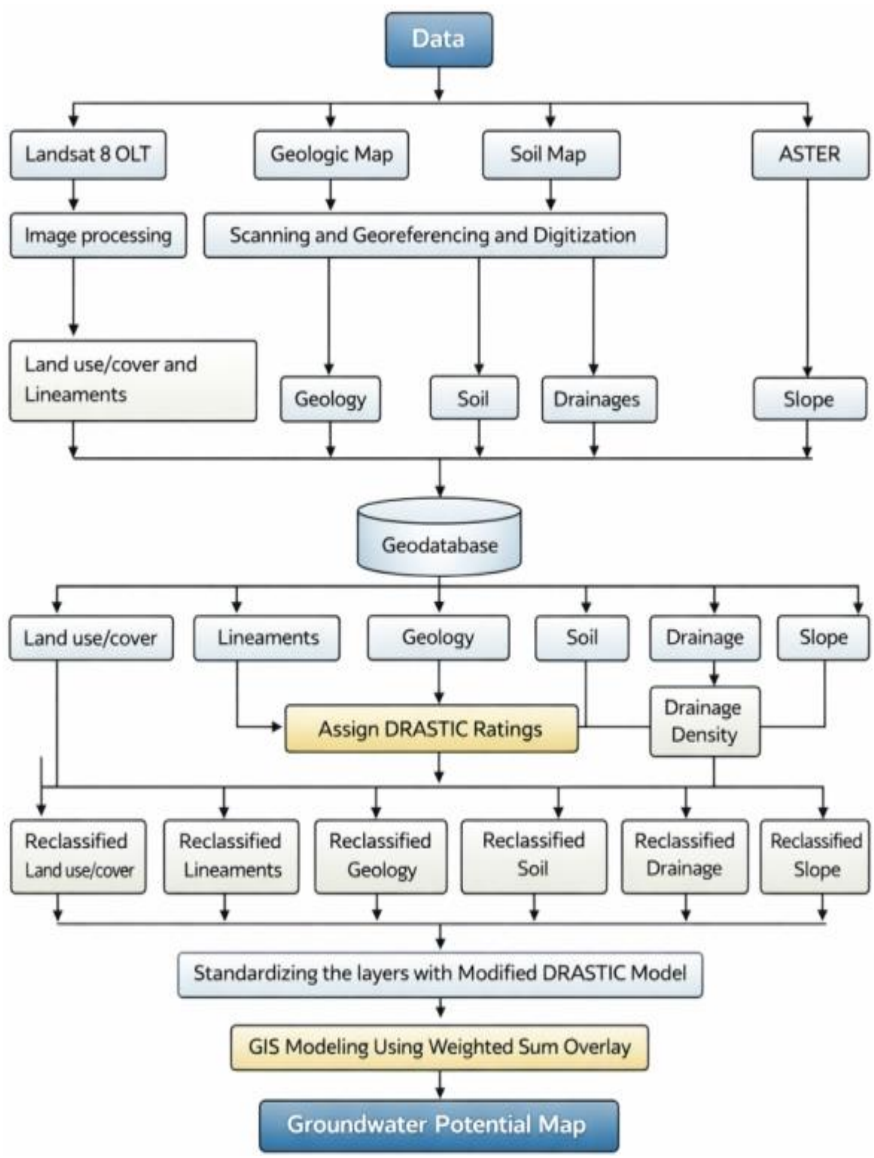

Figure 2. *Modified DRASTIC model flowchart.*

4. Results and Discussion

4.1. Slope

According to Gupta and Srivastava [23], slope is an important topographic feature that influences groundwater recharge potential, infiltration capability, and surface runoff. While moderate slopes enhance penetration, steep slopes prevent groundwater recharging in basement complex terrains by promoting fast runoff. There are five sets of slope values in the research area: gentle (3.143–9.429°), moderate (9.429–20.287°), steep (20.287–37.431°), flat (0–3.143°), and very steep (37.431–72.861°) as summarized in Table 2. The slope values range from 0° to 72.86°.

Table 2. *Slope classification.*

Slope Classes	Degree	Modified DRASTIC Rating
Flat	0 - 3.143	10
Gentle	3.143 - 9.429	8

Slope Classes	Degree	Modified DRASTIC Rating
Moderate	9.429 - 20.287	6
Steep	20.287 - 37.431	3
Very Steep	37.431 - 72.861	1

