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Investigation of the Geomorphology, Mineral and Hydrocarbon Potential of Abia State and Environs, Southern Nigeria Using Landsat Imagery

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ABSTRACT: *Landsat imagery of Abia State and environs was obtained from the United States Geological Survey database in GeoTiff and Metastate format to study the vegetation, drainage and surface temperature. Also data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) were obtained to study the mineralogical and hydrocarbon potentials. Band 10 of the Enhanced Thematic Mapper Plus (ETM+) of Landsat 8 with a scene size of 220km by 110km and a resolution of 100m was used. Acquired data were analysed using Didger 5.0 and QGIS 3.8 software. Results show that the study area has a surface temperature of 20-34^{o}C with a Guinea Savannah and rainforest vegetative cover. It also has a dendritic drainage pattern. 4,090 lineament features were obtained from the landsat imagery and the lineament density ranges from 22.7-113.7km^{-1} with a NE-SW structural trend. Areas like: Bende, Umuahia, Arochukwu and Ohafia (Abia State); Ihuo (Imo state); Afikpo, Amagunze and Eha-Amufu (Ebony State) are most likely to have minerals due to their high lineament density. However, areas like Aba, Abi, Obolo-Eke, and Ikem areas in Abia, Kogi, Benue and Enugu States have low lineament density indicative of their likely potential to have hydrocarbon deposits.*

KEYWORDS: *Lineament density, Landsat, Mineral, hydrocarbon, vegetation, surface temperature*

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I. INTRODUCTION

Remote sensing (RS), also called earth observation refers to obtaining information about objects or areas at the Earth's surface without being in direct contact with the object or area. Remote sensing techniques allow taking images of the earth surface in various wavelength region of the electromagnetic spectrum (EMS). One of the major characteristics of a remotely sensed image is the wavelength region it represents in the EMS. Some of the images represent reflected solar radiation in the visible and the near infrared regions of the electromagnetic spectrum, others are the measurements of the energy emitted by the earth surface itself i.e. in the thermal infrared wavelength region [1].

Some of the most commonly used remote sensing data sets for mapping land use and land cover are those from Landsat, Système Probatoired' Observation de la Terre (SPOT), Indian Remote Sensing (IRS), Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER), Moderate Resolution Imaging Spectrometer (MODIS), Japanese Earth Resources Satellite (JERS-1), NigeriaSat-1 and NigeriaSat-2 satellites. The Landsat data have greater spectral resolution [2].

Landsat is an invaluable resource for monitoring global change and has been used as a primary source of medium spatial resolution earth observations [3] – [10]. Satellite imagery can also reveal subtle variations in soil moisture, soil type, mineral and vegetation distribution, all of which are useful in exploration. It can map and identify large scale geological structures related to hydrocarbon and mineral deposits that ground-based surveys may find more difficult to see: Satellite radar interferometry can precisely identify faults or slight ground motion connected with hydrocarbon reservoir [11].

Geologic information can be extracted from satellite imagery and this can be combined with other geologic and geophysical data to build consistent geological models for the surface and subsurface. It can also generate start models prior to the beginning of a geophysical survey, [12], [13]. Conversely, geological and geophysical data can calibrate models derived from satellite imagery [14]. Satellite imagery can provide detailed models of the surface and near surface which provide input to data quality estimation before and during acquisition. For data processing, satellite imagery can supply input to processes that correct for noise related to near-surface properties [15].

II. THE STUDY AREA

The study area lies in the Southern Benue trough consisting of Abia state and parts of Imo, Enugu, Ebonyi and Benue states. It lies between latitude 5^0 0'N to $7^0$0'N and $7^0$0'E to $8^0$0'E covering about 48,400 km^2. It has an elevation of about 100m to 600m above the sea level. The southern part of the study area has a relatively even topography while the Northern part has a sloppy topography with a highland of 500-600m above the sea level sloping downwards to 100m above sea level. Figure 1 shows the map of Nigeria with the study area while Figure 2 shows the location map of the study area with its elevation.

