Remote Sensing and GIS Techniques for Ground Water Exploration in Ilesha Area, Osun State, Nigeria

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Authors’ contributions

This work was carried out in collaboration between all authors. Author OHO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JAA and ATA managed the analyses of the study. Author JAA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Occurrence of groundwater in the Basement Complex terrain of Ilesha area, southwestern Nigeria is controlled by secondary porosities developed through weathering and fracturing of the crystalline bedrocks. This paper presents the integrated approach of RS and GIS to groundwater potential in the study area. Thematic maps of geology, lineament, drainage and topography were prepared and integrated using ArcGIS 9.3 software to produce the groundwater potential map for the study area. The study adopted the multi-criteria and weighted classification. The groundwater potential in the study areas was categorized into high, medium and low water potential areas. A great portion of the study area falls within the moderate-high groundwater potential area; this includes Ilesha town itself.

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1. INTRODUCTION

Water is one of the basic necessities of life besides food and shelter [1]. Its sources could be classified into; glacier, surface water and groundwater, but the source of interest to this work is the ground water.

Groundwater is a term used to denote all the waters found beneath the ground surface [2,3]. Groundwater aquifers are not just a source of water supply, but also a vast storage facility providing great management flexibility at relatively affordable cost. Groundwater could either be found in the pore spaces within rocks and alluvium, in fractures, in solution openings or conduits in areas underlain by soluble carbonate rocks beneath the visible surface [4]. However, the search for groundwater have been very challenging in some part of the world especially in area associated with basement complex rocks [5]. Dense vegetation in some areas, the increasing population, the rocky nature of the terrain and technical knowhow are some of the problems in accessing groundwater in the study area.

The gross inadequacy of public water supply in Ilesha necessitated a detailed study involving geomorphological, hydrogeological and geophysical assessments. In other to overcome these challenges, the need for the adoption of an effective methodological tool like remote sensing (the science and art of identifying, observing and measuring an object without coming into direct contact with it) and Geographic Information System (GIS) becomes imperative. GIS is a system of computer software, hardware and data, and personal to help manipulate, analyze and present information that is tied to spatial data. ESRI (Earth Science Research Institute). It has the capabilities to integrate multiple factors that could be considered in determining suitable areas for ground water exploration. The necessity of remote sensing based groundwater exploration is to demarcate and delineate all possible features connected with localization of groundwater. These features are extracted from the appropriate satellite data products and integrated with the thematic details obtained from topographic sheets of the desired scale, hence its need for this study. This study is aimed at identifying the potential areas where groundwater can be explored in Ilesha, Southwestern Nigeria.

1.1 Study Area

The study area is geographically enclosed within latitude 7° 30’ 00”N to 7° 36’ 00”N and longitude 4° 38’ 00”E to 4° 50’ 00”E. The landscape of the area is generally described as undulating with ridges formed by quartz-schist or quartzite that trend in the North—south direction. Ilesha is a town in the old Oyo State which was presently part of the present Osun state in southwestern Nigeria (See Fig. 1). Ilesha the study area is famous for gold excavation. It is about 32 km northeast of Ile-Ife and about 30 km southwest of Oshogbo, the state capital, with a population of about 210,141 according to the 2006 population census [6]. The study area is geographically enclosed within the Precambrian rocks typical underlying the basement complex of Nigeria [7]. Some of the main rock types found in this area are granite-gneiss, which occupies most part of the eastern flank, as well as amphibolite complex, quartzite and schist, which occupies other parts of the study area [8]. It has a gentle topography with impermeable basement complex rock outcrops in the northeastern and northwestern parts of the town. This makes water exploration in the area very difficult, and becoming more pronounced as population increases. In other to ameliorate this challenge, the need to employ an effective survey method different from the conventional hydrological survey techniques becomes imperative to ensure water sufficiency for both domestic and non-domestic uses in the areas.

1.1.1 Geology

Ilesha is underlain by metamorphic rocks of the basement complex that outcrops over many places. Rock types here include schist associated with quartzite. The metamorphic rocks are largely undifferentiated, other rock types include migmatite complex, calsilicate, metaconglomerate amphibolite amphibolite and metamorphic iron beds.

1.1.2 Reliefs and drainage

The land surface is generally undulating and descend from an altitude of over 450 m in some areas and 150 m and below in others. Ilesha and some neighboring towns are hilly with a sharp drop in elevation around Erin-Ijesha giving rise to the presence of the popular water fall there.
1.1.3 Vegetation and soil

Ordinarily the area has lowland tropical rain forest vegetation but this has since been taken over by secondary forest regrowth due to anthropogenic activities due to human encroachment. Soil in the area is highly ferriferous tropical red soils associated with basement complex rocks. Two types are distinct, namely the deep clayey soil formed in lower hills and upper slopes and the sandier hill wash soils in the lower slopes. Clayey soil good for cocoa and coffee farming while the sandy is good for cassava, yam and maize cultivation.

2. MATERIALS AND METHODS

This research work used both primary and secondary data. Primary data for the study includes satellite imagery (Nigerian Sat-x) 2012 (Part 190, Row 55), with image spatial resolution of 32m, SRTM (shuttle radar thematic mapper) from NASA 1990. Secondary data used include geology and topography maps of the study area. (From geological survey of Nigeria 2004 at a scale of 1:250000). Both topography and geological maps were scanned, georeferenced and digitized. The multi-criteria approach is a process were by a number of determinant factors were integrated to ascertained how they influence a phenomenon. The parameters selected (lineament, geology, drainage and topography) were weighted and overlay in ArcGIS environment to map out areas suitable for groundwater exploration. (High groundwater potential, Moderate groundwater potential and Low groundwater potential, see Fig. 11). To validate the result (groundwater potential map) the ground control points which are the existing boreholes in the study area were overlaid.

