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Article

Lineament Mapping and Geomorphological Assessment of Olokemeji-Eruwa Area Using LANDSAT 8 (OLI) TM+ Image, Southwestern Nigeria

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Abstract

A satellite-based terrain evaluation of the Olokemeji-Eruwa area, using Landsat images, was carried out in this study in order to evaluate the lineament density, topography and drainage pattern of the area. The study area is predominantly a gneissic terrain with pockets of intrusive rocks spatially distributed within it. The extracted lineament of the area showed heavily fractured bedrock and a lineament density grouped into four categories as micro (< 2km), minor (2-10km), medium (10-199km), and major (100 – 500km). The influence of tectonic events in the study area is showed by the high cross-cutting lineaments. Digital Elevation Model (DEM) and profile graph showed a wide variation in the geomorphology of the study area and this provides a good terrain evaluation to potential miners and explorers. The drainage pattern in the area is predominantly dendritic with few perennial distributaries to the main rivers that drain southwesterly of the study field. The most favorable factors to mineral resource localization in an area are lithology, topography, and geologic formation. A potentially promising site for groundwater availability and mineral deposit occurrence can be assigned to zones with high cross-cutting of lineaments and high lineament density.

Keywords: Landsat, lineament, digital, elevation, localization.

1. Introduction

Lineaments are penetrative geologic features that give information about the subsurface basement geology [1]. Essentially, geological lineaments are Earth's linear, curvilinear, or rectilinear features that reflect tectonic effects on the Earth's crust and appear on the landscape as faults, fractures, veins, the crest of ridges, and linear valleys. Surface geological features are usually not captured by remote sensing methods, therefore, interpretation of the information on such features are deductive based on indirect pieces of evidence.

Mapping of geological features is commonly carried out by field observations of rock outcrops and desktop studies from aerial photographs. Good as these methods are, they lack some precisions like establishing accurate rock boundaries and they do not have a synoptic view of an area under investigation. With the advent of automated satellite image processing techniques like the Shuttle Radar Topography Mission (SRTM) and the Landsat Enhanced Thematic Mapper Plus (ETM+) data, a better assessment of geological structures is now done. Lineaments can be studied using satellite images, which are conventional manual geology field mapping methods.

The use of remote sensing and the geographic information system (GIS) in mapping geological structures has now become a vital tool in the field of applied geology. Accurate sitting of productive boreholes for water supply in urban cities has been guided by a good knowledge of the geological structures (lineaments) and delineation of topographical features associated with hard rock in basement complex terrains [2,3]. In water resource investigation, Landsat images have a demanding application [4,5]. Remote sensing images have the potential to aid in mapping the geology, faults, and fractures that host ore deposits and for identifying hydrothermal alteration zones on altered rocks using their spectral signatures [6].

1.1 Geological Setting

The study area is the Olokemeji-Eruwa area of the Basement Complex of Southwestern Nigeria and it lies within latitude 7^{o}15'N to 7^{o}30'N and longitude 003^{o}21'E to 003^{o}34'E withinIbadan NW sheet 261 of the 1:50,000 topographical map published by the Federal Survey of Nigeria. The vegetation of the area forms part of the rainforest zone in Nigeria characterized by two seasons of namely the rainy (April -October) and dry (November- March) s. The drainage pattern of the area is dendritic with the rivers flowing in the southwesterly direction.

The African continent essentially is a conglomerate of Precambrian terranes of Late Neoproterozoic-Early Paleozoic Pan-African orogeny [7,8]· The cratonic geology of Africa is grouped into West African craton, Kalahari craton, Congo craton, Saharan Metacraton, and Tanzania craton, which are separated by mobile belts. Nigeria is located east of the West African Craton and northwest of the Congo Craton that was affected by the Pan African Orogeny of about 600Ma (Fig.1). Pre-Cambrian basement rocks, younger granites, and sediments ranging in age between Jurassic and Cretaceous to Recent underlie the country.

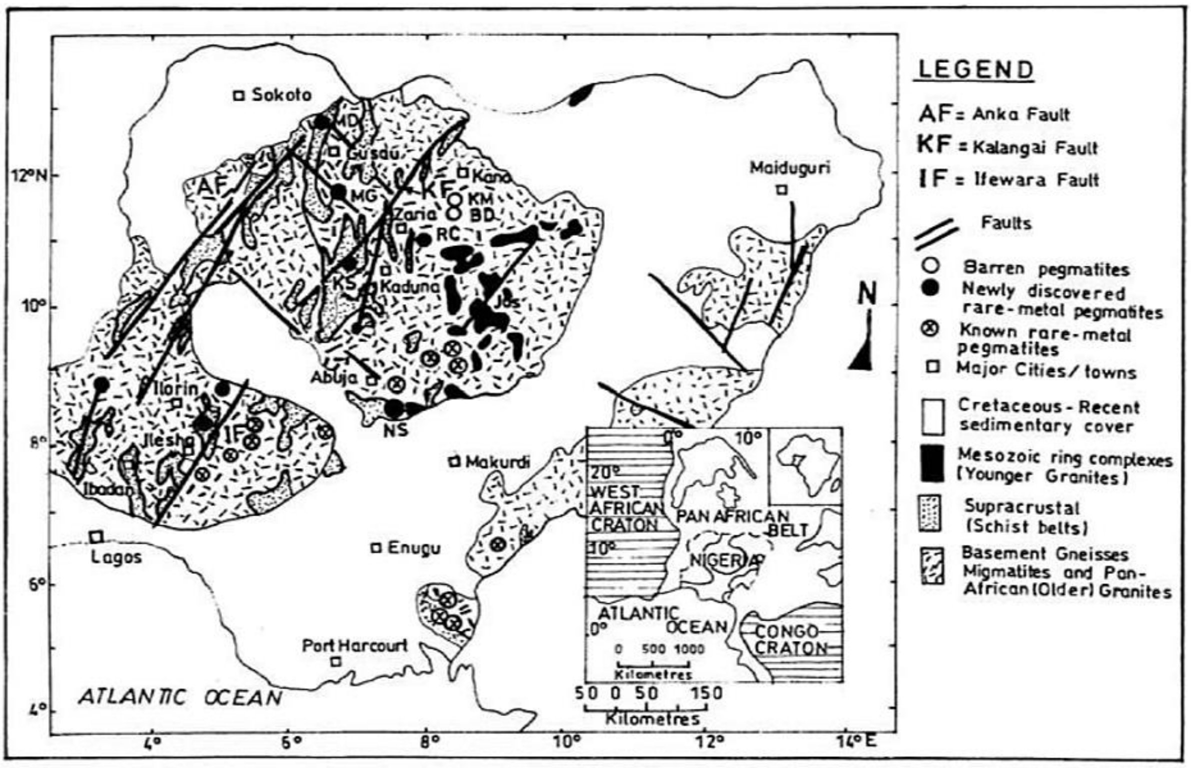

Figure 1: Regional Geology of the Nigerian Pan-African Basement [9].

The crystalline basement rocks of Nigeria cover an estimated 50% of the land area. In the basement complex of Southwestern Nigeria, migmatite-gneiss complex, slightly migmatised to un-migmatized paraschist and metaigneous rocks, chanockitic rocks, Older granites, and the un-metamorphosed dolerite dykes are the major groups of rocks [10]. The Precambrian Basement Complex rocks in the study area comprise of pegmatite, homogeneous granite, amphibolite, schists, biotite-gneiss, quartzite, granite-gneiss, aplite, banded gneiss, and migmatite-gneiss.

