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SIMULATION OF GROUNDWATER POTENTIAL ZONE USING GEOGRAPHIC INFORMATION SYSTEM (GIS) THROUGH RELATED FACTORS

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ABSTRACT

Groundwater is the primary water source for irrigating and drinking in dry seasons. This study assessed groundwater potential in selected locations in Osogbo using GIS based approaches. Soil samples were taken, and soil textural and permeability analyses were conducted. LandSAT imagery was used for classification, and an elevation map was generated using a surface analyst algorithm that was applied on ASTER dam. Hydraulic conductivity and overburden thickness maps were generated from Borehole data parameters. Multi-criteria analysis was used to generate a groundwater potential zone map. Factors responsible for groundwater potential included lineament density (0-0.0028), sand (67.2-89.60%), silt (9.00-30.00%), clay (0.17-2.80%), permeability (0.000010-0.00002), rainfall (1304.02-1469.06mm/yr), hydraulic conductivity (0.21-0.96m/min), land use consisting of degraded forest (48.65%), riparian forest (13.05%), built up (38.29%), and water body (0.001%). The study found that groundwater recharge potential is very good (80%) at Ofatedo, Gbonmi, Oke-Oro, good (18%) at Awosuru, Gbodofon, and Dagbolu locations, but fair (2%) at Mallam Tope location in Osogbo.

Keywords: Remote sensing, groundwater potential, lineament, hydraulic conductivity

1. INTRODUCTION

Because groundwater has a low impurity level and there hasn't been much infrastructure development in the nation, many lives rely on it to survive. According to [1], groundwater serves as both the main supply of water for drinking and irrigation during dry seasons as well as for sustaining the regrowth of native flora. It is anticipated that in arid and semi-arid regions specifically, artificial recharge for consumption will cause groundwater abstraction to rise from 20% during the wet season to over 70% during the dry season [2, 3]. Quantification of groundwater recharge rate is a prerequisite for effective and sustainable groundwater management [4]. A portion of precipitation that falls on the ground infiltrates into the soil, where it is partially used to replenish the soil's moisture deficiency and partially percolates down to the water table. This water that reaches the water table is known as the recharge from rainfall to the aquifer. Rainfall-induced recharge is influenced by a variety of topography, hydro meteorological, and soil properties, as well as the depth of the water table. The portion of infiltration that makes it through the soil profile and reaches the water table is known as recharge, according to [5]. A groundwater circulation system's recharge boundary is characterized as a permeable boundary with a given hydraulic head where water enters the system naturally or through conditions impacted by its use [6]. Recharge estimation should take into consideration several crucial factors, including soil texture, topography, groundwater level, hydro-meteorological conditions, and spatial variation in recharge caused by scattered land-use [7]. According to [8], the water table fluctuation approach provides a direct estimate of recharge by multiplying the rise in the water table throughout the recharge season by the specific yield. But the technique is only effective for a few days at a time. When there is flooding, groundwater recharge can occur as a result of rainfall and water seeping into the water table, replenishing the aquifer. Artificial recharge can be caused by human activities like irrigation, urbanization, drilling injection boreholes, or river spreading. Natural recharge happens when rainfall directly infiltrates the aquifer. An increase in groundwater storage is correlated with rising water tables.

1.1 The study area

The location of the study is shown in Fig. 1. The research region is approximately 9251 km^2, with latitudes 7º46' N and 7.767º N, and longitudes 4º34' W and 4.567º E. The Olorunda and Egbedore local government areas in Osogbo are home to the study area. The rocks of the Precambrian basement complex underlie the research region. These rocks have almost nonexistent permeability and poor porosity by nature. In basement terrains, the places where substantial overburden covers the cracked zones have the maximum groundwater yield. Relatively low resistivity values are frequently found in these zones [9]. In and around the local government areas of Olorunda and Egbedore, there are many rivers and lakes, including the well-known Apala and Osun rivers. The study region has a high forest zone and lush vegetation. The observable green tree vegetation that persists throughout the year is a sign that there is enough soil moisture present to sustain trees and other plant types during the dry season. Conversely, the research area's observed plant pattern indicates increased groundwater infiltration capacity everywhere but in densely populated urban areas and rock outcrops.

