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ANALYSIS OF SPATIAL RELATIONSHIP BETWEEN GROUNDWATER POTENTIAL ZONES AND BOREHOLE YIELDS IN OKENE LOCAL GOVERNMENT AREA, KOGI STATE, NIGERIA

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ABSTRACT

The quantity of water that can be extracted from a borehole is directly related to the groundwater potential of an area among other things. Boreholes drilled in areas of low groundwater potential have every tendency to fail. There have been reported cases of borehole failures in Okene Local Government Area of Kogi state. This study therefore aimed at analyzing the potentiality of groundwater and the spatial relationship between borehole yield and groundwater potential zones in the area. Various data which include Sentinel 2 satellite image, Digital Elevation Model, geological map, rainfall data and borehole yield data were analyzed to produce various zones of groundwater potential, and validated using existing borehole yields and the relationship was tested using Pearson correlation. The result of this study reveals that the low potential zone covers 33.2%; moderate potential zone occupies 44.9% which cuts across the whole of Okene LGA and the high potential zone covers 21.9% mainly found around the western part of the area. The Pearson moment correlation analysis result revealed a strong positive correlation (R) value of 0.919. The correlation value shows that there is a strong positive relationship between the existing borehole yields in the study area and the groundwater potentiality map produced from the analysis. The study concluded that there is a strong positive relationship between the existing borehole yields and the groundwater potential zones in Okene Local Government Area.

Keywords: Groundwater potential, Borehole yield, GIS, spatial relationship, AHP

INTRODUCTION

Groundwater refers to the water found in the opening spaces in rocks and sediments underneath the earth. Its origin is traced to rainfall or snow, which then moves through geologic materials into the groundwater system, where it finally makes its journey back to the surface water sources (Nelson, 2015). The likelihood of groundwater existence in an area is facilitated by factors such as geology, slope, physiography, hydrogeology, depth of weathering, geomorphology, drainage, presence of fractures and surface water bodies (Ghosh and Nag, 2012; Rusia, 2018). Groundwater is unevenly distributed across space and is quite restricted to hard rock terrains (Suryabhagavan, 2017), therefore its occurrence and abundance is location dependent (Adelana *et al*., 2008).

The potentiality of groundwater is the viability of an area to be an aquifer that could be used for groundwater development (Lee *et al.,* 2019). Groundwater potential refers to the likelihood of groundwater being found in commercial quantity in an area (Rahmati *et al.,* 2016). It is the accurate measurement by estimation and prediction of the nature of groundwater that are essential for the efficient exploitation and management of groundwater resources. Groundwater varies across the space and over time and it should be studied more thoroughly with respect to its potentiality and spatial distribution (Oikonomidis *et al.,* 2015). Groundwater potential determines how prolific or not a borehole will be.

The yield of a borehole is the quantity of water that can be pumped out from it within a given timeframe (Midlands pumps, 2023). It can be expressed as liter/second, cube/hour, meter cube/day, or cube/annum. More precisely, a borehole yield test shows the equilibrium between the largest quantity of water that can be recovered out of the borehole and the quantity of water that recharges it from the surrounding groundwater sources. The knowledge of borehole yield is important so as not to pump above the capacity of the borehole which could result in induced saline intrusion and abnormal lowering of the water table, and eventual failure of the borehole (KumbaDirect, 2023). More often there is a cordial relationship between borehole yield and groundwater potential.

The combination of Geographic Information System (GIS) and Remote Sensing methods have been affirmed as efficient tools in analyzing the dynamics of groundwater, most especially, Multi-Criteria Analysis method using raster based GIS offers more and better information about decision making where many criteria or factors are involved (Argaz *et al*., 2019). Among the most effective Multi-Criteria Decision Making (MCDM) techniques is the Analytic Hierarchy Process (AHP), commonly utilized by decision makers to make a better choice in complex problems that involves conflicting and internal multiple criteria (Zeinolabedinia and Esmaeily, 2015). The use of Remote Sensing and Geographic Information System in the study and search of groundwater occurrence has been employed by a many researchers all over the world. This is because Remote Sensing gives access to inaccessible terrains, wide area of coverage in short time and low cost of data acquisition.