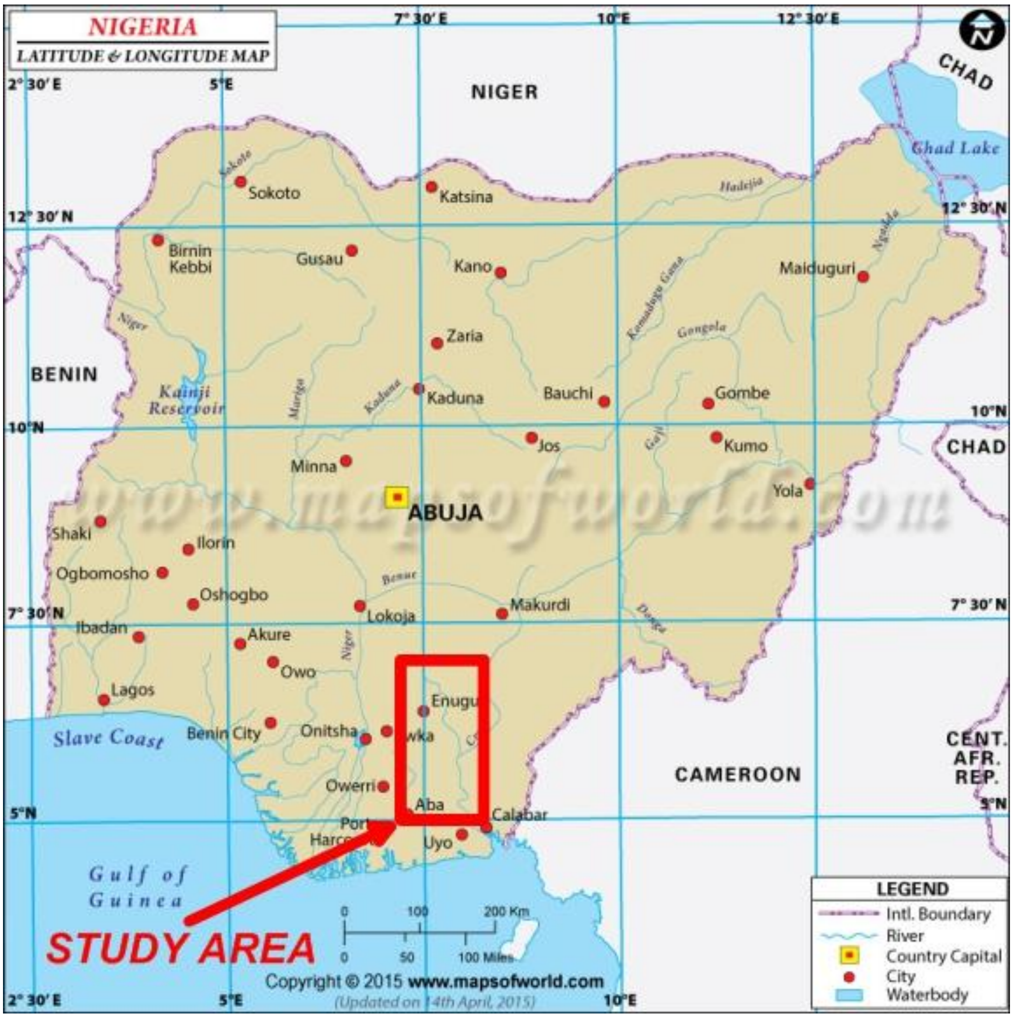

Figure 1. Map of Nigeria Showing the study area.

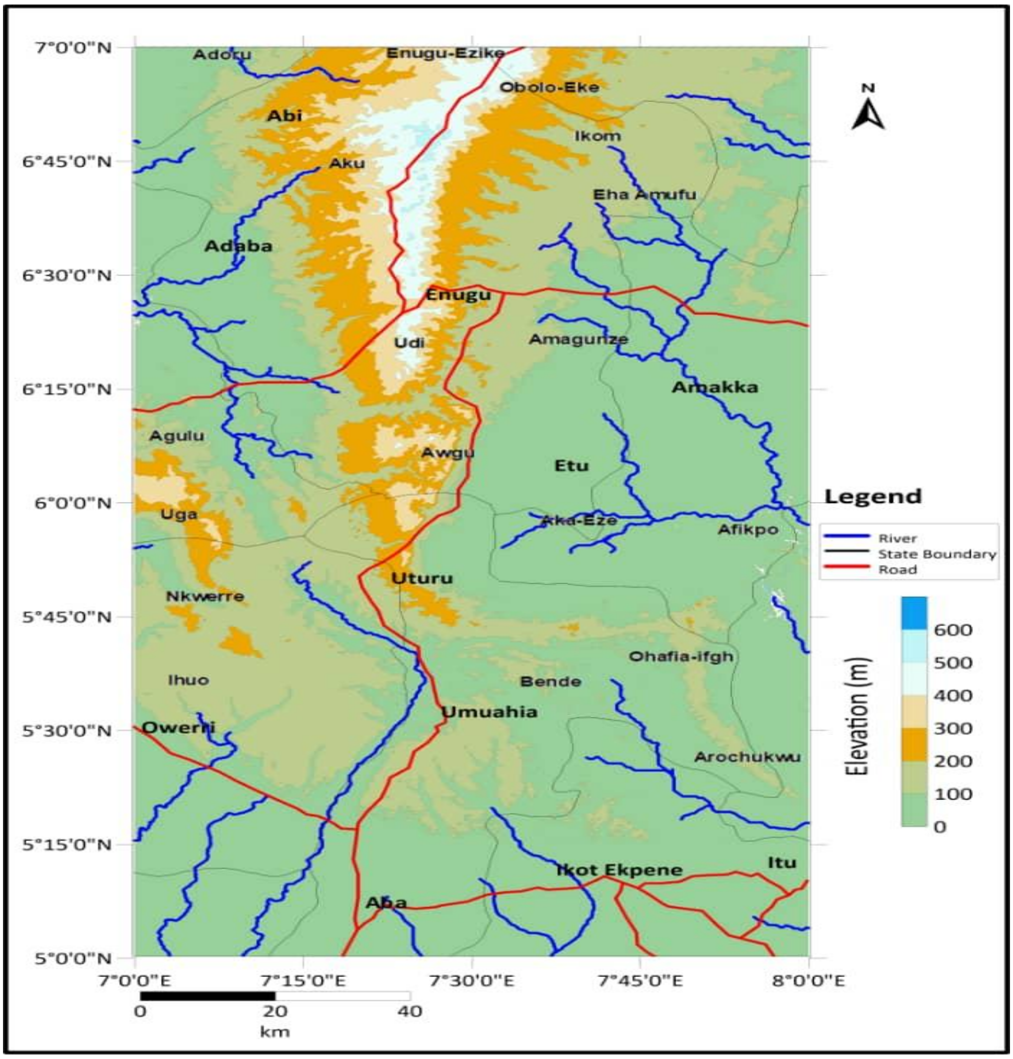

Figure 2: The location map of the study area showing the elevation

2.1 Geology of the Study Area

The study area is part of the sedimentary basin of the Southern Benue Trough full of rocks of Cretaceous to tertiary ages. The stratigraphic history of the Southern Benue Trough is characterized by three sedimentary phases namely; the Abakiliki – Benue phase (Aptian -Santonian), the Anambra – Benin phase (Campanian – Mid Eocene) and the Niger Delta Phase (Late Eocene - Pliocene) [16]. The Southern Benue Trough originated during the separation of the African plate and South American plate as a failed arm of an aulacogen at the time of the opening of the South Atlantic Oceans [17].

