



## Groundwater Potential Mapping of Zaria and its Environs Part of Sheet 102NW, North Central Nigeria

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### ABSTRACT

This research is aimed at providing a cost-effective technique for groundwater exploration in Zaria and its Environs. The study made use of Remote Sensing data to generate thematic maps of a slope, water body proximity and drainage and lineament density. Maps of Geology and Soil were used to generate thematic maps of geology and soil respectively. The pair-wise comparison method was used to weight the thematic layers, while modelling was done by weighted overlay technique in a GIS environment. Results revealed three groundwater potential zones of low potential; medium potential zone; and high potential areas, which was chiefly control by high lineament density and close water body proximity within the study area. In terms of areal extent, the low potential, medium potential and high groundwater potential zones cover 48, 580, and 41 Km<sup>2</sup>, respectively. Validation of the model using dry season groundwater configuration map and flow directions showed reasonable agreement, while field data shows a correlation with other similar works in other parts of Nigeria. It was thus recommended that the techniques should be tested in other parts of the country and adopted in delineating groundwater potential zones because of its effectiveness.

**Keywords:** Remote Sensing, Thematic Layers, GIS, Groundwater, Potential Zones.

### INTRODUCTION

Water occurs as surface water in streams, rivers, lakes seas and oceans and as groundwater when it infiltrates beneath the ground surface. Buchanan (1983) puts the groundwater reserve of the world at about  $5.0 \times 10^{24}$  liters. This volume is more than 2000 times the volume of water in all the world's rivers. Being naturally filtered in its passage through the ground, it is usually clear, colourless and has excellent quality, being free from microbial contamination and requires minimum treatment (Babiker *et al.*, 2007). Ever increasing population is in need of water which is a prerequisite for life. However, the reality on the ground indicates that many communities lack pipe borne water thus, warranting the need for individuals and local communities to look for an alternative to the conventional public water supply (Aggarwal *et al.*, 2009; Chawla *et al.*, 2010). Groundwater exploitation via hand-dug well and boreholes is far cheaper when compared to conventional surface water programmes. Nonetheless, a major constraint is the complex and erratic nature of groundwater occurrences in crystalline basement terrains with the attendant high rate of well/borehole failure in the absence of proper and adequate pre-drilling hydrogeological investigations (Fashea *et al.*, 2013). Also, groundwater prospect in an area is controlled by other factors such as geology, geomorphology, drainage, surface gradient, proximity to surface water bodies, canals, and irrigated fields amongst others.

Though geophysical, geological, hydrogeological, and photogeological techniques have been employed to delineate groundwater potential zones (Teeuw, 1995;

Sander *et al.*, 1996; Edet and Okereke, 1997; Taylor and Howard, 2000; Srivastava and Bhattacharya, 2006), the integration of various conventional methods with Remote sensing (RS) techniques and Geographical Information Systems technology helps to increase the accuracy of results in delineation of groundwater potential zone and also to reduce the bias on any single method (Rao and Jugran, 2003). The present research is aimed at assessing an integrated technique for delineating groundwater potential areas which are the view of proving a cost effective method for groundwater exploration.

### MATERIALS AND METHODS

Six different thematic maps were used in the present study. These thematic layers were extracted from different geologic data ranging from Landsat data, Digital Elevation Model (DEM), geological and soil maps. The layers were selected based on the model used in the present work which is the analytic hierarchy approach (AHP) developed by Saaty (1980; 1992), which is a type of Multi-criteria Decision Analysis technique (MCDA). Factors that affect our goal which in this case is the determination of groundwater potential within the study area were noted to include slope, geology, lineament density, drainage density, water body proximity and soil type. The geological and soil thematic maps were generated from digitization of the existing geological and soil maps of the area. The drainage and slope thematic maps were extracted from the Digital Elevation Model while the lineament map was prepared using the automatic line extraction of principal component analyzed (PCA) from Landsat ETM+ data.

The relative importance of the features of each individual factor to the groundwater potential was determined intuitively. Pair-wise comparison on a scale from 1 to 9 as developed by Saaty (1980; 1992) was used to create a matrix comparing features within each theme based on its importance to groundwater potential following the approach of Rao and Jugran (2003), Machiwal *et al.* (2011), Mukherjee *et al.* (2012), Singh *et al.* (2013), Fashae *et al.* (2013) and Adeyeye (2015). The weights of features associated with individual themes were calculated by the Saaty's AHP and the eigenvector technique.

The classification was done on the basis of weights obtained from pair-wise comparisons done with the help of

Expert Choice 10.0 software. Reclassification was done and weights assigned based on influence on groundwater potential. Drainage proximity map was produced by buffering of rivers. Buffer zones around the streams were subsequently weighted.

