Groundwater Accessibility Using Remote Sensing Technique: A Case Study of Orlu and Adjoining Areas, Southeastern Nigeria

Chikwendu N. Okereke
Department of Geology,
Federal University of Technology,
Owerri, Imo State

Diugo O. Ikoro
Department of Geology,
Federal University of Technology,
Owerri, Imo State
ikorodiugo@gmail.com

Amadi Chinyere
Department of Geology,
Federal University of Technology,
Owerri, Imo State

Okore O. Okorafor
Department of Agricultural Engineering,
Federal University of Technology,
Owerri, Imo State

***Abstract*- The area of study covered Orlu and adjoining areas in the Southeastern Nigeria and bounded by latitudes 5^0 30´ N - 6^0 00´ N and longitudes 6^0 45´ E -7^0 15´ E. The aim of the study bordered majorly on groundwater accessibility in the area using remote sensing technique. The data generated were processed digitally using GIS softwares. The result shows that the lineament density is high around Opor, Osu, Orlu, Ihiala, Ekwulu and Uli which implies high groundwater potentials. This is because groundwater occurs within joints and fractures in rocks. It was also observed that the drainage in the area of study is structurally controlled and mostly influence both the groundwater and surface water flow directions. The major structural trends in the area are in the NE-SW and NNE-SSW directions.**

***IndexTerms*—Lineaments, Lineament density, Groundwater, Structural trends, Orlu**

I. Introduction

With the aid of remote sensing it is possible to develop better regional model of hydrological processes in a drainage basin. Choubey (1996) stated that a rapid and accurate assessment of extent of groundwater potential areas can be made using remotely sensed data. Bierwirth and Welsh (2000) applied remote sensing to determine the preferential path of groundwater recharge area.

Senser et al. (2005) pointed out that remote sensing can effectively identify the characteristics of the earth (such as lineaments and geology) and can also be used to examine groundwater recharge. Mapping of lineaments from various remote sensing imaging is a commonly used step in groundwater exploration in hard rock areas. Fracture traces and lineaments derived from remotely sensed data can be correlated with vertical or near-vertical zones of fracture concentration, which in turn can serve as conduit for the transfer and storage of groundwater (Lattman and Parizeth, 1964; Parizek 1976; Perizeeth et al. 1990).

Optical sensor of moderate spatial resolutions have been used extensively for lineament analysis (Meijerink et al. 2007, Sander 2007, Arellano-Baezo et al. 2006, Ricchetti and Palombella 2005, Ricchetti and Palombella 2005, Inzana et al. 2003, Drury and Andrews 2002. Lee and Moon 2002, Ricchetti 2002, Lloizzo et al. 1994). Krishnamurthy et al. (1992) explored a variety of digital image processing techniques on a landsat TM image of Karnataka, India for groundwater investigations. Their processing resulted in 13 image products, which were assessed to exhibit several geologic and geomorphic features. The assessment was performed in a qualitative manner and the ability of products to exhibit features was ranked as either good, moderate, or poor.

II. GEOLOGY OF THE STUDY AREA

The study area is Orlu and its adjoining areas is situated in the Southeastern Nigeria and bounded between latitudes 5^0 30´ N - 6^0 00´ N and longitudes 6^0 45´ E -7^0 15´ E. The area falls within the Eastern Niger Delta Basin of Nigeria. The modern

Niger Delta started its growth after Paleocene transgression which was followed by a cycle of deposition in the Eocene and continued till the present day (Hosper, 1965). The geology of the study area indicates that it falls within the Benin and Ameki Formations. The thickness is variable within the study area. Some sandstones of Benin Formation are dark coloured and some are dark brown because of the presence of inorganic matter in them. The formation is a continental deposit of probable upper depositional environment. Various geologic structures or structural units are associated with the Benin Formation, which are channel fills, and natural levees. In general, Benin Formation ranges from Miocene to Recent. It is the youngest of Niger Delta sediments. Its thickness is about 6000ft. And very little hydrocarbon accumulation has been associated with Benin Formation. Benin Formation is also known as the coastal marine sand of Nigeria and it is the source of portable drinking water in the place where it is underlain.

The Ameki Formation was deposited during the Eocene. It consists of a series of highly fossilferous grayish green sandy-clays with calcareous shale and white clayey sandstones. The formation displays rapid lateral facies changes and may locally show shaly development or inclusion of white and molted clay stone and sandstone (Rayment, 1965).

Two lithological groups have been recognized in parts of Ameki Formation which are the lower with fine to coarse sandstones and intercalation of calcareous shale and thin shaly limestone and upper part composed of coarse, cross- bedded sandstone, bands of fine grey-green sandstone and shaly clay (Obi and Ofoha 2004).

A greater proportion of the land surface of the study area is of flat topography. The topography is generally, gently undulating and punctuated by few low hills, some of which are relics of sandstone and siltstone deposit that are more resistant to denudation than the surrounding shales. The relief ranges from 75m on the hills to 30m in the adjoining lowlands and valleys.