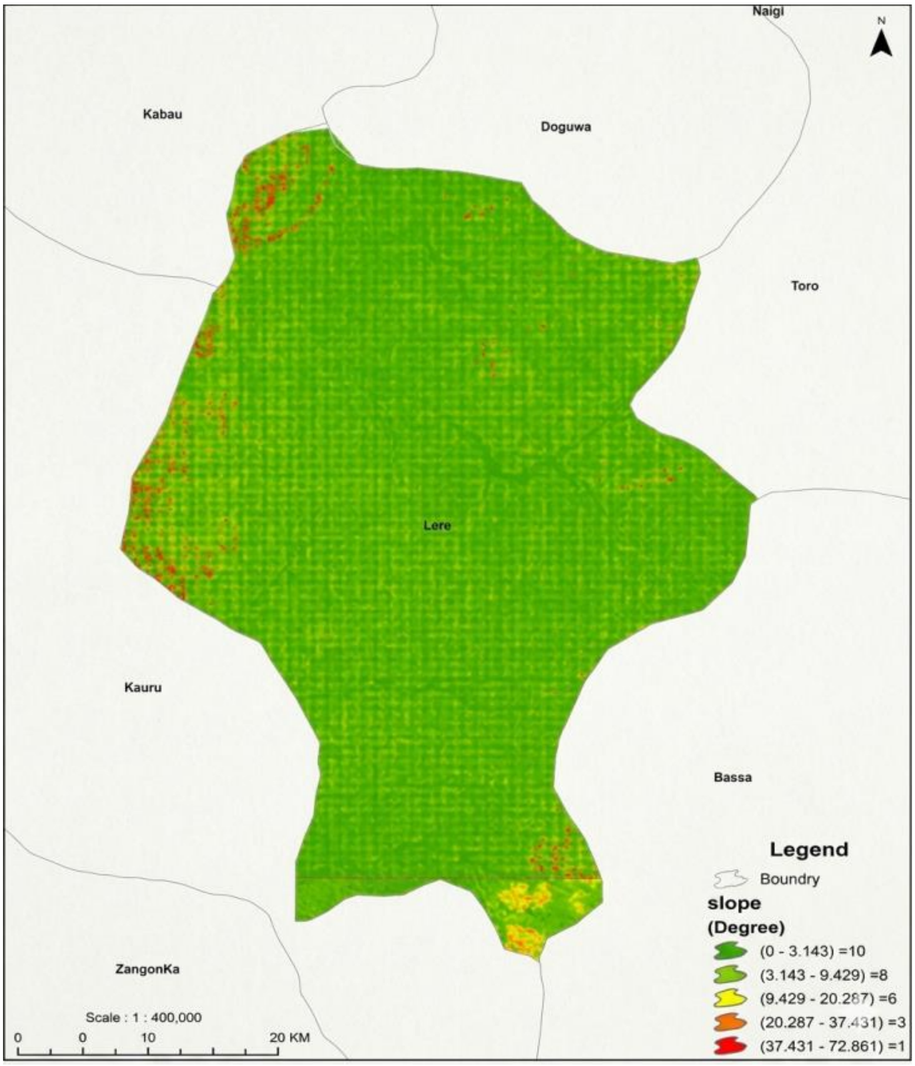

***Figure 3**. Slope map of Lere LGA, Kaduna.*

Given that infiltration is inversely correlated with slope gradient [24], flatter terrains received higher Modified DRASTIC ratings (rating = 10), while steeper slopes received progressively lower ratings (rating = 1). Because of the improved recharge conditions and decreased runoff, low-gradient regions are more suited for groundwater accumulation, according to the spatial distribution of slope classes (Figure 3).

4.2. Lineament Density

In crystalline basement rocks, lineaments are structural discontinuities that improve secondary porosity and permeability. These discontinuities include joints, faults, and fractures [15, 17]. The density and connectedness of these structural elements play a major role in controlling the presence of groundwater in various types of terrains. Based on their contribution to groundwater storage, lineament density values were divided into five groups and given Modified DRASTIC ratings [4, 8] as shown in Table 3. Because of their increased groundwater potential, locations with higher lineament densities were rated higher than those with sparser structural features. Structurally controlled zones that could act as preferred routes for groundwater transport and storage are visible on the lineament density map (Figure 4).

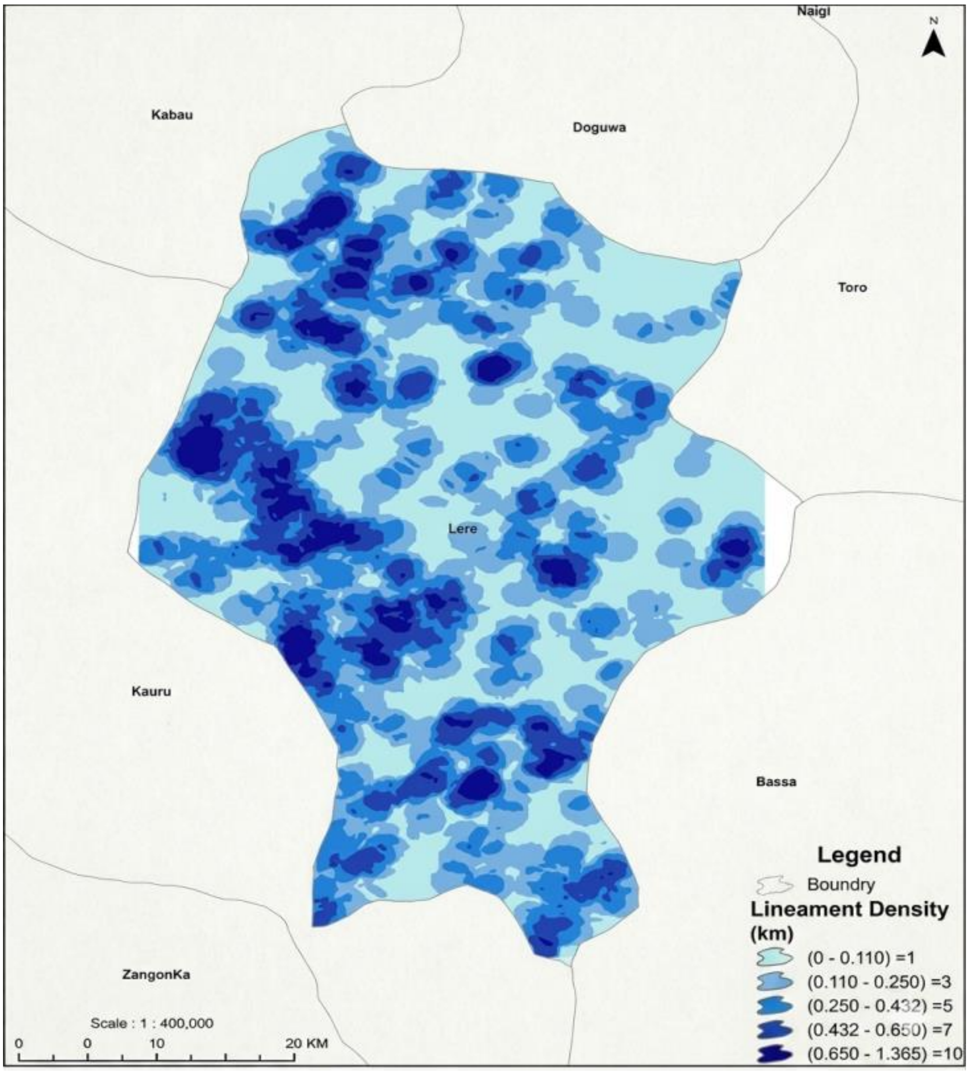

***Figure 4**. Lineament map of Lere LGA, Kaduna.*

***Table 3**. Lineament classification.*

Lineament Classes (km)	Modified DRASTIC Rating
0 – 0.110	10
0.110 – 0.259	8
0.259 – 0.432	6
0.432 – 0.656	3
0.656 – 1.365	1

