



# Greener Journal of Geology and Earth Sciences

ISSN: 2354-2268

Submitted: 01/03/2016

Accepted: 16/03/2016

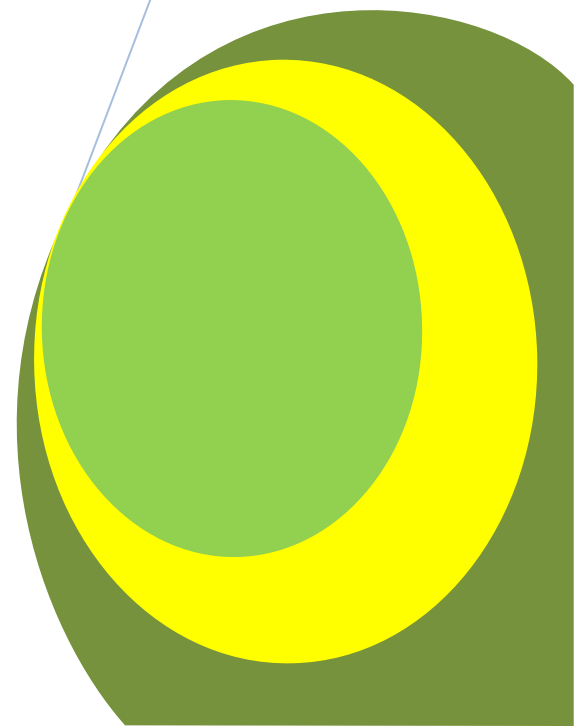
Published: 05/08/2016

DOI: <http://doi.org/10.15580/GJGES.2016.2.030116049>

## **Lineament Mapping Using Remote Sensing Techniques for Geologic CO<sub>2</sub> Sequestration Site Characterization, in Gbaran, Bayelsa State Nigeria**

By

**Benibo Tekena  
Abayomi Alaga  
Ogbole John  
Benibo Irene**



Research Article (DOI: <http://doi.org/10.15580/GJGES.2016.2.030116049>)

# Lineament Mapping Using Remote Sensing Techniques for Geologic CO<sub>2</sub> Sequestration Site Characterization, in Gbaran, Bayelsa State Nigeria

Benibo Tekena<sup>1\*</sup>, Abayomi Alaga<sup>1</sup>, Ogbole John<sup>1</sup>, Benibo Irene<sup>2</sup>

<sup>1</sup>Cooperative Information Network, National Space Research and Development Agency, Obafemi Awolowo University, Ile-Ife.

<sup>2</sup>National Centre for Remote Sensing, Jos, Nigeria.

\*Corresponding Author's Email: geotekben@gmail.com

---

## ABSTRACT

The increase in CO<sub>2</sub> in the atmosphere due to hydrocarbon exploitation, gas flaring, human activities has led to global warming and adverse environmental effect.

Geologic carbon sequestration is one of the environmental mitigation measures for CO<sub>2</sub> reduction and storage in the subsurface. Gbaran in Bayelsa state, is located within the Niger Delta sedimentary Basin, with formations such as depleted oil and gas wells that abound there which could be suitable for geosequestration.

In line with this, geospatial technique was done for lineament mapping in the study area to infer the subsurface structures where faults are located to prevent selecting areas unsuitable for such projects in the future.

Multiple satellite image processing and interpretation techniques were done on false color composite (FCC) band combinations of LANDSAT 8 (OLI) for precise lineament extraction (both manual and automated) as well as spatial analysis. Softwares used include ERDAS, ArcGIS10.3, PCI Geomatica, and Rockwork.

Lineament density maps rose diagram plots, and spatially correlated lineament density maps were produced for various FCC images, showing areas with varying degree of lineament concentration.

The spatial correlated lineament map produced could provide a base line data for geosequestration site characterization in the study area.

**Keywords:** Geologic Sequestration, CO<sub>2</sub>, Lineaments, Geospatial.

---

## 1. INTRODUCTION

One of the main driving forces behind global warming is CO<sub>2</sub> emission from burning fossil fuels, Sadorsky P (2009). Geological CO<sub>2</sub> sequestration is the process whereby CO<sub>2</sub> is captured and separated from a source (such as a high-CO<sub>2</sub> natural gas field, liquefied natural gas or mineral processing plant, or coal-fired power station) and is transported and injected into the geological subsurface for long-term storage Cook PJ, Rigg et al. (2000), IPCC 2005

Knowing where faults are located can prevent selecting areas unsuitable for CO<sub>2</sub> sequestration where a potential leak can occur. Knowledge of fracture sets is critical because fractures can enhance CO<sub>2</sub> storage capacity; however, a large number of open faults intersecting the ground surface (indicated by lineaments) in a particular region indicate that the region should not be considered for CO<sub>2</sub> capture and storage due to potential CO<sub>2</sub> leakage.

Lineaments are commonly surface expressions of tectonic fractures and faults in the bedrock, emphasized on the surface by topography, drainage and vegetation, many can be identified by remotely sensed data; they also give insight into the fracture fabric of the region, an important consideration for CO<sub>2</sub> sequestration. Various data sets including Satellite images were used to map and validate the lineament distribution in the study area. This will provide a base line data for subsurface study in the state for Geologic carbon capture and Sequestration.

Satellite imagery analysis involves extraction of lineaments from varying wavelength intervals of the electromagnetic spectrum. Casas A.M. et al. (2000). The process of extracting such features from satellite maps involves several enhancement techniques or manual interpretation with the scope of analyzing the density, direction, length, orientation, intersection etc, for groundwater modeling, geo-hazard prediction, and mineral exploration purposes. Conventional statistical techniques applied to lineaments include frequency or length against azimuth histograms, Casas et al. (1996), rose diagrams Casas et al. (1995) and lineament density maps. Casas (1999).

## 2. STUDY AREA

Bayelsa is a state in southern Nigeria in the core Niger Delta region. It lies within the fresh water and meander belt geomorphic unit of the Niger Delta, the formation of the present Niger Delta started during early Paleocene as a build-up of fine grained sediments eroded and transported to areas by the river Niger and its tributaries. The regional geology of the Niger Delta consists of lithostratigraphic units, Akata, Agbada and Benin Formations, overlain by various types of Quaternary Deposits. It lies between Latitude  $5^{\circ} 27'52.428''\text{N}$ ,  $4^{\circ}16'20.212''\text{N}$  and Longitude  $5^{\circ}20'28.562''\text{E}$ ,  $6^{\circ}43'55.833''\text{E}$ , the study area is located within the North-Eastern and South Eastern part of Bayelsa state, Figure 1.

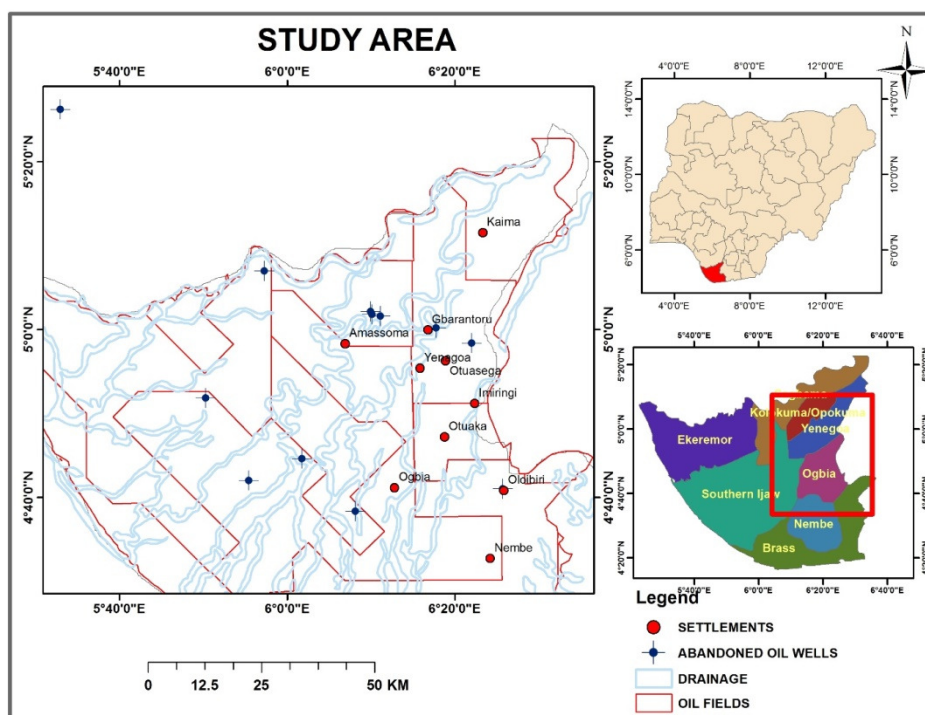


Figure 1: STUDY AREA

## 3. REGIONAL STRATIGRAPHIC SETTING

The geology of Bayelsa is similar to the general geology of the Niger delta region. The formation of the present Niger Delta started during early Paleocene as a result of the buildup of fine grained sediments eroded and transported to the area by the river Niger and its tributaries. The regional geology consists of three lithostratigraphic units, Akata, Agbada and Benin formations Overlain by various types Quaternary deposits Short K.C et al (1967), Wright J.B et al (1985). Kogbe C.A (1989).