The study area consists of the Cretaceous; shale and limestone of the Asu river group, black shale, siltstone and sandstone of the Eze-Aku formation, sandstones, false bedded sandstones, limestone and coal of the Nsukka formation. The Imo group and the Ogwashi-Asaba formations make up the tertiary units with clay, shale and limestone. The quarternary alluvium, sand and clay which are of the Benin formation form the youngest stratigraphic unit of the study area [18], [19]. The geologic map of the study area is as shown in Figure 3.

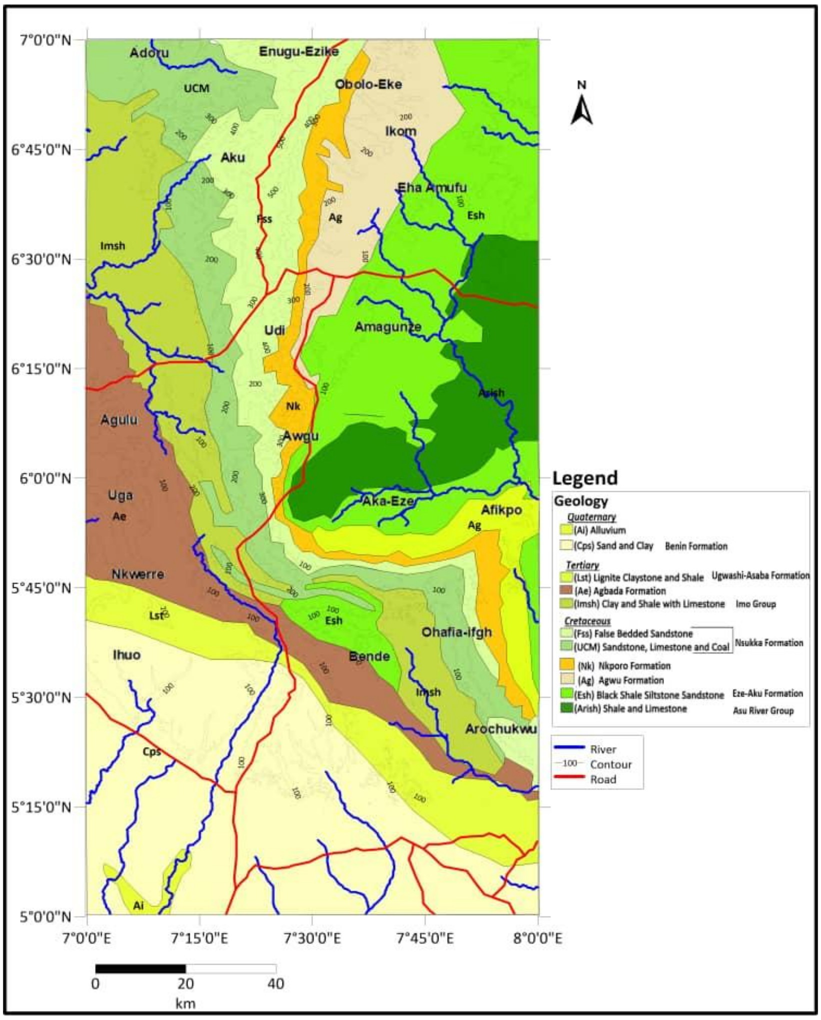

Figure 3. Geologic Map of the Study Area.

III. MATERIALS AND METHODS

The landsat imagery for the study area was acquired from the United States Geological Survey (USGS) database in GeoTIFF and metastate formats to determine the drainage, surface temperature and vegetation of the study Area. The metadata contains all of the ancillary data which are used to calibrate the data to radiances. The earth is observed by satellites along their path called swath and the imageries are specialized data sets called scenes for each spectral band displaying measured intensities. The imagery for the study area was generated by landsat 8 which orbits the earth at an altitude of 705km in a 185km swath as it moves from North to South over the sunlit side of the earth making a complete orbit every 98.8 minutes [20]. Band 10 of the scene in the Enhanced Thematic Mapper Plus (ETM+) of Landsat 8 was used in the study because it provides more accurate surface temperature. The imagery was collected at a resolution of 100m with an approximate scene size of 220km North-South by 110km East-West. The wavelength of the spectral band ranges from10.6 to 11.19 μm

The landsat ETM data of the study area was digitally processed and enhanced to produce single band images, band ratios, colour composites, and classified images complemented by digitized geologic maps for the study area. Drainage patterns and textures, bare rocks and vegetated areas were enhanced in single band images. The colour composites were used as background data for both supervised and unsupervised image classification. The landsat ETM data obtained was subjected to various image enhancement and transformation routines like linear enhancement, statistical analysis, principal component analysis and normalized difference vegetation index (NDVI).

The Elevation and linear structures were mapped from data acquired in 2016 from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). ASTER is a sensor in on board the Terra Sattellite launched into the orbit of the earth by the National Aeronautics and Space Agency (NASA) in 1999. The ASTER image as obtained from NASA's Earth Observing Systems was captured with light reflectance of 45 and 135 degrees at a better resolution of 30m [21]. The World Geodic System 1984 which is the default data coordinate system was used in the georeference projection.

Lineament was extracted from the data from ASTER and enhancement and analysis were carried out. The image enhancements carried out include; contrast stretching, shaded relief, reflectance, edge detection and spatial filtering. These were done to enhance the satellite image's sharpness, visual interpretation and to reduce noise while aiding structural interpretation. Didger 5.0 software was used in the image enhancement while QGIS 3.8 software was used to extract the lineaments and carry out statistical analysis of the interpreted lineaments in the area. Azimuth Distribution Diagram (Rose Diagram) was used to summarize the lineament trend as explained by [22].

