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CONTENTS

Groundwater Potential Mapping in Bosso Local Government Area, Niger State, Nigeria

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ABSTRACT
This study assessed groundwater potential zones in Bosso Local Government Area, Niger State. SRTM dataset was used to derive DEM, Slope, drainage network, drainage density network, convergence index and groundwater potential zones using hydrological tools and weighted overlay analysis in the ARCGIS environment. Results revealed that, groundwater potential zones were classified into three classes as High, moderate, and low zones which covered 128.54km^2 (8.10%), 1315.27km^2 (82.83%), and 144.06km^2 (9.07%) respectively. This groundwater potential information will be useful for effective identification of suitable locations for extraction of water. Furthermore, it is felt that the present methodology can be used as a guideline for further research.

Keywords: *Groundwater potential zones, DEM, Remote sensing and GIS*

1 INTRODUCTION

Ground water is contained in underground rocks, which contain and transmit water in economical rate generally referred to as aquifers (Hussein *et al.,* 2016). Groundwater accounts for 26% of global renewable fresh water resources. Salt water (mainly in oceans) represents about 97.2% of the global water resources with only 2.8% available as fresh water. Surface water represents about 2.2% out of the 2.8% and 0.6% as groundwater. The problem is not only to locate the **groundwater, as it is often imagined, but the engineer's** problem usually is to find water at such a depth, in such quantities, and of such quality that can be economically utilized. Groundwater is a term used to denote all the waters found beneath the ground surface. Groundwater aquifers are not just a source of water supply, but also a vast storage facility providing great management flexibility at relatively affordable costs (Elbeih, 2015).

The amount and distribution of groundwater is a function of the amount of open space and the special extent of these rocks. The behavior of these rocks in turn is function of their formation and geological processes that shaped their status. Conventional groundwater exploration require hydro-geologic investigation to study the lithology, stratigraphy and structural aspects of a region using geologic methods to understand the factors that regulate the amount, circulation and quality of groundwater (Elbeih, 2015). These studies deliver results of various type and quality based on the scale of the study. In recent years, relatively cheap availability of remotely sensed data of higher spatial and spectral resolution and increasing availability image processing algorithms and GIS technology has enabled better efficiency in groundwater resource potential exploration (Mohamed, 2014).

Groundwater (hydrogeological) mapping is one of the main tools for systematic and controlled development and planning of groundwater resources. These maps are used by engineers, planners and decision makers in order to allocate, develop and manage groundwater within a national water policy. Hydrogeological maps present hydrogeological data in a map form. A hydrogeological map shows the geographical distribution of aquifers, and their topographical, geological, hydrographical, hydrological and hydro chemical features. Presentation of these data in the form of maps permits the rapid evaluation of a certain area. Accordingly, hydrogeological maps assist in determining areas needing special protection (Dar *et al.,* 2012).

Many studies have revealed that groundwater potential is related with many factors, such as geological features, terrain features, hydrology features, etc. Digital Elevation Model (DEM) is the digital representations of the topography, the technological advances provided by GIS and the increasing availability and quality of DEMs have greatly expanded the potential of DEMs to applications in many fields (Tarun, 2014). Among those factors related to groundwater potential mapping, most of the information has been proved can be extracted from DEM data, and this made extracting relevant features from DEM for groundwater potential mapping is feasible (Tarun, 2014).

In Bosso Local Government Area of Niger State, groundwater exploration is gaining greater attention due to increasing demand for water supply, especially in areas with inadequate pipe-borne and surface water. The drying up of the hand dug wells in the area worsens the problem which is becoming progressively intense with growing population. This has been attributed to poor assessment of groundwater potential zones prior to water exploration in the area.

Severe water scarcity has been one problem citizens of Bosso Local Government Area had to contend with. Of the 3.9 million people in Niger State, only those in Minna the state capital, could boast of access to potable water, though not all residents of the city have access to drinkable water (Ikegwuonu, 2013). Water projects constructed in the study area are no longer capable of providing enough water for the ever-growing population. This development has subjected the people of the study area to rely on other sources of water such as; rain water and groundwater which are seasonal. Hand dug wells in the area yield little water which dries up eventually due poor construction and also lack of information on groundwater potential zone before groundwater exploration, likewise the poor yields from boreholes constructed by government agencies and other private organizations (Ikegwuonu, 2013) in the study area are some of the water challenges. Several researches has been conducted with regard to groundwater potential mapping both nationally and internationally and they include Bereket (2017); Akinwumiju *et al.*, (2016); Candra *et al.*, (2010); Dar *et al.*, (2010); and Elbeih (2015). There was paucity of knowledge with regard to groundwater potential mapping in Bosso and environ which has created a gap and this study intends to fill. Therefore, the study aimed to assess groundwater potential mapping using Digital Elevation Model in Bosso and environ, Niger State, Nigeria.

