FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 5 No. 4,December, 2021, pp 194 - 204
DOI: https://doi.org/10.33003/fjs-2021-0504-806

DETERMINATION OF GROUNDWATER POTENTIAL AREAS IN KADUNA METROPOLIS, KADUNA, NIGERIA

[*1]Akintayo, T., [2]Bello, S. A., [2]Ugwu, S. J. and [3]Nwali, C. N.

[1]Department of Research and Technical Services, National Water Resources Institute, Mando, Kaduna State, Nigeria
[2]Department of Training, National Water Resources Institute, Mando, Kaduna State, Nigeria
[3]Department of Groundwater, National Water Resources Institute, Mando, Kaduna State, Nigeria.

*Corresponding authors' email: takintayop@gmail.com

ABSTRACT
Groundwater is one of the major resources important for sustainable growth and development. Proper management of the resources is therefore important to meet all the water requirements for human existence to continue. In this study, an investigation is made to explore for groundwater potential areas of Kaduna Metropolis, Kaduna State using remote sensing and GIS technique. The data used for the study are as follows; Landsat 8 (OLI) 30m, Aster data (30m), Geologic map, Soil map and Topographic map was used to generate the factors such as; Land use/cover, Slope, Geomorphology, Geologic rock types, soil textures and drainage density. All the factors and its attributes were weighted and rated respectively and were classified according to their importance to groundwater occurrence using the modified DRASTIC model and the weighted overlay technique was used to create a groundwater potential map of the metropolis. Groundwater potential map were classified into four categories that best describes the potential of each area. These classes are; Poor (21%), Moderate (23%), Good (26%) and Very Good (30.2%) groundwater potential which was found to be concentrated in the central part of the metropolis. This result was verified against existing borehole data and field observations to validate the accuracy and was found to be 76% accurate. The study demonstrated the effectiveness of Remote Sensing and GIS as an effective tool in delineation and identification of groundwater potential areas.

Keywords: Groundwater, geomorphology, GIS, Kaduna Metropolis, Basement Complex

INTRODUCTION
Water resources represent a major prerequisite and driver of socio-economic development. It also plays a prominent role in power and energy generation: hydroelectric power generation's share of total power production has decreased from over 70% in 2004 to about 40% (Oyebande, 2004). Groundwater is widely used because of its high quality as compared to surface water (IWMI, 2001). This is because groundwater usage often brings large economic benefits, reliability, ready local availability, pollution free, good quality requiring minimal treatment and low cost of development are attributes making groundwater more attractive when compared to other sources (Menon, 1998).
Despite the huge groundwater resources, water resources development has not been able to keep pace with the phenomenal population growth (Oteze, 1989).This implies that the population and economic growth have led to ever more demands on the resources. This has led to scarcity of the resources and it has now become very expensive to harness. In Nigeria, water scarcity is as a result of a combination of lack of funds, institutions or knowledge to solve local problem of water use and allocation (Musa, 2011). This implies that water scarcity does not only result from the physical absence of adequate water supply but also difficulties in the sufficient fresh water availability.
Kaduna metropolis is the largest city in north western part of Nigeria. The demand for water is fast outpacing its availability for consumption and the supply of domestic water is seriously constrained by the rising population (Udoh and Etim, 2007). Kaduna State Water Board Authority (KSWBA), whose responsibility is to pump and distribute sufficient clean water to the residents in the study area, is seriously constrained due to its inability to meet the rising demand of domestic potable water as a result of increasing population.
The capacity of groundwater exploitation is limited to selected areas where the water is in abundant quantity. Only a few individuals residing in such area are able to exploit such zones. Geophysical survey has been the major technique used for groundwater exploration in Kaduna metropolis which involves in-situ data collection which consumes time and money. The use of remote sensing and GIS in groundwater study using the same principle have been found to be minimally utilized in the north western part of Nigeria including Kaduna metropolis which has a lot to contribute to the study. This study has provided a spatial perspective of groundwater potential areas in the northern part of Nigeria.

STUDY AREA
Location and Accessibility.
Kaduna metropolis is located between Lat. N10^{0}23' and 10^{0}43'N and Long. 7^{0}17' and 7^{0}37'E consist of Kaduna north and south local government. The area is traversed by major highways from Abuja, Zaria and Kano with a number of dual carriage ways across the city, major and minor roads in all directions.
Geology
The area understudy is underlain by Precambrian rocks of the Nigerian Basement Complex. The weathering of the crystalline Basement Complex rocks under tropical condition is well known to produce a sequence of unconsolidated material whose thickness and lateral extent vary extensively

(Dearmaun *et al.*, 1978). Groundwater localization within the Basement Complex occurs either in the weathered mantle or in the fracturing, fissuring and jointing systems of the bedrock (Jones, 1985; Ako and Olorunfemi, 1989; Olayinka and Olorunfemi, 1992). These unconsolidated materials are known to reflect some dominant hydrologic properties, and the highest groundwater yield in Basement Complex area are found in areas of thick overburden overlying fractured zones and are characterized by relatively low resistivity (Olorunniwo and Olorunfemi, 1978; Olorunfemi and Fasuyi, 1993).

The Basement Complex rocks in the areas mostly consist of migmatite gneiss complex, metasediments/ metavulcanics (mostly schist, quartzite, amphibolites and banded iron formation, pan African granitoids and calc-alkaline granites, and volcanics of Jurassic age (McCurry, 1976). Groundwater in the area has not been adequately developed and as such data relating to their magnitude and mode of formation are lacking. However in the Basement complex, the permeability and storativity of the groundwater system are dependent on structural features such as the extent, and volume of fractures together with thickness of weathering (Eduvie, 1998; Clark, 1985).

