Lineament Mapping for Groundwater Exploration in Kano State, Nigeria

[1]*Maina M. M. and [2]I.Y. Tudunwada

***Abstract*—Climate is changing couple with erratic rainfall, pressure on the groundwater resources is becoming severe and therefore locating and monitoring of groundwater resources is imperative. Sustainable groundwater exploration and exploitation requires lineament analyses for proper siting of boreholes. This study was carried out to demonstrate the capability and emphasize the importance of geospatial systems (Remote Sensing (RS) and Geographic Information System (GIS)) techniques for efficient groundwater resources exploration and management. The study demonstrates the use of LANDSAT ETM+ imagery, ASTER DEM (30m) for mapping and analyses of lineaments. Image processing techniques involving linear/edge enhancement and directional filtering were applied on the image to enhance the edge of the linear features using ENVI 5.1 software. PCI Geomatica was used to extract lineament and lineament intersection map using the lineament model. ArcGIS 10.2.2 were used to create lineament density and finally Rockworks 17 was used for trend analysis to create rose diagram. The lineament/fracture analyses indicated that the area has numerous long and short fractures whose structural trends are mainly in North-South direction. The zones of high lineament intersection density are feasible zones for groundwater prospecting in the study area. The study has led to the delineation of area where groundwater occurrences is most promising for sustainable groundwater exploitation.**

***Keywords*— Extraction, kriging, Lineament, Groundwater, Rose Diagram, Geospatial**

I. INTRODUCTION

Hydrologists and earth scientists have been interested in linear features of the earth's crust since the early period. The linear features, which are faults, folds, and fractures, can give a clue for explorations of minerals and ground water resources. They are also important in some engineering applications such as dams, roads and power plants construction or determining new settlement sites. Using visual interpretation, determining the lineaments on the satellite image is very difficult and sometimes subjective but with experienced interpreter it is possible. However, there are software models and digital mapping which makes it easy to obtain structural and lithological information efficiently and effectively, this can be achieved on the ground using lineament analysis [1]. Many literatures have explain lineament in different perspective. However [2] Described lineament in terms of remote sensing context as "traces on the earth's surface of planar breaks in the crust of the earth. According to [3], "Lineaments are the terrain surface expression of fractures, jointing and other linear geological phenomena that occur anywhere from the terrain surface down to possibly great depths". Not only the lineaments can be tectonic features such as faults, folds, joints and fractures, but they can also be other natural features, such as steep to vertical strata, rivers, vegetation and some cultural features such as roads and boundaries between areas of different agricultural landuse. [4] defines Lineament as a mappable, linear feature of a surface, whose parts are aligned in a rectilinear or slightly curvilinear relationship and differ from the pattern of adjacent features and presumably reflect some subsurface phenomenon. It is acceptable as one the most practical description. Lineament intersection map revealed the hidden subsurface tectonic configuration in form of linear features intersection/cross cutting geological structures that are diagnostics of deep seated fracture/ fault medium [5].

Remote sensing technique provides a means for regional understanding of groundwater system [6]. Its data provides information on spatial patterns groundwater dependent vegetation or salinization. The interpretation of remotely sensed data for linear features mapping is an integral part of groundwater exploration programmes in hard rock terrain [7]. Remote sensing with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within short time has become a very handy tool in assessing, monitoring and conserving groundwater resources.The focus of this work is apply lineament analysis using remote sensing and GIS techniques to establish the areas of high groundwater expectations and accumulation for easy exploitation in Kano state.

II. METHODOLOGY

A. *Description of the Study Area*

Kano State in Nigeria (11o 59''E longitude, 8o 30''N latitude) located within the savannah region of Sudan and having an estimated altitude of 486 m, has an abundance of fertile land. According to the National Population Commission, Kano has a population of over 9,383,682. Out of which 70% are engaged in agricultural activities. The state has 20 dams which have total storage capacity of 3.3 billion cubic meters. The state has total area of 20,760 km2 and an area of over 90,000 ha under cultivation. The main crops of Kano include groundnut, garlic, cotton, guinea corn, millet, maize, rice,

[1] Department of Agricultural Engineering, Faculty of Engineering, Bayero University Kano

[2]Zonal Advance Space Technology Application Laboratory, Bayero University Kano, (emai: mainam@buk.edu.ng)

cowpea, wheat and vegetables such as tomatoes, pepper, onions and cabbage. The southernmost area is characterized by the northern Guinea savannah and the northernmost section by the Sahel thorn shrub. The state has the tropical wet-and-dry type climate with relatively wide and rapid changes in temperature and humidity. The annual maximum and minimum mean temperatures are 31 °C and 21 °C, respectively. The year is divided into well-marked rainy and dry seasons. The dry season lasts from October to June.

