APPLICATION OF INNOVATIVE TECHNOLOGY IN GROUNDWATER RESOURCES PROSPECTING IN AFIKPO SUB-BASIN, NIGERIA

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ABSTRACT

Groundwater is the main source of potable water supply for domestic, industrial and agricultural uses; hence it is a most valuable natural resource and needs judicious use for sustainable management. Groundwater can be effectively managed when reliable information is available for planning purposes. Innovative technologies such as GIS and satellite remote sensing provides synoptic view, which is helpful in identification and delineation of various landforms, linear features, structural elements and terrain characteristics being significant indicators of groundwater potentiality. This study evaluated the groundwater potential zones in Afikpo sub-basin of Nigeria, using thematic maps such as geology, slope, lineament, land use/land cover and drainage map of the study area. All the thematic maps were converted into grid (raster format) and superimposed by weighted overlay method (rank and weightage wise thematic maps). From the analysis, the groundwater potential zones map with excellent, very good, good, moderate and poor prospects covering an area of 136.31 km^2, 1035.44 km^2, 1432.26 km^2, 472.48 km^2 and 13.22 km^2 respectively was produced. The high groundwater recharge potentiality in the Afikpo sub-basin of Nigeria is majorly favored by the high amount of lineaments and the sedimentary geologic environment. The study showed that professionals can effective manage groundwater resources in Afikpo sub-basin and other part of Nigeria if innovative technologies are promoted and welcomed as robust information resource and part of criteria for decision making in prospecting, constructing and managing underground water.

KEYWORDS: Underground water, Sustainable Management, GIS, Remote Sensing and information resource.

1.0 INTRODUCTION

The expediency of groundwater development for irrigation, industry and domestic purpose cannot be over emphasized being a main source of potable water. Hence, it is a most valuable natural resource and needs judicious use in order to achieve sustainable management (Senthil and Shankar, 2014). Hydrological applications such as groundwater for resources assessment, planning, soil erosion and urban drainage system based on remotely sensed data derivative has gained popularity with the advent of raster and vector GIS environment (Burrough, 1986, Brown 1995 and Lyon 2003). Groundwater prospecting and development require large amount of diverse data from various sources. Since groundwater occurrence is a subsurface phenomenon, its prospecting is based on indirect analysis of some directly observable terrain features like geological, geomorphological, structural features and their hydrological characteristics (Senthil and Shankar, 2014).

The concept of integrated remote sensing and GIS has proved to be an efficient innovative tool in groundwater studies (Srinivasan et al., 2013). Recently GIS is being used for various purposes such as evaluation of ground and surface water resources, feasibility of recharge sites, identifying contaminated sites, land use pattern, land cover and others (Sharma et al., 2012). Researchers such as Teeuw (1995); Goyal et al. (1999); Saraf and Choudhary (1998) and Senthil and Shankar (2014), have successfully applied remote sensing and GIS technique for groundwater prospecting and recharge sites. With the capabilities of the remotely sensed data and GIS techniques, numerous databases can be integrated to produce conceptual model for delineation and evaluation of groundwater potential zones (Senthil and Shankar, 2014). It is based on this that the study applied integrated approach innovative technology such as remote sensing and GIS techniques to delineate groundwater prospective zones in the study area.

2.0 DESCRIPTION OF STUDY AREA

Afikpo sub-basin is located in the southeastern part of the sedimentary basin lower Benue Trough. The Afikpo basin is situated in the southeastern Nigeria (figure 1) and it covers about 60, 000 square km (Chukwu et al., 2013). The Afikpo Basin represents an elongate NE-SW depocenter (Chukwu et al., 2013). The climate of the study area is that of tropical rainforest with distinct wet and dry seasons. The wet season is characterized by a period a prolonged period of rainfall which extends from April to October, while the dry season is characterized by a period of dry hot weather. This season extends from November to March including the harmathan period (Offodile, 1992). The mean annual rainfall ranges from 19,900 mm to 2,200 mm (Offodile 1992).

