Groundwater Potential Assessment in Ilorin Metropolis and Environs, North Central Nigeria

[1*]Obimba Harry Ogechukwu, [2]Akinluyi Frank and [3]Meh Ivo Kum,
[1]Cooperative Information Network (COPINE), National Space Research and Development Agency (NASRDA), Obafemi Awolowo University, Ile-Ife, Nigeria
[2]Department of Remote Sensing and GIS, Federal University of Technology, Akure, Ondo State, Nigeria
[3]United Nation High Commission for Refugees, (UNHCR) Sub Office Buea, Cameroon

Abstract: This study is aimed at integrating Radar and Optical data for groundwater exploration in Ilorin and environs, Nigeria. This was achieved via the extraction of satellite based thematic information influencing ground water and result validated using borehole yield. The study employed the use of Radar image from Sentinel 1A to extract lineament of the study area, elevation and drainage from shuttle Radar Thematic Mission (SRTM) data and landuse/landcover from optical Sentinel 1B images. A multi-criteria analysis was performed using the weighted overlay of six parameters and the resulting groundwater potential of the area classified into four (very high, high, moderate and low) based on their influence on groundwater accumulation.Result reveals that the dominant Azimuth frequency trend was N-S, E-W, NE-SW, NNE-SSW directions. Areas around the extreme North generally, North-East and to an extent the North central part of the study area were successfully delineated and shown as the most prospective zones for groundwater.

Keywords*: Sentinel 1A and 2B; thematic maps; Basement complex; MCA*

I. INTRODUCTION

Water is one of the most valuable natural resources vital to the existence of any form of life. Most freshwater occurs in the form of permanent ice or snow, locked up in Antarctica and Greenland or in deep groundwater aquifers.

Groundwater is a dynamic and replenishing natural resource, which forms the core of the ecological system (Mondal, 2012). The occurrence of groundwater at any place on the earth is not a matter of chance but a result of the interaction of the climatic, geological, hydrological, physiographical and ecological factors. Two main types of aquifer in this study area are the weathered basement and jointed/fractured basement aquifers with the latter usually occurring below the former. The movement of groundwater is controlled mainly by porosity and permeability of the surface and underlying lithology. Same lithology forming different geomorphic units will have variable porosity and permeability thereby causing changes in the potential of groundwater. However, the search for groundwater have been very challenging in some part of the world more especially in area associated with basement complex rocks (Ayodeji, *et al* (2012). Surface hydrogeological features like topography, geomorphology, surface water bodies, drainage and so on, play important roles in groundwater replenishment.The inadequate and irregular public water supply in Ilorin and environs despite the efforts made by government such as provision of hand dug wells and boreholes of which a great number end up abortive or dry up quickly during the dry season. This could be attributed probably to lack of detailed hydrogeological and pre-drilling geophysical investigation or poor understanding of the hydrogeological characteristics of the basement complex environment. This necessitated our study involving geomorphologic and hydrogeological assessment of the area using Remote sensing (the science and art of identifying, observing and measuring an object without coming into direct contact with it) and Geographical information system (GIS) from Sentinel 1A and B (medium resolution) images. GIS technology are valuable tools in developing environmental models through their advance features of data storage, management, analysis, and display (Burrough& McDonnell, 1998). It has the ability to integrate multiple factors that are considered to contribute to the occurrence or localization of groundwater, analyze them and give out appropriate results through a process called multi-criteria decision analysis (MCDA).F.D. van der Meer *et al,* (2014), tried simulating Sentinel-2 products that are relevant to the geology and soil science community of the Rodalquilar mining area, Cabo de Gata volcanic field, SE Spain by comparing these with well-established band ratio products from ASTER. K.A. Mogaji*et al*, (2011) in his research work on mapping of lineaments for groundwater targeting in the basement complex region of Ondo state, southwestern Nigeria, using Remote Sensing and GIS, they illustrated the importance and application of Remote Sensing and GIS techniques for groundwater resource exploration and management using LANDSAT 7 ETM+ imagery, ASTER DEMs and geological maps. Bayowa O. Gabriel, et al, (2014), carried out hydro geomorphological, geological/hydrological investigation in the basement complex of Ekiti state with the aim of assessing groundwater potential of the state. Akinwumiju et al, (2016) assessed groundwater potential of Osun drainage basin using GIS to evaluate groundwater potential using several thematic maps and several VES data interpreted to generate aquifer thickness.