The area is generally part of the extensive but gently undulating peneplain, capped at high elevation by patches of laterised terraces of iron oxides, concentration of broken–up concretion ironstones and some quartz (Eduvie, 1998).

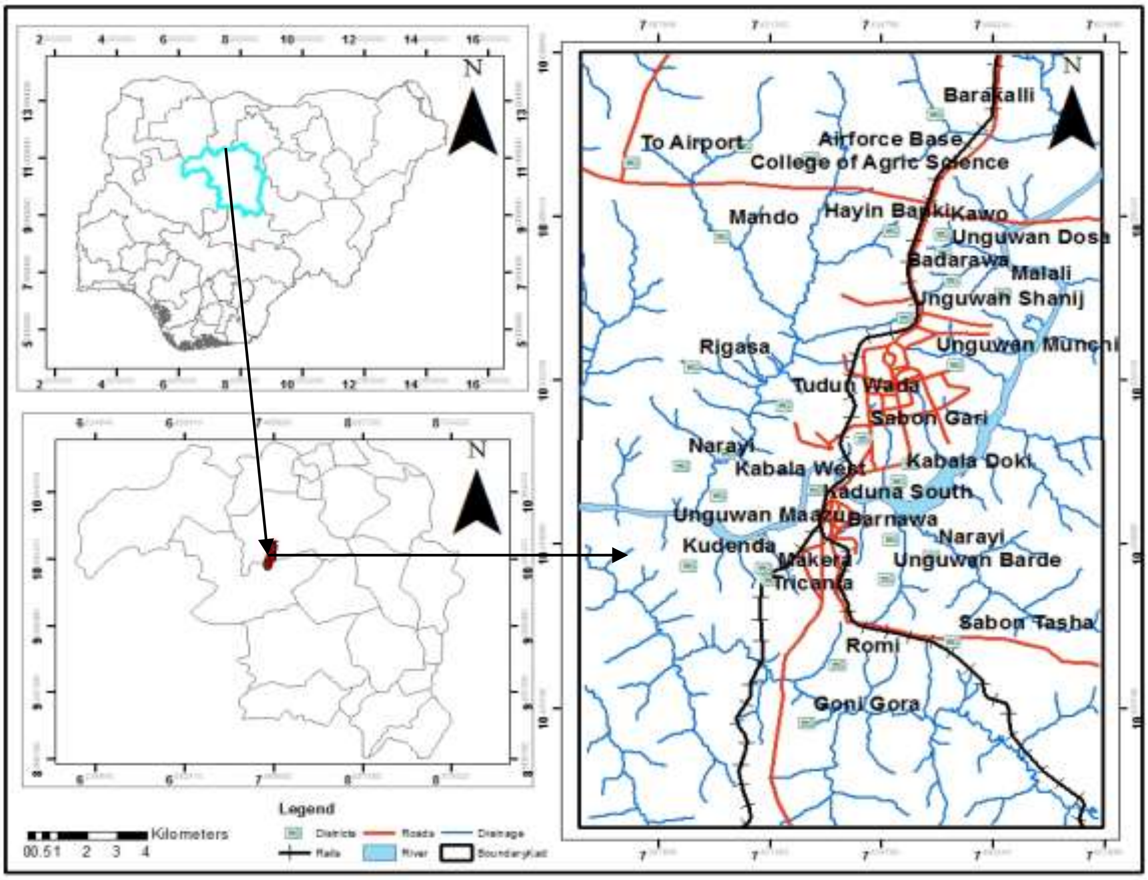


Figure 1: Study Area: Kaduna Metropolis (Source: Author 2021)

METHODOLOGY

The methodology applied in this research is based on a set of parameters that describe the natural occurrence of groundwater accumulation. These include drainage density, geologic formations, soil type, slope, land use/cover, and geomorphology. This involved the delineation of the study area by conducting remote sensing analysis for the extraction of these parameters. Field study which involved ground truthing was employed for verification. All the datasets obtained was weighted based on their contributions to groundwater occurrence and their attributes were also ranked based on the modified DRASTIC Ratings for modeling using GIS. The methodology of this study is summarized in the Flow chart in Figure 2

Data Used

Landsat 8 (OLI) with 30m spatial resolution of Path/Row (189/53), acquired in 2014 with 7 bands and orthorectified. Advance Spaceborne Thermal Emission and Reflection (ASTER) imagery of 30m resolution. Geological map at s scale of 1:250,000, Soil map at a scale of 1:40,000 and Topographic map at a scale of 1; 100,000. Global positioning System (GPS) receiver (Hand Held) was used for point and route data collection.