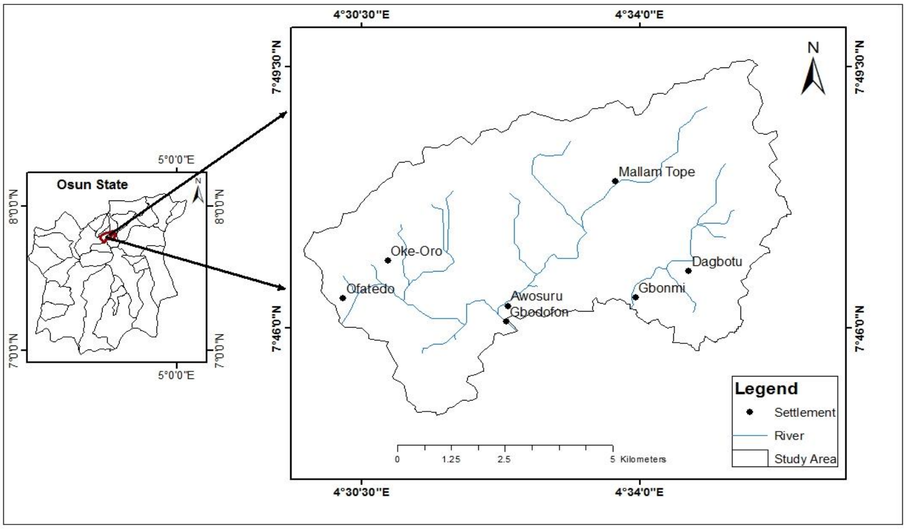

Figure 1. Map of the study area showing Osun State and sample locations

2. MATERIALS AND METHODS

Water found in subterranean pore spaces and defined channels, as those in karst formations formed by the disintegration of soluble rocks like limestone, are referred to as groundwater. Rainfall-induced recharge is influenced by a variety of topography, hydrometeorological, and soil properties, as well as the depth of the water table. The portion of infiltration that makes it through the soil profile and reaches the water table is known as recharge, according to [5]. The study area's potential for groundwater recharge was represented using a GIS technique. Using soil texture (sand, silt, and clay) and permeability, rainfall, land use, hydraulic conductivity, and lineament, a knowledge-based factor analysis was used to identify eligible zones in the research region for groundwater recharge potential. Fig. 2 displays a flow chart that outlines the steps in the research methodology used in this work to identify possible zones for groundwater recharge. Tab. 1 shows the integration of the variables influencing groundwater recharge using the overlay method in a GIS setting.

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Geographic Information Systems (GIS) were utilized in the past by numerous studies to identify prospective zones for groundwater recharge by layering and weighting data. This study employs a subjective methodology, whereby the final outcome is contingent upon the map's level of significance and the weighting variables applied during the investigation.

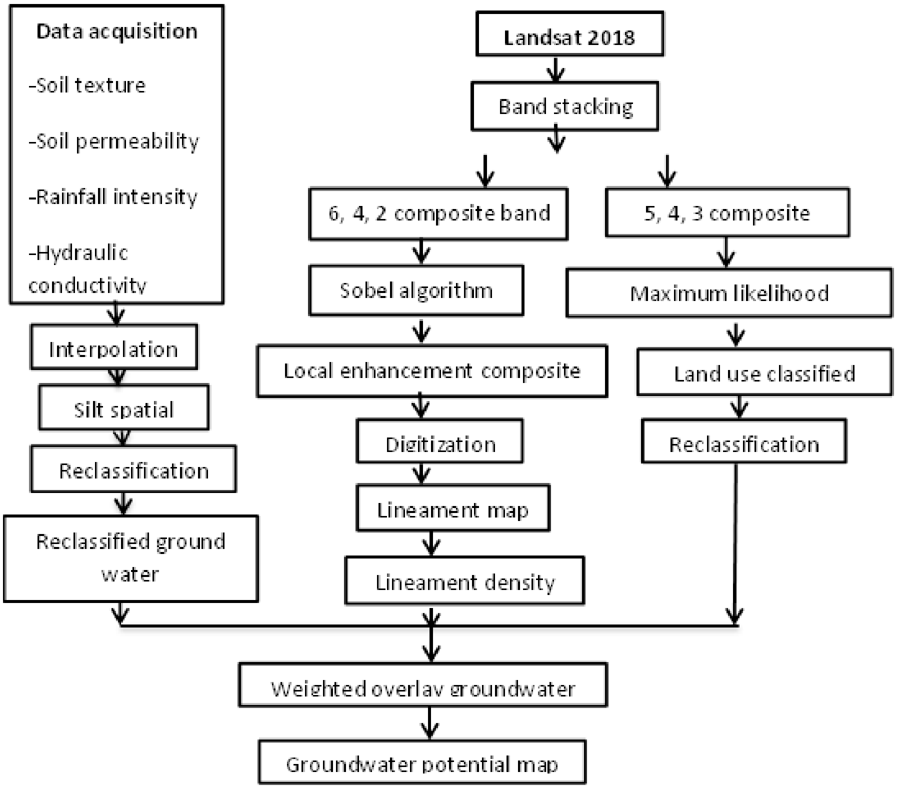

Figure 2.General procedure

Table 1. Weight assigned to factors influencing groundwater recharge potential zone