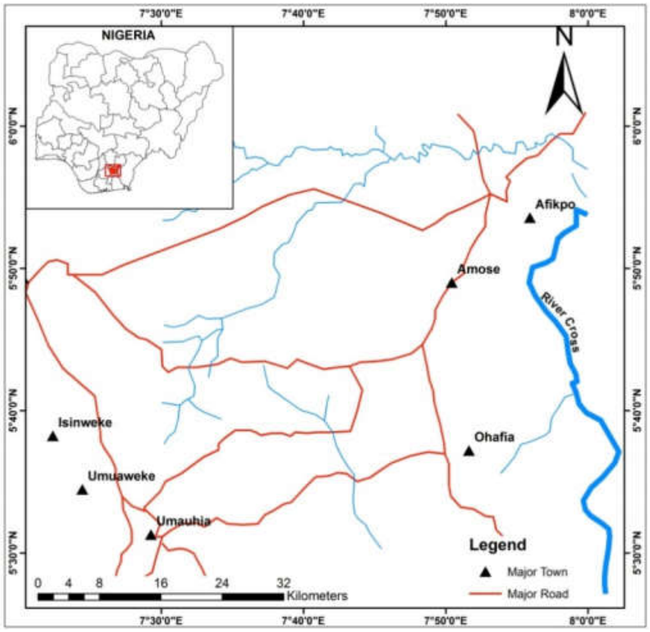

Figure 1: Map of the Study Area

3.0 METHODOLOGY

3.1 Data Collection

The landsat data used was the Operational land Imager (OLI) acquired on 5th of February 2016. The satellite data have 30m spatial resolutions and spectral range of 0.45-2.35 micro meter with bands 1,2,3,4,5,6,7, 8 and 12. Remotely sensed data, such as aerial photos, was used in the present study to identify factors determining groundwater prospect which include geological features, topography, drainage as well as the land use of the study area (Table 1). Geographic Information System (Arc/GIS 10.0) was used for digitization, editing and topology creation. Assignments of weightages of different themes and classes integration of multi-thematic information and delineation of groundwater prospect map generated through the weight overlay tool of Arcmap 10.0.

Table 1: Factors Affecting Groundwater Prospecting Classified Criteria

Factor	Basis of Categorization
Geology	Rock type, weathering character, joint, fractures
Land cover/land use	Type, areal extent, associated vegetation
Lineaments	Lineament density
Drainage	Drainage density
Slope	Slope gradient

3.2 Factor Establishment

Each factor influencing groundwater prospect was examined and was assigned an appropriate weight. According to Hsin-Fu et al. (2009), major interrelationship between two factors could be assigned a weight of 1.0, while a minor interrelationship between two factors is assigned a weight of 0.5. The total weight of each factor is the representing weight of the groundwater prospect. For instance, major interrelationships exist for geology on lineaments, drainage and, land use/cover. Therefore, its evaluated weight is 3.0. This high weight value means that the factor significantly influences the groundwater recharge. The process for determining the relative rate of each factor is shown in table 2. The extent of the influence of every factor on groundwater prospect was assessed from the interrelationships among both major and minor factors. The score of each groundwater prospecting factor was calculated as 100 multiplied by the weight of the groundwater prospect divided by the total weight of each prospect potential factor (Hsin-Fu et al., 2009) (Table 3).

Table 2: Table ***2*** Relative rates for each factor (Adapted from Hsin-Fu et al., 2009)

Rates	Calculation Process	Proposed Relative Rate
Geology	3 x 1.0 = 3.0	3
Land cover/land use	1 x 1.0 + 3 x 0.5 = 2.5	2.5
Lineaments	2 x 1.0 = 2.0	2
Drainage	1 x 1.0 + 1 x 0.5 = 1.5	1.5
Slope	1 x 1.0 + 1 x 0.5 = 1.5	1.5

Table 3: Summary of Map weight

Factor	Calculation Process	Map Weight
Geology	100 x (3/10.5) = 29	29
Land cover/land use	100 x (2.5/10.5) = 24	24
Lineaments	100 x (2/10.5) = 19	19
Drainage	100 x (1.5/10.5) = 14	14
Slope	100 x (1.5/10.5) = 14	14

3.3 Integration of Thematic Maps through GIS

The integration of various thematic maps through GIS tools involves analysis that considers multiple criteria influencing a process. The various thematic maps used in the study were converted into raster form considering 100 m as cell width to achieve considerable accuracy. These were then reclassified and assigned suitable weightage following the methods used by Srinivasa Rao and Jugran (2003), Aravindan et al (2006), Krishnamurthy et al. (1996). The summary of the process in given in table 4, the occurrence and movement of groundwater in the study area is controlled by five various factors with map weight based on their level of influence.