These enhancements help for better visual interpretation to reduce noise distortion in the image prior to multiband image band classification and also to detect line features used in structural interpretation. Lineaments which are linear structures except anthropogenic features like roads, railways, and electronic grids, were enhanced. False colour composites were used to bring out more lineament details. Lineaments were thereafter digitized and the lineament density obtained using equation (1)

$$L_D = \frac{\sum L}{A} \qquad \text{…………….} \ (1)$$

where L = Lineament, A = area.

Lineaments are linear features which provide information about the underlying geological structure [23]. Mapping geological features is an essential tool in oil exploration, groundwater storage and understanding the mechanisms of environmental disasters. Regional geophysical data can be used as an analogue to topographical information to interpret geophysical lineaments. Lineament interpretations based on both topographical and geophysical data are needed in the characterizations of an area as they complement each other [24].

3.1 Calculation of Land Surface Temperature (LST)

There is a positive correlation between true kinetic temperature of a body and the amount of radiant flux emitted by an object and it is on this premise that thermal remote sensing is based on. Therefore, a distantly placed radiometer can easily measure radiant temperature [25]. Data from the landsat-8 thermal band 10 was used to calculate the landsurface temperature of the area under investigation by first converting landsat thermal band digital number (DN) using equation (2) [26].

$$L_\lambda = M_L Q_{cal} + A_L \qquad \text{……} \ (2)$$

where L_λ = Top of Atmosphere (TOA) spectral radiance

M_L = Band-specific multiplicative rescaling factor from metadata

Q_{cal} = Quantised and calibrated standard product pixel value DN

A_L = Band specific addictive rescaling factor from metadata

For spectral band 10, M_L and A_L have identical values of 3.34×10^{-4}.

The spectral radiance was thereafter converted to surface temperature in Celsius using equation 3 as defined by [26].

$$T = \frac{K_2}{In(\frac{K_1}{L_\lambda} + 1)} - 273.15 \qquad \text{…….} \ (3)$$

where T = At-Satellite Brightness Temperature

L_λ = Top of Atmosphere (TOA) spectral radiance

K_2 = Caliberation constant 2 (Kelvin)

K_1 = Caliberation constant 1 ($Wm^{-2}sr^{-1}\mu m^{-1}$)

K_1 and K_2 are coefficients which are determined by the effective wavelength of a satellite sensor. For landsat 8 thermal band 10, $K_1 = 774.89\ Wm^{-2}sr^{-1}\mu m^{-1}$, $K_2 = 1321.08K$.

IV. RESULTS AND DISCUSSION

4.1 Drainage and Vegetation

The drainage pattern of the study area follows a dendritic pattern as the tributaries join the larger streams at acute angles as seen in Figure 4. The prevalent dendritic pattern of is indicative that the region is underlain by homogenous material and the that the geology of the subsurface has a similar resistance to weathering which apparently has no effect and control on the tributaries' directions. Therefore the rock types are mainly impervious and non-porous [27]. The study is drained by different rivers namely; Imo, Orashi, Calabar, Aboine, Aloma and Anambra rivers.

The vegetation on the other hand found to be mainly that of the rainforest and the Guinea Savannah as seen in Figure 5. The rainforest area is characterized by a rainfall of about 1500mm – 2000mm within 8-9 months of rainfall [28]. Trees found around this region mingle together forming a dense canopy cover. Some of them include; oil palm, iroko, mahogany, rubber and walnut. The Guinea Savannah areas are the grasslands which cover the flat and open areas. Natural grasses, sparse woodland or trees are seen in such areas. The trees grow in clusters reaching maximum heights of 6m. Elephant grass fills in between the trees growing to a height of about 3m.

However due to civilization and infrastructural development, there are areas where there are very insignificant vegetation. This can be found mainly in the built up areas and state capitals.