4.3. Land Use/Land Cover

The processes of infiltration, evapotranspiration, and runoff are all greatly impacted by land use/land cover (LULC). Vegetation, barren ground, settlement, hills, and water bodies are the five main LULC categories into which the research region was divided. Because of their enhanced soil structure and root-induced permeability, agricultural and vegetated lands encourage infiltration [1]. Consequently, the highest ranking (10) was given to vegetation. Water bodies received a high rating (8) because they immediately contribute to recharge. Because of its varying infiltration characteristics based on surface compaction, bare land, which makes up the majority of the research region (about 84.57%), was rated as moderate. Because of their impermeable surfaces, which prevent infiltration, settlements received a low grade (3). Because of their steep slopes and increased drainage, hills get the lowest grade (1). Table 4 displays the quantitative distribution for each LULC class. According to the spatial distribution of LULC (Figure 5), low-lying and vegetated areas are strongly associated with groundwater recharge capacity.

Table 4. Land use/cover classification.

Land Use/Cover	Area (Hectares)	Area (%)	Modified DRASTIC Ratings
Water body	7147.8900	0.818	8
Settlement	73760.4900	8.444	3
Vegetation	8.7400	0.001	10
Bare-Land	738756.5400	84.574	6
Hills	53833.6800	6.163	1

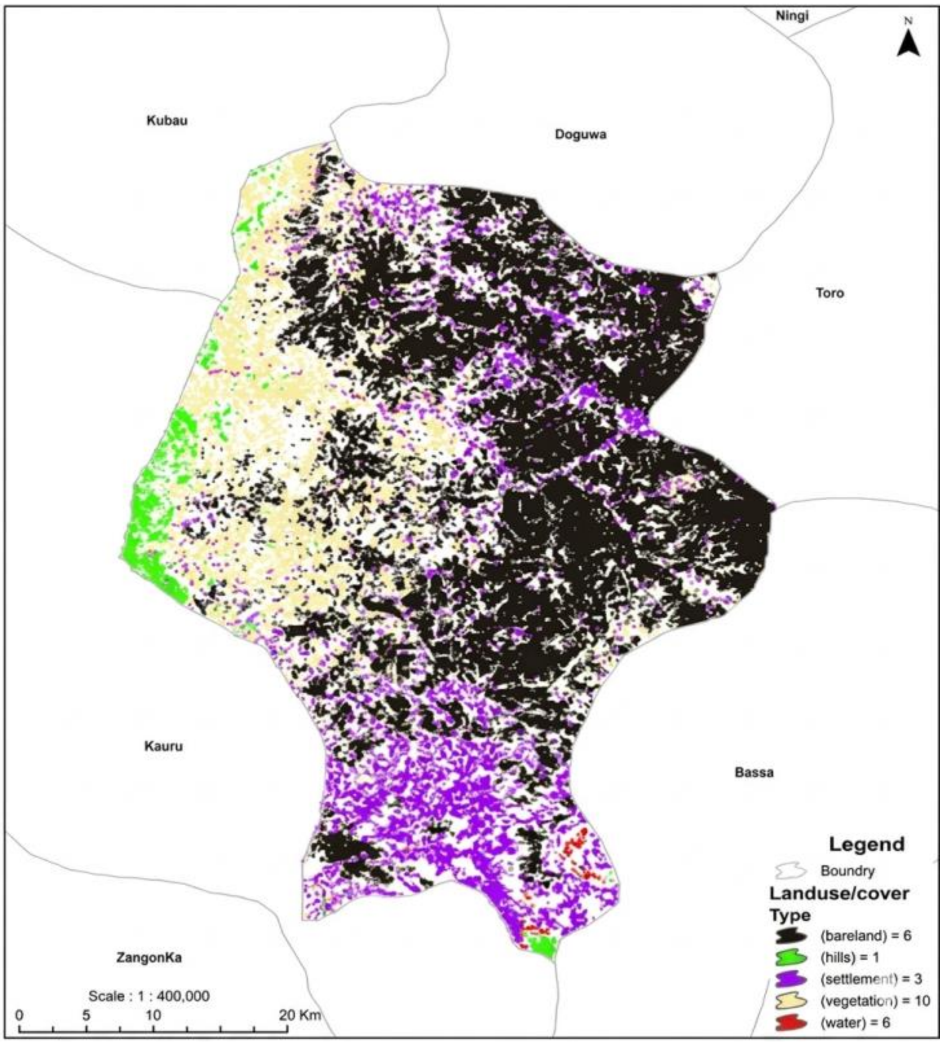

Figure 5. Land use/cover Map of Lere LGA, Kaduna.

4.4. Soil Texture

Permeability, infiltration rate, and water retention capacity are all directly impacted by soil texture [25]. While clay-rich soils tend to limit percolation, sandy and gravelly soils typically show higher infiltration rates [6, 26]. The classification and corresponding Modified DRASTIC ratings of the soil texture are presented in Table 5. Permeability parameters were used to identify and rate six soil units. Because of their advantageous infiltration qualities, sandy loam and shallow, well-drained loamy sand soils were rated higher (9) than other types [8]. On the other hand, because of their relatively lesser permeability, deeper sandy clay units were rated lower. Permeable soil textures are geographically related with zones of moderate to high groundwater potential [27], according to the soil distribution map (Figure 6).

4.5. Geology

Because groundwater storage is mostly limited to weathered and fractured zones, geology has the greatest influence over groundwater occurrence in crystalline basement terrains [28, 27]. The classification and corresponding Modified DRASTIC ratings of the geology are presented in Table 6. Amphibolite, porphyritic biotite granite, leucocratic granite, migmatite, pyroxene fayalite granite, biotite granite, leucocratic granite, and undifferentiated schist are all found in the research region [6, 18]. Because of its improved fracture and weathering properties, granite gneiss was given the highest grade (10) among these units. Because of their structural characteristics, amphibolite and undifferentiated schist were also given comparatively high ratings [27]. Because of their decreased primary porosity, massive granitic units with little fracture received lower scores. The major role of lithology in groundwater distribution throughout the region is confirmed by the geological map (Figure 7), which shows that areas of higher groundwater potential correspond to structurally deformed and weathered lithologies.