## 4. DATA

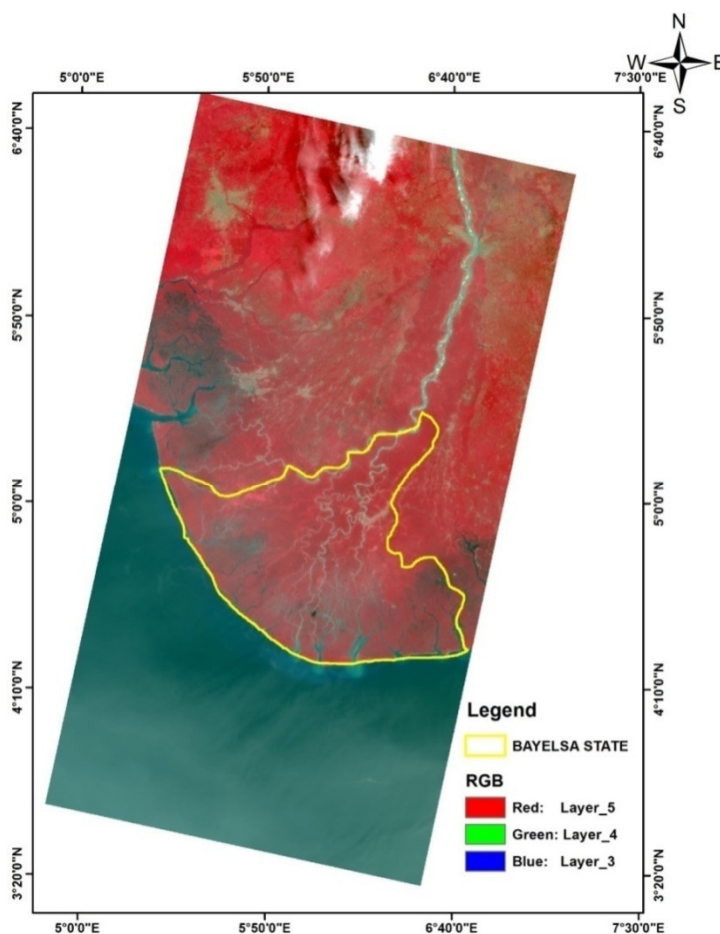
Most of the data used in this project were acquired using remote sensing tools. The main data sets were Landsat, geology map and topographic sheets. See Table 1.

**Table 1: DATA**

S/No.	DATA	ACQUISITION DATE	FORMAT	RESOLUTION SCALE	SOURCE
1	LANDSAT 8 IMAGE (OLI)	2015	DIGITAL	30Metres	GLOVIS
2	TOPOGRAPHIC SHEET	1982	ANALOGUE	1:50,000	OSGOF
3	GULF OF GUINEA ACREAGE MAP	2007	ANALOGUE	1:750,000	CHEVRON
4	GEOLOGY MAP	2006	DIGITAL	1:300,000	NIGERIA GEOLOGIC SURVEY AGENCY
5	GOOGLE EARTH IMAGE	2015	DIGITAL		GOOGLE EARTH

#### 4.1 Landsat Imagery

Landsat images are easily accessible and frequently used for lineament identification Rahiman T et al (2008). Landsat images were obtained free of charge from the Earth Resources Observation and Science (EROS) Center of USGS by using the Global Visualization viewer (<http://glovis.usgs.gov/>). The images captured by the Landsat sensors are identified with their path (longitudinal) and row (latitudinal) designations in a Worldwide Reference System (WRS). Two Landsat scenes were needed to cover the project area with the following paths: 189 and row 56 and 57 (Figure 2).



**Figure 2: Landsat 8 Imagery - Color Infra red R(5)G(4)B(3) Covering the project area with two scenes mosaiced together**

## 4.2 Geology Map

The Geology map was obtained from Nigerian Geologic Survey Agency, (NGSA) which was produced in 2006 on a scale of 1:300,000 the map was georeferenced, vectorized in ArcGIS 10.3 producing vectorized Geologic Formations, drainage network and Growth Faults of the study area, all these features can be related to the Lineament map of the study area as shown in Figure 3.

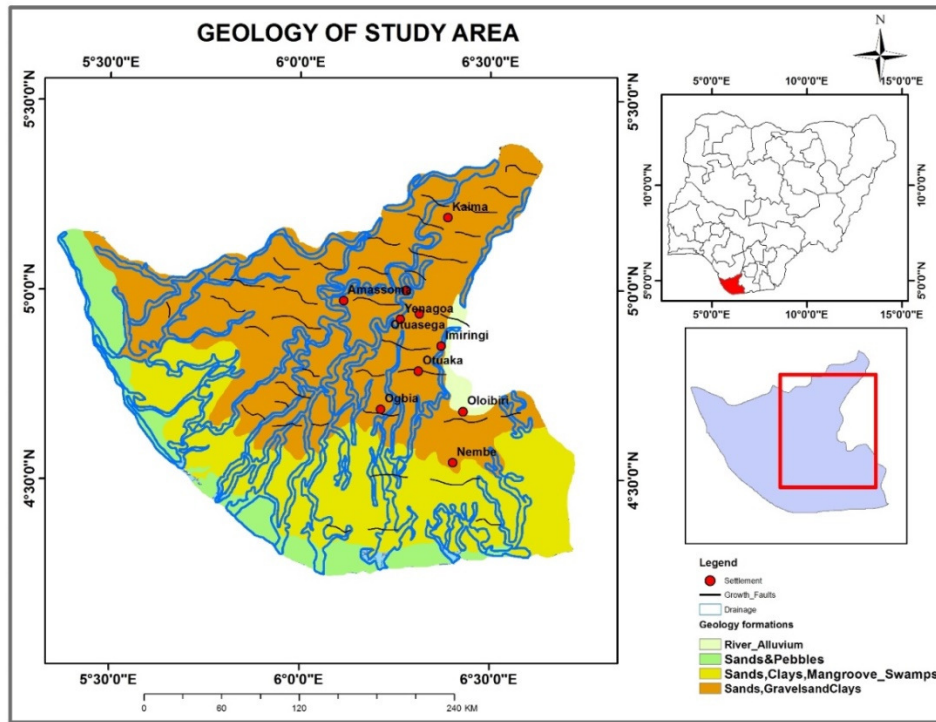


Figure 3

### 4.3 Gulf of Guinea Acreage Map

The Gulf of Guinea acreage Map is a rich source of oil and gas information showing the various oil fields and depleted and active oil wells within the region. It was obtained from Chevron Nigeria, on a scale of 1:750,000, the map was georeferenced and the oil field layer and oil wells were vectorized all of which can spatially be related to lineament of the study area. Figure 4.