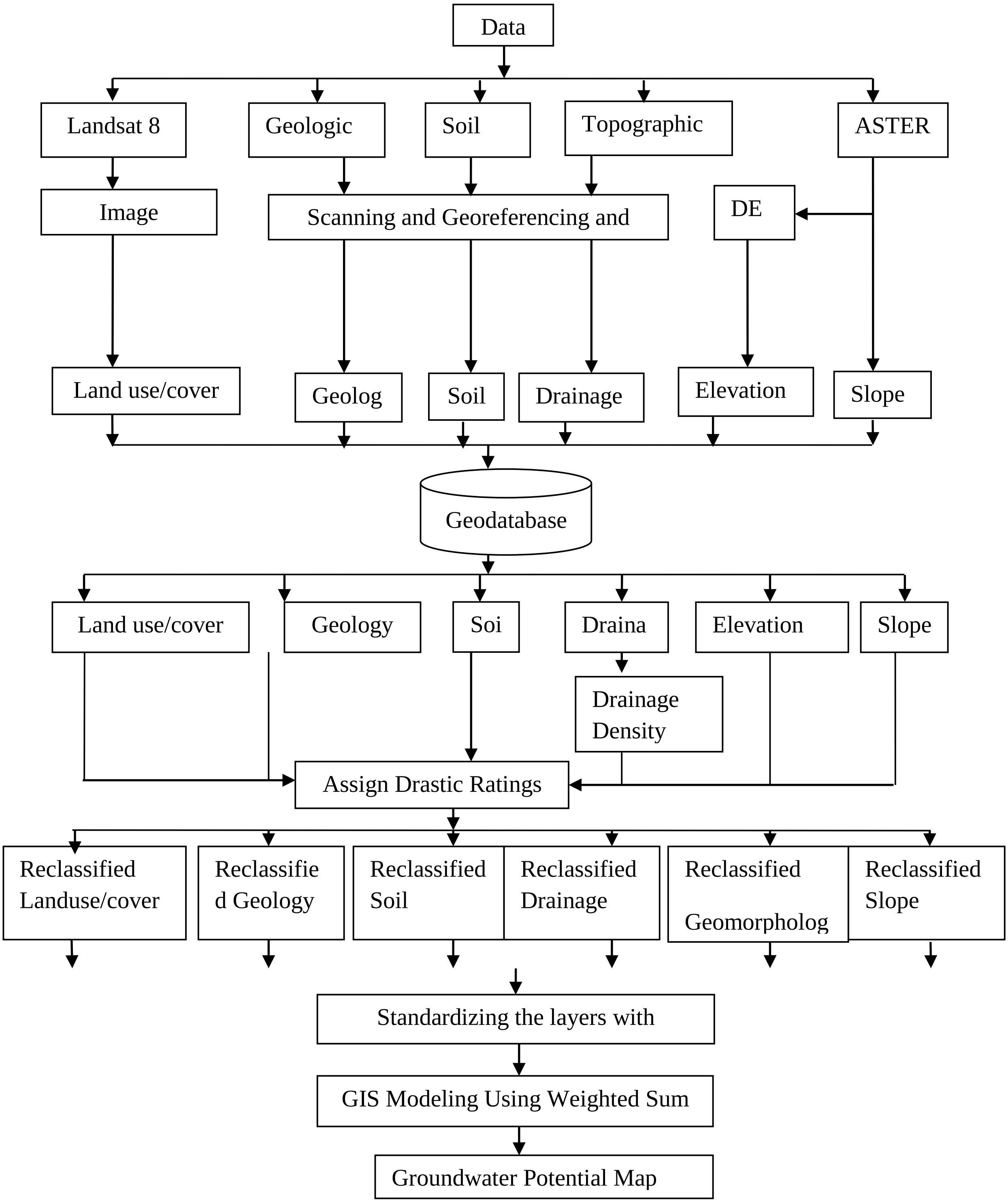


Figure 2: Flow Chart

GIS Modeling Technique

The modeling approach used to determine areas of ground water potential is summarized in the flow chart in Figure (2). The flow chart also shows the different inputs and outputs used to generate the final groundwater productivity map. The method used here has been modified from the well-known DRASTIC model, which is used to assess groundwater pollution vulnerability by the Environmental Protection Agency of the United States of America (Aller et al., 1985). The formula of the Groundwater Productivity map (GP) model is shown below:

$GP = DD + G + Ge + S + Sl + Lu$ ……….(1) Khairul Anam *et al.,* (2000). Where:

Dd: Drainage Density, G: Geology, Ge: Geomorphology, S: Soil, Sl: Slope, Lu: Land Use/Cover

ANALYSIS AND DISCUSSION

Slope relates to the local and regional relief and gives an idea about the general direction of groundwater flow and its influence on groundwater recharge (Gupta and Srivastava, 2010).

The slope classes obtained in the study area had values (degrees) which include (0- 2.31), (2.31-4.01), (4.01-6.48), (6.48-11.57) and (11.57-39.34) which was given classes 1-5 and further classified into flat, gentle, moderate, steep and very steep respectively.

With respect to groundwater occurrences, the slope of an area plays a very significant role in groundwater accumulation in terms of infiltration as well as runoff. Infiltration is inversely related to slope i.e. the more flat the slope, the more infiltration will be more and less runoff (Nag & Anindita, 2011). This is because flat areas where the slope amount is low have high tendency of retaining rainfall and facilitating recharge while steep areas where the slope amount that is high will amount to less infiltration and high run-off.

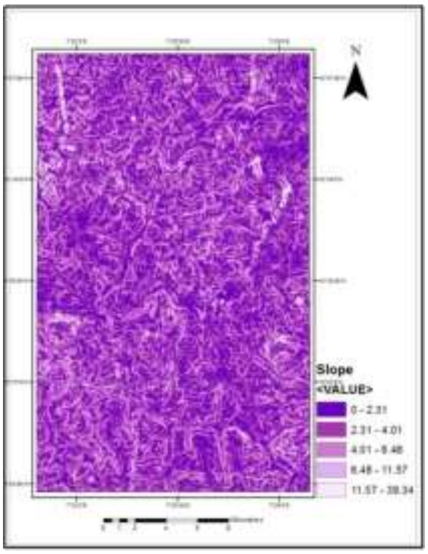


Figure 3: Slope Pattern of Kaduna Metropolis (Source: Author, 2021)

Land use Land cover

With respect to groundwater occurrences, the land use and Land cover of the area provides important indications of the extent of groundwater requirement and utilization. The area with water bodies is good for groundwater recharge and bare land is poor for it (Chowdary et al. 2009). The land use/cover types in the study area were classified into five (5) classes namely; built-up lands, farm land, bare land,Vegetation, water body were identified in the study area.