The drainage system, settlements, road network, lineaments, drainage, topography and geology were extracted from both primary (satellite data) and secondary data (topography and geological map).

The study adopted a multi-criteria and weighted approach in mapping potential areas for groundwater exploration.

The geology of the area was classified into three classes based on their permeability and porosity (due to various degree of weathering and other factors). More weathered rocks have higher ability to allow water passage. Drainage and lineament densities were derived from drainage and lineament maps respectively using ArcGIS 9.3 also, to classify the data into three classes.
A lineament is a linear feature in a landscape which is an expression of an underlying geological structures such as a fault, fractures, lines of weakness etc. [9,10,11]. They were weighted into high, medium and low water potential areas. Stream ordering was done for drainage to ascertain tributaries and distributaries. Areas with more streams or drainages indicates higher ground water potentials. Overlay operation and map calculation was done on the classified data. This method sums up the ranking of the variable used into areas of low, medium and high water potential within the study area.

3. RESULTS AND DISCUSSION

The lineaments mapped in Fig. 3 from the satellite image were those lines of weakness in the study area that indicates areas of possible water seepage into the aquifer (underground reservoir of water). But from the lineament density map we observed that around the metropolis (Ilesha), groundwater potential is moderate while it was high in areas like Odo towards the east. This could be attributed to the higher concentration of these lineaments in that region where more of them crisscross [12,13]. Thus areas with higher lineament density are regarded as good for groundwater development.

Drainage/drainage density of the study area (See Figs. 5 and 6). Drainages were found to be concentrated within the low lying plains of the area. Drainage density is suggested to be a measure for permeability. The map reveals the noticeable concentration of streams at the lower and right side of the study area (odo) and more at the lower left side [NW] (ibede, osu). The lowland part of the study area that are characterized mainly by diverse rock units (porphyritic granite, fine-medium grained granite, granite gneiss and migmatite) presents low density an indication of favorable condition for
vertical infiltration of runoff from surrounding hills and thus enhancing groundwater occurrence. However, the generally moderate to high drainage density implies low or moderate infiltration and recharge potentials for most part of the study area.

Fig. 3. Lineament extraction from Nigeria Sat-x data

Fig. 4. Lineament density map produced from data of Fig. 3.
Fig. 5. Drainage map extraction from Nigeria Sat-x data

Fig. 6. Drainage density map produced from drainage map
Fig. 7. Topographic map extraction from topographic map covering the study area

Fig. 8. Digital elevation model water potential map produced from Topographic map of the study area
Fig. 9. Geological map of the study area

Fig. 10. Water potential map extracted from the geological map of the study area
Topography of the study area (Figs. 7 and 9 respectively). The topography of the study area ranges between 1700 m-850 m. Areas with high elevation or hilly areas (1450 m-1700 m) where observed to have lower ground water potential, this could be attributed to the fact that at high altitude water runs off and has little or no residence time to percolate into groundwater. This is because one of the driving forces for ground water flow is gravity. Water flows from higher elevation to lower elevation and from higher pressure to lower pressure [14]. Areas with topography range of 1150 m-1400 m are regarded as moderate altitude and moderate groundwater potential. Lastly areas with range of 850 m-1100 m are regarded as low altitude and high groundwater potential. The map on Fig. 10 was produced from the geological map of the study area. Based on the water retaining capacity of the rocks in the study area (schists, gneisses and undifferentiated migmatite) the geology was grouped into high, moderate and low groundwater potential depending on their ability to let water pass through them. Usually, massive unfractured lithologic units in Basement Complex setting has little influence on groundwater availability except in cases with secondary porosity through the development of weathered overburden and fractured bedrock units, which form potential groundwater zones. Based on the aim of this research work, the result (Fig. 11) of the study reveals that Ilesha (urban area) is seated on a moderate groundwater potential area. While other settlements like Eyinta, Ibede and Itagunmodi were situated on high groundwater potential zones.

### 4. CONCLUSION AND RECOMMENDATION

This study provides an integrated RS/ GIS technique to groundwater potential exploration in Ilesha Basement terrain to serve as a guide for groundwater studies and development in the study area. As part of the study approach, thematic maps were prepared and subsequently integrated using Arc GIS 9.3 software to produce groundwater potential map of the study area. Generally, the study area could be said to have a moderate ground water potential. High groundwater potential was observed around the NW and some parts of the South. This could be attributed to the fact that the area is low lying and the rock types here are granitic/charnockitic rocks that extends to quartzite-schist granite.
which are relatively porous and permeable. Around the east of the final map shows low groundwater potential, this could be attributed to the high topography that does not give sufficient resident time for water to percolate and the non-porous nature of the rocks there (migmatites and migmatite-gneiss). Study area was categorized into high, moderate and low groundwater potential areas.

This type of study is recommended in areas that has ground water exploration challenges especially on a regional scale and areas not very accessible. A further geophysical investigation to determine the aquifer characteristics and the overburden thickness of various groundwater potential zones highlighted is recommended to compliment the present study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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