The objective of this study is to integrate the use of Radar and Optical data from sentinel satellite images to delineate the distribution of groundwater in Ilorin metropolis and environs using multi-criteria analysis in GIS.

II. STUDY AREA

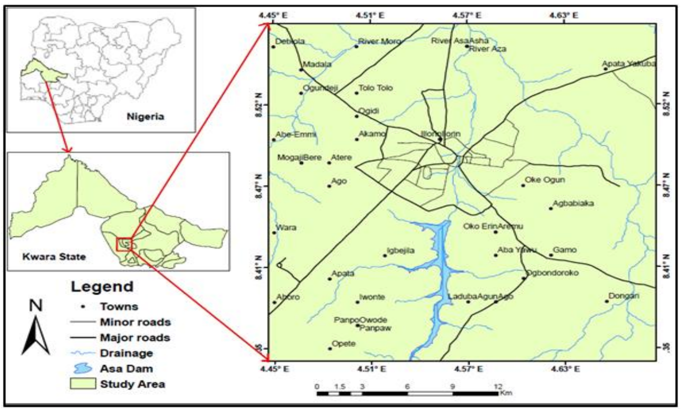

Figure. 1: Study area Map of Ilorin and Environs.

Ilorin is the capital city of Kwara state, north central Nigeria. The state had a population of 777,667 in 2006 and 908,490 in 2011 population census, making it the 6th largest city in Nigeria by population. The area of the study falls mainly within Ilorin west local government area. This area lies entirely within the basement complex rocks of western and north central Nigeria and geographically enclosed within latitude 8° 20' 00″N to 8° 36′ 00″N and longitude 4° 26′ 00″E to 4° 42′ 00″E. (Fig 1.1)

Climate, vegetation and soil type

The climate of the study area is characterized by both the wet and dry season, for about six months. This area is characterized by two seasons, the dry season last from October to February (Harmattan) and the Rainy season in the area begins towards the end of March and ends in October with two peak periods in June and September. Ilorin is within the transitional climate zone of Nigeria, average daily temperature ranges between 26.28˚C and 31.95˚C. Tropically continental climate with high temperature throughout the year.

The vegetation is basically Savannah (Guinea) interspersed with tropical forest remnants, it comprises of derived sparsely spaced trees like Parkiabioglobosa, Actosoniadigitate, Acacias etc. and short grasses and shrubs.

The soils are typically red-brown to red-yellow tropical ferruginous soils and crystalline acid soils. This is good for wide variety of crop farming. Soil is mostly derived from the parent rocks of the basement complex and granite crystalline rocks with a well-developed profiles high nutrient, well structure and high biological activities which enhance farming activities in the study area (Jimoh,1997).

Geology and Hydrogeology of Study Area

Ilorin is underlain by rocks of the crystalline Nigeria basement complex, principally among which are granites and gneisses. These rocks were emplaced in Precambrian times and have over time subjected to tectonic activities characterized by large changes in temperature and the pressure resulting in fractures - like joints, faults and fractures within the basement complex rocks. These fractures influence groundwater in crystalline rocks especially if they are at depth and overlaid by a thick superficial cover (overburden). From geological investigations, it is observed that two prominent aquifers are in this region (overburden weathered aquifer and the fractured crystalline aquifer) interconnected at some places to form a hydrogeological unit of water table surface. (Dan and Olorunfemi, 1999).