The six thematic maps were integrated Weighted Linear Combination (WLC), where each class individual's weight was multiplied by the map scores and then adding the results. The technique has been used in the study of locations of geographic phenomena together with their spatial dimension and associated attributes (Prasad *et al.*, 2008). Figure 1 shows a flow chart of the methodology adopted in this work while Tables gives a summary of the data used and their sources.

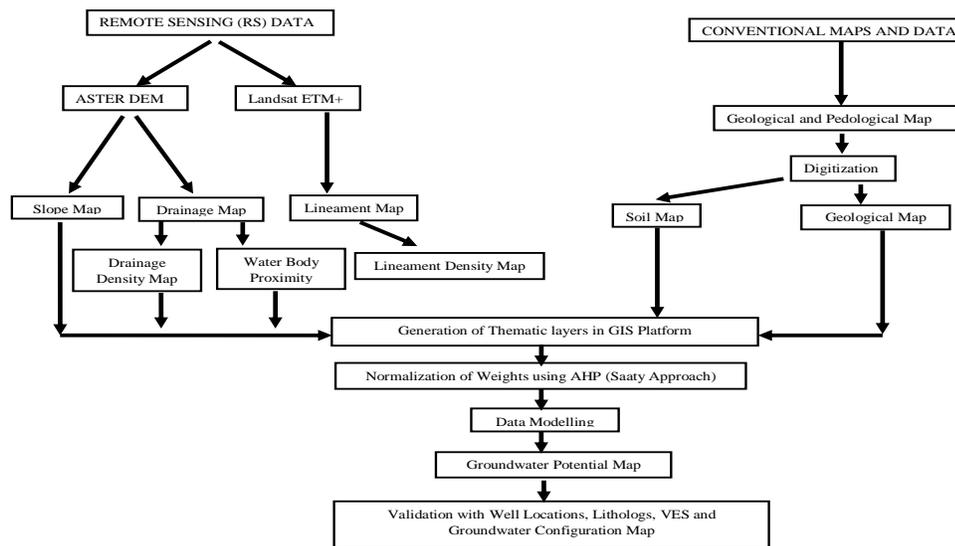


Fig. 1: Flow Chart of Methodology Adapted in the present Work

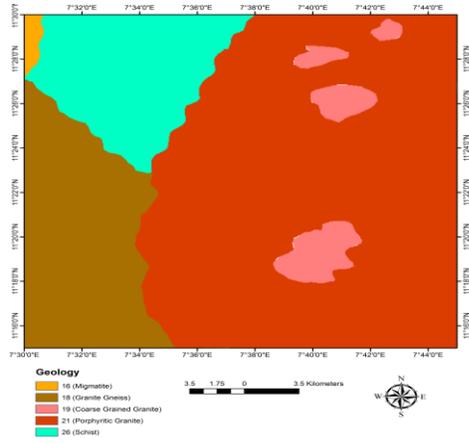
## RESULTS

A total of six thematic maps were generated and were combined (integrated) to produce the groundwater potential map (GWPM). These are geology, soil, drainage density, lineament density, slope, and water body proximity. According to Aponbiede (2015), the study area has five distinctive rock types namely: Schist, Porphyritic Gneiss, Coarse-grained Granite and Migmatite. Normalized weights of respective rocks based on contribution to groundwater potential as obtained by pair-wise comparison are 26,21,19,18 and 16 respectively.

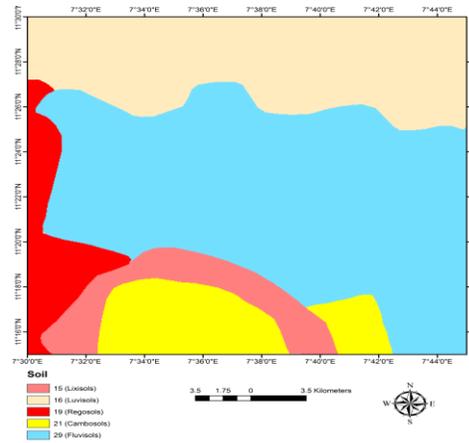
Fluvisols, cambisols, regosols, luminous and lixisols are the soil groups found in the study area (SOW - VU, 1997). Normalized weights of 29, 21, 19, 16 and 15 were assigned to respective soil classes based on their perceived contribution to groundwater potential. The drainage density within the study area ranged from 0 – 1.27 km/km<sup>2</sup> and was reclassified into four categories as 0 – 0.32 km/km<sup>2</sup>, 0.32 – 0.63 km/km<sup>2</sup>, 0.63 – 0.95 km/km<sup>2</sup>, and 0.95 – 1.27km/ km<sup>2</sup>.