S/N	Factors	Weight	Weight (%)
1	Hydraulic conductivity	0.07	7
2	Lineament density	0.17	17
3	Clay	0.1	10
4	Sand	0.17	17
5	Silt	0.13	13
6	Soil permeability	0.19	19
7	Land use	0.08	8

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8	Rainfall	0.09	9
	Total	**1**	**100**

2.1. Soil permeability distribution

Importing the data and modeling it in a GIS context allowed for the creation of the study area's soil permeability map. Interpolation was then used to determine the permeability's geographic variability distribution. An increase in permeability values is predicted to result in a rise in groundwater potential. According to this study, the most important element affecting the groundwater potential in the studied area is soil permeability. Between 14%, 26%, 42%, and 18%, respectively, were the percentage coverage of soil permeability values, which varied between 0.000010 and 0.00002. It is anticipated that greater water infiltration into the subsurface will occur in locations with high permeability ratings; Ofatedo, Dagbolu, and Gbonmi have the highest permeability. In Fig. 3, the soil permeability map is displayed.

2.2. Soil textural distribution

Importing the parameters of the sand, silt, and clay distribution maps into a GIS environment and modeling them produced the maps' spatial variability. To find their geographical variability distribution in the research region, interpolation was used. It is anticipated that places with high clay spatial variability will have less water infiltration into the subsurface, whereas areas with high sand distribution values will see more infiltration. One of the main determinants of groundwater potential recharge has been shown to be sand particles. Sand distribution values were 67.2–89.60, with 28%, 21%, 23%, and 28% of the sample covered by percentage. Silt readings range from 9.00 to 30.00 at different locations, with the corresponding percentages being 27%, 26%, 21%, and 26%. However, the percentage coverage of 24%, 26%, 27%, and 23% is found in the clay values, which range from 0.17 to 2.80. Fig. 4, 5, and 6 displayed the maps of the sandy, silty, and clayey soils.

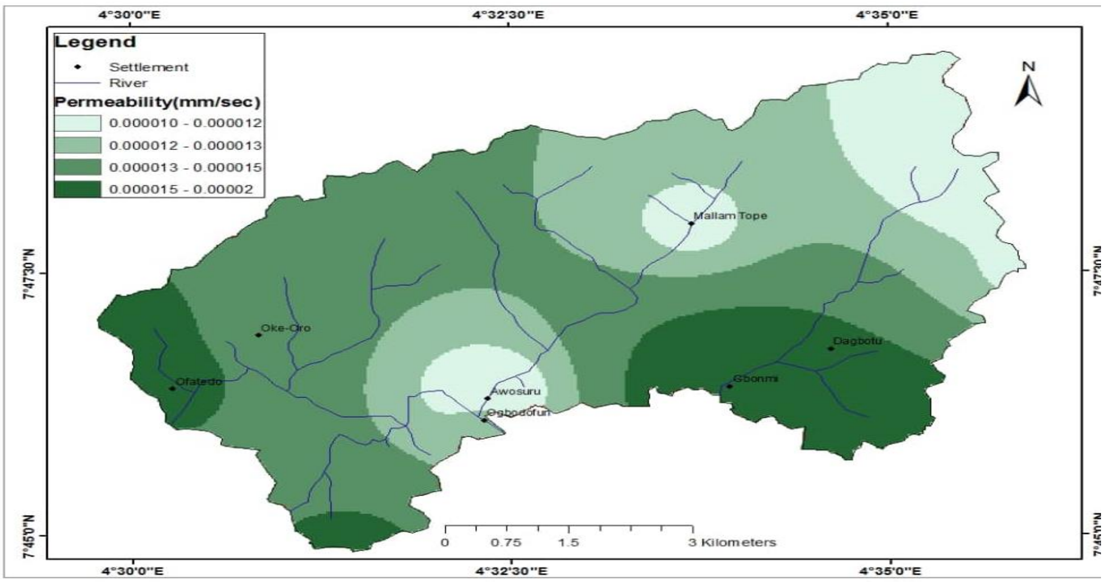

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Figure 3. Soil permeability distribution map