Table 5. *Soil Classification.*

Soil Type	Modified DRASTIC Rating
Very deep well drained sandy loamy sand to sandy clay	3
Very shallow well drained loamy sand to sandy loam	9
Very deep well drained sandy loamy to sandy clay	4
Very deep well drained sandy loamy to loamy sand	9
Moderately deep well drained sandy loam gravelly	7
Deep well drained sandy loam to sandy clay gravelly	5

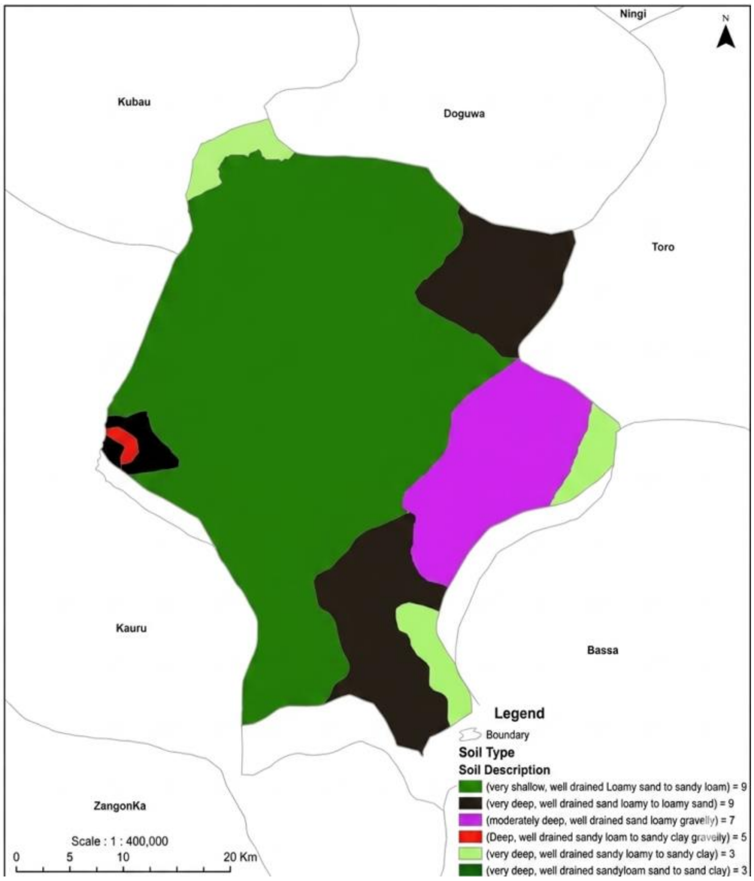

Figure 6. *Soil Map of Lere LGA, Kaduna.*

Table 6. *Geology Classification.*

Geology	Modified DRASTIC Rating
Amphibolite	8
Biotite Granite	2
Porphyritic Biotite and Biotite Hornblend	1
Granite Genies	10
Medium to Coarse Grained Biotite Granite	2
Migmatite	4
Pyroxene Fayalite Granite	1
Undifferentiated Schist	7

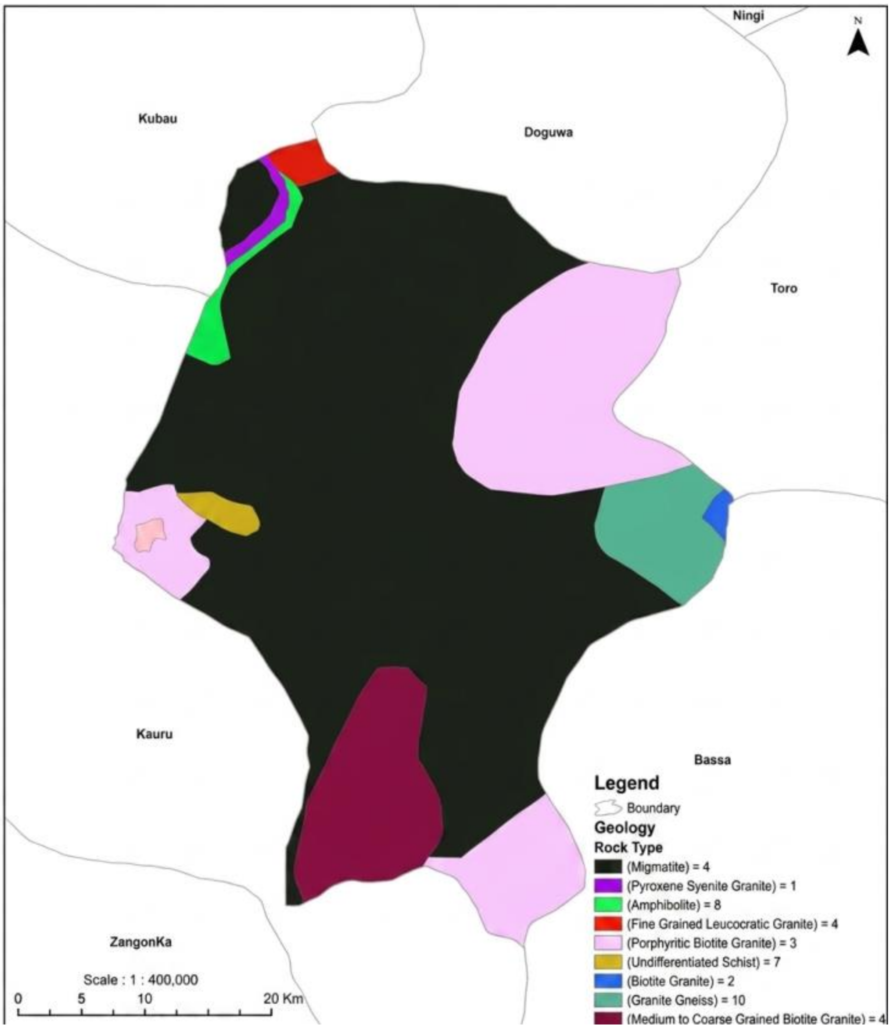

Figure 7. *Geological Map of Lere LGA, Kaduna.*

4.6. Drainage Density

Infiltration capacity and subsurface permeability are indirectly indicated by drainage density, which also reflects the extent of landscape dissection [29]. It is defined as the ratio of total stream length to basin area. From very low to very high, the drainage density values were divided into five groups as presented in Table 7. Areas with very low drainage density received the highest ranking (10), as they promote infiltration and groundwater recharging. However, areas with very high drainage density were given the lowest grade (1) due to their increased runoff and restricted recharge [1]. The drainage density map (Figure 8) is dominated by dendritic patterns, which show consistent lithological conditions with regional structural control.