The different phases of deformation that affected the Southwestern Basement Complex were tight to isoclinals folds (D_1) and open folds of varying styles trending in NNE-SSW direction [11]. The field study also reveals micro and macro-structural defects like folds, fractures, foliation, veins, and vein lets of varying magnitudes characteristic of the basement complex geology. Quartzo-feldspathic veins exist on rock outcrops in varying dimensions, trending in a general NE-SW direction and few cases exist with NNE-SSW and NNW-SSE trending directions.

2. Methodology

2.1 Data Set

This study, involving water sampling, laboratory and data analysis, was carried out at Ladigbolu and Ojongbodu areas of Oyo town which lies between latitude 07^{0} 49′12″N and longitude 003^{0} 54′44″E to latitude 07^{0} 51′36″N and longitude 003^{0} 55′10″E within the crystalline basement complex of Southwestern Nigeria (Fig. 1). The area which is largely residential with such facilities as schools, markets, worship centers, mechanics workshops and pure water factories, is an undulating terrain with altitude ranging between 278m, and 322m above sea level. The drainage pattern influenced by relief is dendritic, with irregular branching of tributaries flowing down slope in the northwest and southwest direction. The area is within the transitional climatic zone between the southern rain forest and the tropical savannah climatic zone marked by mild forest with grasses and shrubs.

The Landsat 8 satellite image was one of the satellite data used for the study. The Landsat 8 satellite was launched February 11, 2013 and this is an earth observation satellite that has application in geology. The imagery was downloaded (Fig.2) from the United State Geological Survey (USGS) website. The two main sensors for Landsat 8 are the Operational Land Imager (OLI), which has bands 1-9 at 15m, 30m, and 60m resolution, and Thermal Infrared Sensor (TIRS) with two thermal bands of 100m spatial resolution.

The Shuttle Radar Topography Mission (SRTM) 1 Arc-Second with spatial resolution of 30m DEM was also obtained from USGS. Both files were downloaded in the GeoTIFF format covering the study area projected into UTM Zone 31 and subsequently, the data was processed using ArcGIS software. The study boundary coordinates were acquired during the ground routing exercise. The site was visited and the boundary coordinates were obtained using the GPS. The coordinates were later projected to UTN Zone 31 coordinate system. The coordinates were plotted on the downloaded satellite imagery and masked out using ArcGIS Software to obtain the extent of the study area (Fig.3). the images of the study area were then extracted from Landsat 8 imagery (Fig.4)

2.2 Image and data processing

The pre-processing operations on the Landsat 8 imagery were radiometric and geometric corrections. The radiometric correction helped to reduce the effect of atmospheric distortion and noise and geometric corrections made the image conform to the true actual coordinate system of the study area.

The Lineament mapping of the study area was facilitated using the pre-processed Landsat 8 of bands 7,6 and 2 which is ideal for geological application. Sobel filtering of the image was done to identify the geological structures and enhance the visualization (Fig.5). The lineaments were manually digitized (Fig 6) and the Digital Elevation Model (DEM) of the area was generated using SRTM of 30m resolution (Fig.7). The DEM was displayed both in 2D and 3D and the 3D was later exported into ArcGIS Software for 3D visualization (8).

