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High-Precision Geospatial Analysis of Surface Features Using Gps and Satellite Imagery in Some Parts of South Eastern Nigeria

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Abstract: The study of landforms is critical for understanding geomorphic processes and environmental changes. This research integrates GPS data and high-resolution satellite imagery to analyze and monitor landform dynamics in some parts of Southeastern Nigeria. Using advanced remote sensing techniques, precise Digital Elevation Models (DEMs) and conducted detailed topographic analyses to identify and classify landforms were generated. The GPS data provided accurate elevation and location information, which was essential for refining DEMs and enhancing the accuracy of landform mapping. Change detection analysis was employed to track temporal shifts in landforms, revealing significant changes in erosion patterns and landslide activities. Ground-Truthing efforts validated the accuracy of the remote sensing data, demonstrating a strong correlation between field observations and the results obtained from GPS and satellite data integration. The findings of this study offer new insights into the geomorphic processes shaping the study area and highlight the effectiveness of combining GPS and satellite imagery for landform analysis. These results have important implications for environmental management, hazard assessment, and future geomorphological research.

Keywords: *Global Positioning System (Gps), Satellite Imagery, Digital Elevation Model, Landforms, Remote Sensing, Geomorphology, South Eastern Nigeria.*

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I. INTRODUCTION

The natural physical feature of the earth surface is said to be landform of a place. It is always exiting to observe how nature has positioned some features over a long period of time without a noticeable change. The mountains and valleys as well as rivers have been there for over one hundred years to say the least. The morphology of the various places differs in rock types. Also the type of crops and plants that grow on them are different. There are marked high lands in some parts of south eastern Nigeria trending with a large expanse of low lands in form of plains and valleys. The textures of the surface rock samples are different, varying from fine grained to coarse grained and from blue-black to brown to reddish colours. The colour variation can also be associated to rock types. The undulations are worth studying and the understanding gained from them should go a long way in explaining the environmental implications of these land forms at any particular location on the surface of the earth. The study of landforms, or geomorphology, has been greatly enhanced by the integration of satellite imagery and Global Positioning System (GPS) technologies, Gibson, P. J., & Power, C. H. (2000). These tools have revolutionized the way researchers observe, analyze, and interpret the Earth's surface, allowing for more precise and large-scale studies that were previously impossible with traditional methods, Tarolli, P., & Sofia, G. (2016).

The study of these land forms can be achieved using geophysical method by means of fine remote sensing applications. The geographic positioning system is used to determine the coordinates and the elevations of each point on the surface of the earth. The satellite imageries of the remote sensing methods will also be used to study the terrain and the vegetations, Nwugha et al, (2017). Satellite imagery provides detailed, high-resolution data across various spatial and

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temporal scales, enabling the analysis of diverse landforms, from mountains and valleys to river systems and coastal regions, Gomez, C., Hayakawa, Y., & Obanawa, H. (2021). The continuous advancements in satellite technology, such as the increasing resolution and frequency of data from platforms like Landsat, Sentinel, and commercial satellites, have significantly improved the monitoring of geomorphic processes and the assessment of environmental changes, particularly in remote and difficult-to-access areas, Casagli, N., Del Ventisette, C., Luzi, G., & Tofani, V. (2017). For example, satellite data is now routinely used to study erosion, sediment transport, and the impacts of climate change on glacial retreat and sea-level rise, Rouyet, L., Kristensen, L., & Eiken, T. (2019).

GPS technology complements satellite imagery by providing accurate, real-time location data that enhances the precision of geomorphic mapping and analysis, Schowengerdt, R. A. (2007). GPS is instrumental in generating high-quality Digital Elevation Models (DEMs), which are critical for terrain analysis and understanding the dynamics of landform evolution, Bishop, M. P., Shroder, J. F., & Haritashya, U. K. (2021). The integration of GPS with satellite data in Geographic Information Systems (GIS) enables the creation of detailed spatial models, facilitating advanced studies in areas like tectonic activity, landslide susceptibility, and coastal erosion, (Bolstad, P. , 2016).