After assigning the weightages to the themes and features, all the themes were converted to raster format using Spatial analyst, extension of Arc/GIS software. Spatial analyst extension of ArcMap 10.0 was used for converting the features to raster and also for final analysis. In this method, the total weights of the final integrated map were derived as sum or product of the weights assigned to the different layers according to their suitability. Further, different units of each theme were assigned knowledgebased hierarchy of ranking from 1 to 5. On the basis of their significance with reference to groundwater prospects, where 1 denotes poor prospects and 5 denotes excellent prospect of groundwater (table 5).

Table 5: Ranks and Weightages for Various Parameters for Groundwater Prospect

Thematic Layers	Map weight (%)	Individual features	Rank	Groundwater Prospect
Geology	29	Afiko Sycline	2	Moderate
		Ajali Formation	5	Excellent
		Alluvium	4	Very good
		Aisu group	4	Very good
		Ecoene formation	5	Excellent
		Exeaku formation	1	Poor
		Mamu formation	3	Good
		Nkporo group	2	Moderate
		Nsukka formation	4	Very good
		Paleouni Imo Shale	4	Very good
Land use/land cover	24	Agriculture Activities	4	Very good
		Developed Land	2	Moderate
		Forest	5	Excellent
		Water Body	4	Very good
Linearment Density	19	High	5	Excellent
		Moderate	3	Good
		Low	1	Poor
Drainage Density	14	High	1	Poor
		Moderate	3	Good
		Low	5	Excellent
Slope	14	High	1	Poor
		Moderate	3	Good
		Low	5	Excellent

4.0 RESULTS AND DISCUSSION OF FINDINGS

The maps of various factors influencing the groundwater prospecting in the study area are presented in this section.

4.1 Analysis of Geology

The geology map revealed that ten types of geologic formations could be observed in the study area (figure 2). The detailed description of the geologic formations is explained by Omoboriowo et al. (2012) and Chukwu et al. (2013). Based on the characteristics of the rocks, all rocks except Afiko syncline, Mamu formation and Nkporo group could be considered as being in favor of high groundwater prospect in the area having high level of percolation of water.

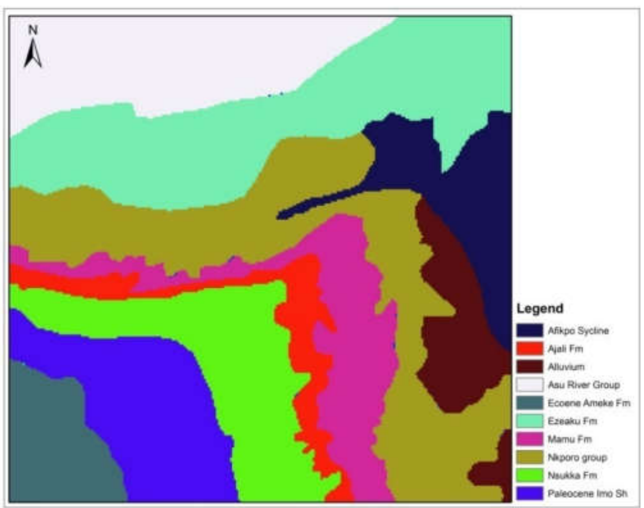

Figure 2: Geology of the Study Area

4.2 Analysis of Land Use/Land Cover

Land use/cover of the study area is depicted in figure 3. It includes the distribution of areas covered by agricultural activities, and forest, developed area and water body. Shaban et al. (2006) concluded that vegetation cover benefits groundwater recharge which also benefits ground water prospect because biological decomposition of the roots helps loosen the rock and soil, so that water can percolate to the surface of the earth easily. Vegetation prevents direct evaporation *of water from* soil, and the roots of a plant can absorb water, thus preventing water loss. It can be seen from that map that large part of the study area is covered by agricultural activities.