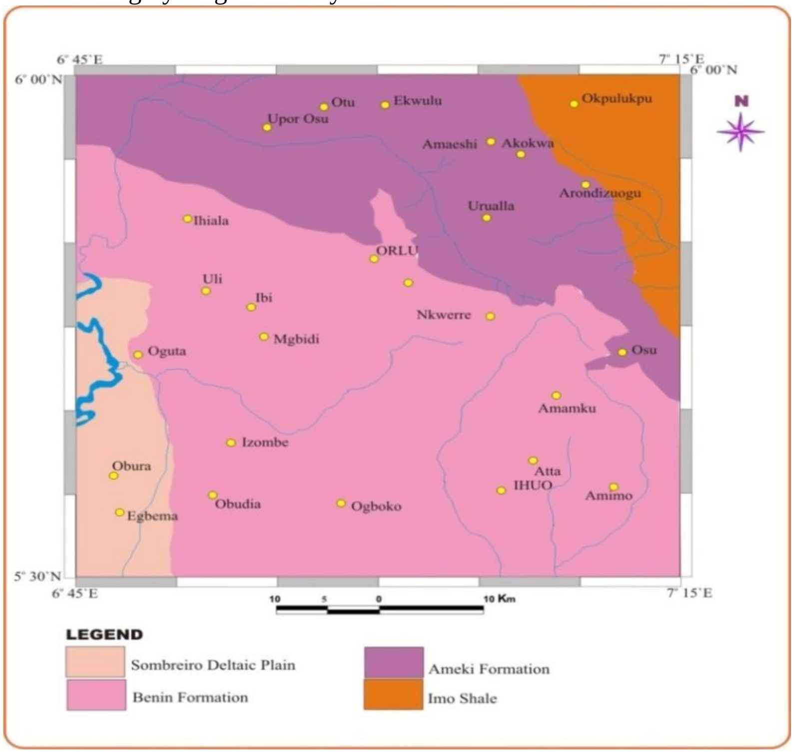

Fig. 1: Geologic map of the study area

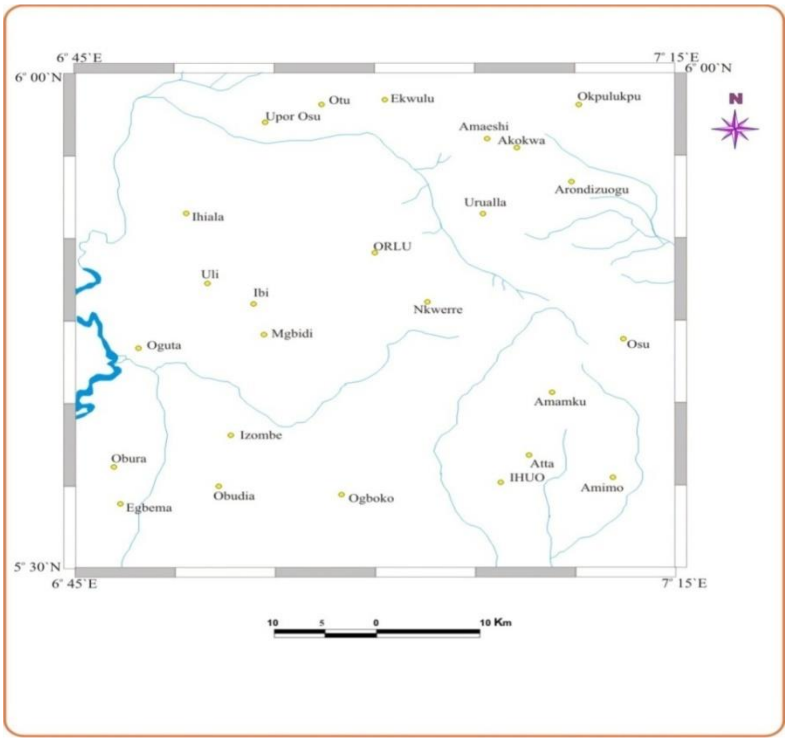

Fig..2: Drainage map of the study area

III. METHODOLOGY

Digital processing and GIS tasks were performed on a PC-based system. This methodology used in the study area follows the standard sequence of drainage, landforms, landcover and lineaments analyses and the integration of their results for geological and hydrogeological assessment. All data were in digital format and stored in a geo-database as GIS layers.

By using the potentiality of GIS software which allows stacking of georeferenced data for comparison and integration and data query for subsetting the needed information, selected layers of the database were superimposed on the landsat.

A layer was created on GIS including the main streams occurring in the region with their attributes (name, location/coordinates, average discharge).

Surface drainage (drainage layer) was also put into the GIS with information extracted from topographic maps.

The GIS layer with information extracted from traditional data were then correlated with information originating from satellite data to avoid potential errors. All data sets were prepared at the same scale of 1:100000.