The remote sensing method uses the technique of aerial photograph and satellite imagery to look at the fractures, vegetations and lineation to interpret the surface and subsurface of the earth. The combined use of satellite imagery, GPS, and GIS has transformed geomorphological research, allowing for the continuous monitoring of landforms and providing valuable data for environmental management, disaster risk reduction, and urban planning, (Lillesand, T., Kiefer, R., & Chipman, J.,2015). This integrated approach is essential for addressing contemporary challenges such as natural hazard mitigation, resource management, and understanding the impacts of global environmental change.

II. LOCATION AND GEOLOGICAL FORMATIONS OF THE STUDY AREA

The study area is located in the South East of Nigeria between Latitudes 5º00′N and 6º00′N and Longitudes 7º00′E and 8º00′E. The major towns within the study area are: Okigwe, Afikpo, Umuahia, Aba, Ohafia, Owerri, Aba, Abiriba, Arochukwu, Ikot Ekpene, Uyo, Abak, etc. The geological formations are Asu River Group and Eze-Aku Group in the Northeastern part. Followed by Nkporo Formation and Mamu Formations. From the NW to SE are other Formations such as Ajalli, Imo Shale Group, Ameki, Ogwashi and Benin Formations, Figure 1.

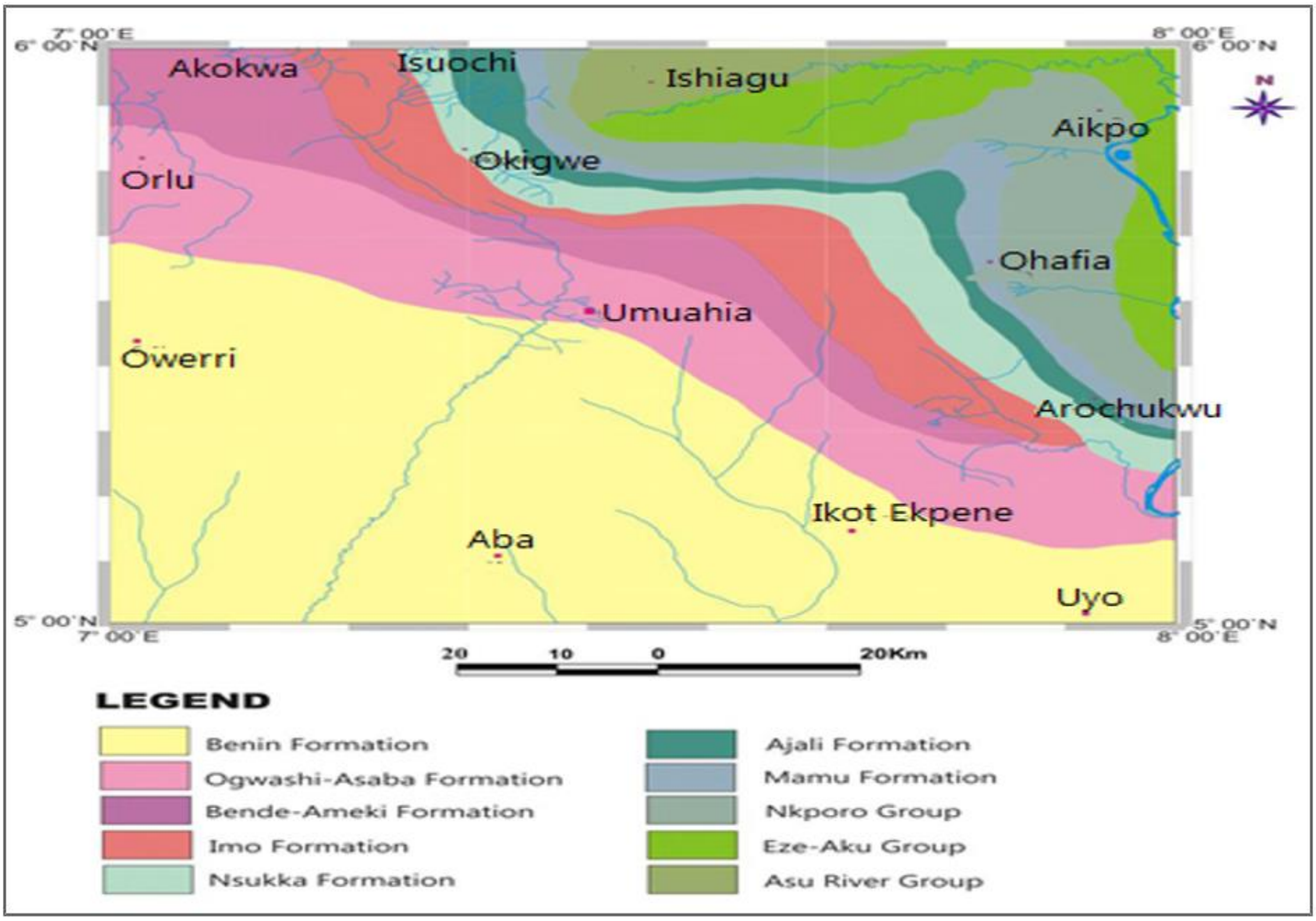

Fig 1 Location and Geological Formations with in The Study Area

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III. DATA ACQUISITION AND METHODOLOGY

This report outlines the data acquisition and methodology utilized for analyzing landform dynamics through GPS data, satellite imagery, and Digital Elevation Models (DEMs). High-precision GPS data were collected from strategically established Ground Control Points (GCPs) to ensure accurate spatial positioning and seamless alignment with satellite imagery and DEMs. Temporal satellite images were sourced from reputable archives and underwent rigorous preprocessing, including radiometric and geometric corrections. High-resolution DEMs obtained from national geospatial databases provided essential elevation data, which, when integrated with GPS coordinates, enhanced the overall accuracy of the spatial datasets.

The methodology employed for topographic analysis included elevation interpolation, slope calculation, curvature analysis, and drainage density assessment. Advanced change detection techniques, including image differencing and change vector analysis (CVA), were applied to the preprocessed satellite images to identify and quantify land cover changes over time. Furthermore, Geographic Information Systems (GIS) facilitated sophisticated spatial analyses, allowing for the development of 2D and 3D models that visualized spatial relationships and helped predict potential future landform changes. This comprehensive approach provides valuable insights into landscape dynamics and the factors influencing alterations in geomorphological features.