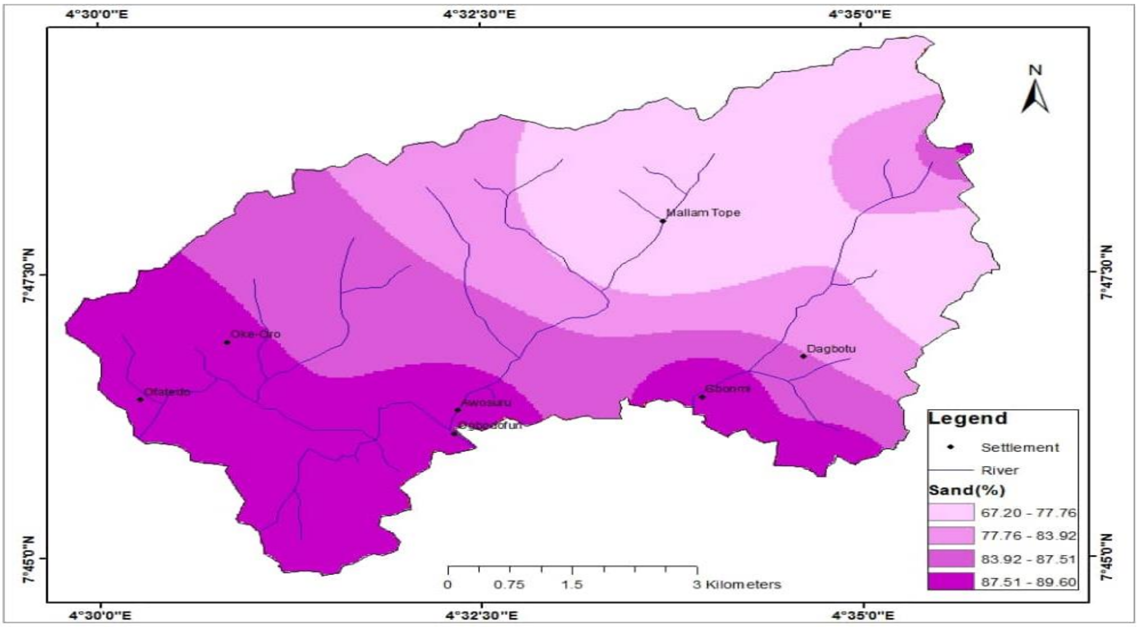

Figure 4. Sandy soil distribution map

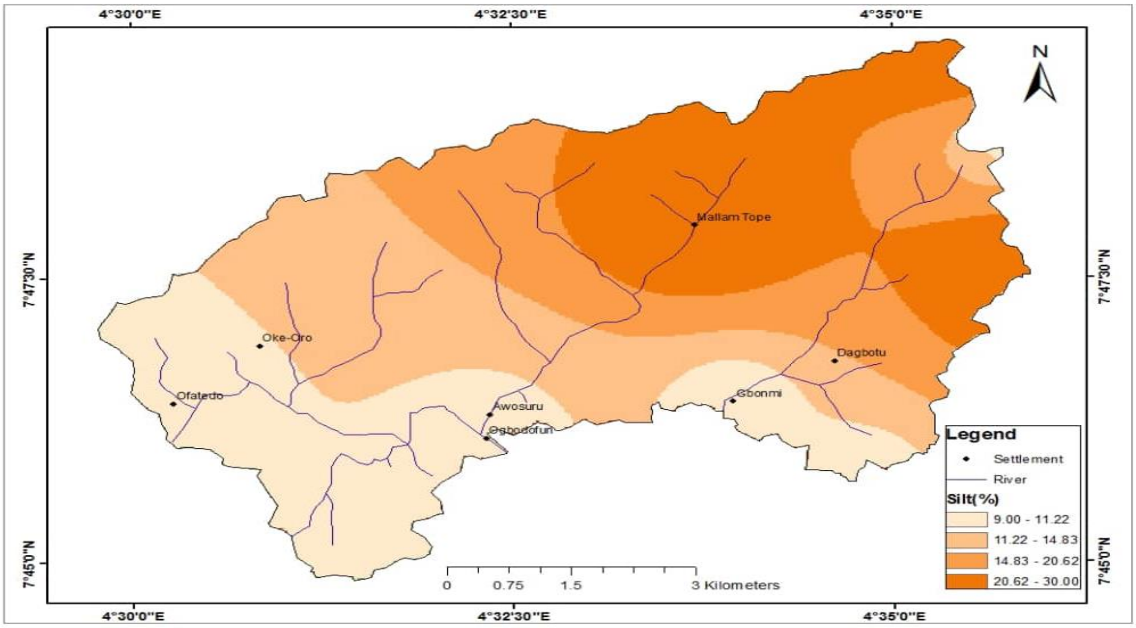

Figure 5. Silty soil distribution map

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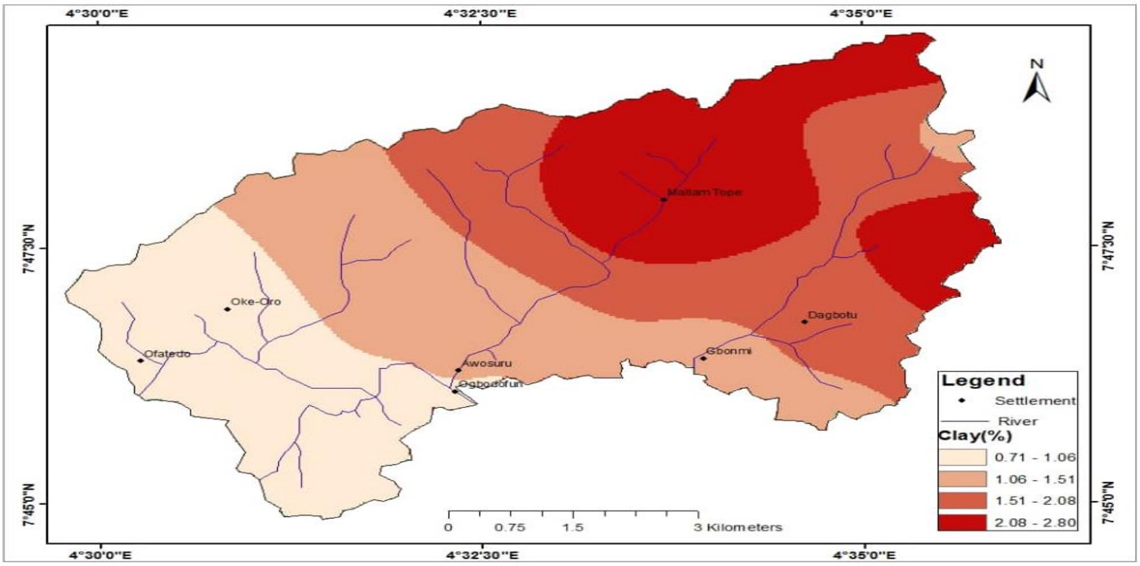

Figure 6. Clayey soil distribution map

2.3. Lineament analysis

Bands 6, 4, and 2 of the LandSAT 8 imagery were layer stacked using a false color composite in order to extract lines of correspondence. The Sobel algorithm was employed to improve the remote sensing data linearly, one after the other. On the detected lineament characteristics, manual extraction was carried out utilizing the digitizing method in a GIS