Remote sensing data were essentially used for the location of the fractures occurring in the study area. As the greatest portion of the study area is flat to gentle rolling with a few clear morphological expression of fracturing, fracture zones may be observed directly through increase soil moisture along them.

The lineament analysis was performed both visually on 1:100000 prints of FCC 357, 751 and 752 (RGB) and directly on the computer screen on a series of data such as the maintained FCC and single near-mid infrared bands (band 4,5) enhancements (edge) and several convolution filters (3x3, 5x5, horizontal, vertical, directional) were applied. Results of the lineament analyses were compelled into only one overlay, after critical review of all data sets. The lineament layer was then transferred to the GIS.

Satellite images were used to generate maps of drainage systems, geologic structures, thermal anomalies, geomorphologic features and the distribution of vegetation. All these are important for the understanding of a region, its environment, and its resources, particularly groundwater. Images must be preprocessed using radiometric correction before data can be analyzed.

In radiometric corrections images collected at different dates and by different sensors were normalized to each other so that they can be directly compared. Geometric corrections were used to counteract sensor irregularities, terrain relief and effects of the curvature and rotation of the earth.

Various colour composition were generated to determine the best band combinations for analyses of lineaments, fracture traces and vegetation anomalies. The landsat data contained bad scan lines which, with the added attention contributed by smoke and dust in the atmosphere, prevented the effective use of TM bands 1 and 2 in the construction of composites, therefore, band combination 357, 751 and 752 in RGB were found to offer the most promise for interpreting the imagery, each color composition was edge enhanced using a 3x3 edge shaping filter. In addition to generating edge enhanced color composition, directionally filtered images were constructed using TM band 4 in a multistep procedure similar to that described by More and Waltz (1983).

In image transformation, several multispectral bands were used to generate a single image that highlight a particular feature or property of the land surface. Examples of transformations include image subtraction and ratios. Image subtractions are used to identify difference or changes among images of the same area acquired at different times. Image ratios are used to enhance particular information about the status of the land surface. For example the normalized difference vegetation index (NDVI) which indicates the amount of green vegetation present in each picture element (pixel).

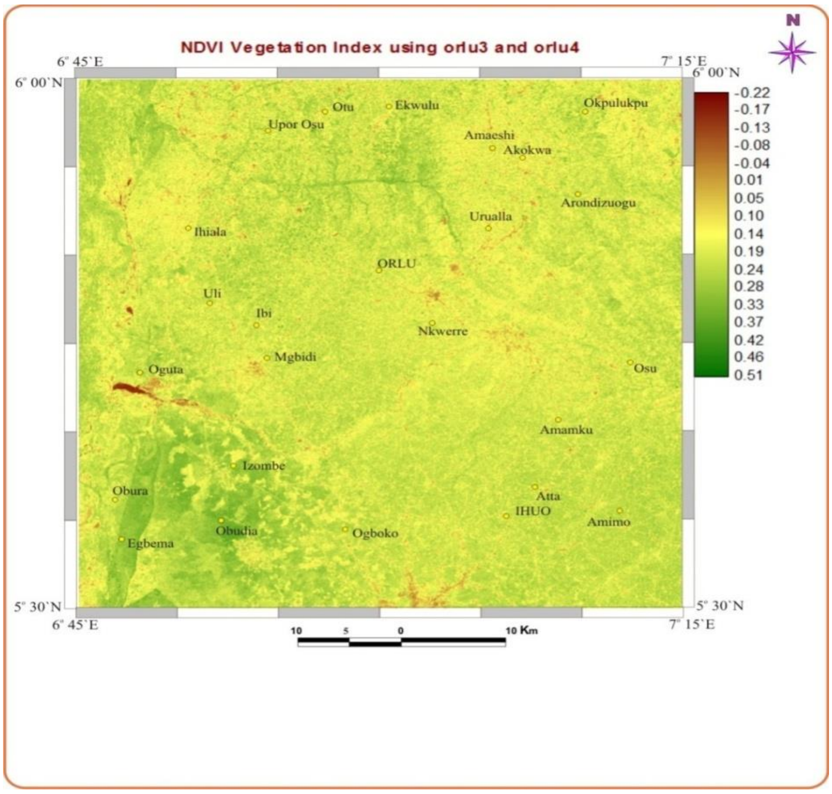

Fig. 3: NDVI vegetation index of the study area.