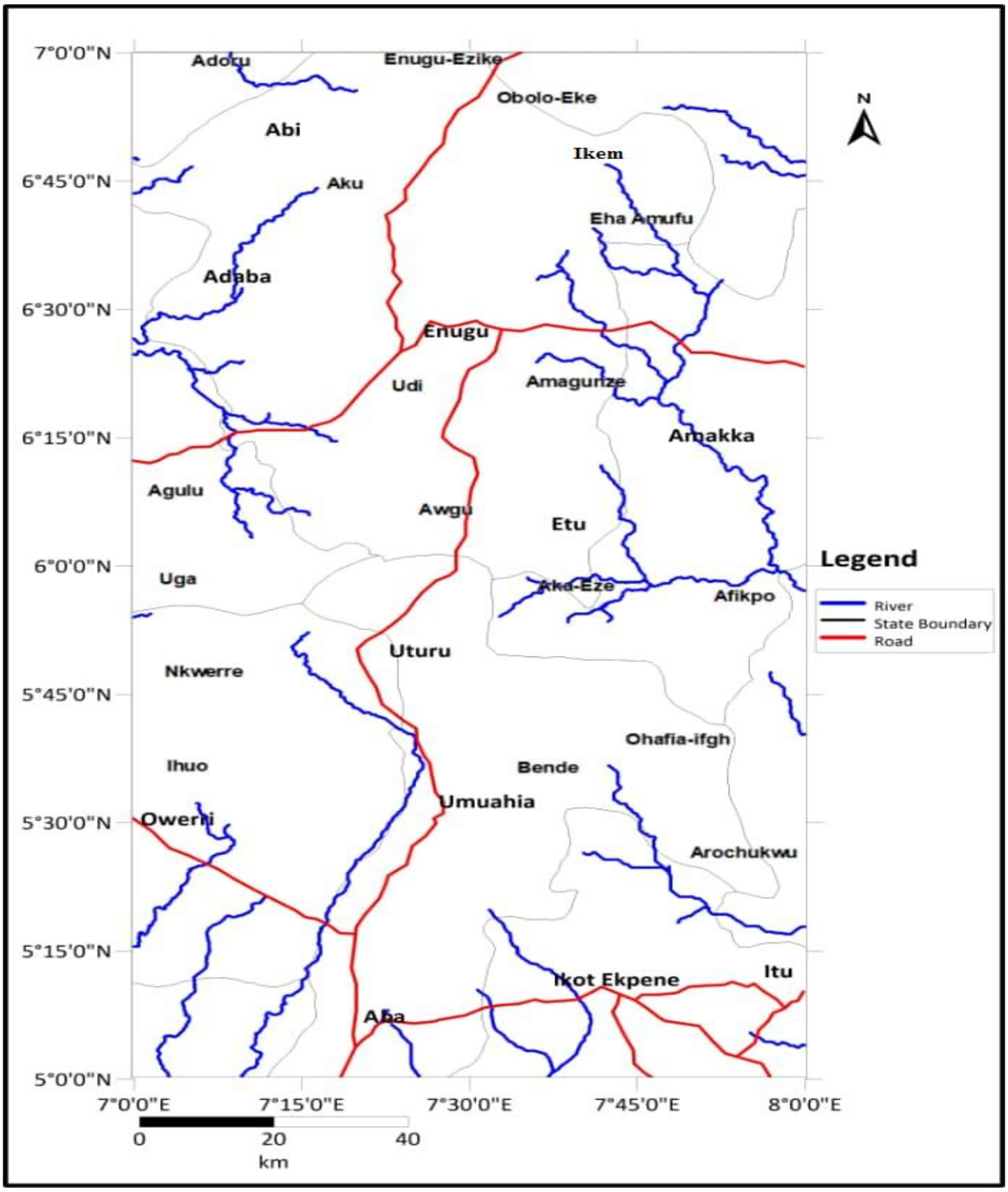

Figure 4: Drainage pattern of the Study area

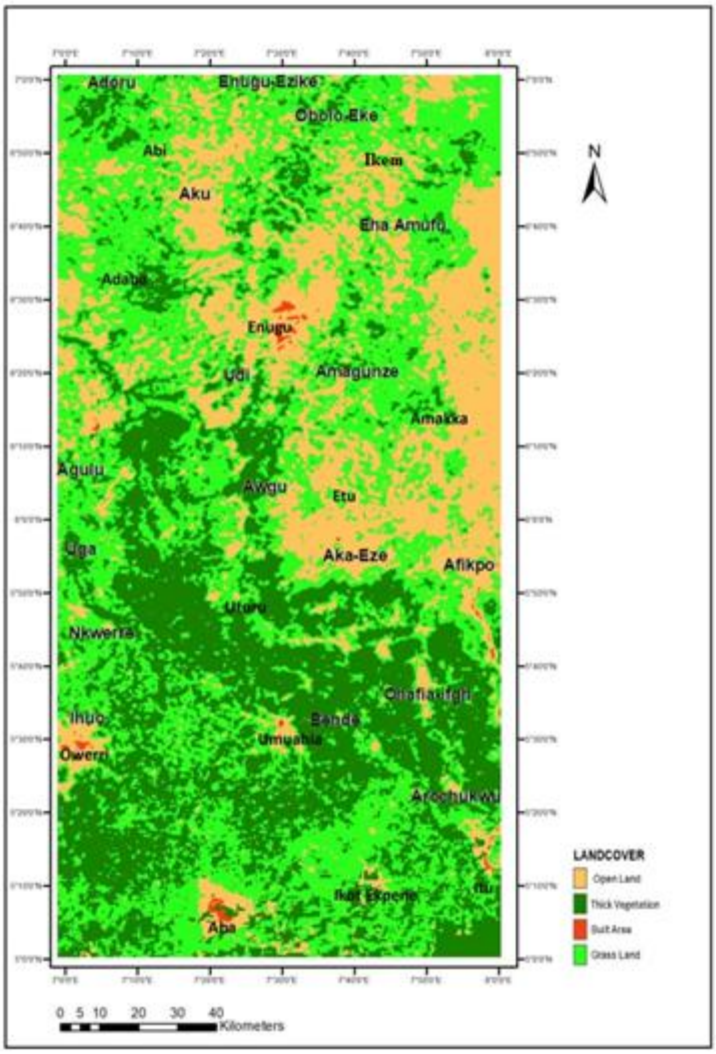

Figure. 5: Vegetation of the Study area

4.2 Land Surface Temperature

The thermal radiance emission from land surface as the incident solar radiation interacts with the heat on the ground or the canopy of vegetative areas determines the LST [29]. Therefore, LST measurement examines the thermal heterogeneity of the surface of the earth and its impact on surface temperature due to natural and human-induced changes [30], [31].

Land surface temperature of the study area is as shown in Figure 6. It has a high surface temperature of 34.303^0C and a low temperature of 20.1826^0C. The North-Eastern Region of the study area is predominantly warmer with high temperatures while the south eastern parts are are cooler with low temperatures. However, the Northwestern and Southwestern regions of the study area have varying temperature values.