context. In the terrain of the Basement Complex, lineaments have been found to have the greatest influence on groundwater potential [9]. This demonstrates that, as supported by the research of [10], the zones with greater lineament density values represent the terrain surface that has a good property to allow surface water trickling downward via rocks and soil. Values for lineament density varied from 0 to 0.0028. With rising lineament density values, a rise in groundwater potential is anticipated. In Fig. 7 and 8, the lineament and lineament density maps were displayed.

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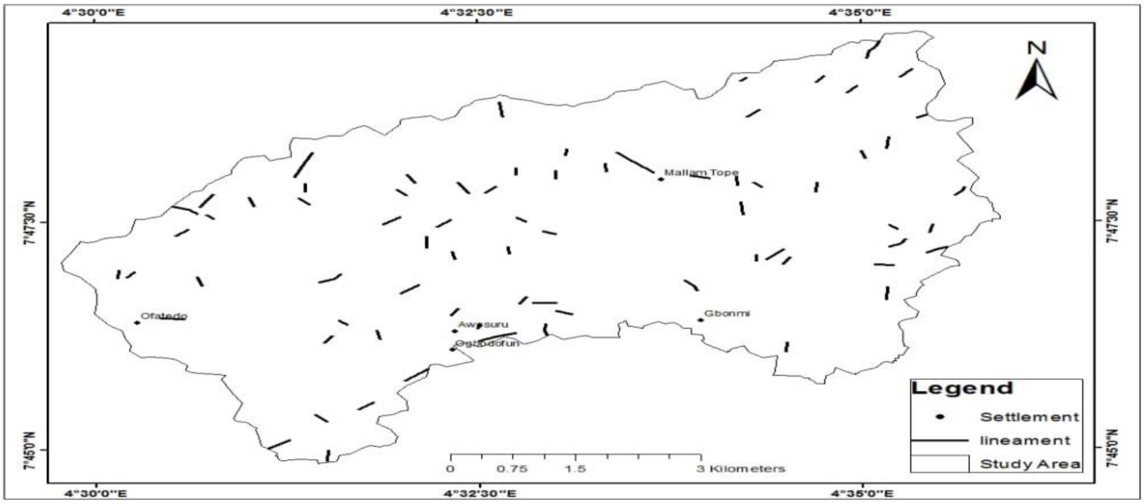