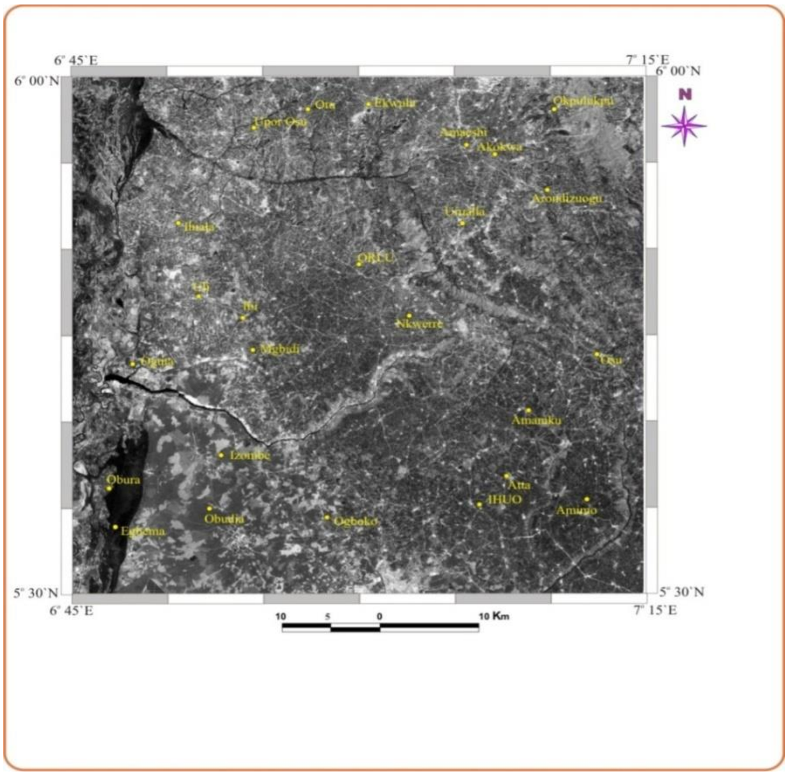

Fig. 4: Image enhancement band 5

Mosaicking of individual statellite scenes provided coverage of the entire area or region. The purpose of mosaicking is to create a seamless image from a group of individual scenes that may vary in brightness.Mosaicking involves three steps: resampling images to refine their resolution, matching the brightness of images and blending overlapping areas

ISSN 2201-2796

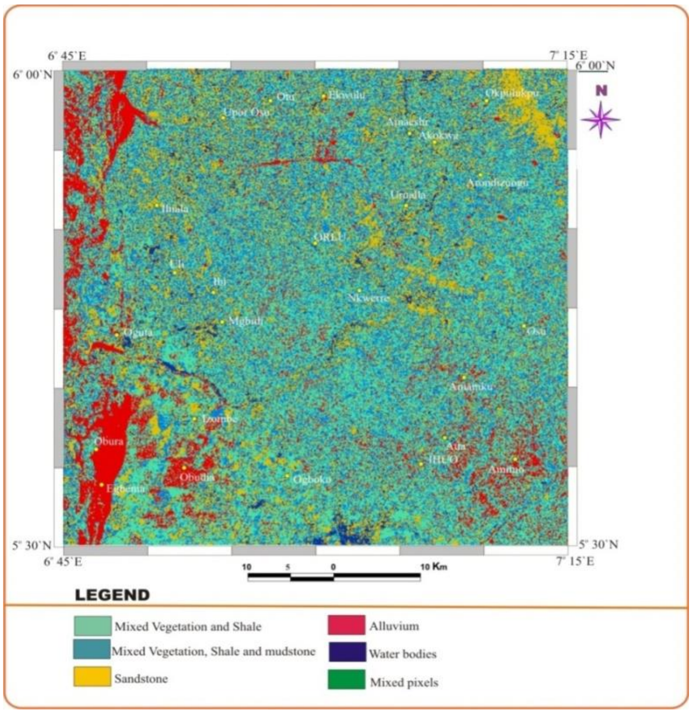

Fig. 5: Unsupervised classification image used for discrimination of spectral classes.