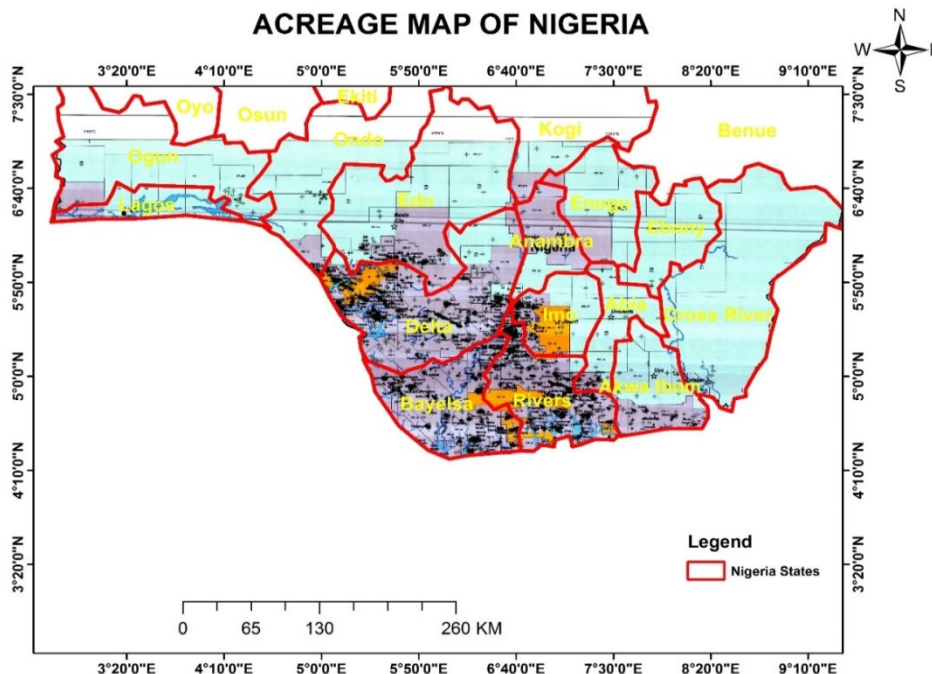


Figure 4: Acreage Map

#### 4.4 Auxillary Data (Topographic Sheet)

The topographic sheet of the part of the study with sheet name Oloibiri N.E and Sheet number (Sheet 327 N.E) was acquired on a scale of 1:50,000 scanned, georeferenced and subsequently digitized producing the point settlements of the area which was then stored in the arc catalogue geo database.

### 5. METHODOLOGY

This project was accomplished by completing the methodology outlined in Figure 5 and the workflow chart Figure 6.

Image processing → lineament extraction → lineament analysis

Figure 5

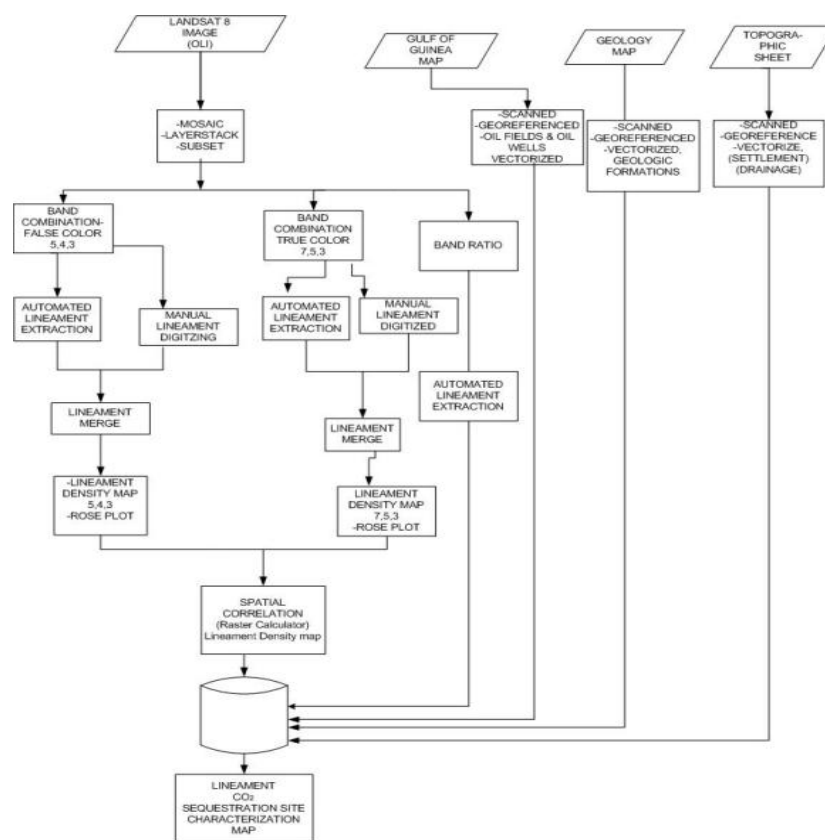


Figure 6: FLOWCHART

#### 5.1 Image Processing and Enhancement

Digital image processing is the manipulation of images using a series of procedures to improve their appearance for visual analysis and interpretation Jensen J.R. (2005), Lilles and T.M. et al. (2004). I applied different image processing methods such as mosaicking, subsetting and band combination for enhancing the appearance of linear features by emphasizing tonal, topographic and textural changes.

#### 5.2 Landsat Imagery

The preprocessing and processing steps of Landsat images included layer stacking, subsetting, georeferencing, mosaicking, and band combinations. The layer-stacking tool combines the Very Near infra-red (VNIR), Short wave infra-red (SWIR), and Long wave infra-red LWIR bands into a new multiband file which enables the manipulations of



all bands simultaneously. The subsetting tool was used to specify the spatial extent of the images for analysis, all of which was done using a wide range of geospatial softwares (ERDAS, ArcGIS10.3, PCI Geomatica 2015). Also color composite images of different band combinations was done, the FCC that combines one visible (VIS), one near-infrared (NIR) and one short-wave Infrared band (R(7),G(5),B(3)), this combination shows a large color variation for different surface materials and is therefore frequently used for geologic interpretation. Figure 7 shows the vegetation in green color, due to the high reflectance of vegetation in NIR, and detects differences in vegetation and moisture content, Jensen J.R, (2005) the Color Infrared Composite band was also done (R(5),G(4),B(3)) Figure 8, the true or natural color composite of R(3), G(2), B(1) shows the image in its natural state. This research analysis relied mostly on using the FCC and the color infrared false color band combinations.

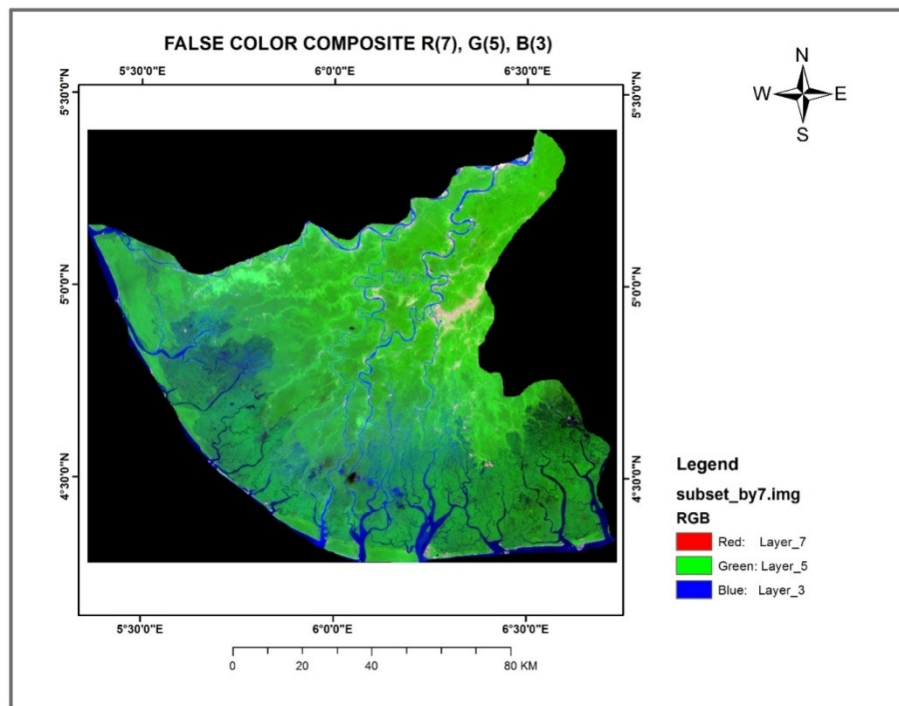


Figure 7: FCC R(7), G(5), B(3)