Figure 7. Lineament map

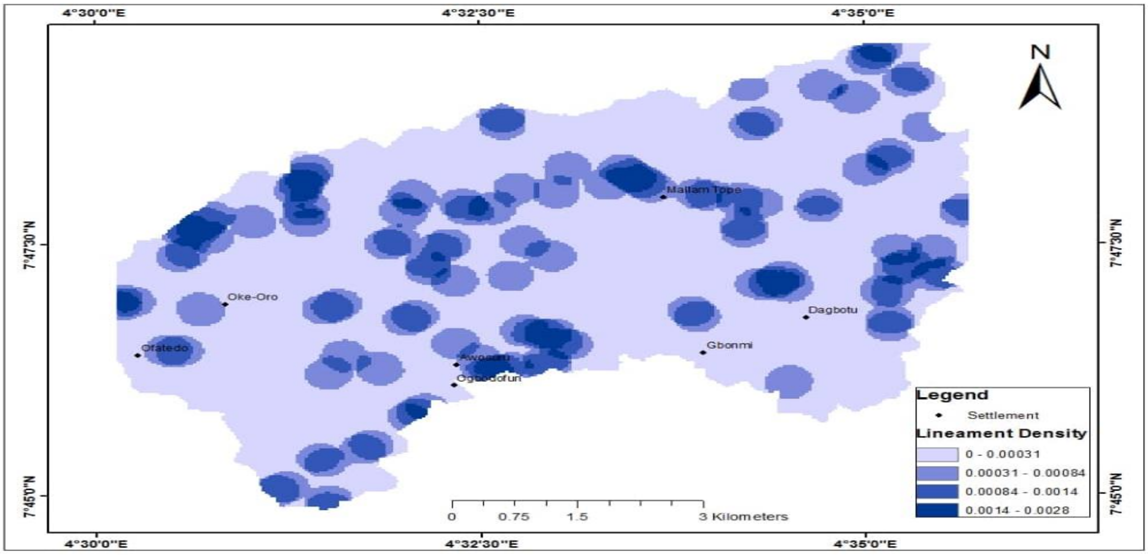

Figure 8. Lineament density map

2.4. Rainfall distribution

The rainfall map was created by interpolating rainfall data that was gathered from My NASA Data between 2010 and 2015 in order to create a distribution map of rainfall. There are two categories for rainfall in the research area: high rainfall and low rainfall. Increased rainfall has the ability to seep into the ground and store as groundwater. Fig. 9 shows the rainfall map for the research area.

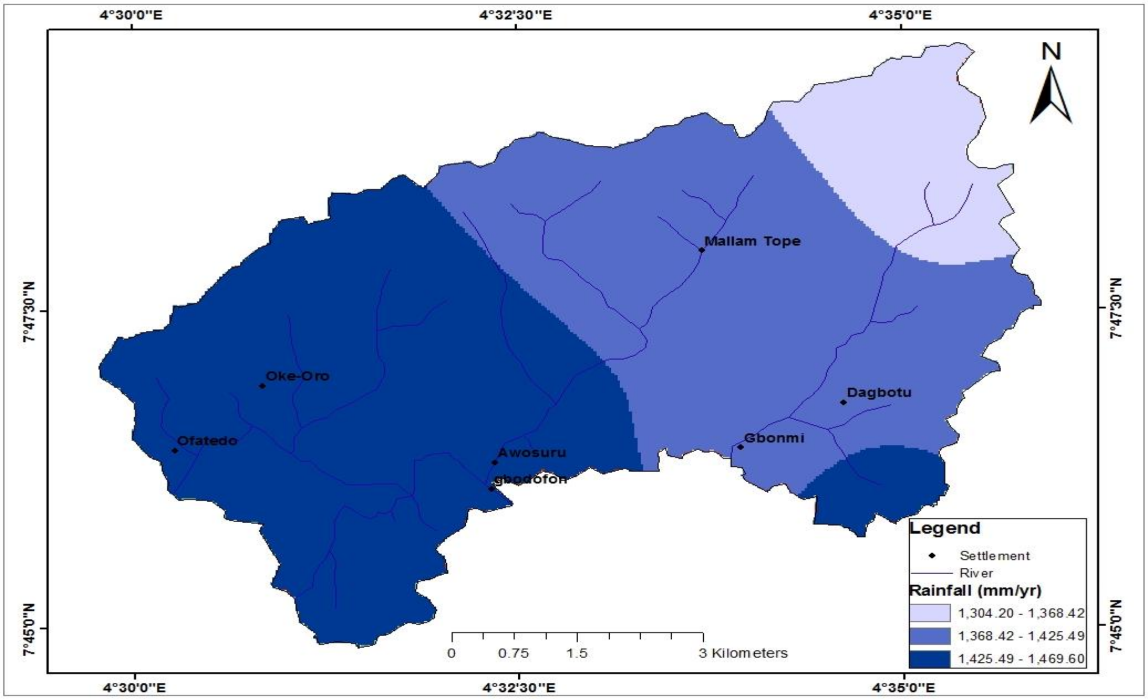

Figure 9. Rainfall distribution map

2.5. Land use

LandSAT imagery was used to classify land use using a false color picture composite of bands 5, 4, and 3. Interpolation was then performed to create a map of the study area's land use. The research region's land use is divided into four categories: built-up area comprises 38.29 percent, riparian forest accounts for 13.05 percent, degraded forest accounts for 48.6 percent, and water bodies cover 0.001 percent. In the research area, developed areas and degraded forests predominated. Compared to land uses without forests, those with significant forested areas have a higher potential for groundwater penetration. Fig. 10 displays a land use map.