Farm land with vegetation is an excellent site for groundwater exploration (Todd and Mays, 2005). This is because vegetation allows proper water infiltration because of the leaves and shrubs while farm land aids infiltration because the land has already been tilted making the soil to be very loose. Water bodies are good for groundwater recharge and bare land is poor for it (Chowdary *et al*., 2009). Bare surface will encourages runoff. This is because the surface is compacted and hard i.e. the pore spaces between the soils are compacted thus increasing surface runoff. Increase in settlement has a negative effect on groundwater accumulation because it completely closes off the sub-surface preventing any form of infiltration.

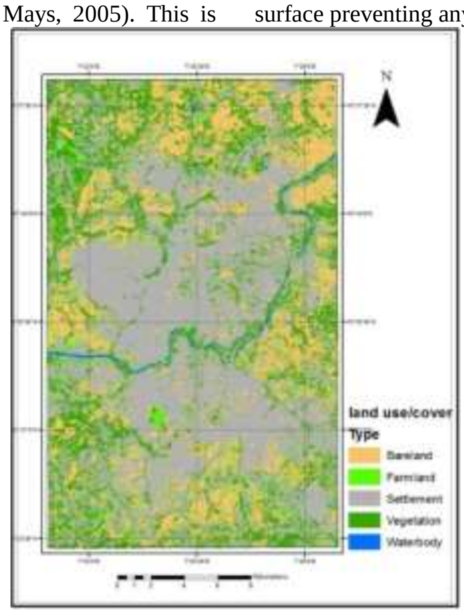


Figure 4: Land use and Land cover of Kaduna Metropolis (Source: Author, 2021)

Soil Textures

The study area is covered by three soil types: Sandune, Sandy clay, Sandy clay loam. With respect to groundwater occurrence, the effect of soil on groundwater infiltration is how it allows infiltration of rainfall into the subsurface (recharge). This is called permeability. The more sandy the soil, the higher the permeability. The Sandune is located at the bank of the river and also in the river. The Sandune has a very high percentage of sand which make it very good medium for water infiltration. The sandy clay and sandy loam differ in their percentage of sand. The sandy loam has greater percentage of sand than the sandy clay which makes the sandy loam better in terms of water infiltration than sandy loam.

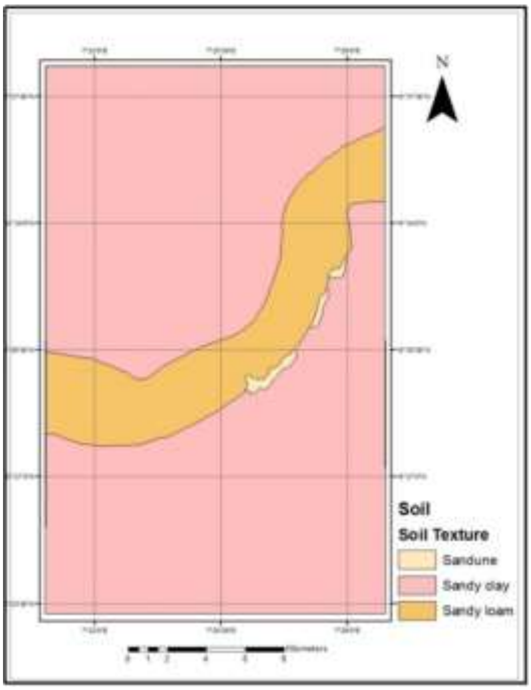


Figure 5: Soil Textures of Kaduna Metropolis (Source: Author, 2021)

Geology

Geology is a major factor controlling the quality and quantity of groundwater occurrence in a given area. It is represented by the distribution of different rock units characterizing the area under study.

The major rock type found in the study area are Biotite and biotite hornblende granodiorite (Pan African Older Granite), Coarse grained porphyriic biotite and biotite hornblende gneises (Pan African Older Granite), Migmatite (Migmatite Gneises Complex), and Schist quartzite pegmatite (Meta-Sedimentary Series

The migmatite complex identified in the study area has the widest coverage in terms of spread.

With respect to groundwater occurrence, the rocks occurring in the study area were ranked according to their age and aquifer characteristics. The age of the rock type ranges from pre-cambrian to Cambrian. The Migmatite and the schist quartzite pegmatite fall in the Pre-cambrian age while the Biotite granodidrite and gneiss fall in the Cambrian age (Nigerian Geological Survey Agency, 2008). The age of the rock affects the degree of weathering as well as accumulation and percolation. Migmatite and schist quazite pegmatite were emplaced earlier than Biotie Granodiorite and Biotite gneiss which makes them better rocks for groundwater accumulation because of the degree if weathering (The Geological Society of America, 2009).

In terms of their hydrogeological characteristics, the quartzite pegmatite are generally good aquifers because they tend to weather to sandy materials with good permeability. However, the schist has a lot of mica which weathers into clay and do not encourage permeability but if intruded with quartzitic materials, the narrow zones can enhance their water bearing capacity. The migmatite tend to have better potential because of the cleavage foliations. Thus their permeability is often enhanced. While the biotite hornblende granodiorite and the porphyriic biotite hornblende gneiss is very poor in groundwater potentials because they do not weather easily but when close to a river they are good medium for water accumulation because the water will help the rock to weather faster.