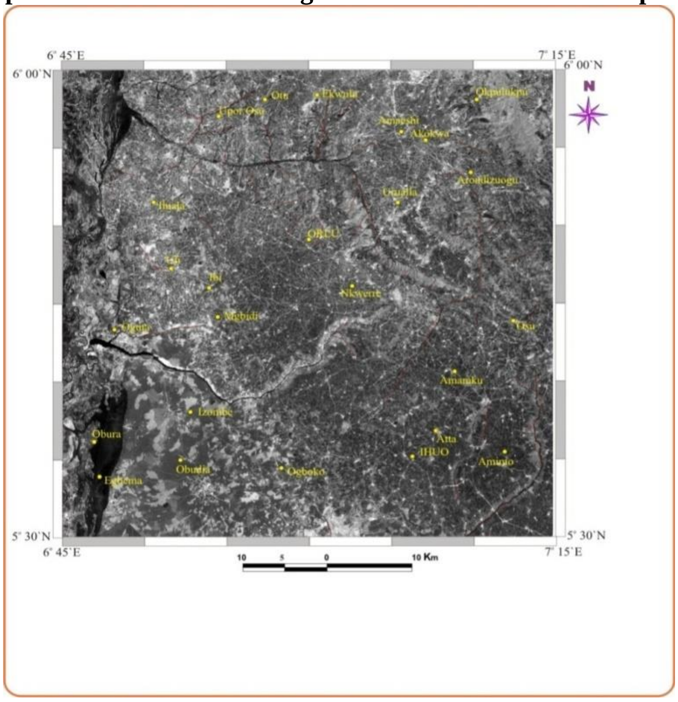

Fig.6: Lineament of edge enhanced band

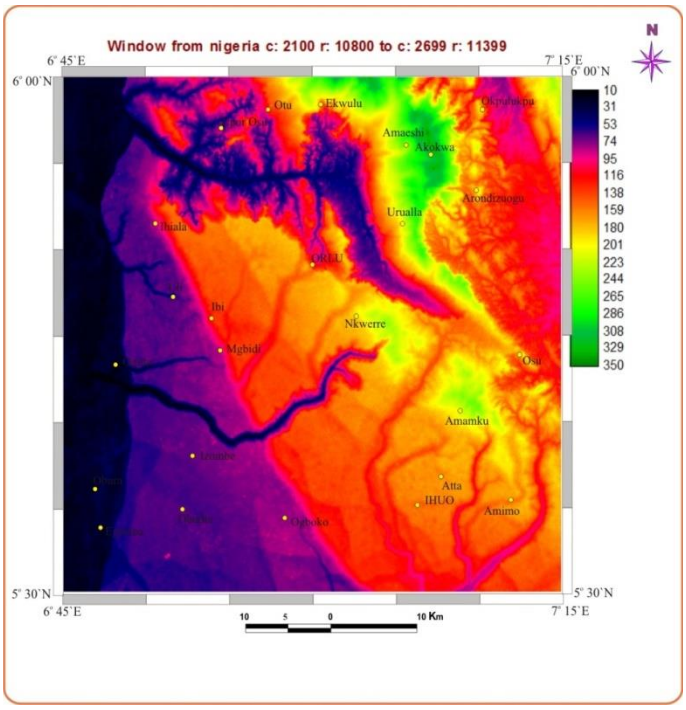

Fig.7: DEM of the study area

IV. INTERPRETATION AND ANALYSIS OF RESULTS

A lineament is a mappable linear or curvilinear feature of a surface whose parts align in a straight or slightly curving relationship (Hung, Bateiean and De Smedt 2005). There are usually an expression of fractures (joints, faults) and or other line of weakness.

The drainage network (Fig. 4) and lineaments (Fig. 6) below, were delineated using ILWIS 3.3. Rose (azimuth-frequency) plots of orientation of these structural elements or lineaments were done.

The drainage network is concentrated around the river found within the study area. The dentritic drainage pattern is the major drainage type observed on the imagery (Fig. 7). It is relatively dense on the northeastern part of the study area. The drainage pattern map (Fig. 7) was superimposed on the lineament map for more meaningful interpretation of the structural control patterns of the drainage system in the area. It is observed from the results that drainage pattern is most likely structurally controlled it is a therefore deduced that both the groundwater and surface water flow directions generally follow the structural strike orientation of lineaments in the area of study.

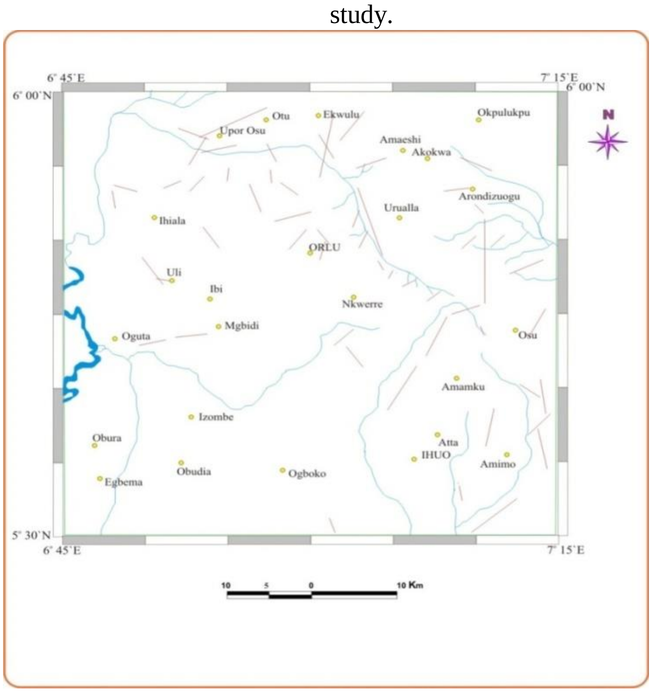

Fig.8: Synthesis map of lineament and drainage of the study area

Lineaments are commonly analyzed using rose-diagrams or azimuth-frequency (Karinineli, Meisels, Fisher and Arkin 1996) and / or lineament density maps (Zakir, Quari and Most 1999). The commonest method used to calculate lineament density is based on the number of lineaments per unit area (number/km) or the total length of lineaments per unit(km/km) or combining both (Hung, Batelaan and de Smedt 2005). However for this study, rose (azimuth-frequency) diagram and lineament density maps were used.