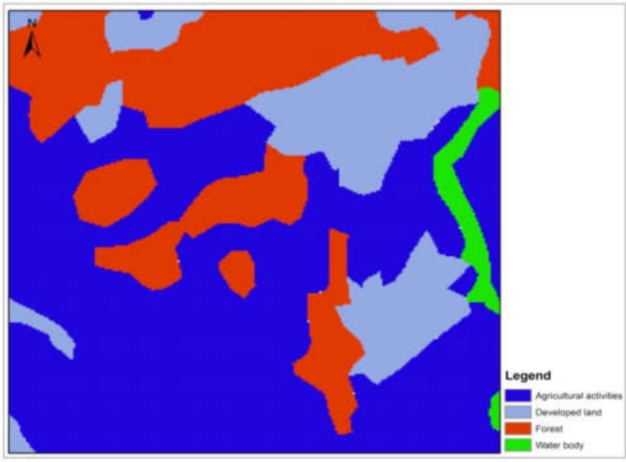

Figure 3: Land use/land cover of the Atudy Area

4.3 Analysis of Lineament Density

Lineaments are linear features in a landscape which is an expression underlying geological structures such as faults (Chukwu et al., 2013), they are generally referred to in the analysis of remote sensing of fractures or structures (Hsin-Fu et al., 2009). As shown in figure 4, a large part of the study area has low lineament density which implies that only few areas could be regarded has having high prospect for groundwater resources. It could be observed that the north-eastern of the study area has large lineament density which is in agreement with Chukwu et al. (2013).

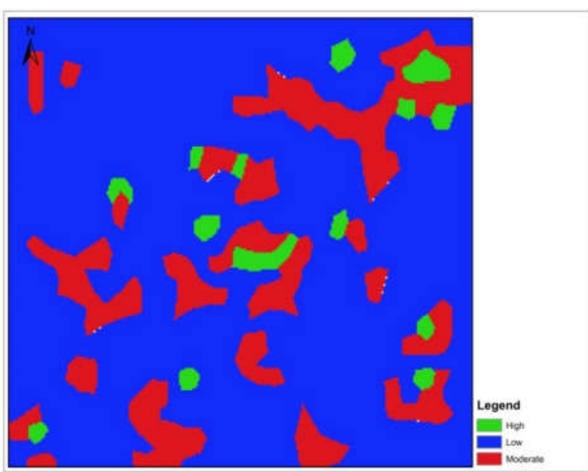

Figure 4: Lineament Density of the Study Area

4.4 Analysis of Drainage Density

The development of stream segments is affected by slope and local relief and these may produce differences in drainage density from place to place (Senthil and Shankar, 2014). The drainage density of the area is shown in figure 5, and were classified into very high, high, moderate and low. Drainage density (km/km2) indicates closeness of spacing of channels as well as the nature of surface material (Senthil and Shankar, 2014). The more the drainage density, higher would be runoff, and vise visa. Since runoff has negative effect of groundwater percolation, it could be posited that larger part of the study area supported high prospect of groundwater resources based on drainage density.

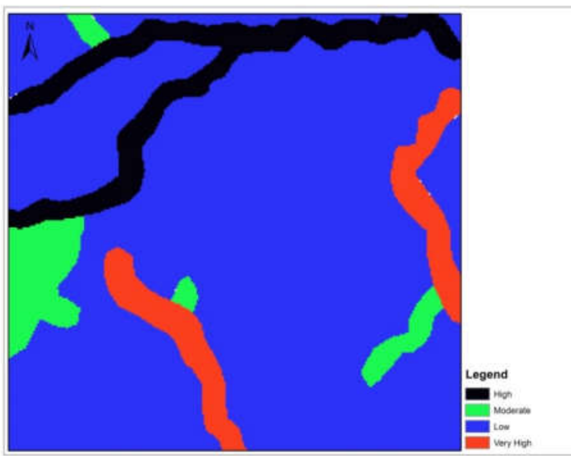

Figure 5: Drainage Density of the Study Area

4.5 Analysis of Slope

The slope analysis function in GIS was used to assess the variation of slope in the study area. as depicted in figure 6, the slope of the area were classified as high, medium and low slope. A precipitous terrain usually causes rapid runoff and does not store water easily, whereas in gentle slope areas, the time for percolation is increased. Therefore, the high slope the lower the groundwater prospect of the area.