Generally, potable water supply in Kogi State and particularly in Okene Local Government Area by the state water corporation has been unreliable as a result of which residents now depend on various alternative water sources like boreholes (Aremu et al., 2014). Groundwater is a promising solution to the water crisis in Okene but since the distribution is not even, and moreover, Okene is notable for failed boreholes attributed to lack of proper survey and demarcation of groundwater potential prior to drilling (Amigun *et al.,* 2015), therefore this study aimed at analyzing the groundwater potential zones and the spatial relationship between borehole yield and the groundwater potential in the Okene LGA.

The study area

Okene LGA in Kogi State, is located between Latitudes 07° 20' and 07° 35' North of the Equator and Longitudes 06° 08' and 06° 29' East of the Greenwich Meridian (Figure 1). It shares boundaries with Adavi to the North, Ajaokuta to the East, Ogori Magongo to the South West LGAs in Kogi State and Okpella to the South in Edo State. Okene LGA located in the north–central geopolitical zone of Nigeria. The climate of the study area is characterized by both dry and wet seasons. Generally, the dry season occurs between October and March while the rainy season starts from April to September of the year. Annual rainfall in the area ranges between 1100 and 1300 mm. The geology of the area comprises of Precambrian basement rocks, notably Migmatite-gneiss complex rock that is associated with series of metasedimentary rocks and older Granite (Annor and Freeth 1985). Occupations of the indigenes comprises of farming for men and weaving of cloth for the women. The minority tribes are traders ranging from distributors to retailers (Aremu *et al.,* 2014). There are artisans like mechanics, tailors, plumbers, and transporters. Okene is also is host to commercial and microfinance banks. Due to prominent commercial activities in the area the demand for water is high; putting pressure on few available yielding boreholes (Amigu *et al.*, 2015).