Table 7. Drainage Density Classification.

Drainage Density	Classes	Modified DRASTIC Rating
0 - 0.564	Very low	10
0.564 - 0.819	Low	8
0.819- 1.081	Moderate	6
1.081 - 1.368	High	4
1.368- 2.172	Very high	1

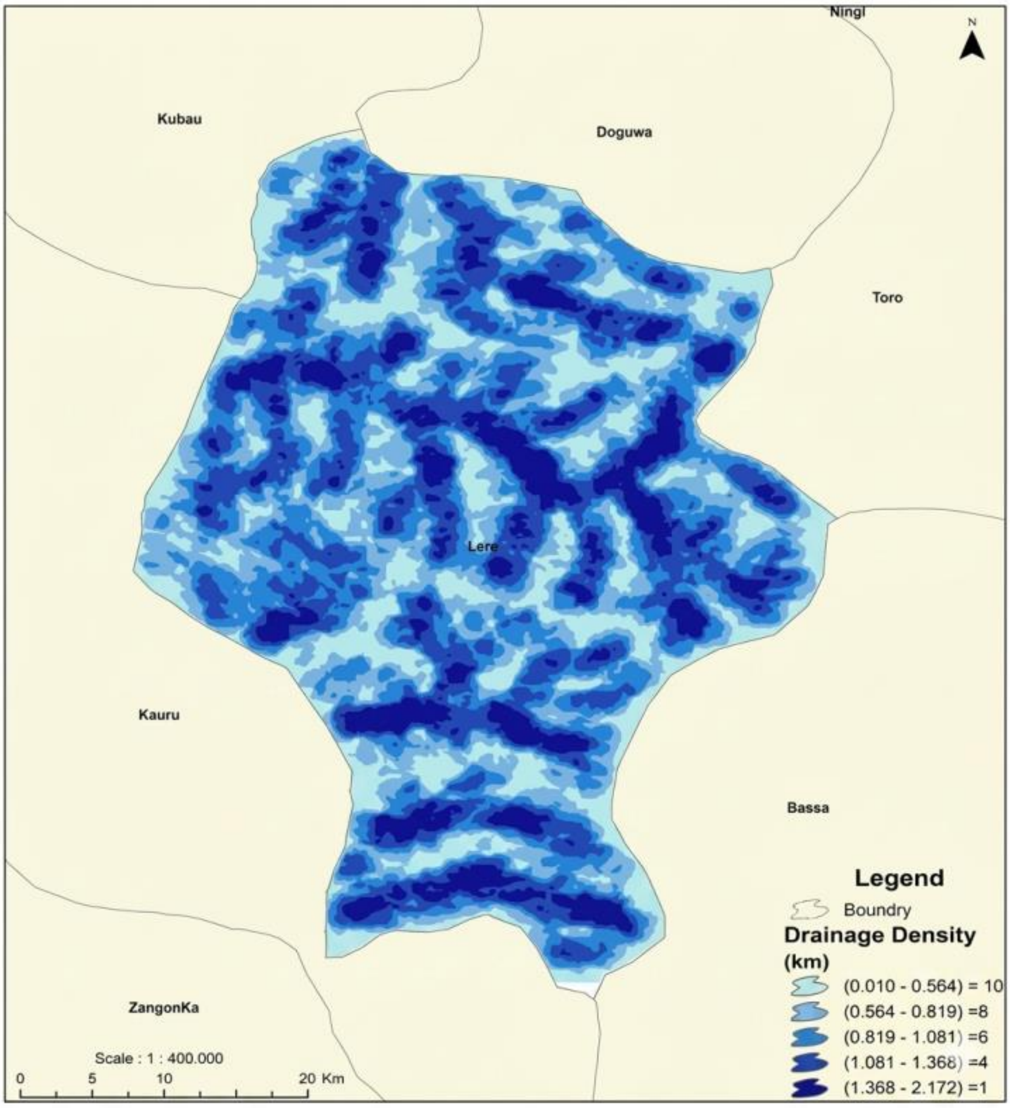

Figure 8. Drainage Density Map of Lere LGA, Kaduna.

4.7. Groundwater Potential Map

Within a GIS framework, a weighted linear combination strategy was used to merge all theme layers as summarized in Table 8. Geology received the highest weight (5), followed by lineament density (4) and slope (4), soil texture (3), drainage density (2), and land use/land cover (1), all of which were ranked according to their relative hydrogeological relevance [4]. A composite Groundwater Potential Index (GPI), which reflects the combined impact of all characteristics, was produced using the weighted overlay analysis [8, 30]. The study region is divided into three main classes—high, moderate, and low potential zones—by the resulting groundwater potential map (Figure 9). Low slopes, low drainage density, permeable soils, vegetative land cover, granite gneiss, and fractured lithologies are the main characteristics of high potential zones. The combined effects of intermediate slope gradients and soil properties are reflected in moderate zones. Large unfractured granitic rocks, steep topography, and regions with high drainage densities are the main locations for low potential zones [27, 29]. The spatial patterns indicate that the lithological and structural regulation of groundwater occurrence in Lere LGA is significantly influenced by secondary porosity.