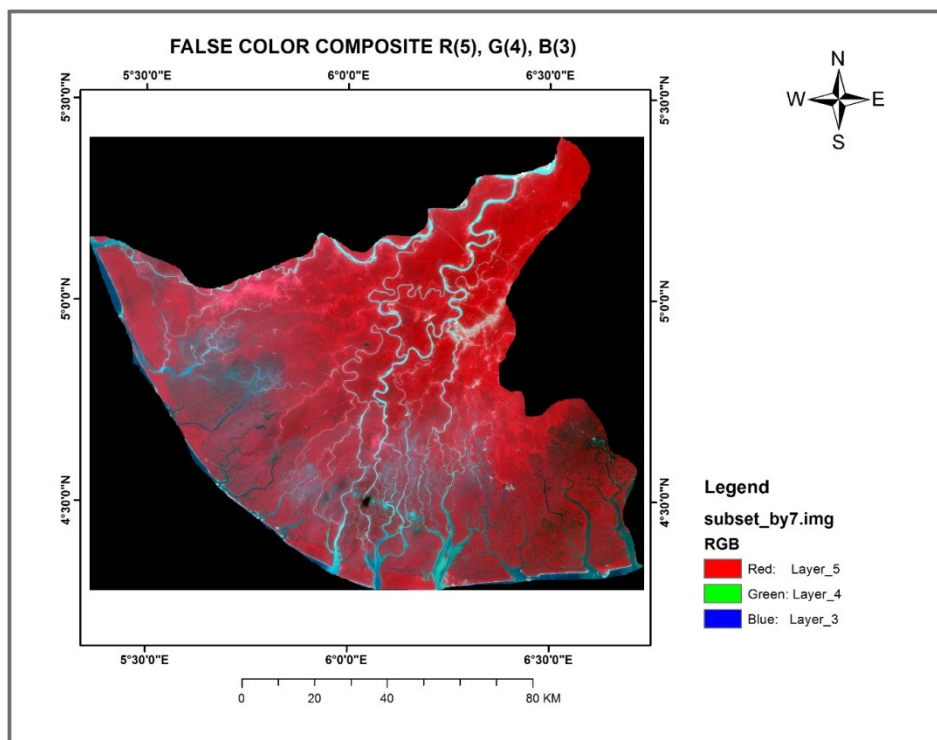


Figure 8: FCC R(5),G(4),B(3)

### 5.3 Lineament Extraction, Analysis and Interpretation

#### 5.3.1 Lineament Extraction

The methodology followed in this project was similar to the procedure presented by, Rahiman T. et al (2008), who used four major steps in lineament analysis.

Lineaments were extracted both Manually and Automatically, the image bands were combined forming image composites, these FCC images were imported into a ArcGIS 10.3, and displayed with some auxiliary data showing roads, settlement and hydrology. The auxiliary data (topographic sheet) were overlain on the image mosaic to assure that man-made features were not mistakenly identified as a structurally-related lineament. This created a situation in which geological structures coincident with man-made features could be distinguished and excluded.

To store the digitized lineaments as poly lines together with associated lineament information such as the length, orientation and category, a geodatabase was created using ESRI's ArcCatalog.

- **Manual / Visual Lineament Extraction**

Manual extraction was done for both FCC images Figure 9 and 10. This method was done based on expert judgment image interpretation and clues used for lineament mapping, namely drainage pattern, tonal variation, vegetation difference, or the presence of a series of connecting streams, with near linear pattern, This method is quite subjective as it requires a high level of image interpretation skills, expertise and training, to ensure the lineament were properly extracted, a decision was made to verify lineaments extracted by showing it to another trained image interpreter to validate the extracted linear features on the satellite image.