III. MATERIALS AND METHODS

Both primary and secondary data were used to achieve the set objectives. GPS points collected of the spatial location of observed boreholes constitutes our primary data while the secondary data include, Sentinel 2 (earth observatory/optical image) satellite data covering the study area. This was orthorectified using WGS 1984 projection to generate the land use and land cover map using supervised classification in ERDAS IMAGINE 2014. Lineament extraction for the study area was done using PCI geomatica with LINE modular under user suggested parameters values. Sentinel-1A data is from a constellation of two satellites (1A and 1B) that provides C-Band SAR data of medium to high resolution. The data were acquired in IWS (Interferometric Wide Swath) mode with dual-polarization capability (VV+VH or HH+HV) and are delivered in Level-1 GRD (Ground Range Detected High Resolution) C-band products and goes through geometric and radiometric corrections. Administrative map of study area provided towns of administrative division and processed in ArcMap, Shuttle Radar Topographic Mission (SRTM) covering the study area and environs was downloaded from http//www.glovis.usgs.gov in GeoTIFF file format and subset to the Area of Interest (AoI) using the polygon shape file marking the study area, this was used to derive the drainage network, drainage density and elevation. Geology map was derived from scanned georeferenced and subset secondary geological and mineral resource map of Kwara state, at a scale of 1: 500,000 published in 2006 (NGSA). Soil map of study area was scanned, georeferenced and subset from dominant soil map of Nigeria 1997 at a scale of 1: 1,300,000. Individual soil types were then digitized and labeled accordingly. Digital Elevation Model (DEM) was created from the clipped SRTM image of the study area in global mapper. Nigerian map containing the 36 states shape file and topographic map of the study area from the office of the surveyor general of the federation (OSGOF).All parameter was ranked,weighted according to their contribution to groundwater accumulation and Multi-criteria evaluation (MCE) carried out to generate the final composite groundwater map of the area. The area was further classified into very high, high, medium and low groundwater potential. Borehole yield data information acquired from existing boreholes, Nigerian hydrology and survey agency (NIHSA), ministry of water resources, Kwara state were used to validate the groundwater distribution in the study area.

IV. RESULTS AND DISCUSSION

Occurrence of groundwater in areas underlain by crystalline rocks depends on the thickness of the overburden or the presence of fractures that are capable of holding water mainly among other factors (Olorunfemi M.O *et al*.,1983). Fig 2 shows the lineament map of the study area. Lineaments have been identified as the most influencing factor of groundwater potential in the Basement Complex terrain (Olorunfemi, 1989). Here also the movement and occurrence of groundwater depends mainly on secondary porosity and permeability resulting from folding, faulting and fracturing.They indicate areas of possible water seepage into the aquifer. Areas with high intersection of these lineaments exhibit higher tendency of accumulating groundwater, these are fracture zones (Edet et al, 1998).

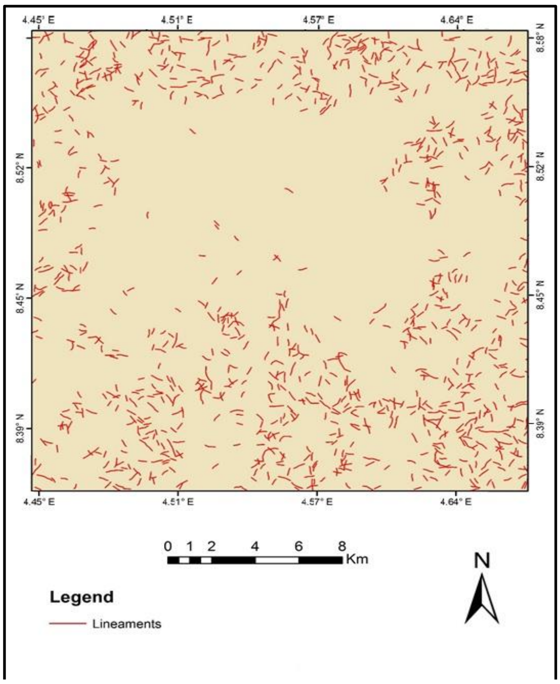

Fig. 2 lineament map of study area

Places on the map like Madala (NW), Gbagede (SE) and Igbejila (S) Whereas Ilorin, Tolotolo (NW) and some others in the central areas of the mapshow low lineament density. Around Owode is intermediate. Migmatite rock dominated areas has low lineament density compared to granite and gneiss dominated areas. Figs 3,4 and 5 shows lineament density map, lineament intersection map and rose diagram respectively. The rose diagram indicates the directions of groundwater movement in the study area (Owoade and Moffat., 1989). It is observed that the prominent structural trend is in the NE-SW direction while some minor trends are observed in the E-W direction. This is in agreement with the major Ifewara fault trend within the schist belt of the area (Hubbard, 1975).