Table 8. *Weighted Table Overlay.*

RASTER	WEIGHT	ATTRIBUTES	RATINGS
		Biotite Granite	2
		Porphyritic Biotite and biotite hornblend	1
		Fine Grained Leucocratic Granite	4
		Granite Gneiss	10
		Medium to coarse grained biotite gneiss	2
		Migmatite	4
		Pyroxene Fayalite Granite	1
		Undifferentiated Schist	7
Lineament	4	0 - 0.110	1
		0.110 - 0.259	3
		0.259 - 0.432	5
		0.432 - 0.656	7
		0.656 - 1.365	10
Slope	4	0 - 3.143	10
		3.143 - 9.429	8
		9.429 - 20.287	6
		20.287 - 37.431	3
		37.431 - 72.861	1
Soil Texture	3	Very deep well drained sandy loamy sand to sandy clay	3
		Very shallow well drained loamy sand to sandy loam	9
		Very deep well drained sandy loamy to sandy clay	4
		Very deep well drained sandy loamy to loamy sand	9
		Moderately deep well drained sandy loam gravelly	7
		Deep well drained sandy loam to sandy clay gravelly	5
Drainage Density	2	Very Low Drainage (0-0.010-0.564)	10
		Low Drainage (0.564-0.819)	8
		Moderate (0.819-1.081)	6

RASTER	WEIGHT	ATTRIBUTES	RATINGS
		High Drainage (1.081-1.368)	4
		Very High Drainage (1.368-2.172)	1
Land use/cover	1	Vegetation	10
		Hills	1
		Water Body	8
		Bare surface	6
		Settlement	3

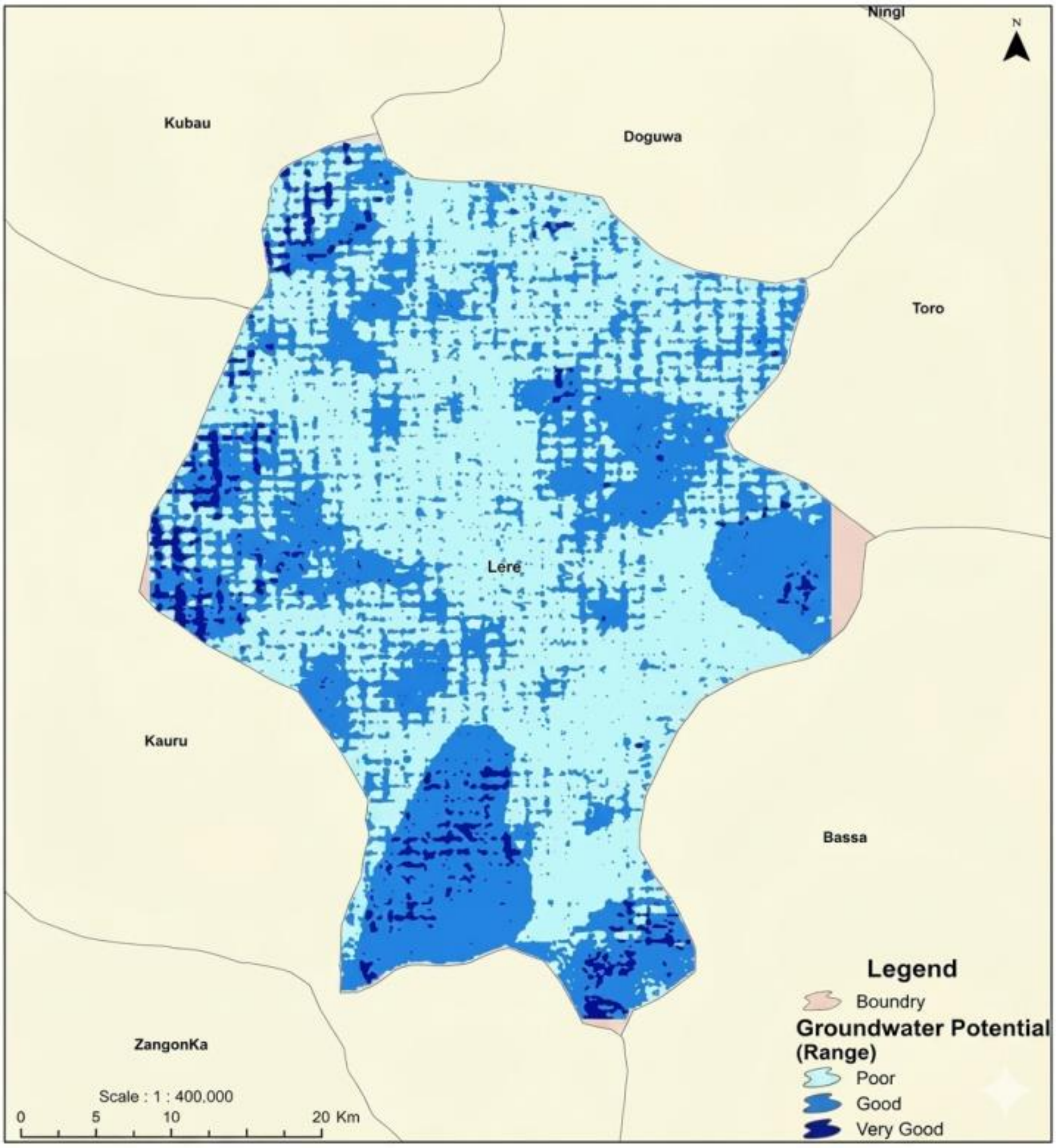

Figure 9. Groundwater potential map of Lere LGA, Kaduna.