During the months of November to February, the Harmattan (dry north-easterly winds) is at its peak, blowing thin dust over the state from the Sahara Desert. During this time, temperatures may drop to as low as 6 °C. However, from March to May the dry cold air humidifies and changes to beamingly hot air with temperatures rising up to 40 °C. Rainfall is concentrated between July and September with maximum and minimum monthly rainfall of 300 mm and 132.7 mm, respectively. The rains are preceded by violent dust storms around May and June. The average annual rainfall is 745 mm, about 60% of which falls in July and August. Average annual rainfall varies considerably from year to year, ranging from 480 mm to 821 mm.

The satellite data used were downloaded from earthexplorer.usgs.gov and the area of the scenes cover from path 188 and row 51 and path 189 and row 53 of the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) of 2005 and 2010 respectively.

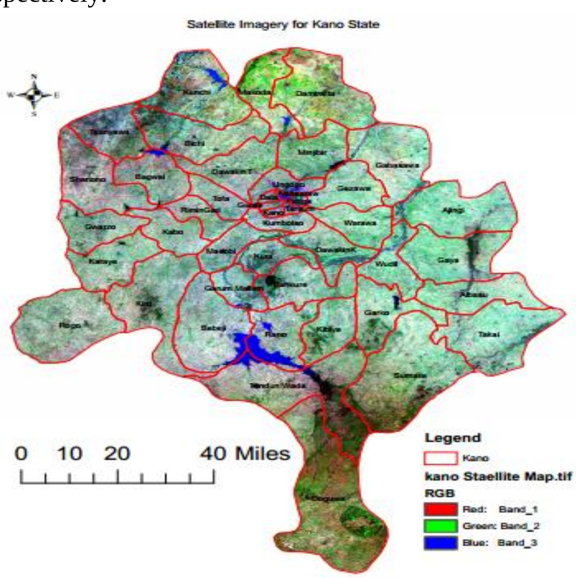

Fig. 1 Map of Kano state overlays Landsat imagery

B. *Lineament Extraction*

The imagery was sharpened in ENVI 5.1 and compute statistics on band 1to convert it to 8bit image file and then using PCI-line module for automatic lineament extraction by three steps; 1. Edge detection, 2. Thresholds and 3. Curve extraction. The extracted lineaments were now fed into ArcGIS 10.2 to split vertices and generate line density. Trend analysis was done using Rockworks 17 to create rose diagram from end-point data

III. Result and Discussions

The results of the analysis are presented as lineament density map, lineament intersection map and rose diagram (figures 2, 3 and 4) respectively.

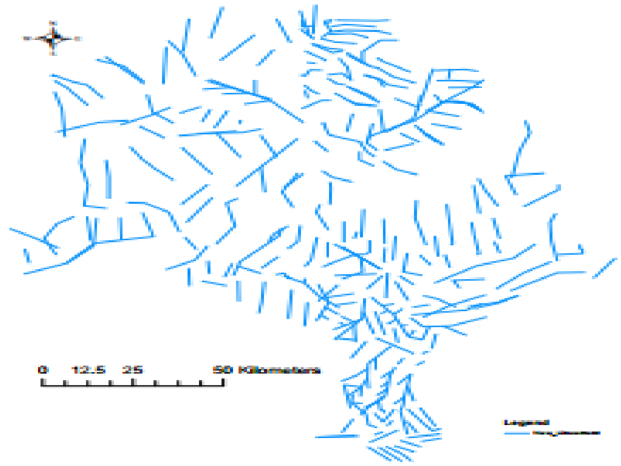

Fig. 2. Lineament intersection Map of kano state

A comparison of Figure 3 with Figure 6 - Lineament density variation map, shows that the areas underlain by high density are characterized by relatively high lineament intersection value. The zones of high lineament intersection over the study area are feasible zones for groundwater potential evaluation.