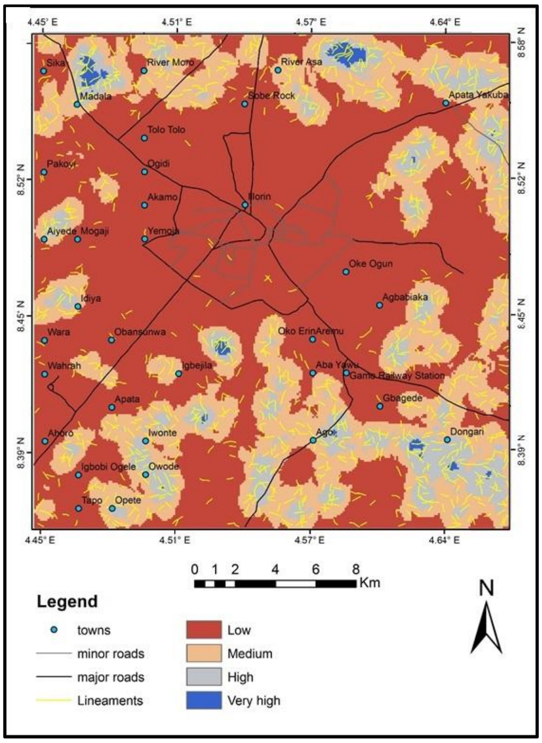

Fig 3: lineament density map

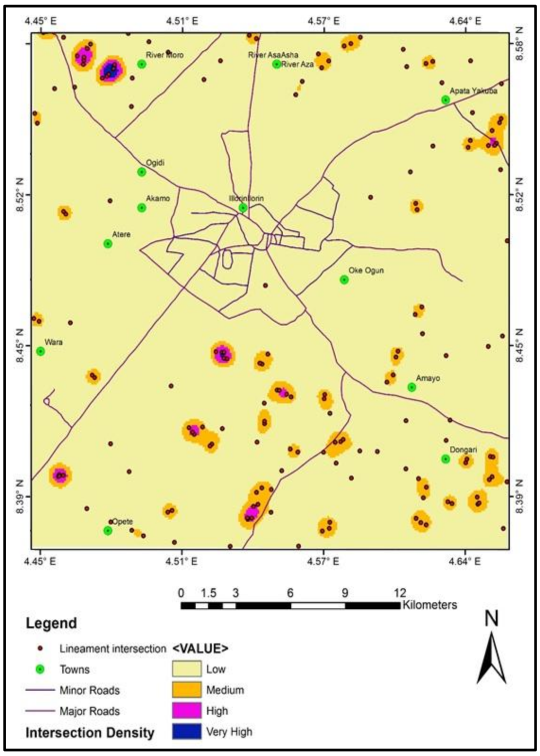

Fig 4: lineament Intersection Map of Ilorin and Environs.

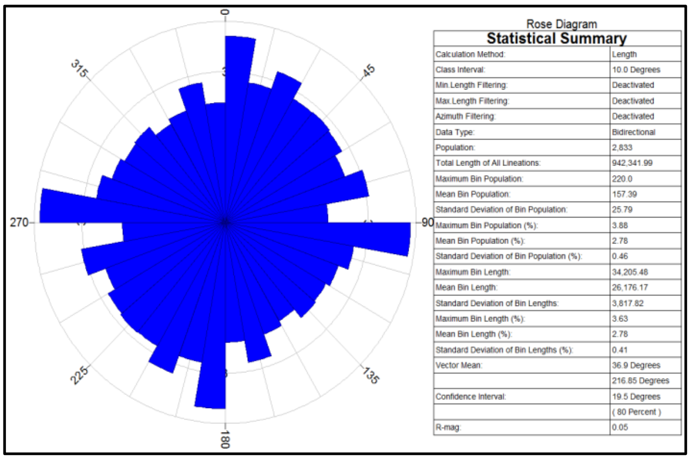

Fig 5: Rose diagram of Lineament Orientation.