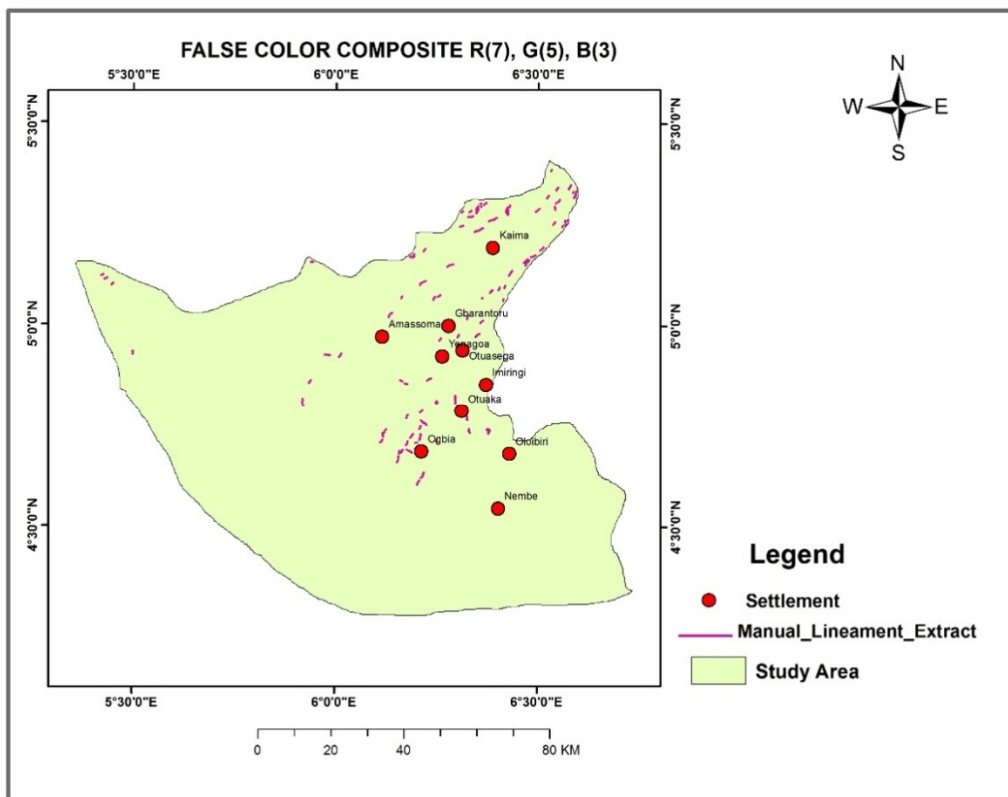


Figure 9: Manual Lineament Extract from FCC 7,5,3

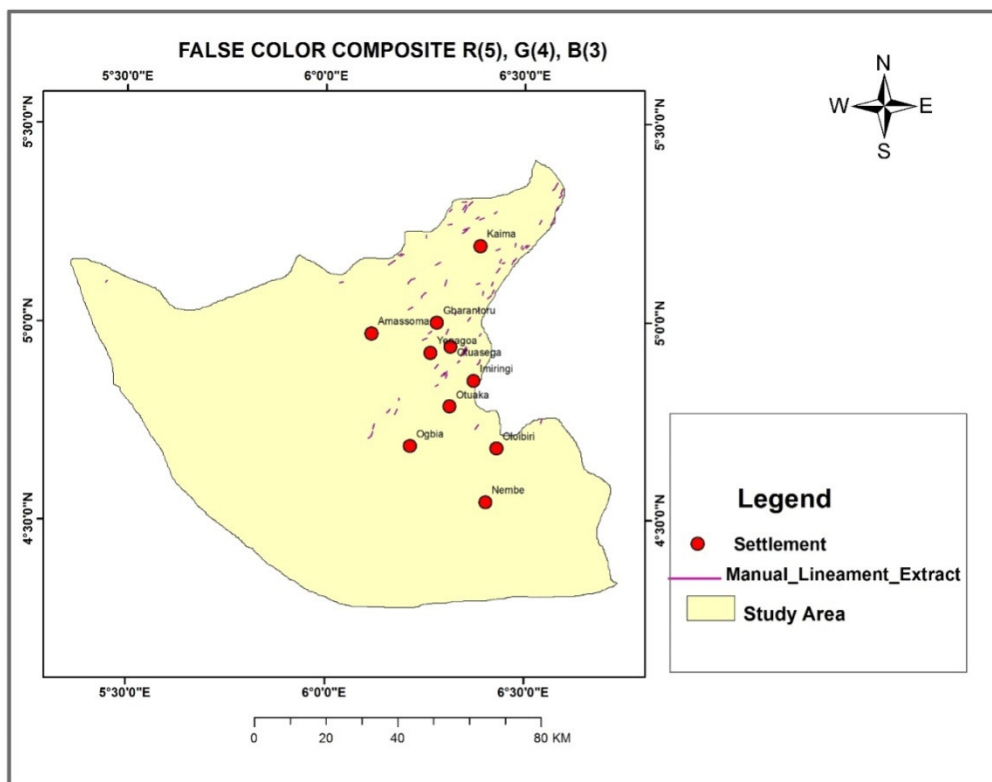


Figure 10: Manual Lineament Extract from FCC 5,4,3

### ▪ Automated Lineament Extraction

There are various computer-aided methods for lineament extraction that have been proposed. Most methods are based on edge filtering techniques. The most widely used software for the automatic lineament extraction are ERDAS, ENVI and PCI Geomatica

This analysis employed the use of PCI Geomatica 2014 geospatial software, it helped reduce subjectivity, save time and aided comparison and validation with the manually extracted lineaments. Automatic extraction was done for both false color composite images. Figure 11 and Figure 12

The algorithm parameters involved in automated extraction using PCI Geomatica are:

- RADI - Radius of filter in pixels
- GTHR - Threshold for edge gradient
- LTHR - Threshold for curve length
- FTTH - Threshold for line fitting error
- ATHR - Threshold for angular difference
- DTHR - Threshold for linking distance

The algorithm consists of three stages (PCI Geomatica Manual, 2013):

- Edge Detection
- Thresholding
- Curve Extraction

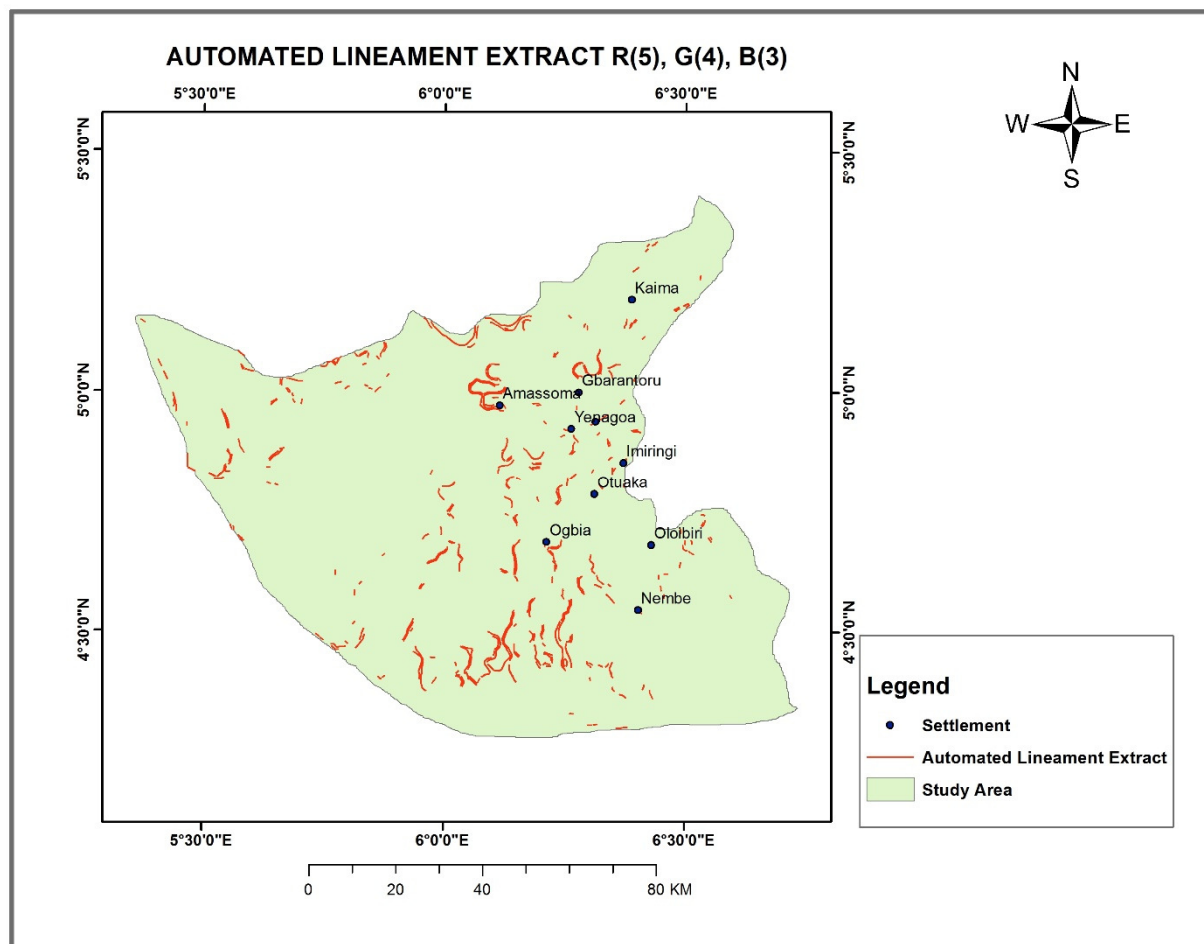


Figure 11: Automated Lineament Extract from FCC 5,4,3

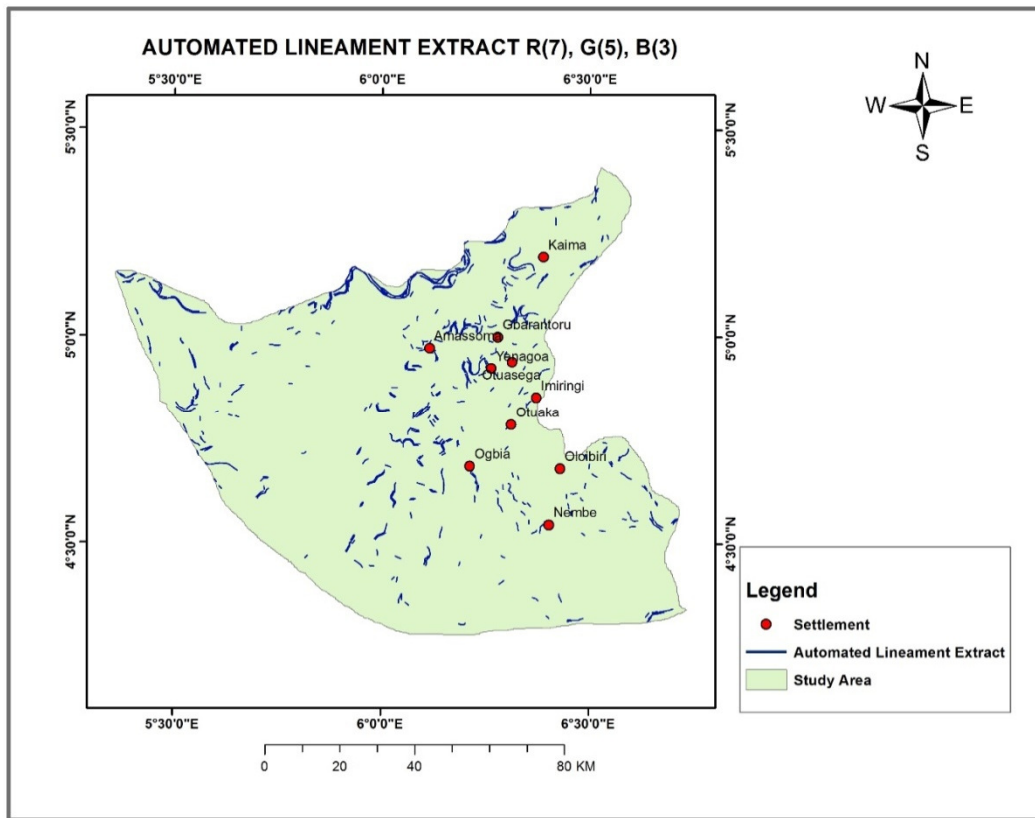


Figure 12: Automated Lineament Extract from FCC 7, 5, 3

### 5.3.2 Lineament Merge

The lineament extracted manually from both FCC 7,5,3 and FCC5,4,3 images were viewed and compared with their corresponding automated lineament extract from FCC 7,5,3 and FCC 5,4,3. Manual lineament extract from FCC 7,5,3 and automated lineament extract from FCC 7,5,3 were compared while manual lineament extract from FCC 5,4,3 and automated lineament extract from FCC 5,4,3 were also compared.