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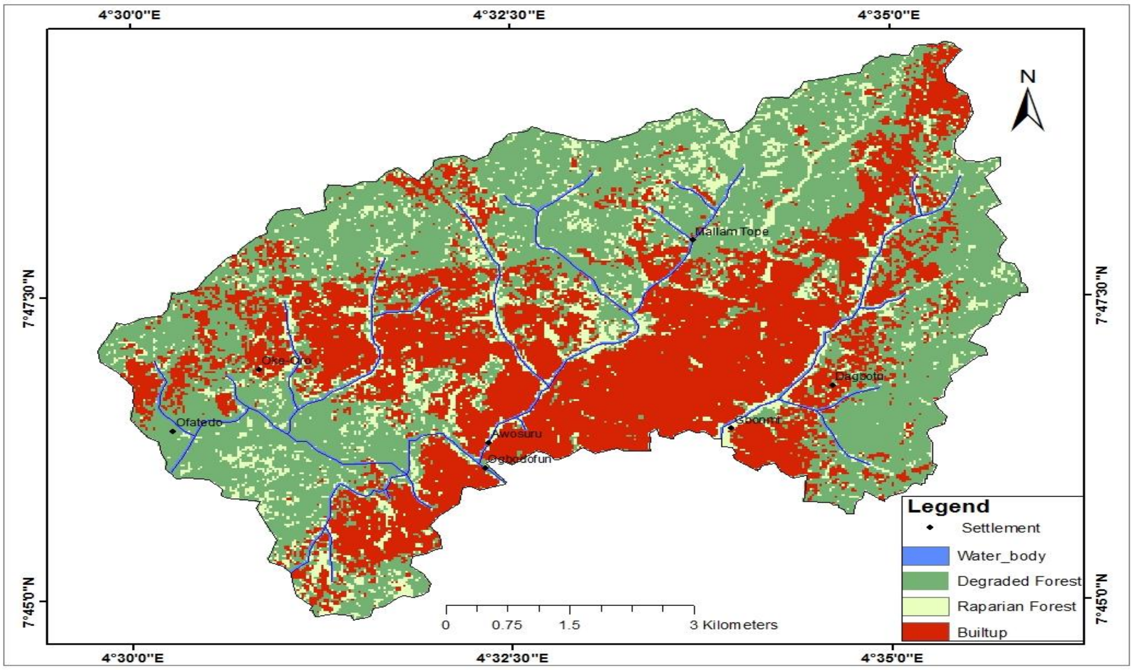

Figure 10. Classified land use map of the study area

2.6. Hydraulic conductivity

The Osun Rural Water Supply and Sanitation Agency (RUWESA) provided the borehole data parameters that were used to determine the hydraulic conductivity of the aquifer. These parameters were then interpolated to create a map showing the distribution of hydraulic conductivity. The research area's hydraulic conductivity is classified as high or low based on the geology's characteristics. The rate at which water is transmitted increases with hydraulic conductivity and vice versa. Fig. 11 displays the hydraulic conductivity map for the research area.

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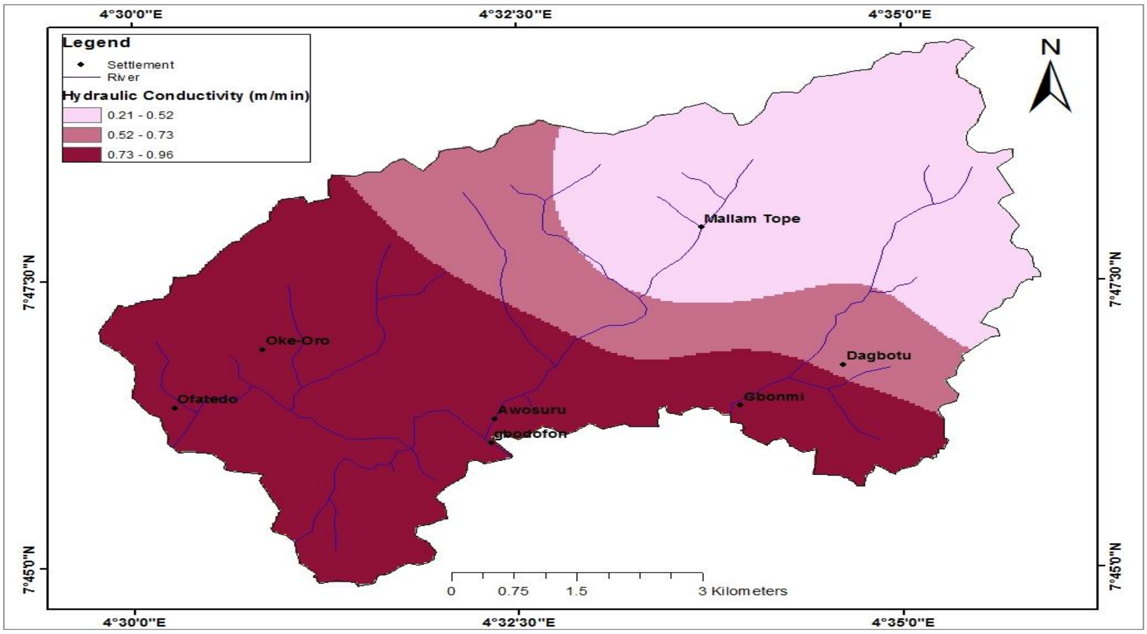