Geology formations in the study area include Banded gneiss(BG), medium to coarse grained Biotite and Hornblende Granite(OGE), Migmatite (M), Granite gneiss(GG), and Flaggy quartz with biotite gneiss(Q). They range in age from pre-Cambrian to Pan-African). Based on the water retaining capacity of the rocks in the study area, the geology was grouped into very high, high, moderate, low and very low groundwater potential. The magnetite is mostly distributed in the study area (over 70%). They are older in age with less porosity and permeability due to the effect of weathering and erosion over long period of time. The youngest is the Pan-African biotite hornblende around AgalaYakubu, they contribute more to groundwater accumulation.

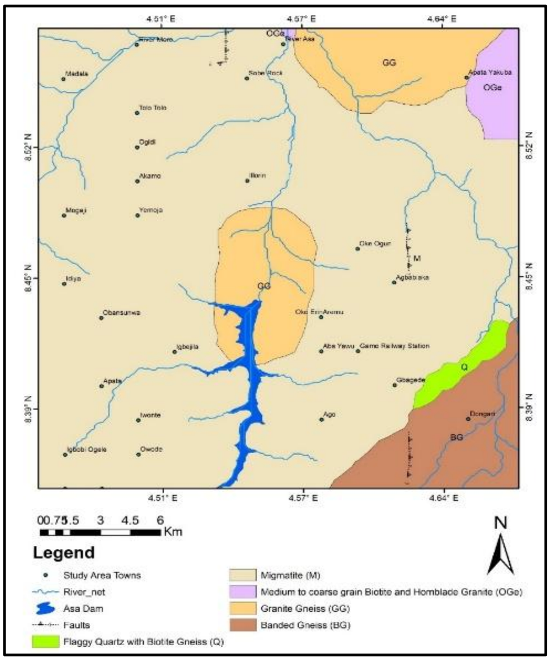

Fig 6: Geology map of Ilorin and Environs.

The effect of LULC is manifested either by reducing runoff and facilitating recharge or trap water on plant leaf and water droplets go down to recharge groundwater or negatively they facilitate loss by evapotranspiration (especially in arid and semi-arid areas). Supervised classification map of land use/land cover is shown in Fig 4. In the forest areas like Dongari and Owode on the final map, infiltration will be more and runoff will be less whereas in urban areas like Ilorin metropolis, rate of infiltration may decrease due to high run off rates (L.Shaban et al. 2006).

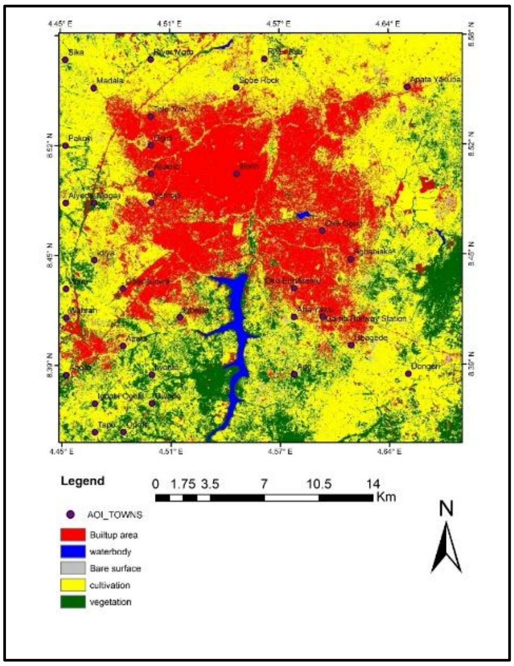

Fig 4: LULC Map of Ilorin and Environs

Generated soil map of the study area is presented in Fig 4.5. Two out of the thirty soil groups by the food and agriculture organization (FAO) classification were observed in the study area, these are the Luvisols soil group (well drained, found in flat-gentle slopes, coarse grained and rich in silicate clay) and the Lixisol soil group (relatively poorly drained and fine grained). a great portion of the built-up area like Ilorin metropolis, Mogaji up to Madala has Lixisol soil type, hence cause low infiltration, high runoff and consequently low *in situ* groundwater accumulation. While other parts like Ago, Agbabiaka, Dongari and many others are dominated by Luvisol soil hence higher groundwater percolation.