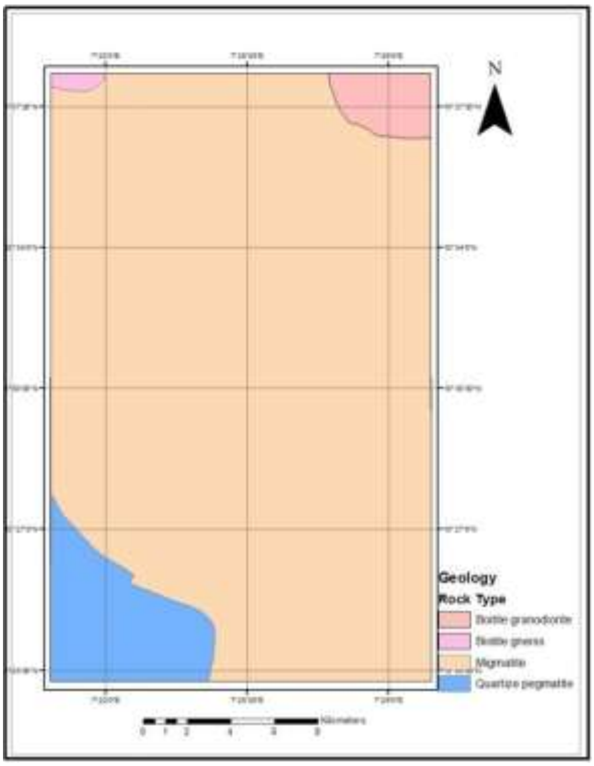
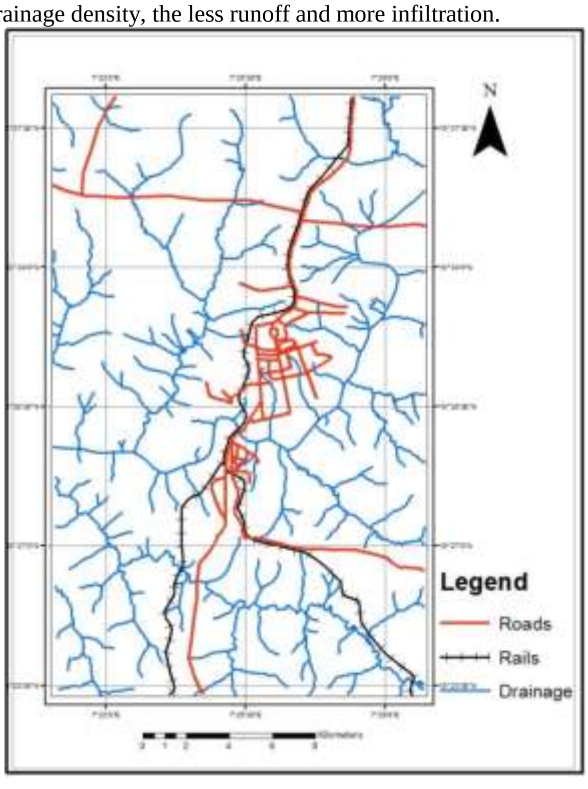


Figure 6: Geologic Rock Types of Kaduna Metropolis (Source: Author, 2021)

Drainage

A drainage map of the area gives an idea about the permeability of rocks and also gives an indication of the yield of the basin (Wisler and Brater, 1959). Drainage pattern is one of the most important indicators of hydrogeological features, because drainage pattern and density are controlled in a fundamental way by the underlying lithology (Charon, 1974). In the study area, four (4) types of drainage classes have been identified as: very low, low, moderate, high and very high drainage density. With respect to groundwater occurrence, high drainage density is an unfavorable site for groundwater existence because it increases runoff and less infiltration while less/no drainage density is high groundwater potential zone (Todd and Mays, 2005). This means that the lower the drainage density, the less runoff and more infiltration.



Figurem 7: Drainage Pattern of Kaduna Metropolis (Source: Author, 2021)

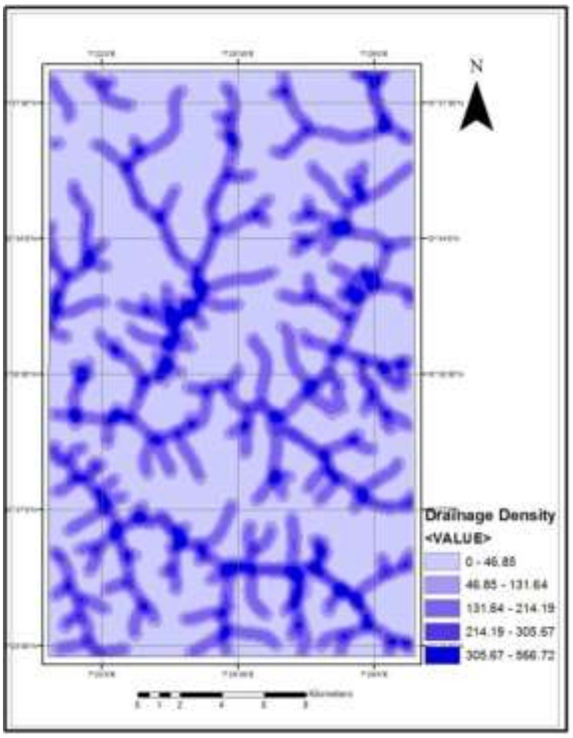


Figure 8: Drainage density Pattern of Kaduna Metropolis (Source: Author, 2021)

Geomorphology

The geomorphology describes the different landforms present in an area. It is well known fact the climate and geomorphological characteristics of a basement area affect its response to a considerable extent. Thus, linking of geomorphological parameters with hydrological characteristics provides a simple way to understand their hydrological behavior. The various types of geomorphologic unit present in the study area are as follows: highlands, lowlands, alluvial plains and river.

With respect to groundwater occurrence, In Fig 9 the high lands occur mostly on the northern part of the metropolis with an elevation of about 670m above sea level. Water will generally slip down from the highland to a lower level. They are considered poor zones for groundwater accumulation. Alluvial plains occupy the second largest area of the catchment and are characterized by light to medium texture sediments. The porosity and permeability of the alluvial plains are very high so they are considered as very good zones for groundwater. The river will generally serve as source for recharge for groundwater.