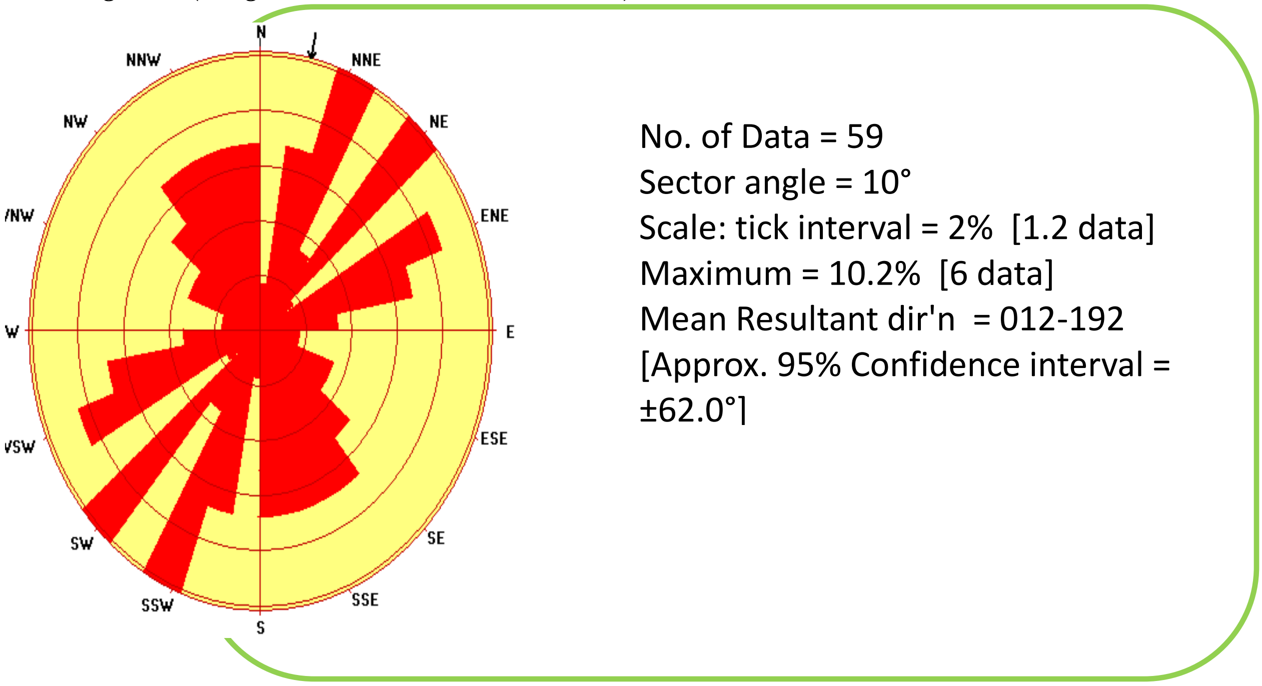

Fig. 9: The Rose (azimuth frequency) diagram of the lineaments delineated on the imagery showing lineament orientation

The observed trends were NE – SW, NNE -- SSW, NW-SE, NNW – SSE and N-S directions (Fig. 9). The NE-SW and NNE-SSW directions are the major trends in the area.

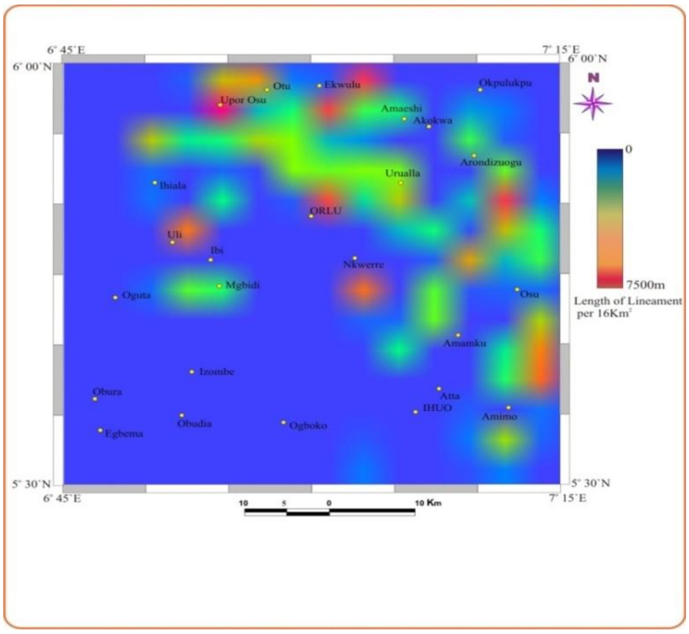

Fig. 10: Lineament Density map of the study area

The lineament density of the study area was computed based on the number of lineaments per unit area (number/ km) of grid. The lineament density map shows that the lineament density is high around Opor Osu, Orlu, Ihiala, Ekwulu, Uli and Osu with regards to groundwater exploration these aforementioned areas may have high groundwater potentials due to high concentration of lineament density, since ground water occurs within joint and fractures in rocks. Also from the result, the drainage pattern is structurally controlled and mostly influences both the groundwater and surface water flow directions in the area.