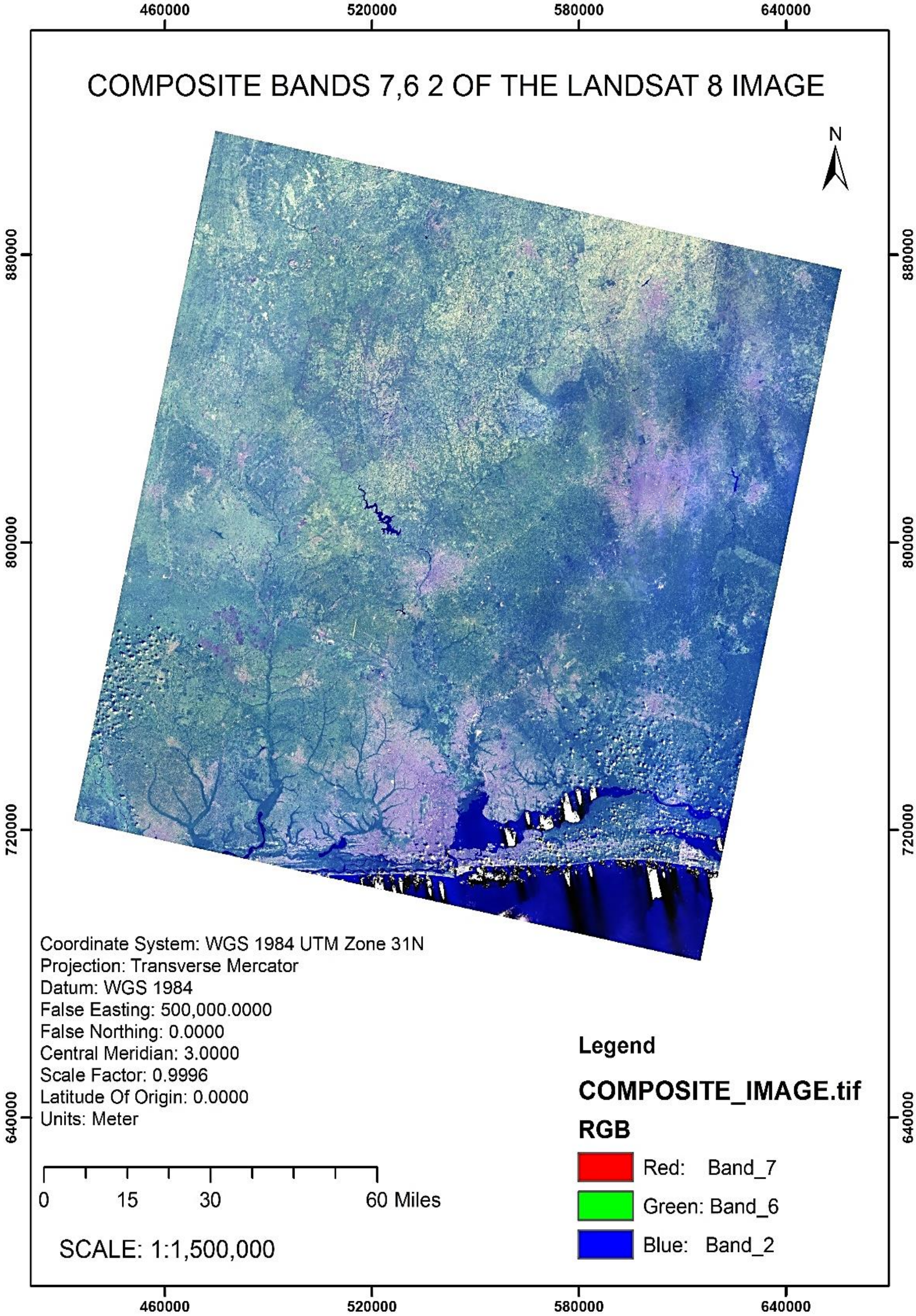

Figure 2: Downloaded Landsat Image Scene**.**

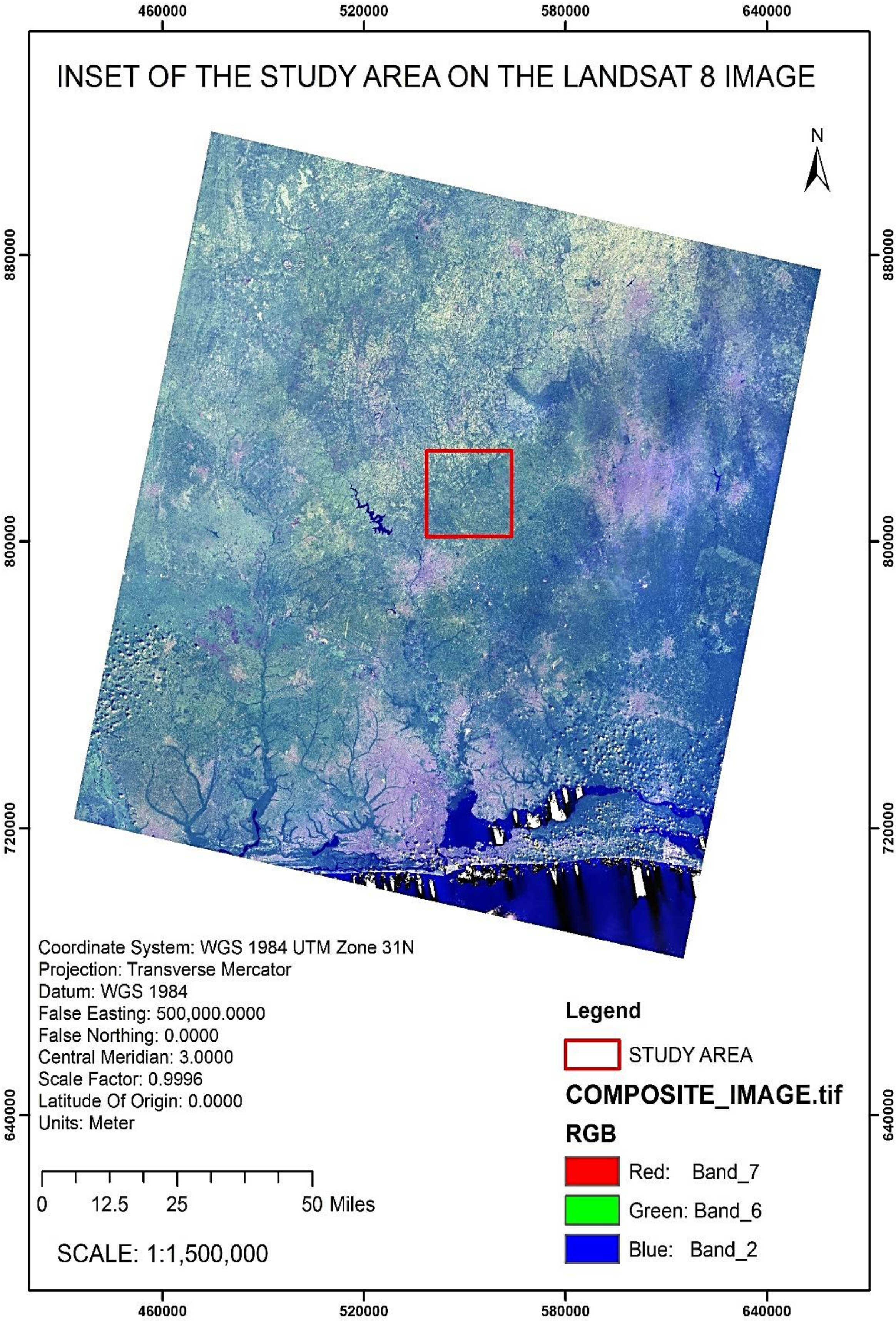

Figure 3: Inset of the study area on the downloaded Landsat 8 Image

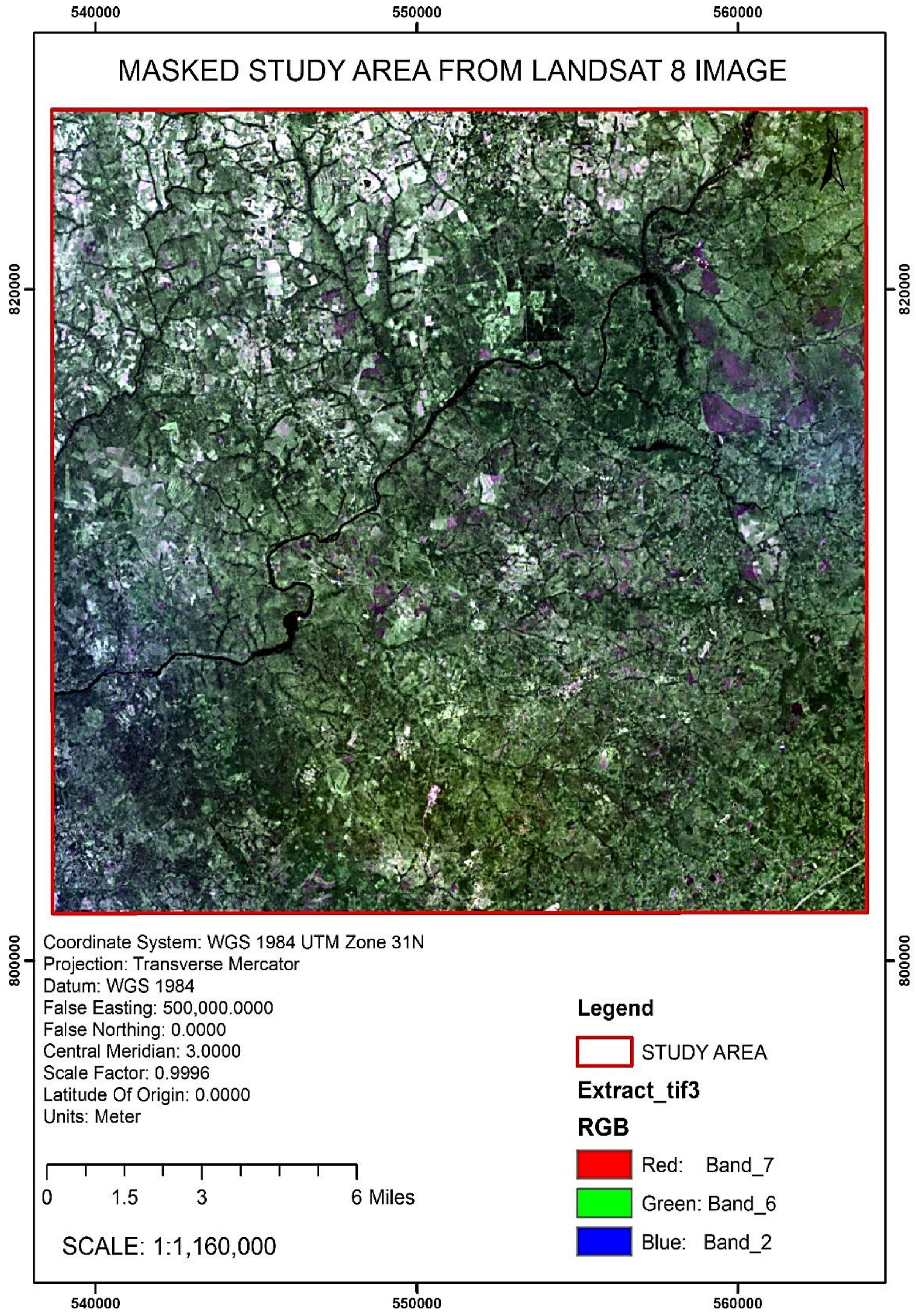

Figure 4: Study area imagery extracted from Landsat 8 image

Figure 5: Enhanced Study area image for edge detection

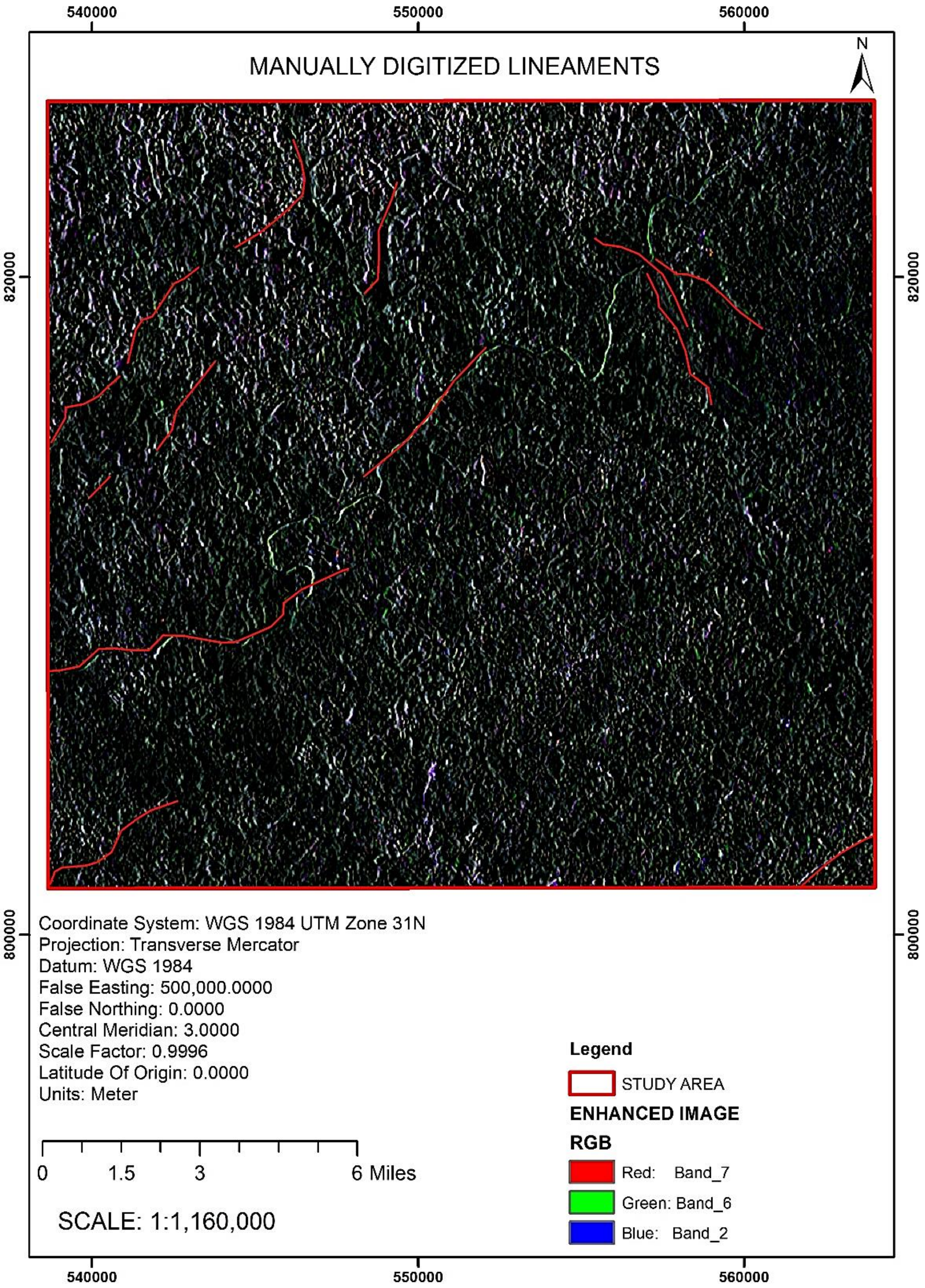