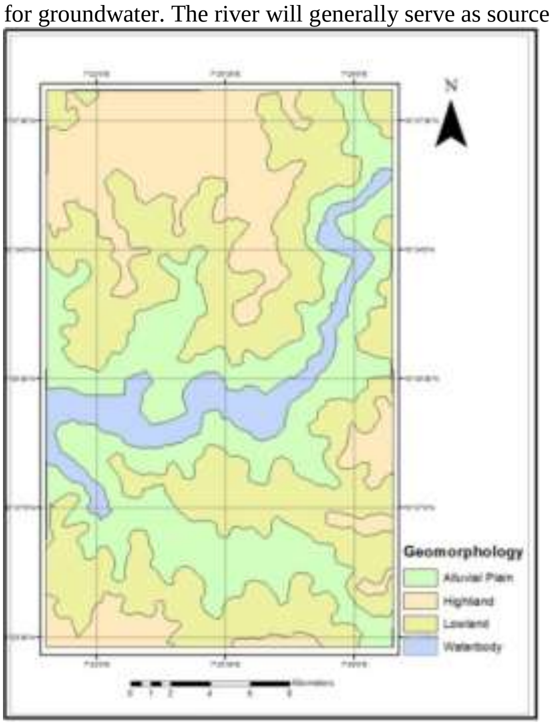


Figure 9: Geomorphologic Structure of Kaduna Metropolis (Source: Author, 2021)

Categorization of Groundwater Producing Zones (GIS Modeling)
Groundwater Potential Map

All the hydrogeological factors were assigned DRASTIC Weight to show their importance to groundwater occurrence in the study area. The weight produce showed their importance to groundwater accumulation. The geology of the study area was considered to be the most significant factor for groundwater accumulation because it takes into consideration the rock type, degree of fracturing, grain size reflecting the geologic history of the study area. it also takes into consideration the degree of different porosity and permeability levels caused by groundwater accumulation. The geomorphology was also weighted high because it is produced as a result of the geology.

Other hydrogeological factors such as slope, soil texture, drainage density, land use/cover and water bodies play an important role in groundwater replenishment

Table 1: Summary of Weighted Table Overlay

RASTER	WEIGHT	ATTRIBUTES	RATINGS
Geology	5	Migmatite	9
		Schist Quartizite Pagmatite	7
		Biotite Gneises	4
		Biotite Granodiorite	2
Geomorphology	5	Alluvial Plain	10
		Low Land	7
		Water body	5
		High Lands	4
Slope	4	Flat	10
		Gentle	9
		Moderate	5
		Steep	3
		Very Steep	1
Soil Texture	3	Sandune	10
		Sandy Loam	8
		Sandy Clay	6
Drainage Density	2	No Drainage	10
		Low Drainage	7
		Moderate	5
		High Drainage	2
		Very High Drainage	1
Land use/cover	1	Vegetation	10
		Farmland	8
		Water Body	5
		Bare surface	3
		Settlement	1

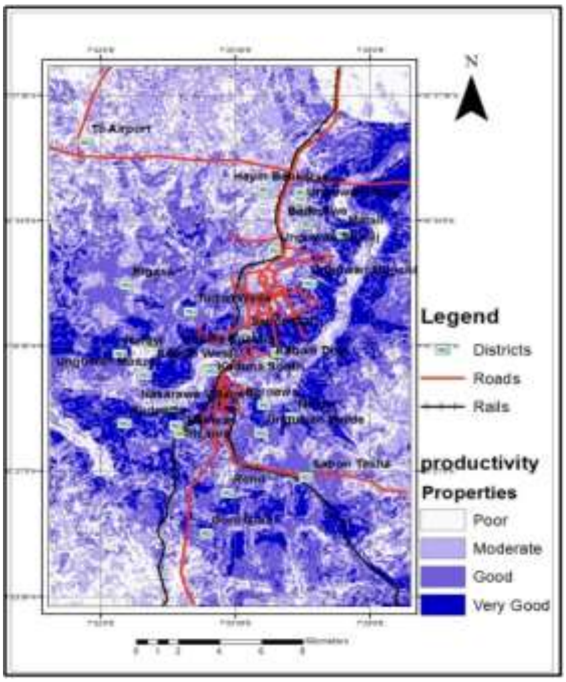


Fig 10: Groundwater Potential Areas of Kaduna Metropolis and Districts (Source: Author, 2021)