Since LST is more sensitive to variations in the density of vegetation [32], one can observe that the LST of Figure 6 has a correlation with the vegetation of the study area in Figure5 in that areas with thick vegetation cover are relatively cooler than areas with sparse vegetation cover. This is due to the fact that the trees in thick vegetation cover help to sequester the carbon (iv) oxide emitted due to human activities in burning fossil fuels thereby reducing warmth [33]

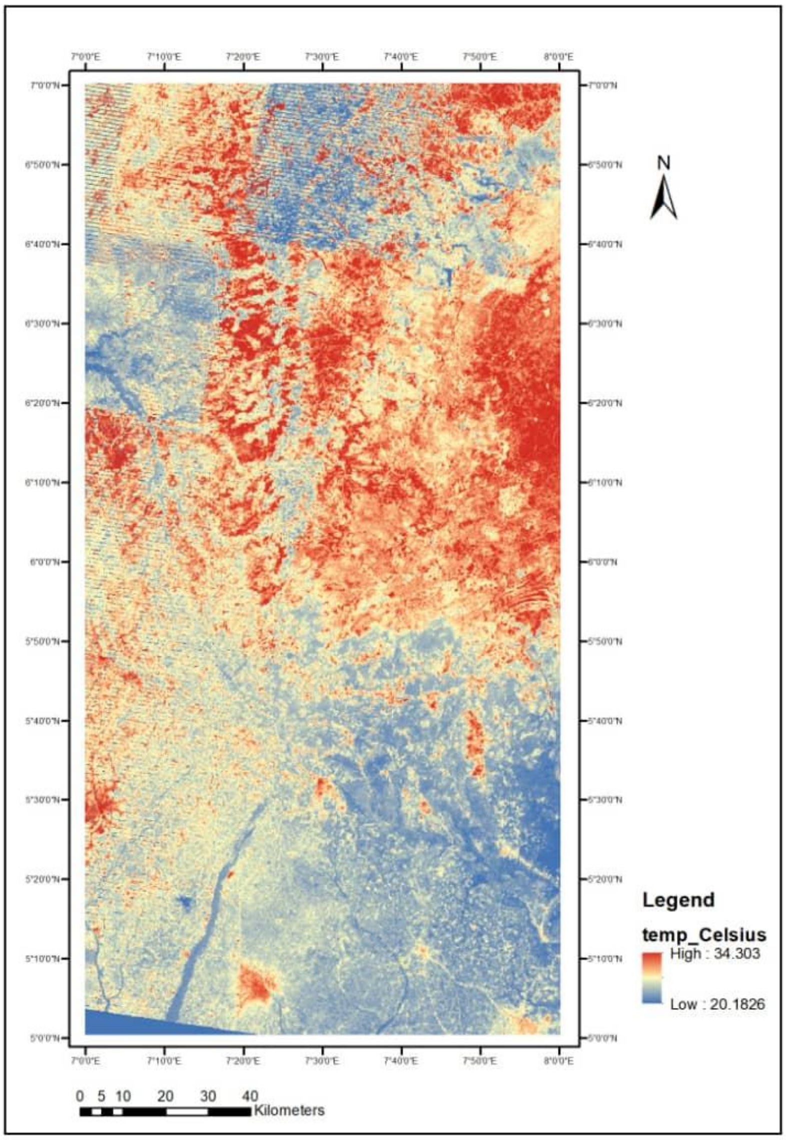

Figure 6: Land surface temperature of the study area

4.3 Lineament

The structural lineament map is as shown in Figure 7. It shows the structural features of the study area. Areas with high lineament density indicates the closeness of the basement (underlying rocks) to the earth surface and becomes a possible mineral deposit, while areas with lesser lineament density indicates plane grounds mainly composed of sedimentary rocks and therefore becomes a possible site for hydrocarbon reservoir if other geological factors are considered [34] The areas of high lineament density is the Northwest and Southeast regions of the study area while the Northeast region has the lowest lineament density as shown in the lineament density map in Figure 8. This implies that the Northwestern and Southeastern areas will have mineral ore close to the surface while the Northeast region may have a potential for hydrocarbon. A total of 4,090 lineament features were identified as well as their orientations as shown in Table 1. The rose plot of the study area is as shown in Figure 9. The main trend of the lineament is NE-SW with subordinate NW-SE which is in conformity with the structures produced by the pan-African Orogeny.