Figure 6: The manually extracted lineaments of the study area

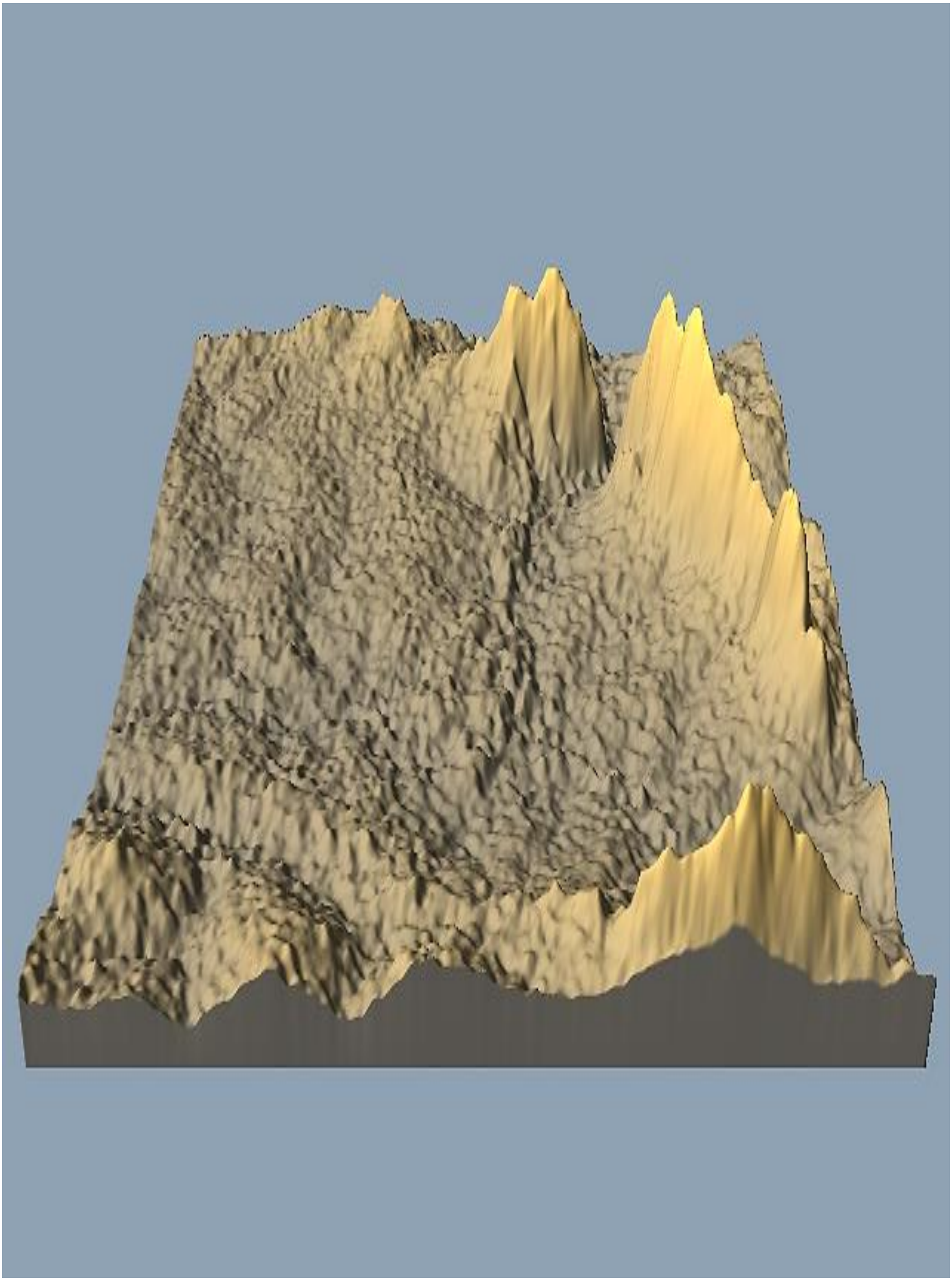

Figure 7: Digital elevation model of the study area

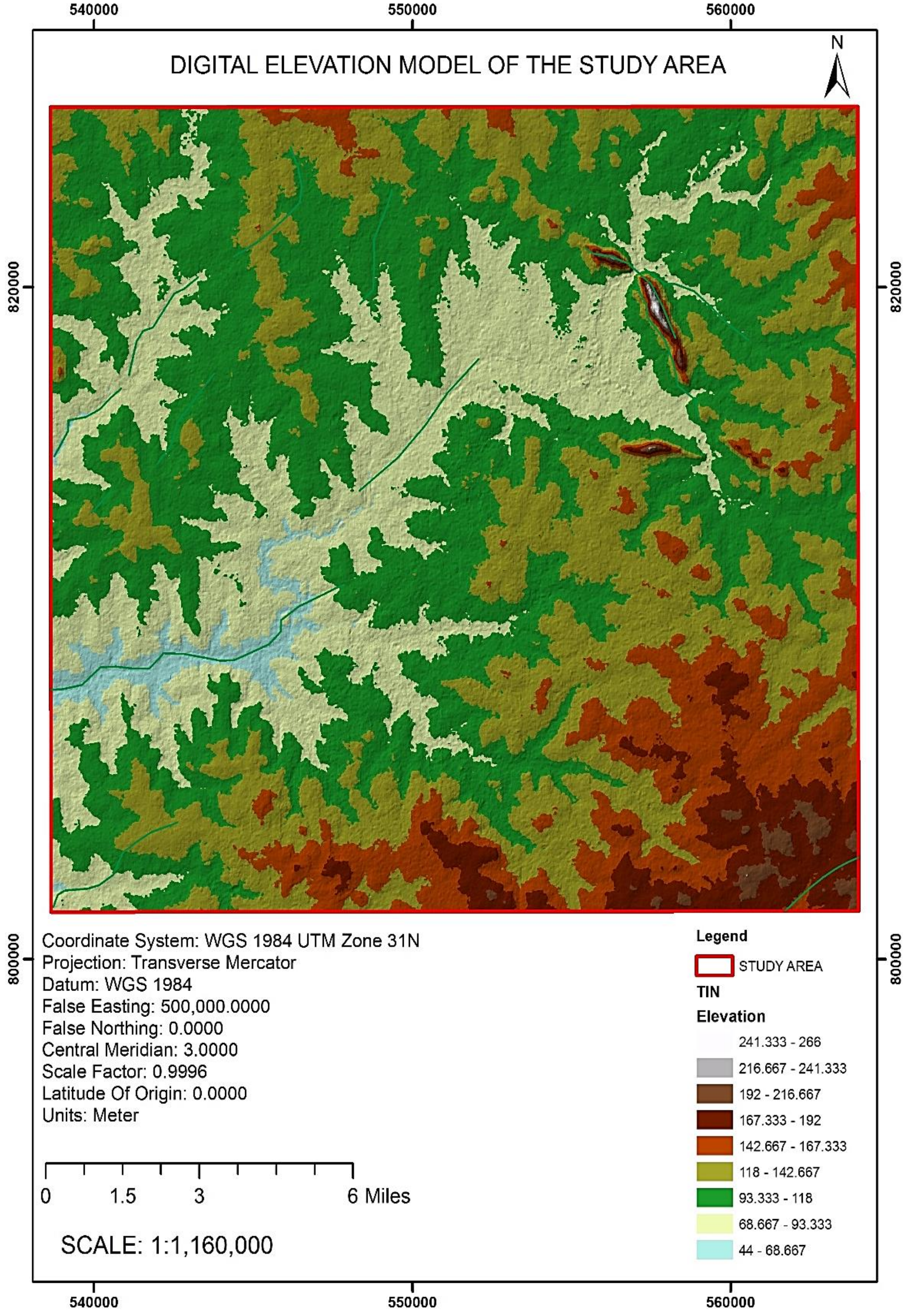

Figure 8: A 3D display of digital elevation model of the study area

3. Results and Discussion

3.1 Lineament Density Analysis

Lineaments can be classified based on their length as (i) micro: <2km, (ii) minor: 2-10 km, (iii) medium: 