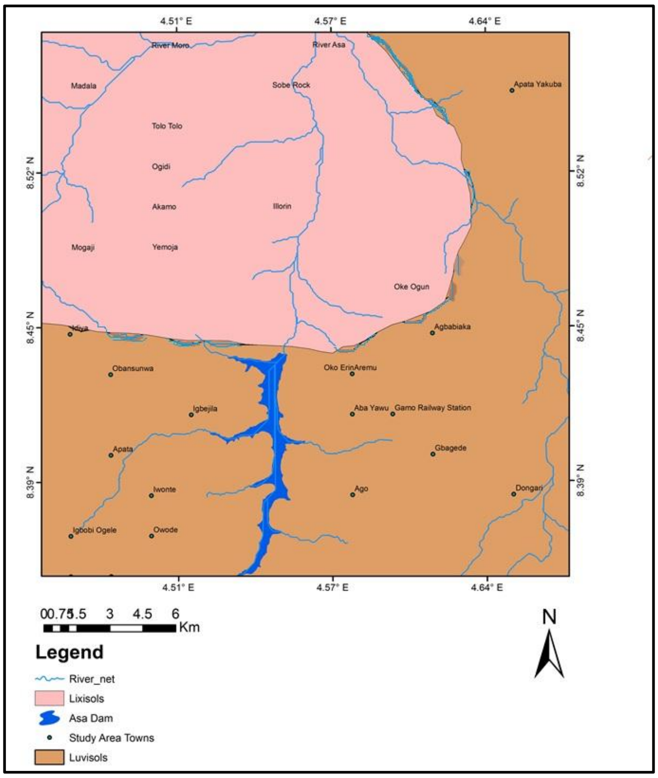

Fig 5: soil map of Ilorin and Environs

Drainage density and type of drainage gives information related to runoff, infiltration relief and permeability. (Jha*et al.*, 2007; Sander, 2007).The higher the drainage density the less the infiltration capacity. i.e., low void ratio of the terrain which in turn the lesser the groundwater potentiality (Parasad*et al*, 2008). But in basement complex terrains, higher drainage density is of importance in groundwater accumulation (Lee,2008; Akinwumiju, 2015). Areas like Dongari, Sobe and Moro on the final map have high drainage density as a resunt of weak or impermeable subsurface material or sparse vegetation. Drainage and drainage density maps are seen in Figs 6 and 7 respectively.

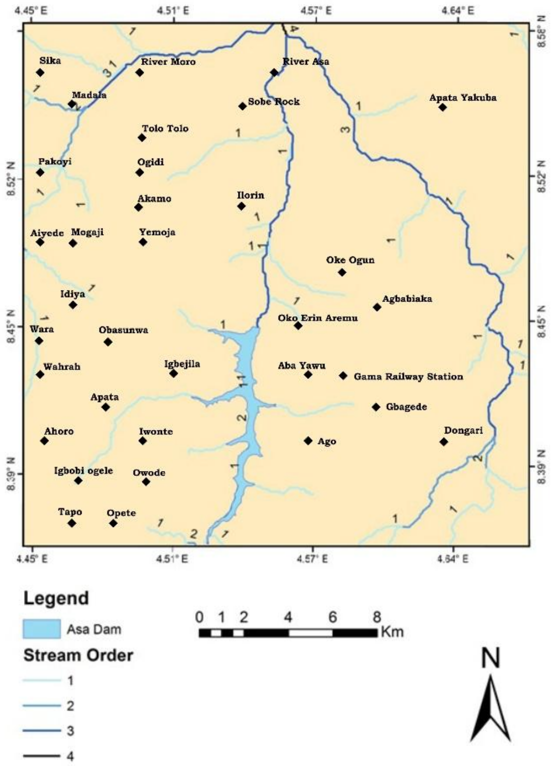

Fig 6: Drainage and stream order map of Ilorin and Environs.