The lineament density maps are very important in groundwater explorations. High lineament density areas usually imply areas with high fracture density. Many workers (Bala, 2001, Bassey, Ezeigbo and Kwache, 1999, Drahovzal 1973) have shown that groundwater accumulation and water well production or yields increase with increasing lineament density. Therefore groundwater exploration in the study area should be concentrated on area with high lineament density as mentioned earlier.

V. DISCUSSION OF RESULTS

The mapped structural lineaments were analyzed using lineament density (LD) and lineament frequency (LF) parameters (Solomon and Ghebreab, 2006). The result of the analysis are presented as lineament density map, lineament of drainage map, and rose diagram (Fig.10, 8 and 9 respectively). The lineament density variation map (Fig.10) shows the lineament numbers varying between 7 and 16.

In this study, a thematic map that shows the vegetation cover and its alignment in the in study area was generated using ENVI 4.7 tool. The NDVI method has been used to identify and map geologic linear features (lineaments) in most areas based on tone, colour and textual identifying pattern. Some part of the area such as Opor, Osu and Ihiala have a relative high density. According to Edet et al (1998), the zones of relatively high lineament density are identified as zones of high degree of rock fracture, which are prerequisites for groundwater conduit development in an area. The lineament intersection map provides interpretation of hidden subsurface tectonic configuration in the form of linear feature intersection/ cross cutting geological structure, which are indicators of deep seated fractures/ fault medium. It is observed from the lineament maps that areas underlain by high density are characterized by relatively lineament intersection value. The zones of high lineament intersection over the study area are feasible zones for groundwater targeting in the study area.

The rose diagram (Fig.9) shows the directional frequency of the mapped lineaments over the area of study. It was interpreted as a statistical means of representing the anisotropy of the fractured environment, as well as fissure development tenancy on a regional scale. The rose diagram of the detected lineaments shows two prominent trends in the direction NE – SW and NNE-SSW directions. This can be an indication of groundwater movement in the study area. The research findings of Owoade and Moffat (1989) in the determining the groundwater prospects in south-western Nigerian corroborate the above hydrogeological dedication which emphasized that groundwater movement and its accumulation always explored the fissures/ fractural/ weathered column of basement rocks. Therefore, the fracture anisotropy of the detected lineaments trends presented in Fig.9 can be investigated for groundwater potential of the study area.

VI. CONCLUSION

The development of remotely sensed data introduced valuable and supplementary information of terrain characteristics. Linear features for ground water exploration, the subject of this information. Thus, several recent studies tackled these features, but the purpose and approaches of analysis differ from one study to another.

However Orlu and adjoin areas of south-eastern Nigeria was selected for this study. This area is underlain by Benin and Ameki formation. Plots of the lineaments observed on the imagery show dominant trends in NE-SW and NNE-SSW directions. The lineament density of the study area was calculated using the number of lineaments per unit area (number/km) of grid.

Each of the lineaments observed treats certain geologic and geomorphologic criterion some lineaments appear disconnected (as short linear) may be due to existence of human activities along the lineament alignments of these lineaments. Short lineament alignment is important in water infiltration while long ones serve in groundwater flow regime for long distances.

Three forms of lineament density maps were produced and they are lineament density contour map, lineament density image map, and lineament density surface map of the area. These maps show that lineaments density is relatively high in areas like Opor, Ozu, Orlu, Ihiala, Ekwulu, Uli and Osu. Lineament analysis shows that groundwater potential is high in areas with high lineament density. Therefore, surface water and groundwater exploitation structures should be

constructed taking cognizance of the high lineament density areas and the general lineament strike orientation directions in the area.

REFERENCES

[1] Amos, B.J., and Greenbaum, D., (1989). Alteration detection using TM imagery: The effects of supergene weathering in arid climate. Int. J. Remote Sensing, 10, pp. 515-527.

[2] Drug S.A and Andrew Deller M.E. (2002). Remote Sensing And Locating New Water Sources

[3] Goetz, A.F., Rock, B.N., and Rowan, L.C. (1983). Remote Sensing for Exploration: an overview. Economic Geology, 78, pp.573-590.

[4] Greenbaum, D. (1987). Lineament Studies in Masvingo Province, Zimbabwe, British Geological Survey Report WC/87/7.

[5] Hunt, G.R. (1979). Near-infrared (1.3-2.4 µm) spectra of alteration minerals – potential for use in remote sensing.Geophysics, 44, pp.1974-1986.

[6] Hunt, G.R. and Salisbury, J.W. (1970). Visible and near-infrared spectra of minerals and rocks: I Silicate minerals. Modern Geology, 1, pp.283-300.

[7] Hunt, G.R. and Ashley, R.P. (1979). Spectra of altered rocks in the visible and near-infrared.Economic Geology, 74, pp.1612-1629.