10-100 km, (iv) major: 100-500 km, and (v) mega: >500 km [12]. The lineament density observed in the study area can be classified as micro, minor, medium, and major from the density classes identified in Figure 9.

The general orientation of the lineaments is presented on a rose diagram (Fig.10) and the areas with predominantly gneissic rocks were observed to have heavily distributed lineaments along the N-S and E-W directions and multiple lineaments in the N-S, NW-SE, NE-SW directions.

The thick rainforest characteristic of the area could aid easy weathering of the gneissic rocks contributing to the high lineament density and the predominantly dendritic drainage pattern of the area.

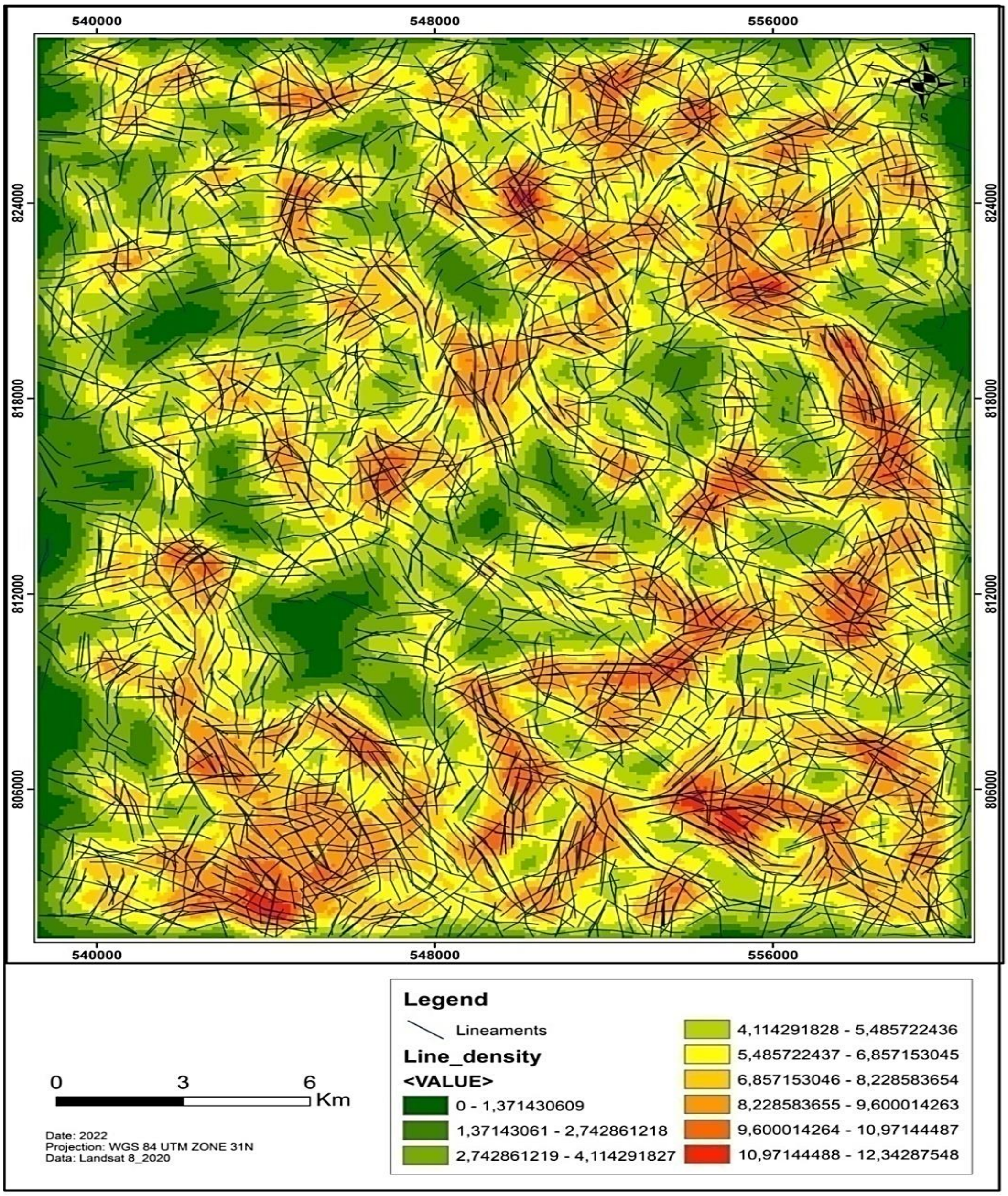

Figure 9: Lineament density map extracted from landsat 8 TM image of the study area