Figure 11. Hydraulic conductivity map

3. RESULTS AND DISCUSSION

Fig. 12 displays the groundwater potential zone results for the research area. Geographic information system techniques are used to reclassify, weight, and overlay several parameters (maps) such as lineament density, hydraulic conductivity, land use, rainfall intensity, soil texture (sand, clay, and silt), and permeability in order to create the groundwater potential map. There are three classes for the groundwater recharge potential zone: fair, very high, and poor. Based on the final map, the research region is covered by sites with very good coverage (18%), good coverage (80%), and fair coverage (2%). In the study region, places like Ofatedo, Gbonmi, Oke oro, Awosuru, Gbodofon, and Dagbolu have very good to good groundwater recharge potential.

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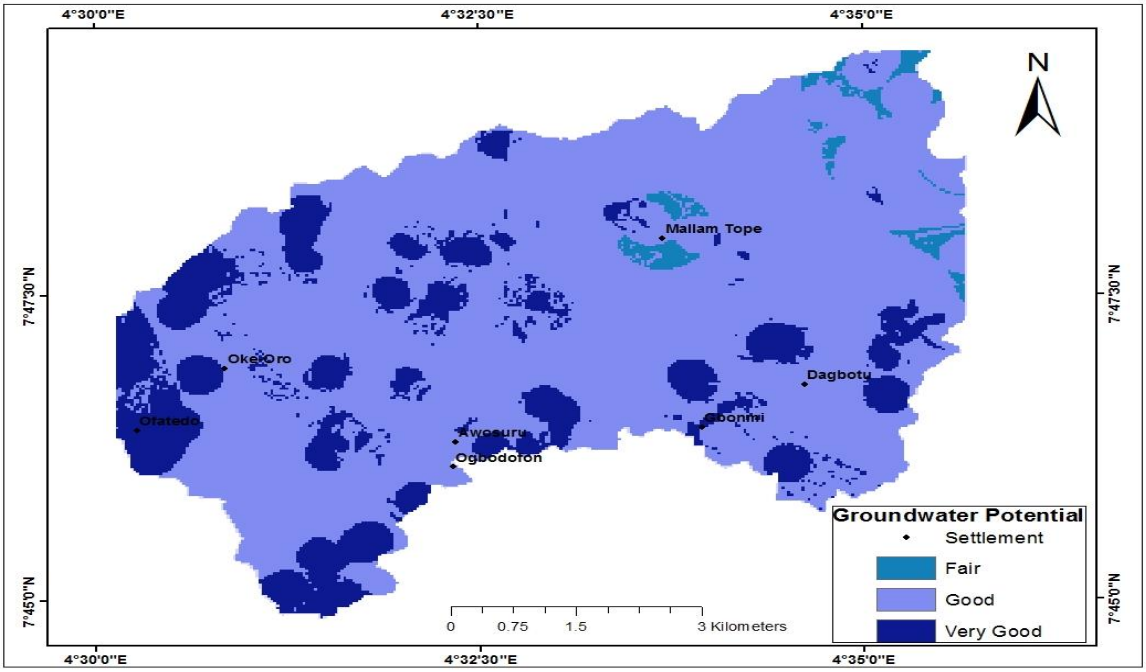

Figure 12. Groundwater recharge potential zone map of the study area

4. CONCLUSIONS

Using remote sensing and Geographic Information Systems to map possible zones for groundwater recharge is an effective method. The study's findings, which identify the areas where pollutants may infiltrate groundwater, might be used by policymakers to protect and conserve groundwater. This study distinguished between three classes of groundwater potential: extremely good, good, and fair.

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