[8] Hung L.Q Baleloan O and De Smedit F. (2005). Lineament Extraction and Analysis Compression Of Landsat ETM And ASTER Imagery Case Study Of Suoimuoi Tropical Karst Catchment, Vietnue In: Remote Sensing For Environmental Monitoring GIS Application And Geology, By M Ehlers And U Michea (Ed_ Proc. Of Spie 59635983OT

[9] Kar, A. (1994). Lineament control on channel behaviour during the 1990 flood in the southeastern Thar Desert.Int. Jour. of Remote Sensing, 15, pp.2521-2530.

[10] Karnieli A, Meisels A., Fisher, L And Arkin V. (1996). Automatic Extraction Of Geological Linear Features From Digital Remote Sensing Data Using A Hough Transform Photogrammetiric Engineering And Remote Sing 62:525 – 531.

[11] Koopmans, B.N. (1986). A comparative study of lineament analysis from different remote sensing imagery over areas in the Benue Valley and Jos Plateau Nigeria.Int. Jour. of Remote Sensing, 7, pp.1763-1771.

[12] Krishnamurthy J P. Menavlan and V. Saivasan (1999). Application Of Difital Enhancement Techniques For Groundwater Exploration In Hard – Rock Terrains, International Journal Of Remote Sensing Vol 13 NO 15 Pp 2925-2942.

[13] Lattman, L.H. and Parizek, R.R. (1964). Relationship between fracture traces and the occurrence of groundwater in carbonate rocks. Jour. Of Hydrology, 2, pp. 73-91

[14] Lattman, L.H. (1958). Technique of mapping Geologic Fracture Traces and Lineaments on Aerial Photographs, Photogrammetric Engineering, 19, 4, pp.568-576

[15] Magowe, M. And J.R Carr,. (1999) Relationship Between Lineaments And Groundwater Occurnace In Western Bostware Groundwater, Vol 37 No 2, Pp 282 – 286.

[16] Medirink A.M J. D . Banner, O Bateloan, M.W. Luberztnski and T. Pointet, (2007). Remote Sensing Applications To Groundwater In IHP Vi Series On Groundwater No 16 United Nation Educations, Scientific An Cultural Organization, Paris, France Pp 304.

[17] Machmood, A (1996) Lineaments As Groundwater Exploration Guides In Herd Rock Terrances Of Arid Regions, Canadian Journal Of Remote Sensing, Vol 22, No 1 Pp 108-116.

[18] Mostafu E. Moshemmed Youset H.T Ouari (1995). An Exact Technique Of Conuting Lineaments. Engineering Geology 3a (1995) 5-16

[19] Mostafa, M.E and A.Z Bishta (2005) Significance Of Lineament Pattern In Rock Unit Classification And Edesignation. A Plot Study on the Gharib – Buru Area

[20] Novak, I.D And Soulakellis N (2000) Indemnifying Geomorphic Features Using Landsat 5/TM Data Processing Technqies On Lesons Freace Geomorphotogy, 34 (7) Pp 101-109.

[21] Ricchetti, E and M. Ralombella (2005) Application of Landsat 7 EMT Imagery For Geological Lineament Analysis Of Southern Italy IEEEE Pp 5200-50203.

[22] Sabins, F. F., 1987. Remote Sensing Principles and Interpretation.(San Francisco, Calif.: W.H. Freeman), 449pp.

[23] Sander P T.,B.Minor and M.M Charley (1997). Groundwater Exploration Based On Lineament Analysis and Reproducibility Test, Groundwater Vol 35. No 5 Pp 888.

[24] Sawa Ya K. E, L.G Olmanson, N.J Heinert P.L Bresomk and M.E Bauer, (2003). Extending Satellite Remote Sensing To Local Scales: Land and Water Resource Monitoring Using High-Resolution Imagery, Promote Sensing Of Environment, W I 88 Pp 144-156.

[25] Solomon S, Ghebreb W. (2006). Lineament Characterization and The Technic Significance Using Land TM Data And Field Studies In The Central Highlands Of Ertirea). Afr. Earth Sci. 46:371-378.

[26] Suzen, M.L. and Toprak, V. (1998). Filtering of satellite images in geological lineament analysis: application to a fault zone in Central Turkey.Int. J. Remote Sensing, 19, pp. 1101-1114.

[27] Taud, H. and Parrot, J.F. (1992). Detection of circular structures on satellite images.Int. J. Remote Sensing, 13, pp. 319-335.

[28] Welsh G.J (2000) Geologic Controls on Remotery Sensed Lineaments in Southeastern New Hampshere

[29] Yun, S and W.M Moon (2001). Lineament Extraction from DEM Using Drainage Network IEEE Pp 23372339.

[30] Zakir, F Qari M Mostta M (1999) A New Optinsing Technique For Preparing Lineament Density Maps International Journal Of Remote Sensing 20 : 1073 (1085 198