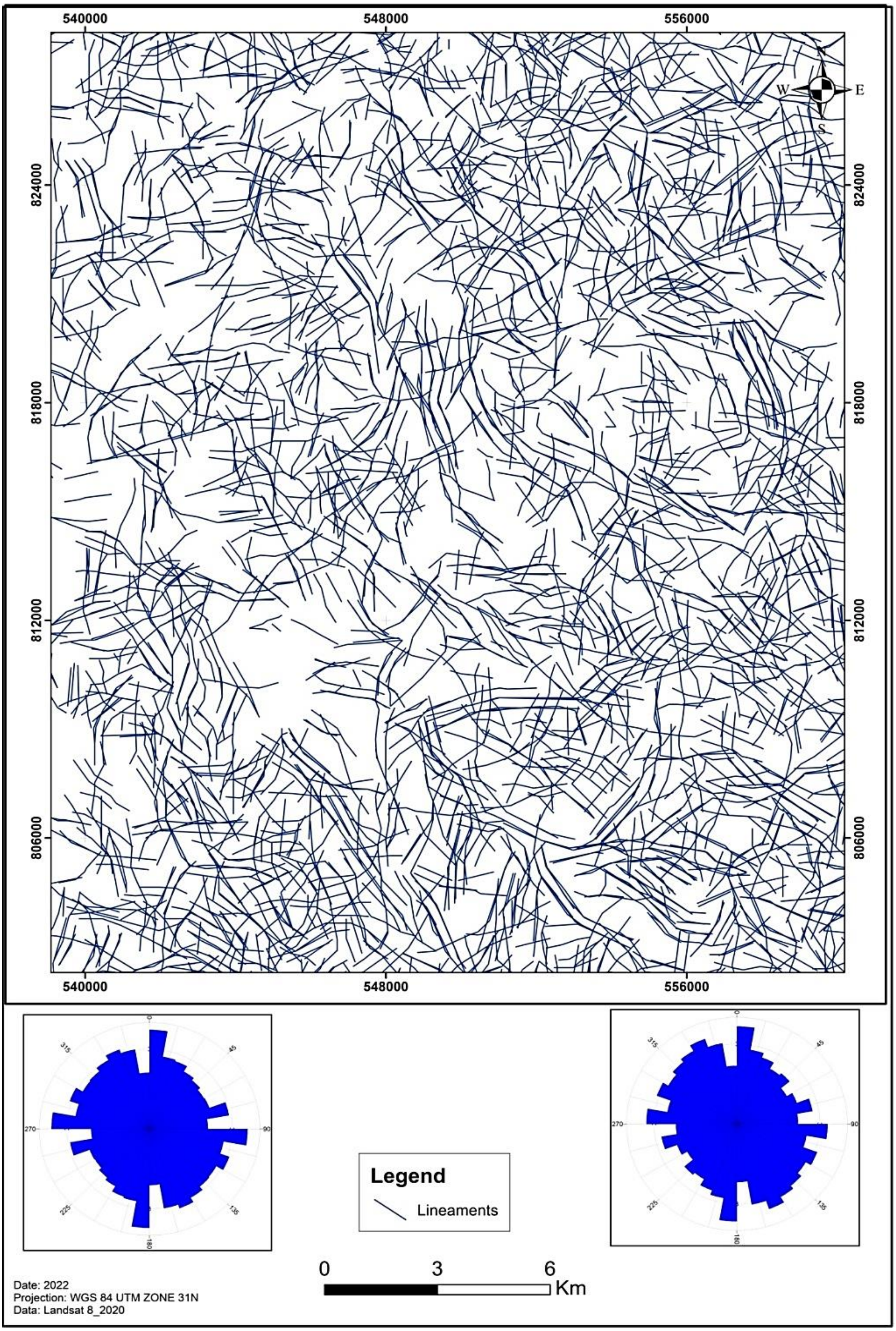

Figure 10: Lineament density map incorporating rose diagram

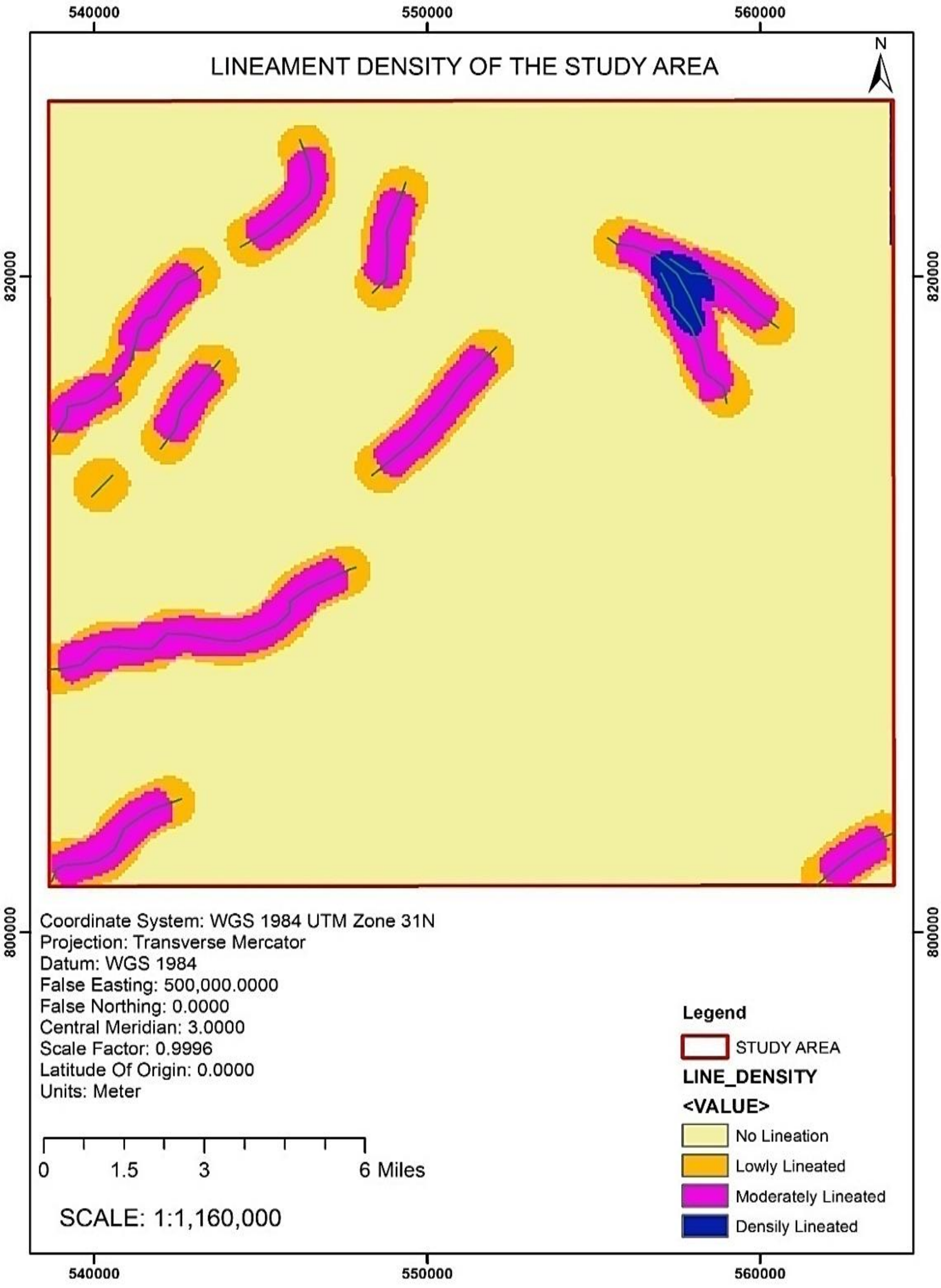

Figure 11: Lineament density mapping of the study area

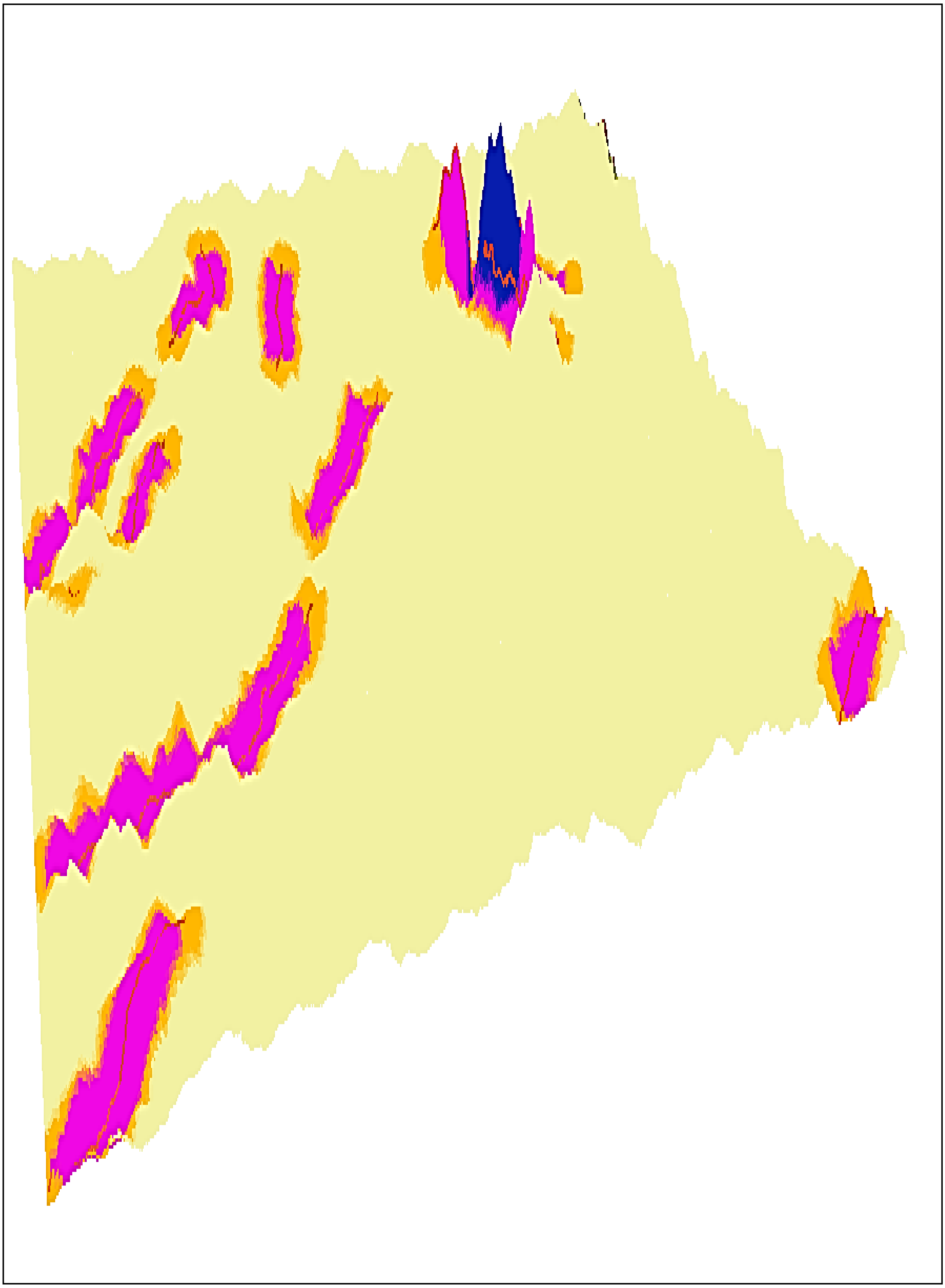

Figure 12: Draping of the lineament density on the DEM

3.2 Extracted lineaments superimposed on the geology map of the study area.

The lineament density map was superimposed on the geological map of the study area to evaluate the distribution of the lineaments across the entire area (Fig.13). The heavily fractured area lies within the gneissic rocks and indicates multiple fractured basement rocks in the area. The rose diagram shows N-S, and E-W major fractures with multiple cross fractures across the entire field. This can be traceable to the humid environment and the gneissic rocks that are easily weathered because of the high content of felspathic minerals in the rock. The digital elevation model (Fig.7) and the profile map of the study area (Fig.14) show the ruggedness of the terrain.