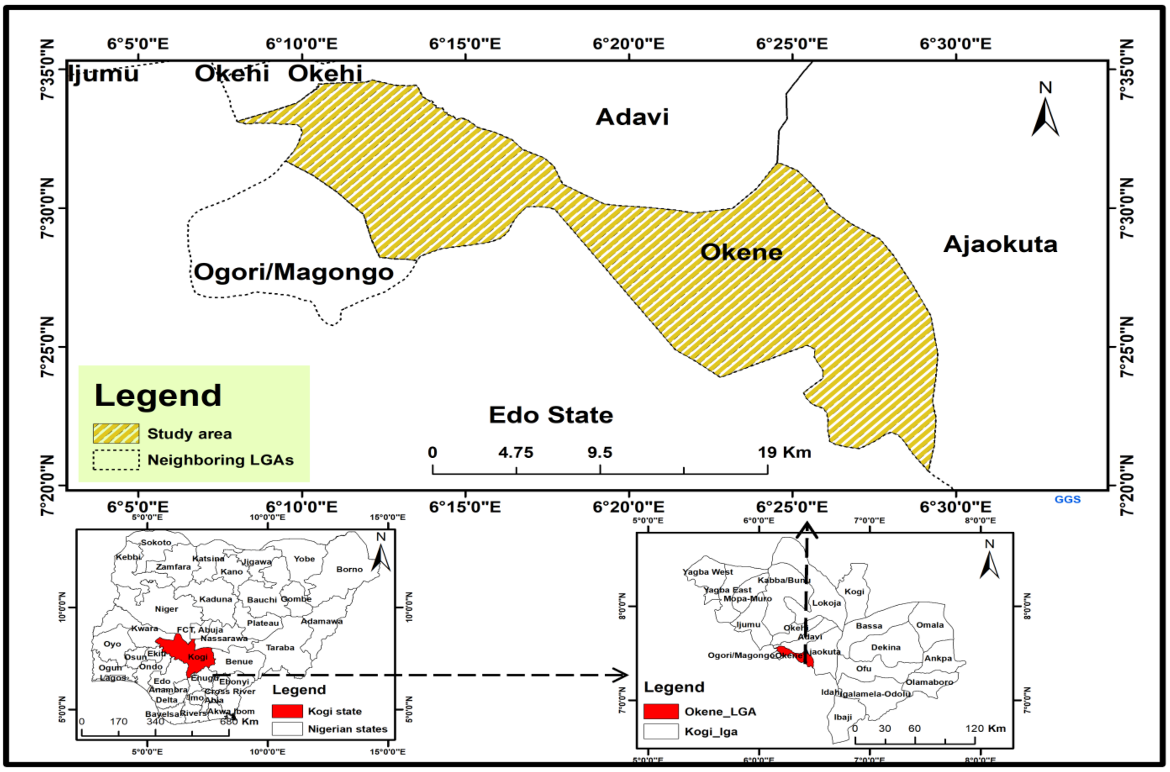

Figure 1: Okene Local Government Area
Source: Adapted from the LGA administrative map

MATERIALS AND METHOD

Criteria or factors selection is a critical step in groundwater potential analysis. The groundwater potential influencing factors that were considered in this study include rainfall, lineament density, geology, drainage density, land use/land cover and slope. The study area being a crystalline terrain, literatures have shown that the afore-mentioned factors are of great importance in influencing groundwater potential of such terrain (Benjmel *et al.*, 2020; Balakrishnan, 2019; Suryabhagavan, 2017).

Various data acquired from different sources were used in the course of this study. These include 10m resolution Sentinel 2 satellite image (from USGS), Digital Elevation Model (from USGS), geological map (from NGSA), rainfall data (from PERSIANN) and borehole yield data (from Aquatech Drilling Services and ATK Water). Each of the factors considered in this study were analyzed individually in GIS environment. The different factors (rainfall, lineament density, geology, drainage density, land use/land cover and slop) influencing groundwater occurrence were weighted with the help of AHP. The AHP uses pairwise comparison to calculate weight based on the influence each criterion has on the occurrence of groundwater. The weighting was done using a scale of 1 to 9. 1 means equal influence between criteria, 3 means slightly influential, 5 means strongly influential, 7 means very strong influence and 9 for extremely influential (Saaty, 1980). The most influential criterion for groundwater occurrence had the highest weight while the least influential criterion had the lowest. The weighted thematic maps were integrated through the weighted overlay function in the spatial analyst tool in ArcGIS environment to produced Groundwater Potential Zones (GWPZs). The GWPZs produced was reclassified into 3 zones of low, moderate and high potential zones. The GWPZ was validated using the existing borehole yields and the relationship was tested using Pearson correlation. The significance of the correlation result was tested using the student t-test

RESULTS AND DISCUSSION

Groundwater Potential Zones of Okene Local Government

Figure 2 shows the groundwater potential zones in Okene LGA. It was reclassified into three zones namely; low potential, moderate potential and high potential zones. The areas with high groundwater potential are mainly found in the western part, this also correspond with the fact that the western part of the study area received the highest rainfall in addition to high concentration of lineament and drainage density. This is contrary to the work of Masitoh *et al.* (2022) who found that the most influencing groundwater potential factor was geology with soil texture being the least in Brantas Basin