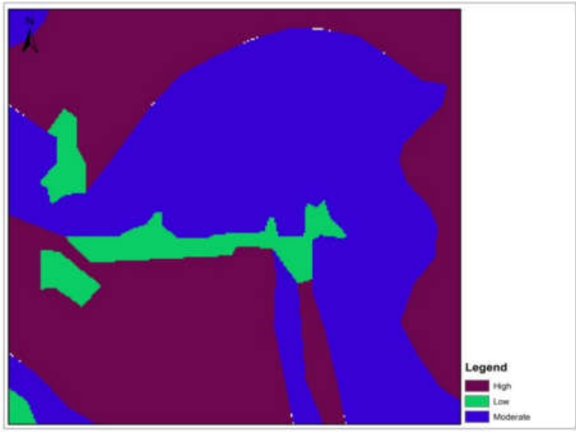

Figure 6: Slope Map of the Study Area

4.6 Delineation of Groundwater Prospect Zones

In order to delineate the groundwater prospect of the study area, each thematic maps such as geology, lineament density, slope, Landuse/landcover, and drainage density were integrated with appropriate factors using GIS. The summary delineated area is presented in table 6, the table shows larger part of the study area has good prospect for abstracting groundwater resources, while 0.4% of the area has poor groundwater prospect. The high groundwater recharge potentiality in the Afikpo sub-basin of Nigeria is majorly favored by the high amount of lineaments and the sedimentary geologic environment. Furthermore, figure 7 shows the spatial distribution of groundwater resources category with excellent, very good, good, moderate and poor prospects covering an area of 136.31 km^2, 1035.44 km^2, 1432.26 km^2, 472.48 km^2 and 13.22 km^2 respectively.

Table 6: Summary of Groundwater Potential Zones

Groundwater Potential	Area (Km^2)	Percent
Excellent	136.31	4.4
Very good	1035.44	33.5
Good	1432.26	46.4
Moderate	472.48	15.3
Poor	13.22	0.4
Total	3089.71	100

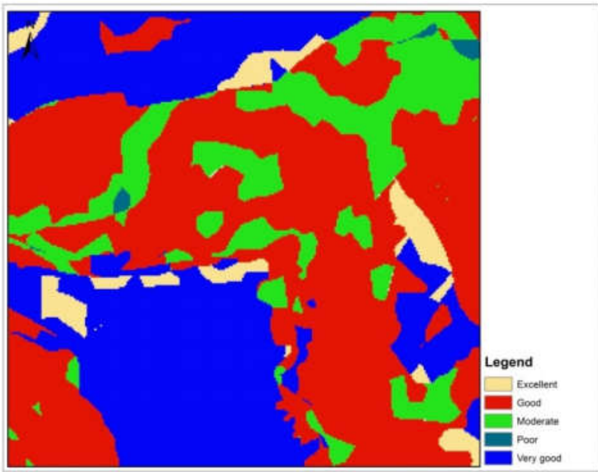

Figure 7: Groundwater Prospect Potential Map

4.7 DISCUSSION OF FINDINGS

The findings of the study demonstrate that the groundwater potential zone based on its suitability for abstraction in Afikpo sub-basin can be divided into five categories, namely very good, good, moderate, Excellent, and poor, based on the analysis of the five factors of groundwater potential. Innovative technologies such as remote sensing and Geographic Information System (GIS) are very constructive because it involves the integration of various geospatial data especially for groundwater potential zone mapping (Senthil and Shankar, 2014). Analytical results also demonstrate that the good groundwater prospect potential zone is concentrated in the study are due to the distribution of sedimentary geologic formations, forest and agricultural land which have high infiltration ability. The findings of the study could be useful for water supply planners in strategizing for abstraction of groundwater, it could be of help to environmental engineers assessing landfill construction prospecting, and other stakeholders in promoting sustainable development within the study area.

5.0 CONCLUSION

The study showed that professionals can effective manage groundwater resources in Afikpo sub-basin and other part of Nigeria if innovative technologies are promoted and welcomed as robust information resource and part of criteria for decision making in prospecting, constructing and managing underground water.

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