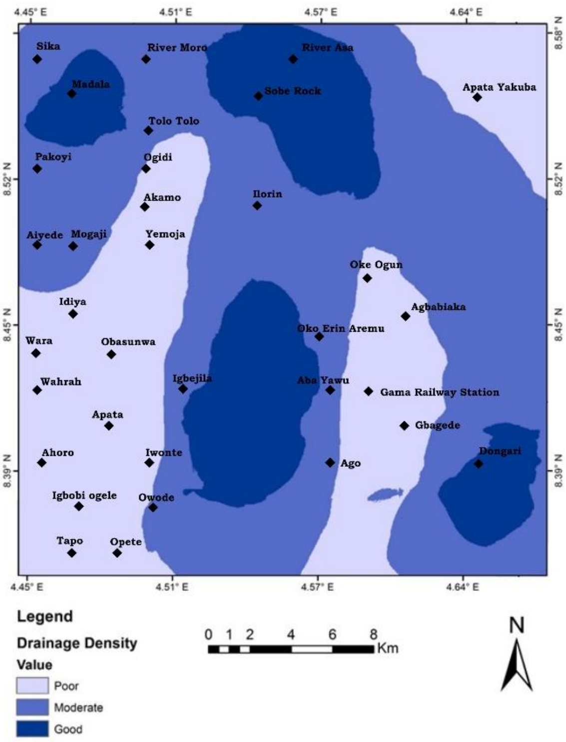

Fig 7: Drainage Density Map of Ilorin and Environs.

Fig 8 shows the elevation map of the study area. Water tends to store at lower topography than at higher topography and at lower pressure compared to higher pressure (Toth, 1963). Study area elevation ranges from 254m to 414m above sea level. Higher elevations are observed mostly around the eastern part of the area such as Apata Yakubu, Agbabiaka and Igbobi Ogele while Ilorin town fall under low lying area.