2 METHODOLOGY

Several datasets were used for estimating the groundwater water potential zones over the study area. The study used Digital Elevation Model (DEM) derived from ASTER in conjunction with field Geographical Position System (GPS) Points obtained during field survey.

Drainage network, drainage density network, aspect, and slope was extracted from DEM using the spatial hydrological tools in the ArcGIS 10.5 environment. Convergence Index (CI) adopted from Kiss (2014) was used to distinguish flow convergent area from divergent area, thus could be used for groundwater potential modelling. CI was calculated based on the aspect which will be extracted from DEM. The CI was obtained by calculating the average angle between the aspect of adjacent cells and the direction to the central cell and then subtracts 90^0. Positive CI values represent divergent area while negative CI values represent convergent area. Thus a lower CI value associated with groundwater accumulation and have a higher groundwater potential value. The overlay process is carried out to obtain the final map of potential groundwater zones by using weighted overlay function in

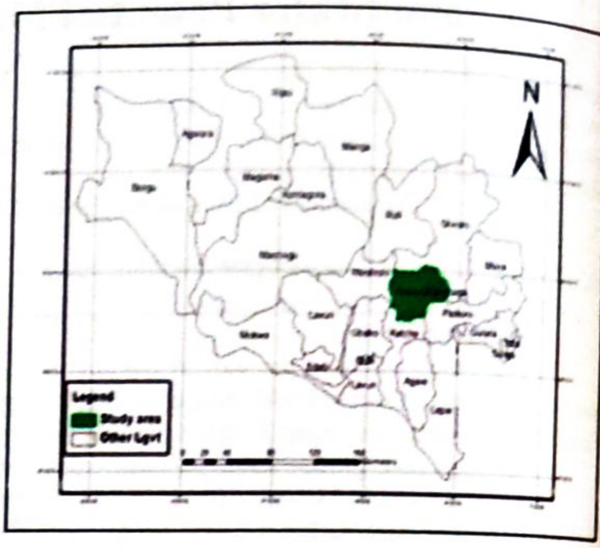

Figure 1: Location of Study Area (Bosso LGA).

the ArcGIS environment. The resulting map is classified into five different classes (High, Moderate, and Low) potential groundwater zones.

2.1 STUDY AREA

Bosso Local Government Area lies between longitude 6^0 33" E - longitude 6^0 37" **E and latitude** 9° **33" N** - latitude 9° **38" N, on a geological base of undifferentiated base** complex of mainly gneiss and magnetite situated at the base of prominent hills in an undulating plan. Bosso Local Government Area is situated on Niger valley. It is located in the south eastern part of Niger State with elevation in height between 100 feet (300 meters). The area geographically shares boundaries with Wushishi Local Government to the west, Chanchaga Local Government Area to the east, Shiroro Local Government Area to the north and Katcha Local Government Area to the south as indicated in Figure 1.

3 RESULTS AND DISCUSSION

3.1 DIGITAL ELEVATION MODEL

Figure 2 shows the elevations over the study area with the highest elevation of 452m located at the North eastern part of the study area and 71m as the lowest elevation found at the southwestern part respectively. The high elevation points have low potential of groundwater and low elevation has moderate and high groundwater potential in the study area.