Lineament density within the study area ranged from 0 – 2.45 Km/Km<sup>2</sup> (Figure 4.5a) and was classified into five categories as follows 0 - 0.49 Km/Km<sup>2</sup>, 0.49 – 0.98km/km<sup>2</sup>, 0.98 – 1.47 km/km<sup>2</sup>, and 1.4 – 1.96 km/km<sup>2</sup> and 1.96 – 2.45 km/km<sup>2</sup> covering 610 Km<sup>2</sup> (79%), 105 Km<sup>2</sup> (14%), 39 Km<sup>2</sup> (5%), 11 Km<sup>2</sup> (1%) and 5 Km<sup>2</sup> (1%) of the study area accordingly. In the same vein, normalized weights of 9, 12, 18, 25 and 36 were assigned to the successive categories based on their perceived contribution to groundwater potential using pair-wise comparison.

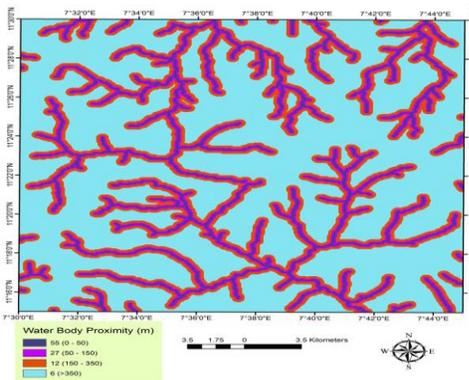
The slope of the ground within the study area ranged from 0 – 9.35% (Figure 4.4a) and was grouped into three classes namely: 0 – 3.11%, 3.11 – 6.24% and greater than 6.24% (Figure 4.3b) with each respective class covering 764 Km<sup>2</sup> (99%), 5 Km<sup>2</sup> (0.7%), and 0.3 Km<sup>2</sup> (0.3%) of the study area respectively. The various categories were correspondingly given normalized weights of 55, 25 and 20 using pair-wise comparison. The classified maps of the various thematic layers used in the present study given in



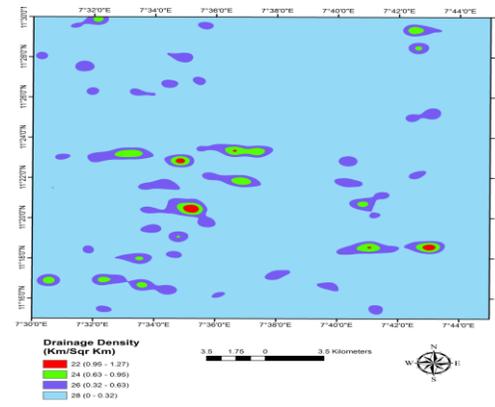
**Fig. 2:** Classified Geologic Map of the Study Area



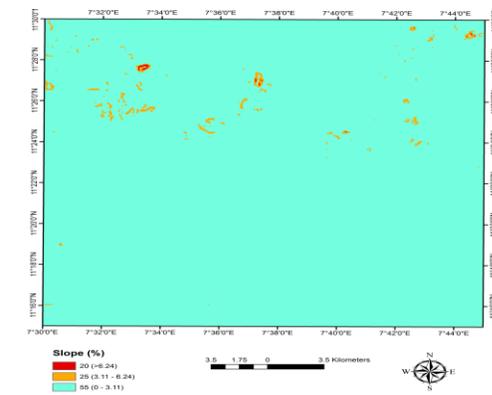
**Fig.3:** Classified soil map of the study area.



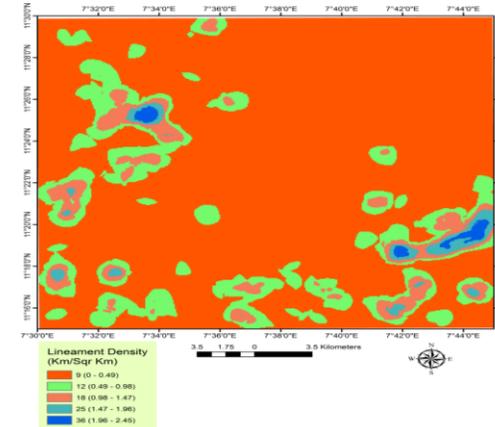
**Fig.4:** Classified water body proximity map of the area.



**Fig. 5:** Classified Drainage Density Map of the study area



**Fig. 6:** Classified Slope map of the study area



**Fig. 7:** Classified Lineament Density of the study area.



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