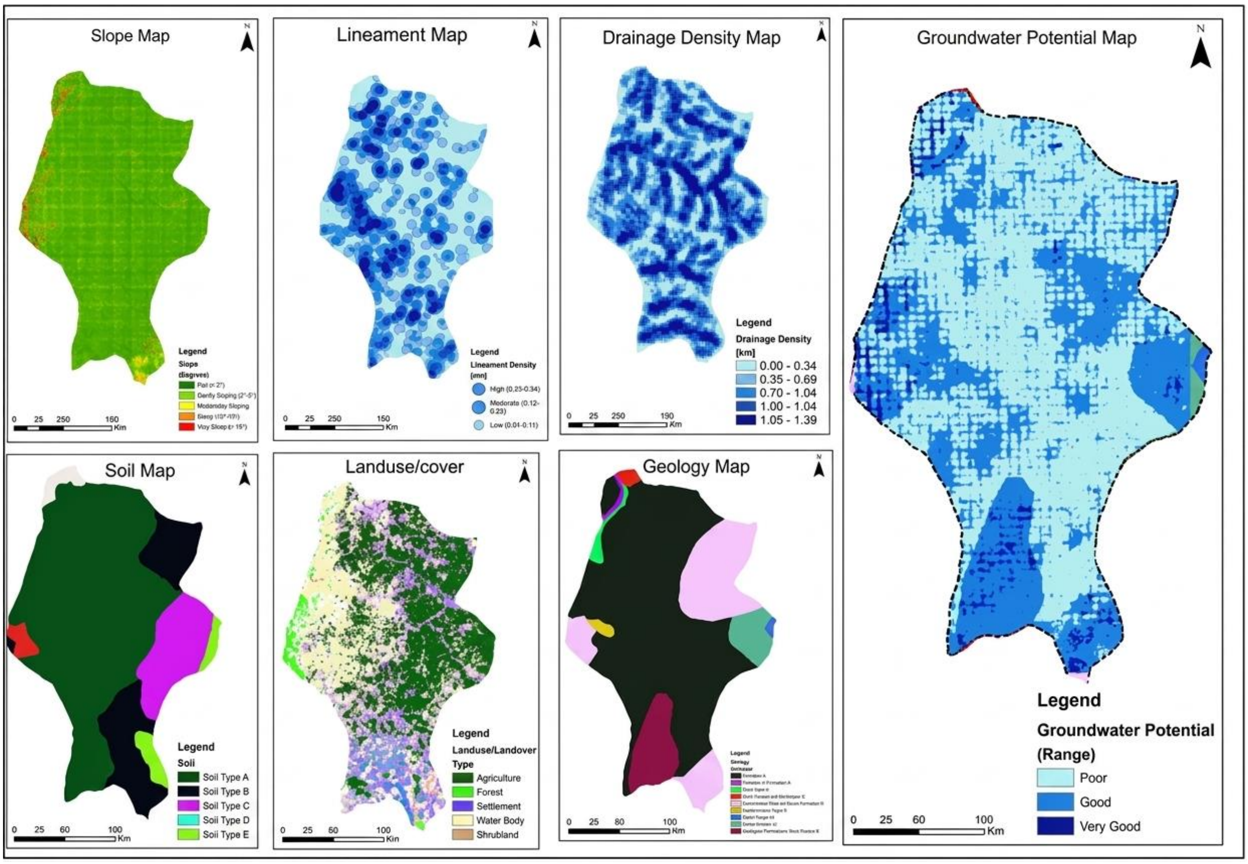

__Figure 10.__ Groundwater potential map showing all hydrogeological parameters used.

The integrated modeling technique (Figure 10) demonstrates how effectively remote sensing and GIS approaches complement each other for groundwater research in complex subsurface ecosystems.

5. Conclusion

This study used a modified DRASTIC multi-criteria evaluation model and an integrated remote sensing and GIS technique to define groundwater potential zones in Lere Local Government Area, Kaduna State, Nigeria. To create a Groundwater Potential Index (GPI), six important hydrogeological factors were combined and weighted: geology, lineament density, slope, soil texture, drainage density, and land use/land cover. The findings show that lithology and structural characteristics have a major role in regulating groundwater occurrence in the crystalline basement terrain of Lere LGA. Because of their increased secondary porosity and permeability, worn and fractured rocks like schist, amphibolite, migmatite, and granite gneiss have higher groundwater potential. While steep slopes, large unfractured granites, and highly dissected terrains correspond to limited groundwater potential, high lineament density, gentle slopes, low drainage density, permeable soils, and vegetative land cover further encourage infiltration and recharge. The region was divided into high, moderate, and low potential zones on the final groundwater potential map. Low-potential zones are primarily linked to upland and poorly broken terrains, moderate zones exhibit intermediate traits, and high-potential areas correspond with good geological and structural conditions. Overall, the study shows that combining remote sensing and GIS offers a practical decision-support tool for borehole siting and sustainable groundwater development in Lere LGA and similar basement complex environments, as well as a dependable and affordable framework for groundwater assessment.

Abbreviations

ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
DEM	Digital Elevation Model
DRASTIC	Depth, Recharge, Aquifer Media, Soil Media, Topography, Impact of Vadose Zone, Hydraulic Conductivity
FAO	Food and Agriculture Organization
G	Geology
GIS	Geographic Information System
GPI	Groundwater Potential Index
GP	Groundwater Potential
GPP	Groundwater Pollution Potential
GPS	Global Positioning System
LGA	Local Government Area

LD	Lineament Density
LULC	Land Use/Land Cover
MCE	Multi-Criteria Evaluation
MCDM	Multi-Criteria Decision Making
NWRI	National Water Resources Institute
OLI	Operational Land Imager
RS	Remote Sensing
S	Soil
SL	Slope
ST	Soil Texture
USGS	The United States Geological Survey
WOA	Weighted Overlay Analysis
NIMET	Nigerian Meteorological Agency
NGSA	Nigerian Geological Survey Agency
r	Rating
w	Weight
km/km^2	Kilometers per Square Kilometer
m	Meter
mm	Millimeter
°	Degree

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Author Contributions

Alfred Habila Zingchang: Conceptualization, Methodology, Project Administration, Writing – original draft, Writing – review & editing

Tavershima Stephen Ingoroko: Conceptualization, Formal Analysis, Methodology, Project Administration, Writing – review & editing

Segun Peter Michaels: Methodology, Validation, Writing – review & editing, Formal Analysis

Toyin Akintayo: Data curation, Software, Writing – review & editing

Ashe Abubakar Wulet: Methodology, Resources, Validation, Writing – review & editing

Abdul-Qadir Dauda Aliyu: Formal Analysis, Resources, Writing – review & editing

Kassim Abdullahi Baba: Investigation, Resources, Validation, Writing – review & editing

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Data Availability Statement

The data supporting the outcome of this research work has been reported in the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Alfred Habila Zingchang is a hydrogeologist with more than 20 years of experience working in government, education, research, and construction. His work focuses on researching groundwater, giving lectures, and studying climate change. He graduated from the University of Jos with a degree in geology and mining, and Kwame Nkrumah University of Science and Technology awarded him an MSc in water supply and environmental sanitation. At the University of Jos, he is presently working on a PhD in environmental geology. He conducted geotechnical assessments for hydropower dams, developed Nigeria's Code of Practice for Dams and Reservoir Operations, and investigated the effects of climate change on groundwater in the Chad Basin. He is married, has four kids, and likes to read, travel, study, and engage in politics.