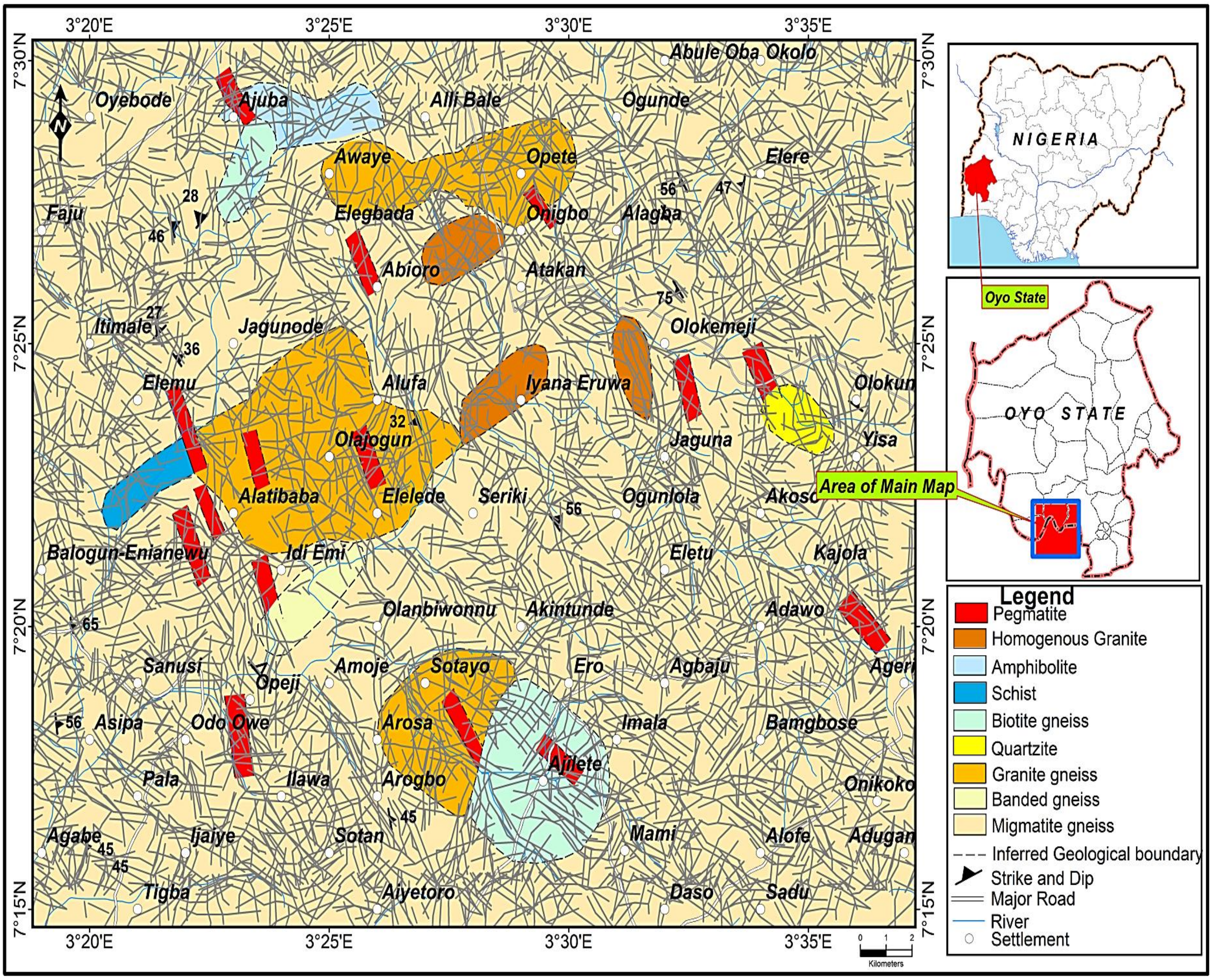

Figure 13: Geological map of study area superimposed on the lineaments source (Author's field work, 2021).

3.3 Digital elevation model

The digital elevation model (DEM) of the study area representing the ground topography (valleys, mountains and landslides) and excluding terrestrial objects like trees, buildings, and other surface objects in three-dimensional representation (3D) is presented in Fig. 2. The elevation of the study area is grouped into nine (Figs.7 and 8): (241.333 – 266, 216.776 – 241.333, 192 – 216.666, 167.333 – 192, 142.667 – 167.333, 118 – 142.667, 93.333 – 118, -68.667 – 93.333, 44 – 66.667) m. These values reflect the undulating nature of the area and this was further shown in the profile picture of Figure 14. This is a raster GIS layer reference to a vertical datum or a surface of zero elevation.

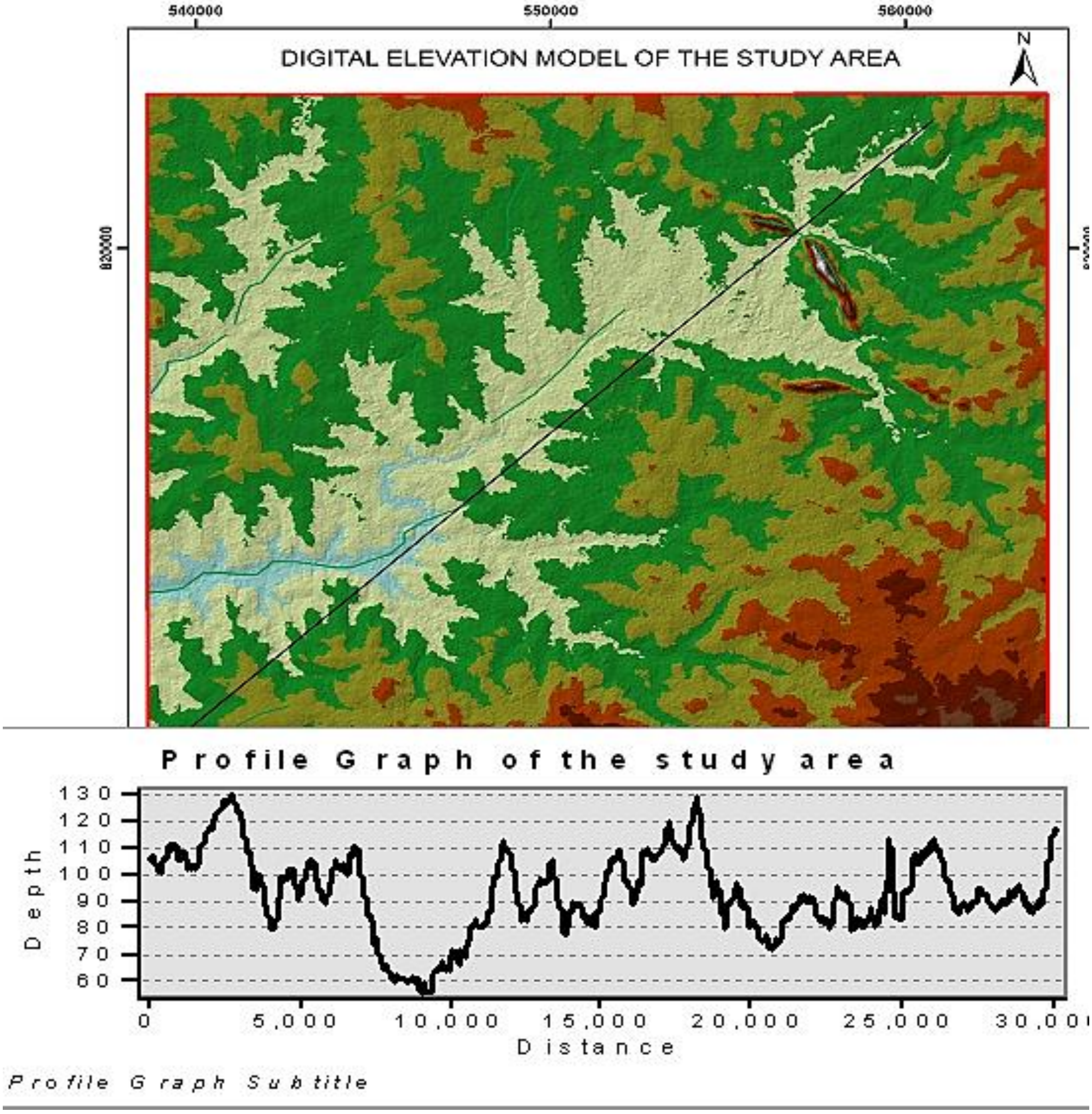

Figure 14: Interpolate line form the SW corner to the NW corner and the profile graph of the study area

4. Conclusions

This study verified the relevance of remote sensing and the GIS as a complementary exploration tool in geology because of its synoptic coverage of an area of interest. The lineament configuration, which represents fractured bedrocks in the area, was successfully extracted from satellite images. The area is heavily fractured with lineament density falling into micro (< 2km), minor (2-10km), medium (10-199km) and major (100 – 500km) range. The areas with the high cross-cutting lineament show weak or destructive zones that can be linked to tectonic exercises in those areas. The lineaments superimposed on the geology map of the study area show the high lineament density towards the eastern and southern portions of the map. The central and north-western parts of the study area show low lineament density. Lineament density information is a good indicator of possible areas of mineralization, which can serve as guides to mineral explorers. The zones of high lineament densities are potential areas for possible groundwater and mineral prospecting. The geomorphological outlook of the area is presented as a digital elevation model (DEM) and the profile graph in Figure 14 shows a wide variation of the elevation and a good terrain evaluation of the area to potential miners and explorers.

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