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

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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.

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°23’ and 10°43’ N and Long. 7°17’ and 7°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.
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(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 Oluronfemi, 1989; Olayinka and Oluronfemi, 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 (Oluronniwo and Oluronfemi, 1978; Oluronfemi 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 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.
GIS Modeling Technique

The modeling approach used to determine areas of groundwater 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:

\[ GP = DD + G + Ge + S + Sl + Lu \]  

Khairul Anam et al., (2000). Where:

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

Figure 2: Flow Chart
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.

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

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

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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.

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 porphyric 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 porphyric 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 5: Soil Textures 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.
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.
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 Quartzite 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 (°) | Y (°) | 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   | Uguwan-Kaji            | 7.455 | 10.6  | Moderate                            | 0.2                               | Poor                             | Coincide |
| 5   | Dalei 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  | Naraiy                 | 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  | Uguwan 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                            | 0.2                               | 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  | Uguwan. 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 |
| 49  | Rafingusa              | 7.47  | 10.5998| Good                               | 0.7                               | Good                             | Coincide |

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

\[
\text{Accuracy of Validation} = \frac{\text{Total number of coincide borehole with yield map} \times 100}{\text{Total number of actual drilled boreholes}} \times 100 = 76\%
\]

**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 mainly 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.
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