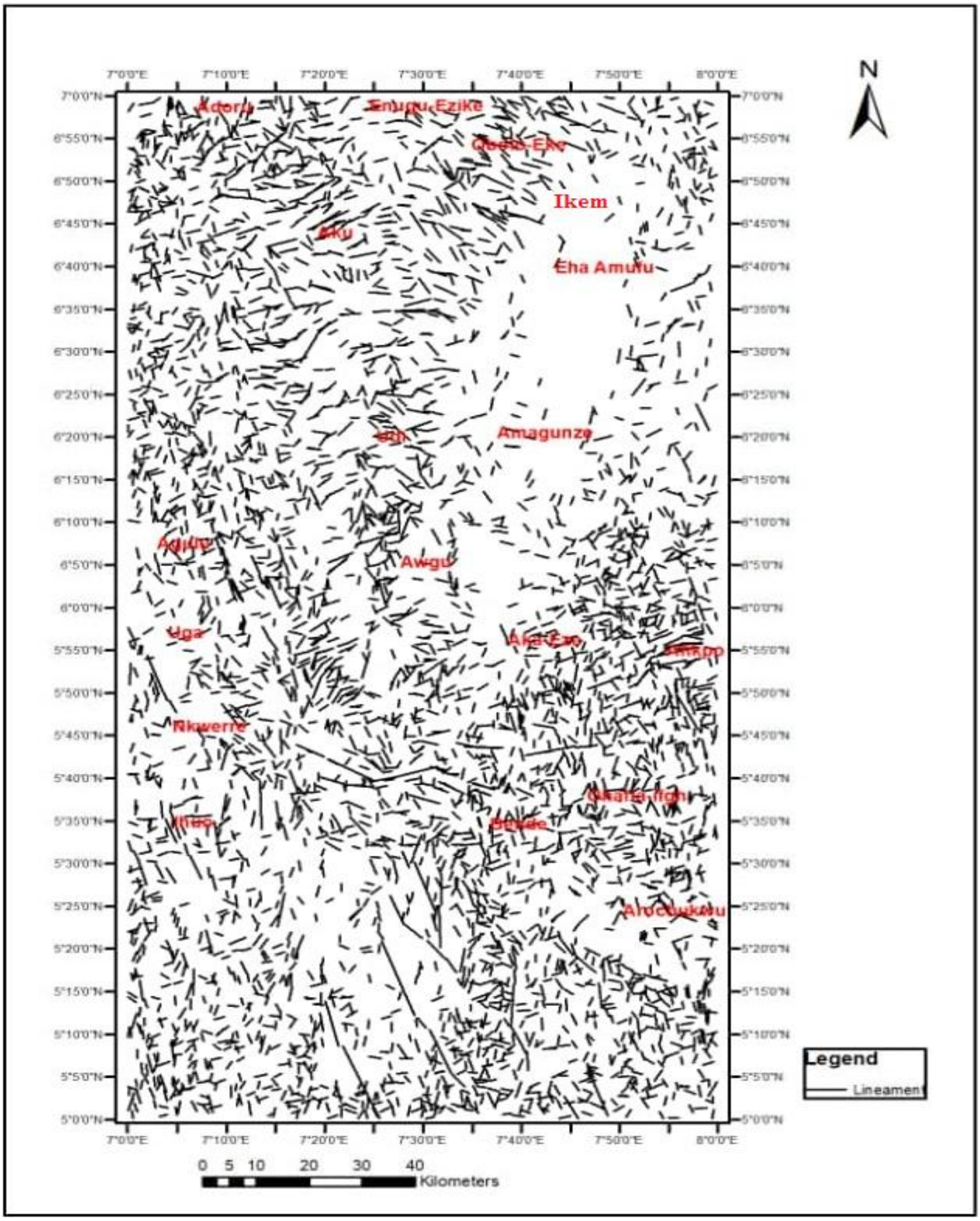

Figure 6: Lineament map of the study area

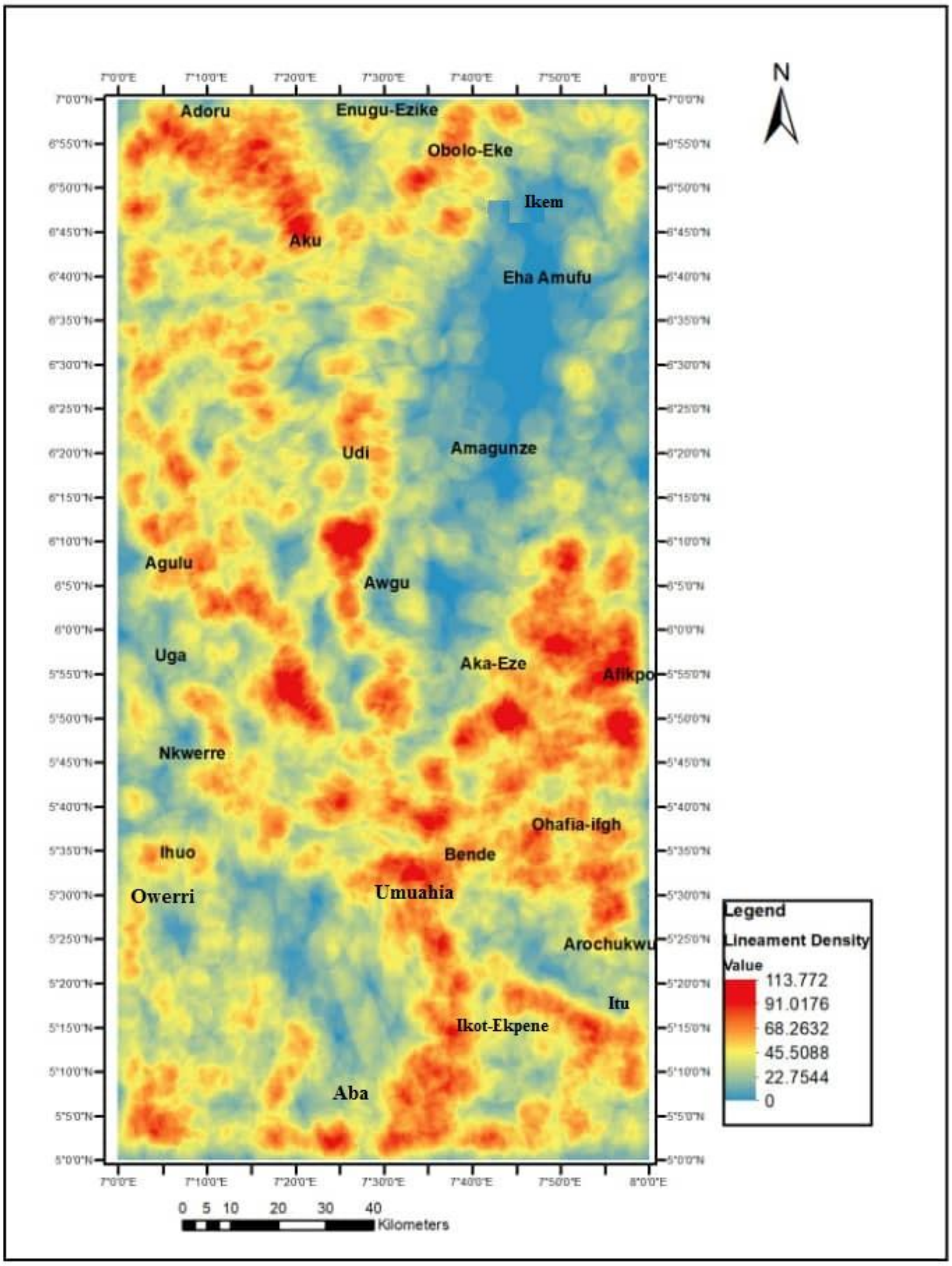

Figure 8: Lineament density map of the study area

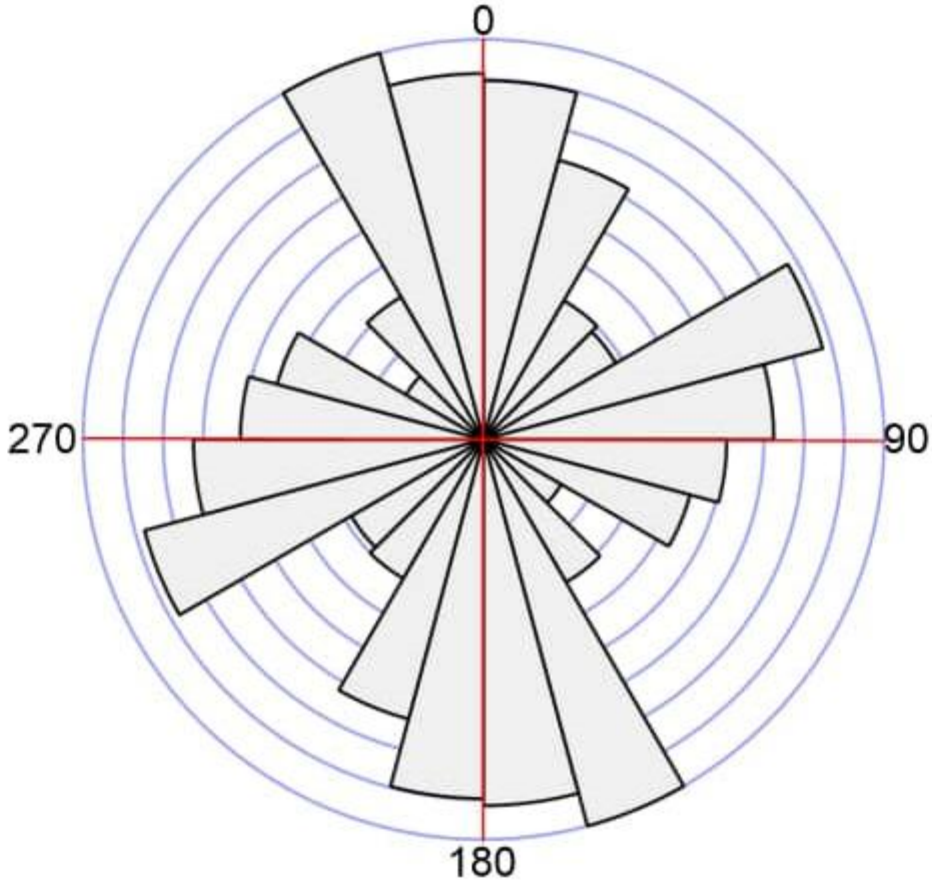

Figure 9: Rose plot of the study area

Table 1 Orientation of Lineament

Orientation (Azimuth)		
Start Angle	**End Angle**	**Number of Lineament**
0	**15**	**515**
15	**30**	**402**
30	**45**	**206**
45	**60**	**198**
60	**75**	**465**
75	**90**	**394**
90	**105**	**341**
105	**120**	**270**
120	**135**	**116**
135	**150**	**202**
150	**165**	**485**
165	**180**	**496**

From the above discussions and studying the lineament density map, Bende, Ohafia, Arochukwu which are Northern parts of Abia State are most probable areas for mineral exploration. Umuahia the state capital also has potentials for mineral exploration as can be noticed from the lineament density map. Other neighboring towns viable for mineral exploration are Afikpo (Ebonyi State), Ikot-Ekpene (Akwa-Ibom State), Agulu (Anambra State), Ihuo(Imo State), Aku (Kogi State) and Obolo Eke (Benue State). This agrees with previous studies on the study area comfirming the presence of some minerals like lead zinc, fluorites, calcites, kaolinites, graphites and sulphides discussed by [19], [35] – [40].

On the other hand, Aba which is in the Southern part of Abia State may have potential for hydrocarbon exploration due to its low lineament density. Also, Amagunze and Eha-Amufu area of Ebonyi State as well as Ikem area of Enugu State may have potential for hydrocarbon exploration. This however is subject to further comfirmatory studies.

V. CONCLUSION

Landsat Imagery has over the years been used in remote sensing. It enables us to use imageries of remotely sensed data to investigate physical features on the earth and the subsurface. Landsat Imagery of the study area was obtained and analysed in order to determine its mineralogical and hydrocarbon potential. Aba shows a low lineament density as well as Amagunze and Eha-Amufu of Ebonyi state. Ikem Area of Enugu State also shows low lineament density indicative of probable potential for hydrocarbons. Conversely, areas with high lineament densities have potentials for minerals. Ohafia, Arochukwu, Bende and Umuahia all in Abia State as well as Afikpo (Ebonyi State), Ikot-Ekpene (Akwa-Ibom State), Agulu (Anambra State), Ihuo (Imo State), Aku (Kogi State) and Obolo Eke (Benue State) are areas of potential mineral abundance. Some of those areas have been previously studied and the presence of minerals comfirmed. Therefore, lineament features as obtained from landsat imagery can be used in mineralogical studies.

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