For both sets of comparisons, lineaments that occurred as duplicates between the automated and manual were deleted leaving only one of the set of lineaments. This procedure is done to further validate the authenticity of lineament extracted, after which the corresponding sets of manual and automated lineament for each FCC images are then merged into a single database. Figure 13 and Figure 14

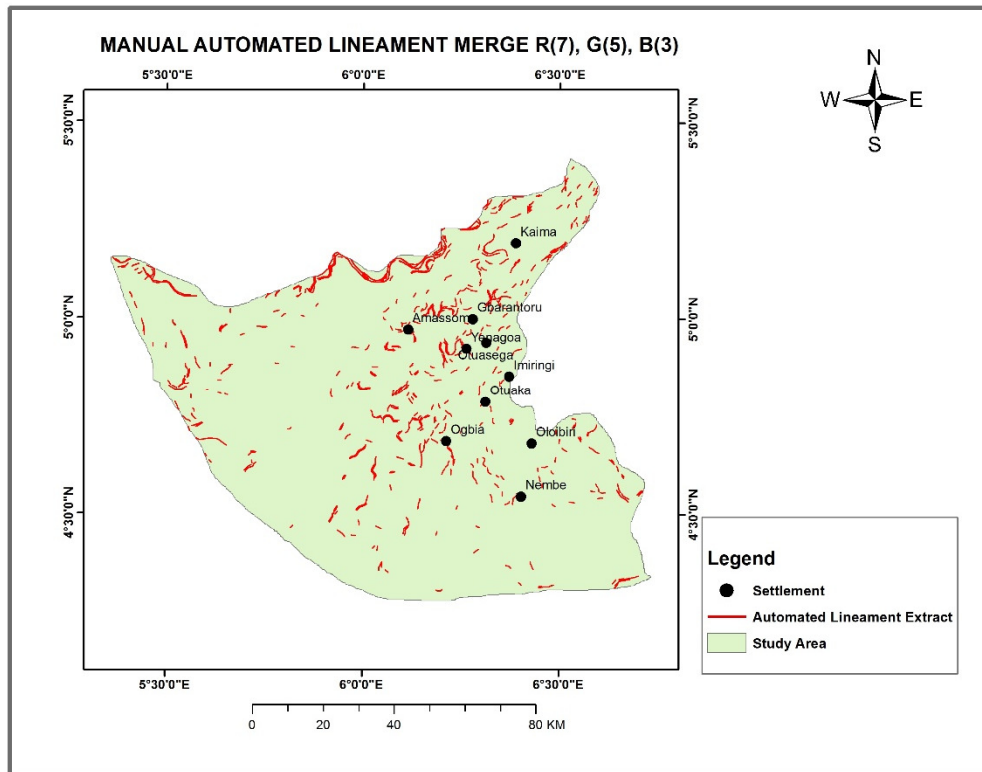


Figure 13: Manual & Automated Lineament Merge FCC 7,5,3

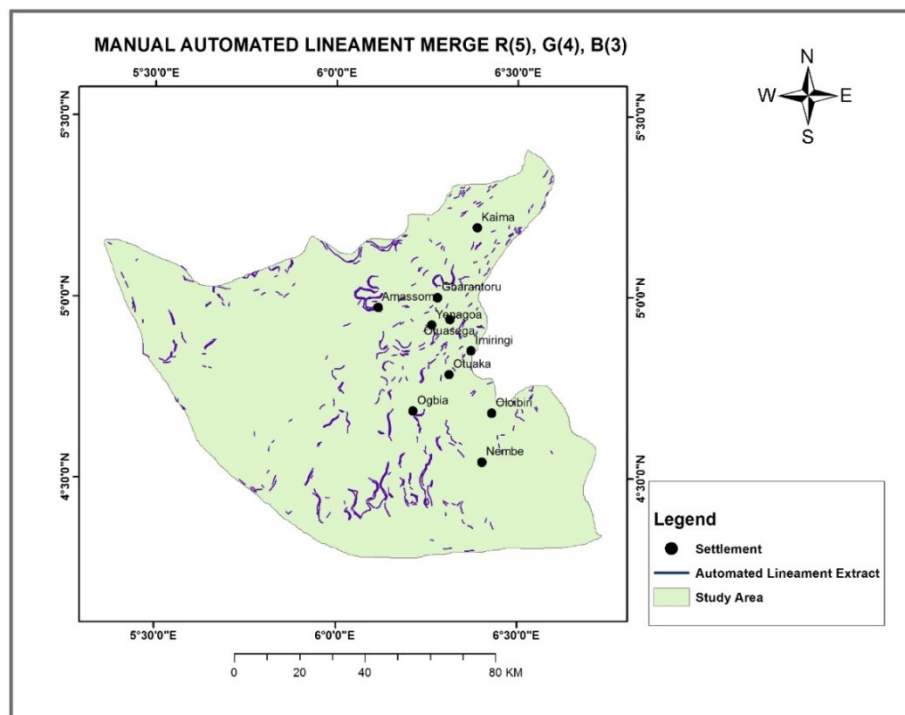


Figure14: Manual & Automated Lineament Merge FCC 5,4,3

After the merger of the manual and automated lineaments, a density map is produced for both FCC images; both density maps are then spatially correlated.

Spatial correlation refers to the degree to which a set of spatial features and their associated data values tend to be clustered together in space. Hence In order to increase the robustness of the lineament density of the study area, spatial correlation was done on the two output lineament density raster map using the raster calculator in the map algebra (spatial analyst tool box) in ArcGIS, the density map were summed up and divided using the division operation.

The lineament density raster of the two FCC images were combined and divided by Two (2), using the raster calculator, in order to find an average of the lineament density cluster and an average of the spatial distribution of the lineament across the study area. Thereby producing a spatially correlated lineament map Figure 18.

## 6. RESULTS AND DISCUSSION

Result shown in Table 2 is the number of lineament extracted both manually and automated for the various FCC images.

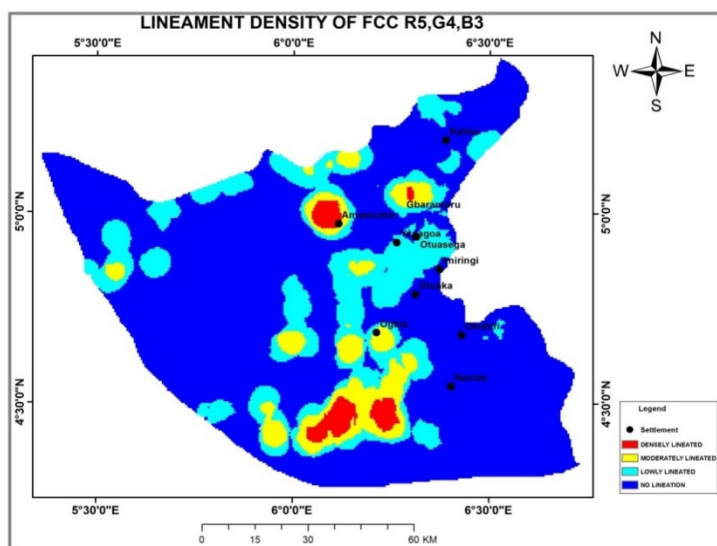
**Table 2: Number of lineament extracted**