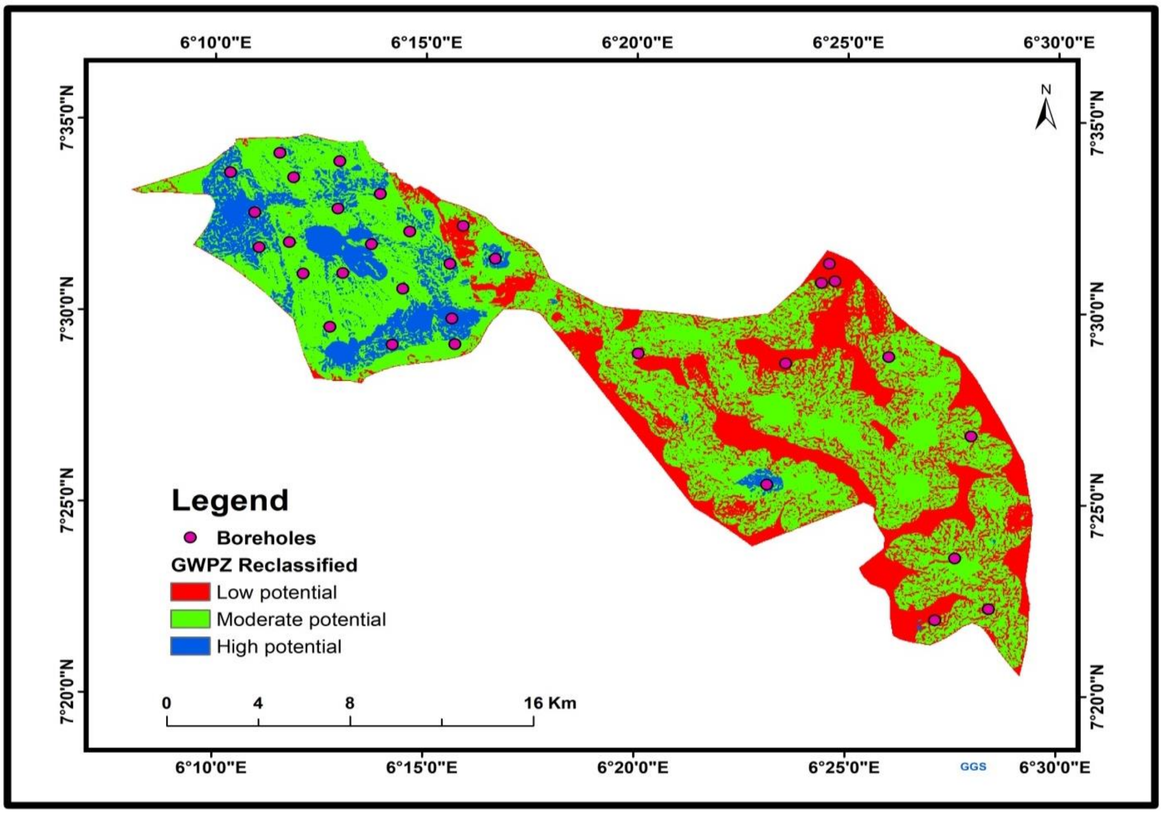

Figure 2: Reclassified Groundwater Potential Zones of Okene Local Government

The high availability of groundwater in the western part may be the major factor for high settlement in the areas compared with other parts. The moderate potential zones cut across the whole study area, so also the low potential zones. This is similar to the work of Gidado and Abdulkadir (2018) who found that each of groundwater potential zone cuts across many parts of Ilorin Metropolitan Area. The area extent occupied by each groundwater potential zone is shown in Table 1

Table 1: Area Extent of Groundwater Potential Zones in Okene LGA

GWPZs	Area (km^2)	Percentage (%)
Low Potential	108.7301	33.2
Moderate Potential	147.0477	44.9
High Potential	71.72259	21.9
Total	327.5004	100

As seen in Table 1, moderate potential zones covered an area extent of 147.0477 km^2 representing 44.9%, low potential zones covers an area of 108.7301 km^2 which represent 33.2% of the whole of Okene LGA whereas, the high potential zone covers 71.72259 km^2 (21.9%) of the study area. The high potential zone covering only 21.9% of the study area may be responsible for borehole failure in Okene reported by Amigun *et al.* (2015). This finding is nonetheless contrary to the work of Sangana *et al.* (2019) who found that very good groundwater potential zones accounted for less than 3% of Dodoma City, Tanzania.

The relationship between existing borehole yields and the groundwater potential zones

Ten (31.25%) of the boreholes had high yield, 14 (43.75%) had moderate yield and the remaining 8 (25%) of the boreholes had low yield (Appendix 1). However, when overlaid on the GWPZ 81.25% of the boreholes fell on areas corresponding to their yields while 18.75% of the boreholes fell on areas different from their yields on the groundwater potential map produced. This result is contrary to the finding of Hyeman *et al*. (2020) which found that 62% of boreholes fell in groundwater potential zones corresponding to their yields in Kaduna Metropolis.