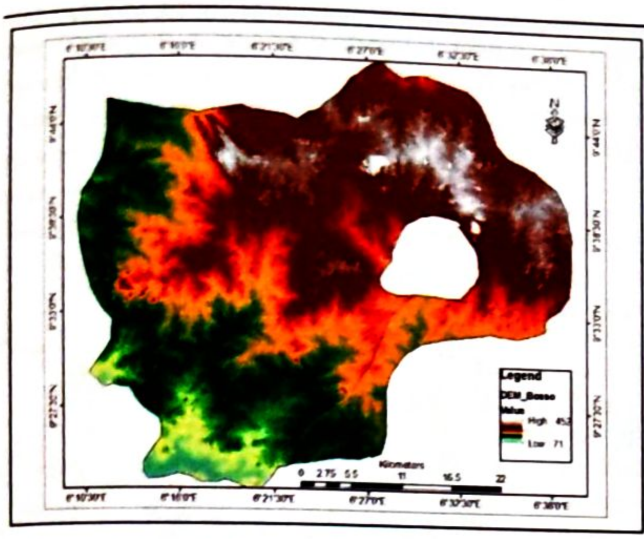

Figure 2: Digital Elevation Model over the study area

3.2 DRAINAGE NETWORKS ORDER MAP

A drainage basin is a natural unit draining runoff water to a common point. This map consists of water bodies, rivers, tributaries, perennial & ephemeral streams, ponds. The study area is fourth order basin joining the rivers, tributaries based on topography depicted in Fig.3.

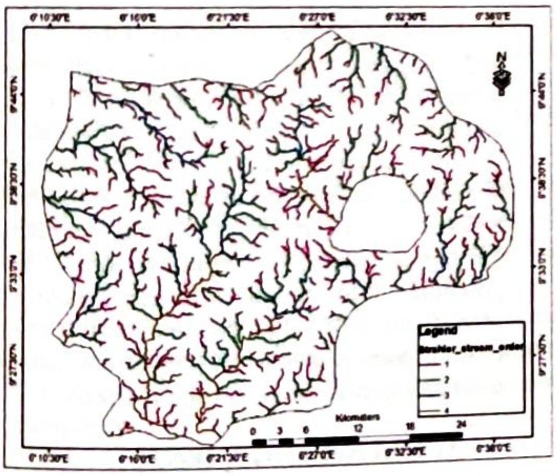

Figure 3: Drainage network order over the study area

3.3 DRAINAGE DENSITY NETWORKS MAP

A drainage basin is a natural unit draining runoff water to a common point. Drainage density is an inverse function of permeability. The less permeable a rock is, the less the infiltration of rainfall, which conversely tends to be concentrated in surface run-off. The area of very high drainage density represents more closeness of drainage lines and vice-versa. Fig.4 revealed the areas with high, moderate, and low drainage density covered 590.37km^2 (37.18%), 648.67km^2 (40.85%), and 348.83km^2 (21.97%) respectively. High drainage density is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture. The drainage density characterizes the runoff in an area or in other words, the quantum of relative rainwater that could have infiltrated. Hence the lesser the drainage density, the higher is the probability of recharge or potential groundwater zone. Drainage Density is calculated using Focal statistics spatial analyst tool in ArcGIS 10.5.

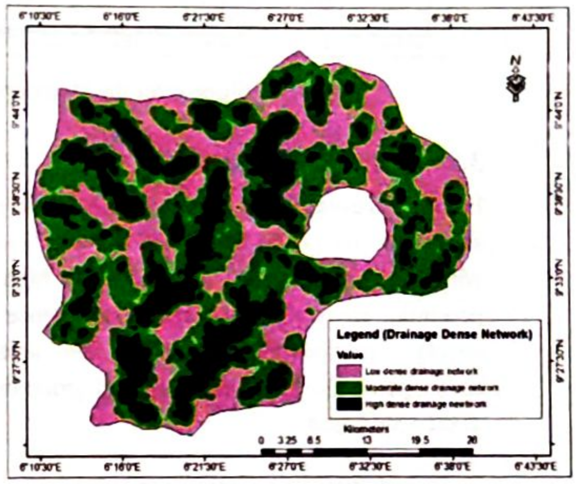

Figure 4: Drainage density network over the study area

3.4 SLOPE

Slope is an important factor in the analysis of ground water. The slope degree refers to the rate of change in elevation over distance with lower the slope value representing flatter terrain and higher values representing steeper terrain. Greater the slope, more runoff and lesser gradient tend to spread the overland flows thus favoring the infiltration and ground water prospects. Slope map was prepared with hydrological tools in the spatial analyst in ArcGIS 10.5. The study area was classified into three categories such as 0 to 2°, 2 to 5°, and above 5° based on slope measured in degrees. It is shown in Fig.5. that area with low slope (0° to 2°) covered an area 390.94km^2 (24.62%) and is excellent from the point of occurrence of ground water. While moderate and high slope area covered 428.95km^2 (27.01%) and 767.98km^2 (48.37%) respectively.