SATELLITE COMPOSITE	IMAGE	Manually Extracted	Automated Extraction
R(7), G(5), B(3)		105	645
R(5), G(4), B(3)		87	671

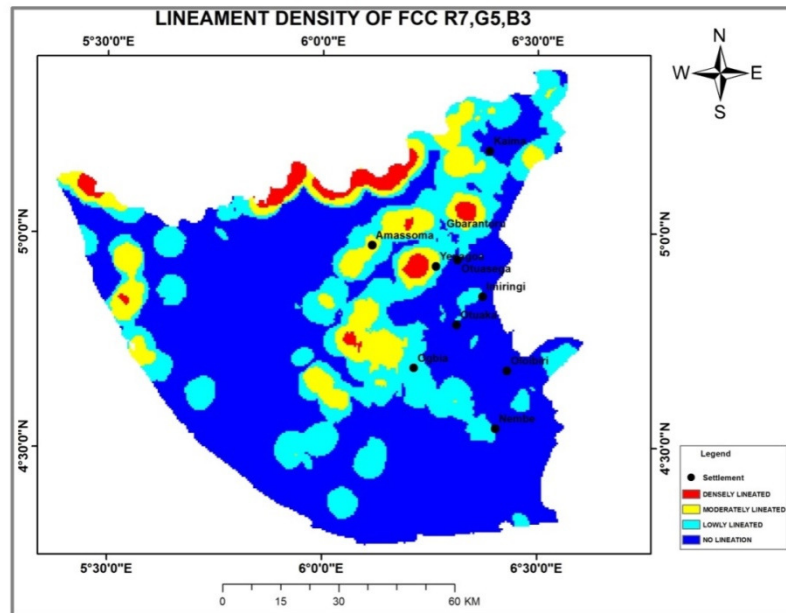
Color composite images of different band combinations was done, the false color composite (FCC) that combines one visible (VIS), one near-infrared (NIR) and one short-wave Infrared band (R(7),G(5),B(3)), this combination shows a large color variation for different surface materials and is therefore frequently used for geologic interpretation (Figure 7). This composite shows the vegetation in green color, due to the high reflectance of vegetation in NIR, and detects differences in vegetation and moisture content, Jensen J.R, (2005), the Color Infrared Composite band was also done (R(5),G(4),B(3)) (Figure 8), the true or natural color composite of R(3), G(2), B(1) shows the image in its natural state. This research analysis relied mostly on using the FCC and the color infrared false color band combinations.

### 6.1 Analysis (Lineament Density Map)

After extraction and merger of the manual and automated lineaments from the various FCC band combinations, a lineament density map was produced to show the number of lineaments per unit area, facilitating the identification of regions with high lineament density and areas lacking lineaments. lineament density maps were produced for merged lineament (Figure 16 and Figure 17).



**Figure 16: Lineament Density Map FCC 5,4,3**



**Figure 17: Lineament Density Map FCC 7,5,3**

It was observed that for both lineament density maps produced, from figures 16 and 17, the concentration of lineament were more in the North Eastern part of Bayelsa around Gbarantoru area and the south eastern part, while the north western part had the least lineament extract.

The proposed site for the gas capture facility is within the North eastern axis, the area showed variation in lineament density, the Gbaran area showed moderate lineation in both density maps produced.

In order to validate the lineament density of the study area, a method was employed to spatially correlate both FCC 7, 5, 3 and 5, 4, 3 lineament density maps to find a similarity and average spread of lineament from both density maps producing the spatially correlated map (figure 18). Spatial correlation refers to the degree to which a set of spatial features and their associated data values tend to be clustered together in space.

Spatial correlation was achieved by the lineament density raster of the two FCC images combined together and divided by two (2), using the raster calculator operation, in ArcGis Tool box, an average of the spatial distribution of the lineament across the study area is obtained .

It was observed that when the merged lineaments ( manual and automated) from both the FCC 5,4,3 and 7,5,3 were overlaid on the correlated density map, the concentration of lineaments when viewed coincided with varying degree of lineament density intensification. It was seen that after correlating the two density maps, the correlated map showed averagely that the lineaments were lowly lineated, and that the lineament concentration were still seen to be more within the North Eastern region of the study area in Gbaran community.

This map could be used for baseline study and aid in future research for geosequestration processes and for CO<sub>2</sub> sequestration site characterization, showing densely lineated areas which could be unlikely suitable for such projects in the future.



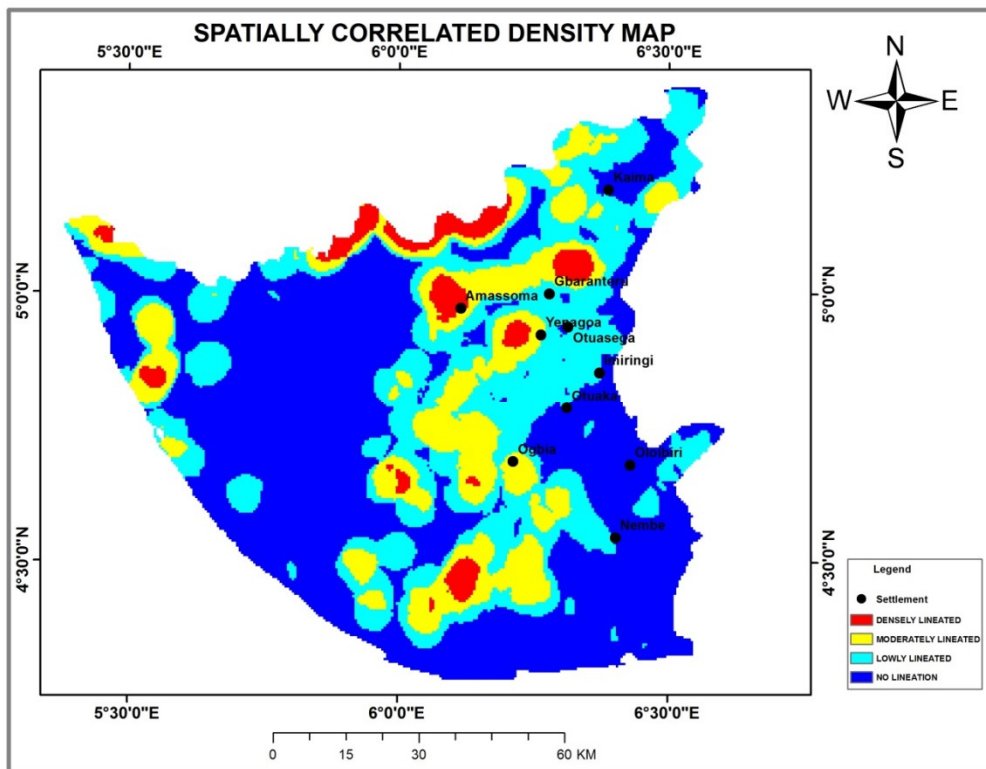


Figure 18: SPATIALLY CORRELATED LINEAMENT DENSITY MAP

**ROSE DIAGRAM**

Rose diagrams were also done on the lineament using Rockwork-v.2014 software to determine the structural trend and directional frequency of the mapped lineament over the study area, the rose plots were analysed for both the two FCC lineament extracts. (Figure 22 and Figure 23). It was observed that the trend of lineaments extracted in the study area for both composite images were similar, Table 3 with both having the dominant primary orientation in the NNE direction and SWS direction. This further goes to show that the lineament across the study area are significantly similar in structural orientation and also corroborates the result of the spatially correlated density map produced, from the FCC of 7,5,3 and 5,4,3.