As shown in Table 2, the result of Pearson moment correlation indicates that R is positive of 0.919. This is meant to show the direction and strength of the relationship between the yields of existing boreholes and the groundwater potential map. The relationship is a positive one meaning that as groundwater potential increases borehole yield increases correspondingly. The strength of the relation is very strong (R = 0.919). This result is in agreement with the work of Ahmed and Sajjad (2018) carried out in Lower Barpani Watershed, which found groundwater potential in the watershed to have positive relationship with borehole yields in the area.

Table 2: Correlation Table

	GWPM	Borehole Yields
GWPM	1	
Borehole Yields	0.919014958	1

The significance of the correlation result of 0.919 was tested using the student t-test

H_o: there is no significant relationship between the existing borehole yield and groundwater potential in Okene LGA, Kogi State

$t = \frac{R\sqrt{n-1}}{\sqrt{1-R^2}}$

R = 0.919

n = 32

Therefore, calculated t = 11.91

Tabulated value 0.05 level of significance at 30 degree of freedom was found to be 2.024 while the calculated t-test value was 11.91

Decision rule: Since tabulated student t-test (2.024) is lower than calculated t-test value (11.91), we are rejecting the null hypothesis that states that there is no significant relationship between the existing borehole yield and groundwater potential in Okene LGA, Kogi State.

CONCLUSION

This study analyzed and found that groundwater potential zones were low potential (33.2%), moderate potential (44.9%) and high potential zone (21.9%) in Okene LGA. The high potential zone covering only 21.9% of the study area may be responsible for borehole failure reported in the area. Given the correlation value of 0.919 between the existing borehole yield and groundwater potential in Okene LGA, it can be concluded that there is a strong positive relationship between the existing borehole yields and the groundwater potential map produced from the analysis.

Table 3: Borehole Yields and Groundwater Potential Map values

Borehole points	Longitude	Latitude	Borehold Yields	Potential (yield)	Normalized GWPM	Potential (Map)
1	6.182571	7.542537	1.5	Moderate	0.35	Moderate
2	6.232078	7.550787	1.6	High	0.8	High
3	6.241215	7.509553	1.2	Moderate	0.45	Moderate
4	6.228661	7.528847	1.5	Moderate	0.7	High
5	6.411946	7.513876	0.3	Low	0.21	Low
6	6.433392	7.480914	1.5	Moderate	0.67	High
7	6.452183	7.366418	0.4	Low	0.12	Low
8	6.201839	7.51594	0.91	Low	0.51	Moderate
9	6.172797	7.559894	2	High	0.87	High
10	6.264908	7.537096	0.5	Low	0.23	Low
11	6.197763	7.55787	1.11	Moderate	0.28	Low
12	6.260722	7.49674	2.1	High	0.91	High
13	6.277671	7.522868	2	High	0.83	High
14	6.212495	7.492854	1.45	Moderate	0.48	Moderate
15	6.334373	7.481973	1	Moderate	0.27	Low
16	6.392664	7.477964	0.59	Low	0.26	Low
17	6.38548	7.425056	1.05	Moderate	0.41	Moderate
18	6.459952	7.393342	1.3	Moderate	0.50	Moderate
19	6.466068	7.446572	0.67	Low	0.27	Low
20	6.216015	7.565038	1	Moderate	0.52	Moderate
21	6.192265	7.568489	1.1	Moderate	0.49	Moderate
22	6.18438	7.527363	2.1	High	0.73	High
23	6.259758	7.520588	1.78	High	0.39	Moderate
24	6.243812	7.534524	1.33	Moderate	0.37	Moderate
25	6.215332	7.544355	1.89	High	0.81	High
26	6.217494	7.51622	1.6	High	0.41	Moderate
27	6.237149	7.485222	2.1	High	0.73	High
28	6.261972	7.485574	1.9	High	0.76	High
29	6.409698	7.5215	0.56	Low	0.26	Low
30	6.406581	7.513018	0.2	Low	0.14	Low
31	6.473335	7.371259	1.1	Moderate	0.36	Moderate
32	6.196235	7.529614	1.2	Moderate	0.47	Moderate

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