A comparison of Figure 3 and Figure 4 Lineament density variation map shows that the prominent lineament trends (N-S) are correlated with high density variation zones of the study area. This can be an indication of the direction of groundwater movement in the studied area, and this can be supported by figure 5 (kriged groundwater levels in Kano state).

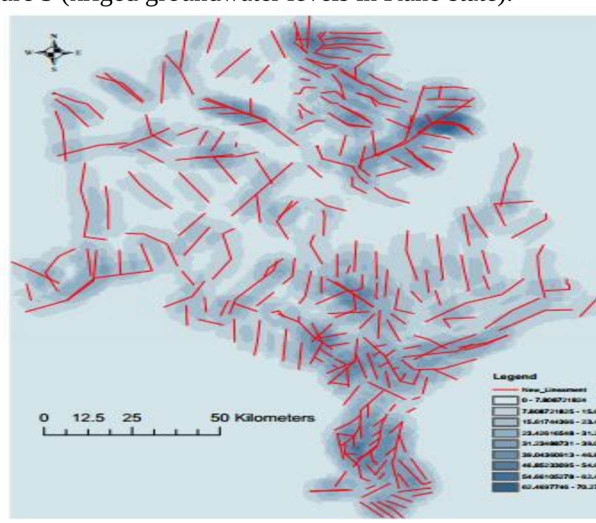

Fig. 3 Lineament density map of Kano state

It can be observed that in some zones, the rose petal length does not vary within a thickness which indicates a consistency in lineament orientation. When the orientation of fractures is consistent over a thickness, it implies a consistent mechanism of fracture over a long period of time. This indicates a complication in fracture lineaments of the area. The yellow arrow shows a strong N-S lineament

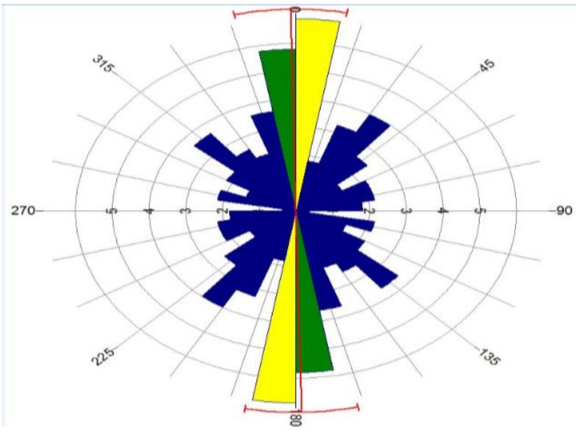

Fig. 4. Rose diagram of the lineament

TABLE I: LINEAMENT ROSE DIAGRAM

Kano Lineament Rose Diagram

Statistical Summary

S/n	Calculation Method	Length
1	Class Interval	10.0 Degrees
2	Min Length Filtering	Deactivated
3	Max. Length Filtering	Deactivated
4	Azimuth Filtering	Deactivated
5	Data Type	Bidirectional
6	Population	138
7	Total length of all Lineaments	20.35
8	Maximum Bin Population	19
9	Mean Bin Population	7.67
10	Standard Deviation of Bin Population	4.29
11	Maximum Bin Population (%)	6.88
12	Mean Bin Population (%)	2.78
13	Standard Deviation of Bin Population (%)	1.55
14	Maximum Bin Length	1.68
15	Mean Bin Length	0.57
16	Standard Deviation of Bin Lengths	0.42
17	Maximum Bin Length (%)	8.25
18	Mean Bin Length (%)	2.78
19	Standard Deviation of Bin Lengths (%)	2.07
20	Vector Mean	178.8 Degrees 358.81 Degrees
21	Confidence Internal:	12.3 Degrees (80 Percent)
22	R-mag	0.35

Figure 4 shows the directional frequency of the detected lineaments over the area of study. It shows a statistical means which represent the different fractured environment, as well as the fissure development tendency on the area. The length of the rose's petals represents the intensity of lineaments within the analysis area and the denser the lineaments indicated the intense of rock fracturing which is a prerequisite for development of hollow passages over an area. The rose diagram of the identified lineaments indicated the trends in the direction of N-S axis which is also the principal direction of the regional structures directions, with the north axis tilted a little bit eastward. They are as around the middle, North-eastern and south-western parts of the study area has a relatively high density value.