Table 3

FCC	Dominant Orientation	Lineament	Less Dominant	Minor Orientation
R(5), G(4),B(3)	NNE-SWS		WNW-ESE	ENE-WSW
R(7), G(5), B(3)	NNE-SWS		WNW-ESE	ENE-WSW

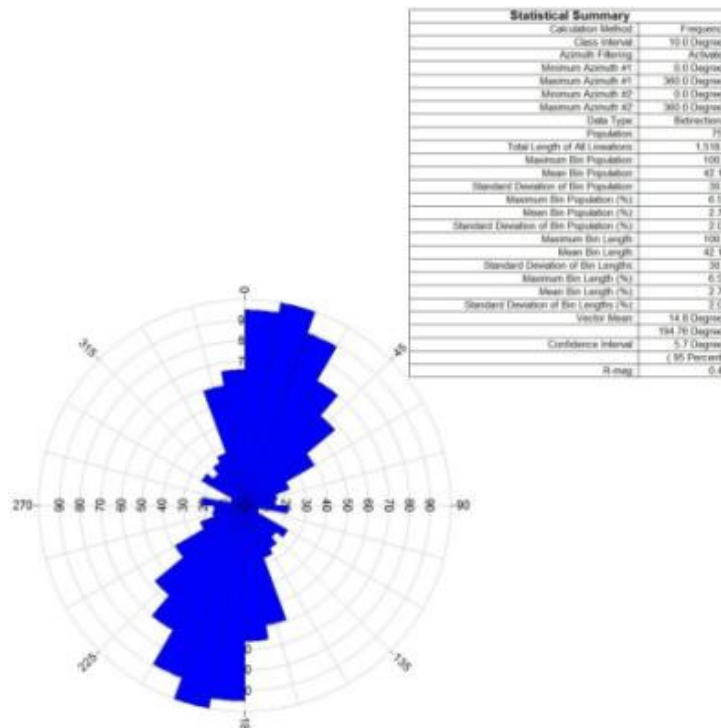


Figure22: Rose Plot for FCC 5,4,3 lineament extract

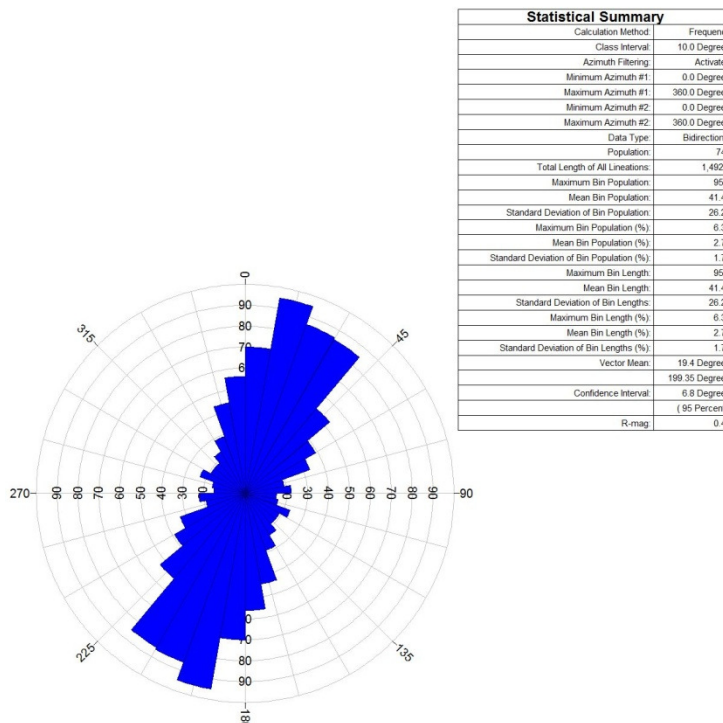


Figure 23: Rose plot for FCC 7,5,3 Lineament extract

**CONCLUSION AND RECCOMENDATION**

The main goal of the project was to identify and digitize lineaments from various remote sensing data, Landsat images with varying composite band combination with the aim of creating a comprehensive lineament map of Bayelsa state with focus on the North eastern part of the state . The data types , image processing techniques ,

lineament identification method and advanced interpretation techniques such as density maps, rose diagram, spatial correlation allow for the identification of lesser-known structures, which could be potentially related to the overall regional structural geology. A consistent way of mapping lineaments was developed and maintained throughout the project that could be repeated in other locations for faster lineament identification over large regions. It was expected that the digitized lineaments could be related to known structural geology features, such as fractures and faults.

The result of the study shows the spatial auto correlated lineament density averagely and the lineament concentration across the study area.

Also, rose diagram plot were done on the various false color composite bands to show the structural lineament orientation.

The final goal of the project was to identify a region potentially suitable for CO<sub>2</sub> sequestration within the project area. The research could aid as a base line for future research for geosequestration processes and the avoidance of highly lineated areas where there could be possible leakage of the sequestered CO<sub>2</sub>.

Although geologic storage of carbon is an evolving technology especially in developing countries like Nigeria, this research could serve as a base line study for future projects within the region.

The lineament were extracted from satellite data at a resolution of 30m., for detailed lineament analysis, a higher resolution of 10m or 20m which could be acquired from Digital Elevation Model (DEM) and ASTER data would aid increased lineament extraction.

Subsurface geophysical data, data of depleted oil and gas wells, if available would go a long way when correlated with the lineament map information, to produce a detailed comprehensive map of site suitability for CO<sub>2</sub> sequestration in the study area and generally the region.

## REFERENCE

- Casas AM, Cortes AL, Maestro A, Soriano M.A, Riaguas A, and Bernal J. 2000, "A program for lineament length and density analysis", *Computers and Geosciences*, Vol. 26, No. 9/10, 1011-1022.
- Cook PJ, Rigg AJ and Bradshaw J, 2000. "Putting it back from where it came from: is geological disposal of carbon dioxide an option for Australia". *The APPEA Journal*, vol.40 (1), pp. 654-666.
- Holloway S, 2005, Underground sequestration of carbon dioxide--a viable greenhouse gas mitigation option: *Energy*, v. 30, no. 11-12, p. 2318-2333.
- IPCC 2005. *IPCC Special Report on Carbon Dioxide Capture and Storage*. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [Metz, B, Davidson, O, de Coninck, H C, Loos, M and Meyer, L A (eds.)]. Cambridge University Press, New York.
- Jensen JR, 2005, "Introductory Digital Image Processing - A Remote Sensing Perspective" Prentice Hall Series in Geographic Information System: Upper Saddle River, Pearson Prentice Hall.
- Kogbe CA, 1989, "The Cretaceous and Paleogene sediments of southern Nigeria In: *Geology of Nigeria*", C.A kogbe, (editor), Elizabethan Press, Lagos, pp. 311-334.
- Lilles and TM, Kiefer RW and Chipman JW, 2004, "Remote Sensing and Image Interpretation": Hoboken, John Wiley and Sons.
- Mostafa ME and Zakir FA. 1996, "New enhancement techniques for azimuthal analysis of lineaments for detecting tectonic trends in and around the AfroArabianShield. *International Journal of RemoteSensing*", Vol.17, No.15, 2923-2943.
- Nalbant S and Alptekin Ö, 1995, "The use of Landsat Mapper imagery for analysing lithology and structure of Korucu-Dugla area in western Turkey", *International Journal of Remote Sensing*, Vol.16, No.13, 2357-2374.
- Rahiman T and Pettinga J, 2008, "Analysis of lineaments and their relationship to Neogene fracturing, SE Viti Levu, Fiji": *Geological Society of America Bulletin*, v. 120, no. 11/12, p. 1544-1555.
- Sadorsky P, 2009, "Renewable energy consumption, CO<sub>2</sub> emissions and oil prices in the G7 countries": *Energy Economics*, v. 31, no. 3, p. 456-462.
- Short KC and Stauble AJ. 1967. Outline of the Geology of the Niger Delta. *Bull. AAPG*. 51, 61-779
- Wright JB, Hasting DA, Jones WB and Williams HR, 1985. "Geology and mineral resources of West Africa", Allen and Unwin Limited, UK, 107pp,
- Zakir FA, Qari MHT and Mostafa ME, "A new optimizing technique for preparing lineament density maps", *International Journal of Remote Sensing*, Vol. 20, No. 6, 1073-1085. 1999.

**Cite this Article:** Benibo T, Abayomi A, Ogbale J, Benibo I (2016). Lineament Mapping Using Remote Sensing Techniques for Geologic CO<sub>2</sub> Sequestration Site Characterization, in Gbaran, Bayelsa State Nigeria. *Greener Journal of Geology and Earth Sciences*, 4(2): 023-039, <http://doi.org/10.15580/GJGES.2016.2.030116049>