Table 2: Showing Locations of Groundwater Potential within the Metropolis

s/n	Locations	X (^{0})	Y (^{0})	Expected Yield description from Map	Actual Yield from drilled borehole	Actual borehole yield description	Remarks
1	Barkin-Lahu	7.456	10.62	Good	0.8	Good	Coincide
2	NTI	7.483	10.619	Moderate	0.6	Moderate	Coincide
3	Trade fair complex	7.483	10.605	Good	1.2	very good	Not Coincide
4	Uuguwan-Kaji	7.455	10.6	Moderate	0.2	Poor	Coincide
5	Dalet Baracks	7.455	10.595	Poor	0.3	Poor	Coincide
6	Airforce Base	7.433	10.607	Good	0.7	Good	Coincide
7	Hayin-Banki	7.44	10.597	Moderate	0.5	Moderate	Coincide
8	Rafin Guza	7.461	10.591	Moderate	0.2	Poor	Not Coincide
9	Uguwan-Dosa	7.451	10.577	Poor	0.4	Poor	Coincide
10	NDA Baracks	7.437	10.572	Moderate	0.5	Moderate	Coincide
11	Water Resource Int	7.387	10.584	Good	1.5	very good	Not Coincide
12	Airport Road	7.368	10.612	Good	0.7	Good	Coincide
13	Badarawa	7.454	10.586	Poor	0.4	Poor	Coincide
14	Malali	7.468	10.552	Poor	0.3	Poor	Coincide
15	Arewa House	7.452	10.552	Poor	0.8	Good	Not Coincide
16	Uguwan Rimi	7.464	10.535	Moderate	0.5	Moderate	Coincide
17	Muritala Square	7.448	10.533	Very Good	1	very good	Coincide
18	KASU	7.436	10.526	Good	0.6	Moderate	Not Coincide
19	Police College	7.452	10.523	Good	0.6	Moderate	Not Coincide
20	Central Market	7.425	10.514	Very Good	1	very good	Coincide
21	Tuudun Wada	7.41	10.531	Moderate	0.6	Moderate	Coincide
22	Rigasa	7.383	10.602	Poor	0.7	Good	Coincide
23	Kabala West	7.395	10.52	Good	0.8	Good	Coincide
24	Aguwan Muazu	7.386	10.5	Moderate	0.6	Moderate	Coincide
25	Living Faith Church	7.444	10.486	Moderate	0.6	Moderate	Coincide
26	Barnawa	7.443	10.48	Good	0.7	Good	Coincide
27	Narayi	7.459	10.476	Good	0.7	Good	Coincide
28	Psychiatric Hospital	7.428	10.467	Good	0.8	Good	Coincide
29	Tricania	7.395	10.47	Very Good	0.5	Moderate	Not Coincide
30	Kudenda	7.373	10.474	Good	0.8	Good	Coincide
31	Television Garage	7.428	10.45	Good	0.8	Good	Coincide
32	Uuguwan Sunday	7.464	10.465	Good	0.8	Good	Coincide
33	Sabon Tasha	7.464	10.447	Good	0.7	Good	Coincide
34	Kamazo	7.495	10.448	Moderate	0.7	Good	Not Coincide
35	Bagi Village	7.448	10.441	Moderate	0.6	Moderate	Coincide
36	Uguwan Romi	7.427	10.44	Moderate	0.6	Moderate	Coincide
37	Goni Gora	7.418	10.417	Moderate	0.6	Moderate	Coincide
38	NNPC	7.392	10.435	Very Good	1	very good	Coincide
39	Hayin Banki	7.495	10.407	Moderate	0.6	Moderate	Coincide
40	Kabala West	7.442	10.577	Moderate	0.5	Moderate	Coincide
41	U. Rimi Central Msq	7.389	10.497	Good	0.7	Good	Coincide
42	Badarawa	7.463	10.53	Good	0.7	Good	Coincide
43	Uuguwan. Kanawa	7.464	10.561	Good	0.7	Good	Coincide
44	Kawo	7.443	10.559	Moderate	0.8	Good	Coincide
45	Kawo New Ext	7.47	10.585	Very Good	0.3	Poor	Not Coincide
46	Ahmed Aminu	7.473	10.587	Good	0.8	Good	Coincide
47	Hayin Banki	7.476	10.599	Good	0.6	Moderate	Not Coincide
48	Kawo Market	7.472	10.559	Good	0.8	Good	Coincide
50	Rafingusa	7.47	10.5998	Good	0.7	Good	Coincide

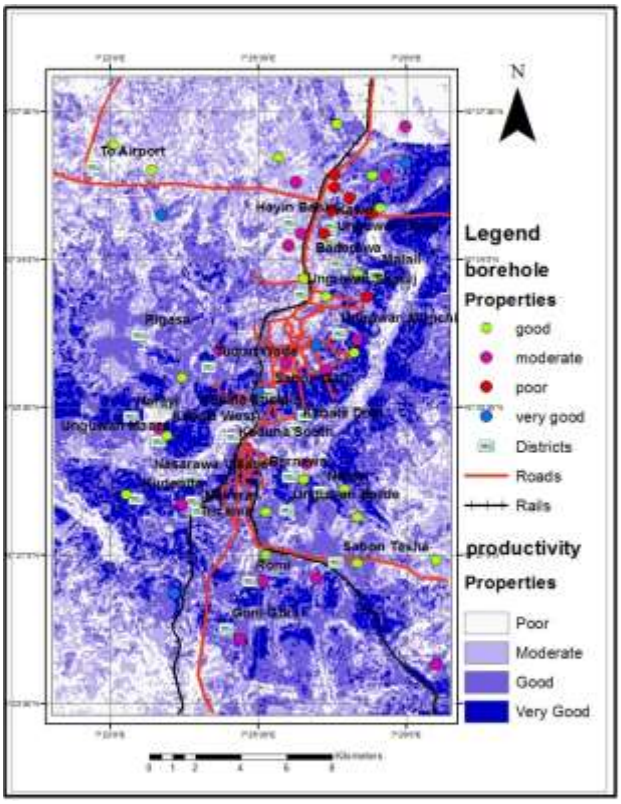


Figure 11: Correlation of Borehole and Groundwater Potential of Kaduna Metropolis (Source: Author, 2021)

To validate the groundwater productivity map of the study area showing if the model used was successful, was determined by this calculation below

$$\frac{\text{Total number of coincide borehole with yield map}}{\text{Total number of actual drilled boreholes.}} \times 100 \quad (4.2)$$

$$\text{The Accuracy of Validation} \quad \frac{38}{50} \times 100 = 76\%$$

DISCUSSION OF RESULTS

The research has demonstrated the application of using remote sensing and GIS combined with the modified DRASTIC model technique to generate the groundwater producing zones of Kaduna Metropolis. The research also shows that the geology, geomorphology, slope, drainage density land use/cover and the soil texture have interrelated relationships which are major and minor determinants of groundwater availability in any particular basement rock respectively. From the groundwater productivity map generated (Fig 10), four major group of groundwater producing levels were delineated and was grouped as: very good, good, moderate and poor. The various patterns shown reflect the concept of the model that was used for the research. Areas that are very good and good groundwater producing zones occur mainly at areas that are favorable in terms of geology and geomorphology. For geology, they occur mainly in areas of Migmatite. This is because the Migmatite tend to have better potential because of the cleavage foliations. Thus their permeability is often enhanced. In terms of the geomorphology, they occur majorly in areas of alluvial plains. Areas with moderate are attributed to contributions from the combination of slope, land use/cover and landforms. Areas of poor groundwater producing zones are spatially distributed along highlands and lithology.