Tavershima Stephen Ingoroko is a Nigerian Civil and Water Resources & Environmental Engineer and Lecturer at the National Water Resources Institute, Kaduna. He is currently pursuing a Ph.D. in Water Resources & Environmental Engineering at Ahmadu Bello University, Zaria, where he also obtained his M.Sc. in the same field. He holds a B.Eng. in Civil Engineering from the Federal University of Agriculture, Makurdi, and a Proficiency Certificate in Management from the Nigerian Institution of Management. His work focuses on groundwater exploration, water quality assessment, hydrogeological studies, and sustainable water resources management. He has extensive experience in teaching, research, project supervision, and consultancy, with several publications in reputable journals and contributions to national conferences. He is a registered engineer with COREN and a member of NSE, NICE, NIWE, and NIM.

Segun Peter Michaels is an academic and water resources specialist with a focus on environmental studies and hydrogeology. In 2022, he received a PhD in Water Resources Engineering and Management from Kwame Nkrumah University of Science and Technology, a MEIA from Kaduna State University, and a BSc and MSc in Hydrogeology from Ahmadu Bello University. Hydrogeochemistry, isotope hydrology, groundwater research, and environmental toxicity are among his areas of interest. Dr. Michaels has published widely in both domestic and foreign periodicals. He is currently the National Coordinator of the National Water Resources Capacity Building Network and a Senior Lecturer at the National Water Resources Institute. He also likes to travel and read, and he is an active member of a number of professional associations.

Toyin Akintayo is a Hydrogeologist and GIS Analyst with over 10 years of experience in Remote Sensing and GIS applications for water resources management and environmental sustainability. She currently works as a Hydrogeologist and GIS/Remote Sensing Expert at the National Water Resources Institute (NWRI), Kaduna, Nigeria. She holds an M.Tech in GIS and Remote Sensing from the Regional Centre for Training in Aerospace Surveys (RECTAS) in affiliation with the Federal University of Technology, Akure, a B.Tech in Applied Geology from the Federal University of Technology, Akure, and an ND in Mineral Resources Engineering from Kaduna Polytechnic. Her current work focuses on hydrological modelling, groundwater assessment, climate change adaptation, and GIS-based decision support systems, contributing to projects such as the PIDACC/NB programme and other National Water Resource Management initiatives.

Ashe Abubakar Wulet is a hydrogeologist at the National Water Resources Institute (NWRI), Kaduna, Nigeria. She is currently pursuing a Ph.D. in Water Resources and Engineering Management at Kwame Nkrumah University of Science and Technology (KNUST), Ghana. She holds a Master's degree from Kaduna State University and a Bachelor's degree from the University of Maiduguri. Her professional work focuses on hydrogeological studies, groundwater exploration, and sustainable water resources management. Ashe is actively involved in research addressing climate variability and its impact on water systems. She is a registered member of the Nigeria Mining and Geoscience Society (NMGS) and the National Association of Hydrogeologists (NAH), reflecting her commitment to professional excellence and development in the field of hydrogeology.

Abdul-Qadir Dauda Aliyu is a Senior Lecturer and Research Engineer at the National Water Resources Institute. He is in charge of the Hydraulics Division and the Department of Agricultural and Bioenvironmental Engineering Technology. Additionally, he makes contributions to the Regional Center for Integrated River Basin Management of UNESCO. He has an MSc in Civil Engineering from RUDN University, a BEng in Irrigation Engineering from Bayero University, and a PhD at Ahmadu Bello University. Water resources engineering, irrigation, hydrology, flood risk assessment, groundwater investigations, and water quality management are some of his areas of interest. He has written more than 40 publications and worked on projects related to drinking water quality evaluation, irrigation development, flood mapping, sedimentation analysis, and dam viability.

Kassim Abdullahi Baba is a PhD candidate in Agricultural and Bio-Environmental Engineering at the Federal University of Technology, Minna. He holds an ND in Agricultural Engineering and HND in Soil and Water Engineering from Federal Polytechnic, Bauchi, and a PGD and Master's from FUT Minna. His research focuses on smart agriculture, controlled environment agriculture, hydroponics, and soil-water management. He has designed and constructed hydroponics and greenhouse systems, trained over 500 beneficiaries in smart agriculture across Nigeria, and contributed to green projects with expertise in irrigation and drainage. He is a member of COREN, NATE, and the Nigerian Institution of Agricultural Engineers (NIAE).

Research Field

Alfred Habila Zingchang: Climate change, Groundwater, Geochemistry, Environmental geology, GIS and Groundwater modelling

Tavershima Stephen Ingoroko: Groundwater Exploration, Water Quality Assessment, Hydrogeological studies, Climate Change and Environmental Sustainability, and Sustainable Water Resources Management

Segun Peter Michaels: Hydrogeochemistry, Isotope Hydrology, Environmental, Groundwater Toxicity, and GIS and Remote Sensing

Toyin Akintayo: Flood Risk Vulberability Assessment, Climate Change Vulnerability Assessment, Water Resources Management, Geospatial Analysis and Remote Sensing, Urban Environmental Management

Ashe Abubakar Wulet: Climate resilience in water systems, Groundwater exploration, and development, Drought assessment and climate variability, Geospatial analysis for water resources management

Abdul-Qadir Dauda Aliyu: Water Resources Engineering, Irrigation Systems, Hydrology and Flood Risk Assessment, Groundwater studies, and Water Quality Management

Kassim Abdullahi Baba: Smart Agriculture & Precision Farming, Controlled Environment Agriculture (CEA), Soil-Water-Plant Relations, Agricultural Biotechnology, and Green Technology & Climate-Smart Systems