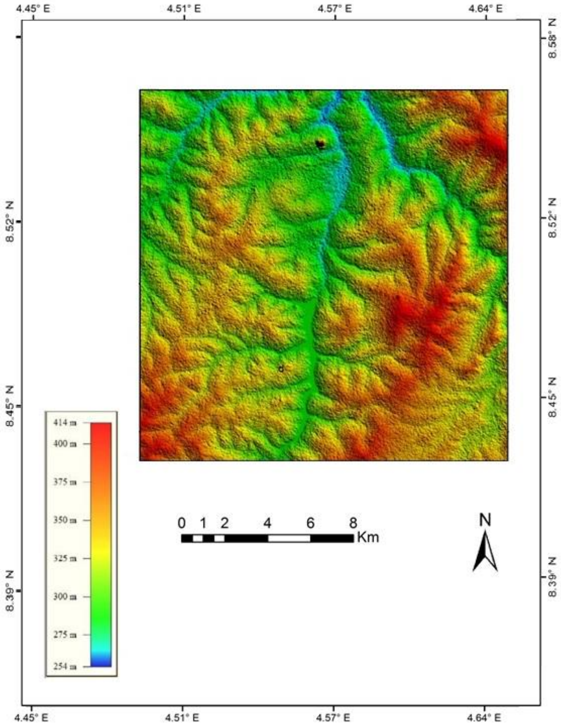

Fig 8: Elevation map of Ilorin and Environs

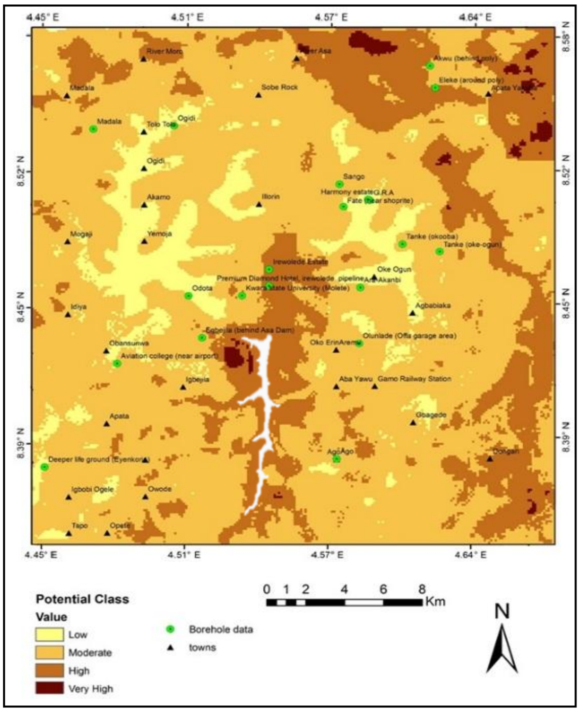

Fig 9: Groundwater Potential Map

CONCLUSION

Thematic maps of various parameter associated with groundwater accumulation were analyzed in GIS environment to produce a final composite map of groundwater potential of the study area. This generated map was validated with borehole yield data of the area. Ilorin and environs was classified into 4 groundwater potential zones (very high, high, moderate and low). This study predicted very high groundwater potential for less than 1% of the study area (North Eastern part around Apatayakubu and central parts like Egbejila and pipeline), 22% was rated high (Dongari, Madala and Gbagada), 68% moderate (Tanke, Ago and Sango) and about 9% low groundwater potential (Ilorin, Tolotolo, Agbabiaka and Idota). This pattern of groundwater potential distribution corroborates the groundwater prospect of a typical basement complex terrain (Olorunfemi and Fasuyi, 1993; James *et al.*, 2002; Mbiimbe,2012; Abdulahi and Iheakanwa, 2013; Akinluyi, 2013; Bayowa,2013; Akinwumiju, 2016.).

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APPENDIX

Table 1: Rank and Weight for different parameter of groundwater potential zones

S/N	Location	Depth of Borehole (m)	Latitude	Longitude	Bore Hole Status	Yield data (l/s)
1	Egbejila (behind Asa Dam)	150m	8.438892 N	_	Good Yield	_
2	Olunlade (Offa garage area)	120m	8.436102 N	4.593311 E	Good Yield	_
3	Gamon (glorious seed Nur/Prim school)	35m	_	_	Good Yield	_
4	Tanke (oke-ogun)	120m	8.477974 N	4.628578 E	Good Yield	1.50
5	Tanke (jalala)	100m	_	_	Good Yield	_
6	Tanke (okooba)	50m	8.481355 N	4.612375 E	Abortive	_
7	Okolowo area (fadama project)	80m	_	_	Low Yield	_
8	Akwu Village (behind poly)	60m	8.562750 N	4.624698 E	Fair Yield	_
9	Fate (near shoprite)	130m	8.498629 N	4.586740 E	Good Yield	_
10	Aviation college (near airport)	50m	8.427297 N	4.487990 E	Good Yield	1.25
11	Deeper life ground (Eyenkorin)	45m	8.380113 N	4.456165 E	Fair Yield (basement)	_
12	Odota	50m	8.458129 N	4.519140 E	Fair Yield	_
13	Kwara state University (Molete)	80m	8.458129 N	4.542459 E	Good Yield	_
14	G.R.A	50m	8.501457 N	4.598241 E	Good Yield	_
15	Touheed road	90m	_	_	Good Yield	_
16	Eleko (around poly)	50m	8.552795 N	4.626957 E	Low Yield	_
17	Sango	35m	8.508879 N	4.585054 E	Good Yield (highly weathered area)	1.50
18	Harmony estate	35m	8.501816 N	4.597445 E	Good Yield (overburden)	_
19	Irewolede Estate	25-35m	8.470031 N	4.554253 E	Good Yield	_
20	Ogidi	50m	_	_	Good Yield (basement)	_
21	Ogbodoroko	45m	_	_	Fair Yield (basement)	_
22	Ara-Akanbi	_	8.4616 N	4.5939 E	Fair Yield	2.70
23	Premium Diamond Hotel, irewolede. pipeline	_	8.4625 N	4.5542 E	Good Yield	_
24	Al-Hikmah University	180m	_	_	Good Yield	_
25	Ajegunle Street off Asa Dam Road	100m	_	_	Weathered Basement (good yield)	_