CONCLUSION

This research combined Remote Sensing and GIS within a DRASTIC Model for the assessment, evaluation and analysis of spatial distribution of ground water producing zones of Kaduna Metropolis.

The groundwater producing zones of Kaduna Metropolis have been produced using six thematic maps from exiting data and field data. The groundwater produced map was compared and validated by existing discharge data obtained from different locations from the study area. The result showed a considerable level of accuracy. The most promising potential zone in the area is related to geology and geomorphology with less drainage density. Most of the zones with moderate to poor groundwater potential lie mostly in the highland where the rock types are Pre-Cambrian basement complex. This study generally demonstrates that GIS and Remote sensing techniques combine with DRASTIC Model in addition to field data could be used for the assessments of ground water producing zones in an area. It can be considered as a time and cost-effective tool for delineations and identification groundwater producing zones.

REFERENCES

Ako, B., & Olorunfemi, M. (1989). Geoelectric Survey of Groundwater in The Newer Basalt of Jos, Plateau State. *Journal of Mining and Geology 25* , 247-250.

Aller, L., Lehr, J., & Petty, R. (1987). *DRASTIC: A Standardised System To Evaluate Groundwater Pollution Potential Using Hydrogeological Settings.* U.S: US EPA Report 600/2-87-035, U.S. Enviromental Protection.

Chowdhury, A., Jha, M., Chowdary, V., & MAL, B. (2009). Integrated remote sensing and GIS-based approach for assessing groundwater potential in West Medinipur district,West Bengal, India. . *Int. Jour. Remote Sensing, v.30* , 231-250.

Clark, L. (1985). Groundwater Abstraction From the Basement Complex Areas of Africa. *Quarterly Journal for Engineering Geology, London, Vol 18* , 25-34.

Clark, L. (1985). Groundwater Abstraction From the Basement Complex Areas of Africa. *Quarterly Journal for Engineering Geology, London, Vol 18* , 25-34.

Dearmaun, W., Dayness, F., & Irfar, T. (1978). Engineering Grading of Weathered Granite. Engineering Geology Granite. *Engineering Geology No. 12* , 345-374.

Eduvie, M. (1998). Groundwater Assesment and Borehole Characteristics: Case Study of Kaduna Metropolis. *Paper Presented at a Workshop Organized by Kaduna State Water Board. Nigeria Teachers Institute* . Kaduna, Kaduna, Nigeria.

Gupta, M., & Srivastava, P. (2010). Integrating GIS and remote sensing for identification of groundwater potential zones in the hilly terrain of Pavagarh, Gujarat, India. *Water Int., v.35* , 233-245..

IWMI. (2001). *The Strategic Plan for IWMI 2000–2005.* Colombo, Sri Lanka: International Water Management Institute.

McCurry, P. (1976). The Geology of The Precambrian to Lower Paleozoic Rocks pf Northern Nigeria:. In C. (. Kogbe, *Geology of Nigeria* (pp. 15-38). Ibadan: Elisabeth Publication Company, Ibadan, Nigeria.

Musa, I. (2011). Looming Water Scacity: The Challenges and Prospects of Integrated Water Resources Management in Nigeria. *Paper Presented at the 7th Annual Lecture of the School of Engineering and Engineering Technology*, (p. 54). Federal University of Technology, Akure, Ondo State.

Nag, S., & Anindita, L. (2011). Integrated approach using Remote Sensing and GIS techniques for Delineating Groundwater Potential Zones in Dwarakeswar Watershed Bankura District, West Bengal. *International Journal for Geomatics and Geosciences. Vol 2, No 2* , 430-442.

Nigerian Geological Survey Agency (2008). *Geologic Map of Kaduna.* Abuja: Authority of The Federal Republic of Nigeria.

Olayinka, A., & Olorunfemi, M. (1992). Determination of Geoelectric Characteristics in Okene Area and Implication of Borehole Sitting. *Journal of Mining and Geology 28* , 403-412.

Olorunfemi, M., & Fasuyi, S. (1993). Aquifer Type and The Geoelectric Hydrogeologic Characteristics of Part of The Central Basement Terrain Nigeria (Niger State). *Journal of Africa Earth Sciences 16* , 309-317.

Olorunniwo, M., & Olorunfemi, M. (1987). Geophysical Investigation of Groundwater in Precambrian Terrains: A Case History of Ikare, South-western Nigeria. *Journal of African Earth Sciences 6* , 787-796.

Oteze, G. (1989). The Hydrogeology ofthe North-Western Nigeria Basin. *Kogbe C.A. Rockview (Nig) Ltd, Jos -Nigeria* , 455=472.

Todd, D., & Mays, L. (2005). *Groundwater Hydrology. 3rd ed.* Hoboken: John Wiley & Sons.

The Geological Society of America (2009). *Geologic Time Scale.* USA: Cambrige University Press.

Udoh, E., & Etim, N. (2007). Analysis for Domestic Water Consumption by Farming Households in Itu, Akwa Ibom State, Nigeria. *European Journal for Social Sciences* , 76-82.

Wisler, C., & Brater, B. (1959). *Hydrology.* New York: Willey