Figure 5 indicated part of the state that has low groundwater level with the lowest at 3.88 m and highest groundwater level of 28.7 m. This indicates the abundance of groundwater in the state of which groundwater level is anticipated to receive its recharge from the numerous surface water bodies of 20 different dams within Kano state. The southernmost part of the state has abundant groundwater resources unlike the northern part of the state with deep groundwater water levels.

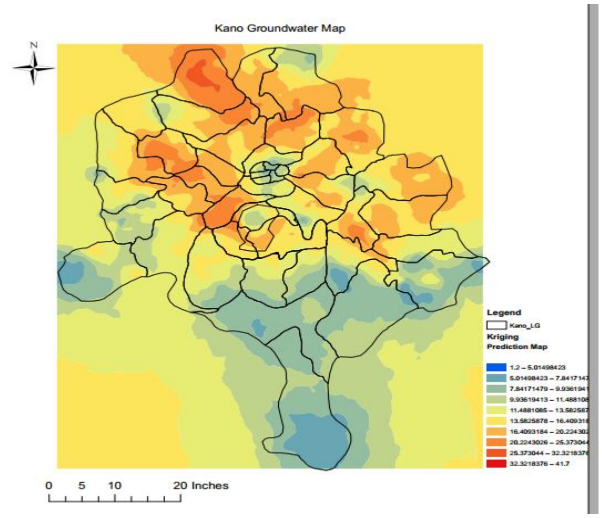

Fig.5 Kriged groundwater levels of kano State

IV. CONCLUSION

Remote sensing has proved to be a useful tool in lineament identification and mapping. A digital elevation model was also analyse to improve the interpretation. The result of the analysed lineament/fracture indicated that the area has numerous long and short fractures whose structural trends are mainly in north-south direction. The cross-cutting lineaments are relatively high areas around the south-western parts of the study area but low in the other areas. The zones of high lineament intersection density are feasible zones for groundwater prospecting in the study area. It was found that most of the major orientations in the areas could be successfully detected from the remotely sensed imagery. The results from the study show that the remote sensing technique is capable of extracting lineament trends over a large area. It is therefore suggested that the high lineament intersection density should be combed with detailed electrical sounding survey for quantitative evaluation of the groundwater potential of the study area.

REFERENCES

[1] Ölgen M. K. (2004). Determining Lineaments and Geomorphic Features using Landsat 5-tm Data on the lower Bakirçay plain, Western Turkey. Aegean Geographical Journal, Vol. 13, 47-57.

[2] Koch, M. and Mather, P. M., (1997). „Lineament mapping for groundwater resource assessment: a comparison of digital Synthetic Aperture Radar (SAR) imagery and stereoscopic Large Format Camera (LFC) photographs in the Red Sea Hills, Sudan" International Journal of Remote Sensing, Volume 18, Issue 7 May 1997, pages 1465 –1482. https://doi.org/10.1080/014311697218223

[3] Magowe, M. and J. R. Carr (1999). Relationship between lineaments and ground water occurrence in western Botswana., Ground Water, 37(2), 282–286, 1999. https://doi.org/10.1111/j.1745-6584.1999.tb00985.x

[4] Manghany M., M. Hashim and S. Mansor, (2009). Geologic mapping of United Arab Emirates using multispectral remotely sensed data. Am.J.Eng. Applied Sci.m, 476-480

[5] Aboyeji O. S; K. A. Mogaji and R. O. Oyinloye (2012). Structural Interpretation of Remotely Sensed Data sets, its Hydrogeological Implication over Ile-ife and Environs. Ozean Journal of Applied Sciences 5(1), 2012.

[6] Meijerink, A. M. J., Bannert, D., Batelaan, O., Lubczynski, M. W., and Pointet, T. (2007). Remote sensing applications to groundwater. IHP-VI series on groundwater, United Nations Educational, Scientific and Cultural Organization, Paris, 311 pp., 2007.

[7] Waikar M. L. and Aditya P. N. (2014). Identification of Groundwater Potential Zone using Remote Sensing and GIS Technique. International Journal of Innovative Research in Science, Engineering and Technology Vol. 3, Issue 5, May 2014.