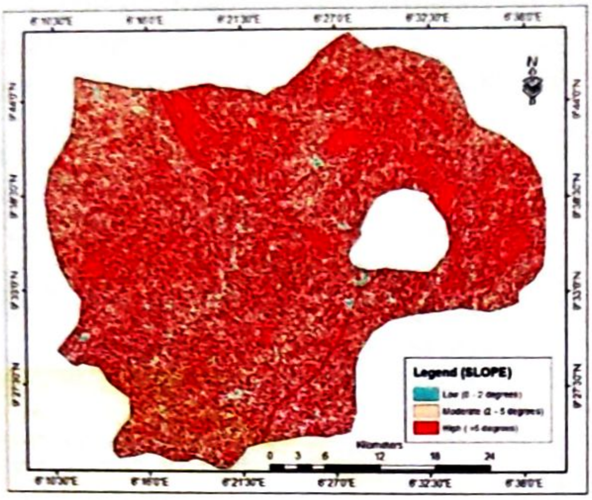

Figure 5: Slope over the study area

3.5 CONVERGENCE INDEX MAP

Figure 6 revealed the convergence index map over the study with most part of the area having low index. Areas with high convergence flow indicate high groundwater potential; areas with moderate convergence flow indicate average groundwater potential and areas with low convergence flow indicate low or no groundwater potential in the study area.

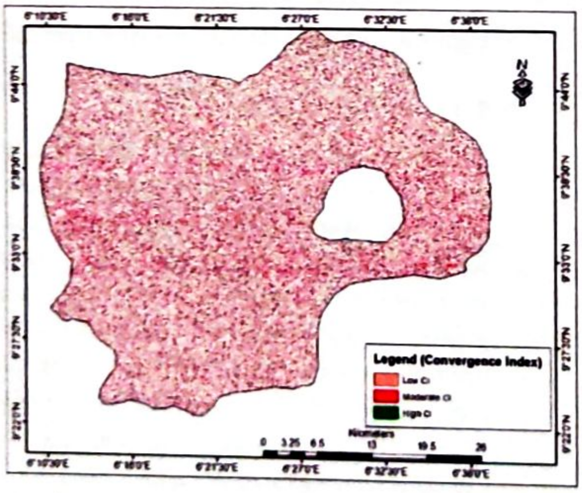

Figure 6: Convergence index over the study area

3.6 GROUNDWATER POTENTIAL MAP

Each thematic map such as drainage density, convergence index, elevation and slope provides certain clue for the occurrence of groundwater. In order to get all this information unified, it is essential to integrate these data with appropriate factor. Using weighted overlay analysis tool in ArcGIS all the thematic maps were integrated. The weightage for different layers have been assigned considering similar work carried by many researchers as studied in literature review. A simple arithmetical model has been adopted to integrate various thematic maps by averaging the weightage. The final map has been categorized into three zones, from groundwater potential point of view High, moderate, and low which covered 128.54km^2 (8.10%), 1315.27km^2 (82.83%), and 144.06km^2 (9.07%) respectively as shown in Figure 7.

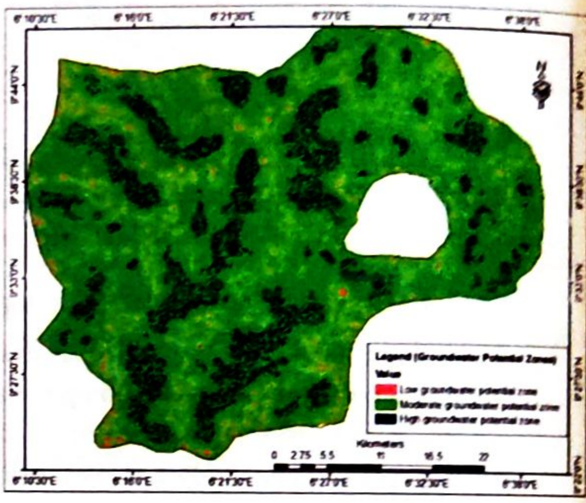

Figure 7: Groundwater potential zones over the study area

4 CONCLUSION

From the study it is concluded that based on overlaying and analysis of thematic maps in GIS three, groundwater potential zones have been delineated i.e. High, Moderate and low. Area covered by high groundwater potential zone is 8.10 km^2 mostly in the lower central part of the study area. Thus, integration of maps prepared from RS and GIS analytical tools proved an efficient method for delineation of groundwater in the study area. This groundwater potential information will be useful for effective identification of suitable locations for extraction of water. Furthermore, it is felt that the present methodology can be used as a guideline for further research.

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