This report outlines the data acquisition and methodology utilized for analyzing landform dynamics through GPS data, satellite imagery, and Digital Elevation Models (DEMs). High-precision GPS data were collected from strategically established Ground Control Points (GCPs) to ensure accurate spatial positioning and seamless alignment with satellite imagery and DEMs (Huang et al., 2022). Temporal satellite images were sourced from reputable archives, such as the Sentinel-2 mission, and underwent rigorous preprocessing, including radiometric corrections to standardize pixel intensity across different images and geometric corrections to rectify distortions caused by sensor angles and the Earth's curvature (Ponzanelli et al., 2023). High-resolution DEMs obtained from national geospatial databases, such as the USGS 3D Elevation Program, provided essential elevation data. These datasets were integrated with GPS coordinates through interpolation techniques like Kriging or Inverse Distance Weighting (IDW), enhancing the overall accuracy of the spatial datasets (Liu & Zhang, 2023).

The methodology employed for topographic analysis included elevation interpolation, slope calculation, curvature analysis, and drainage density assessment. Slope was computed using digital elevation data, applying algorithms that measure terrain steepness and landform gradients (Sinha et al., 2023). Advanced change detection techniques, including image differencing and change vector analysis (CVA), were utilized to analyze temporal satellite imagery, highlighting significant changes in land cover over time (Zhou et al., 2022). Furthermore, Geographic Information Systems (GIS) facilitated sophisticated spatial analyses, including buffering and slope stability assessments, allowing for the development of 2D and 3D models that visualized spatial relationships and predicted potential future landform changes (Li et al., 2023). This comprehensive approach provides valuable insights into landscape dynamics and the factors influencing alterations in geomorphological features.

IV. RESULTS

➢ *Terrain Analysis*

A Digital Terrain Model (DTM), Figure 2, was constructed using IDRISI 3.2 with Shuttle Radar Topography Mission (SRTM) data processed through color shading. The DTM reveals peak elevation areas (365m - 417m) identified in dark green, located around Ichida, Akokwa, Urualla, Isuochi, and Lekwesi. Surrounding zones display gradient elevation shifts, including light green (260m - 365m) and yellow bands (208m - 260m), outlining two major topographic belts running NW-SE. Ground-truthing via handheld GPS confirmed elevation accuracy, (Figure 3) showing high correspondence between DTM and GPS-derived elevations, particularly in Isuochi and Akokwa.

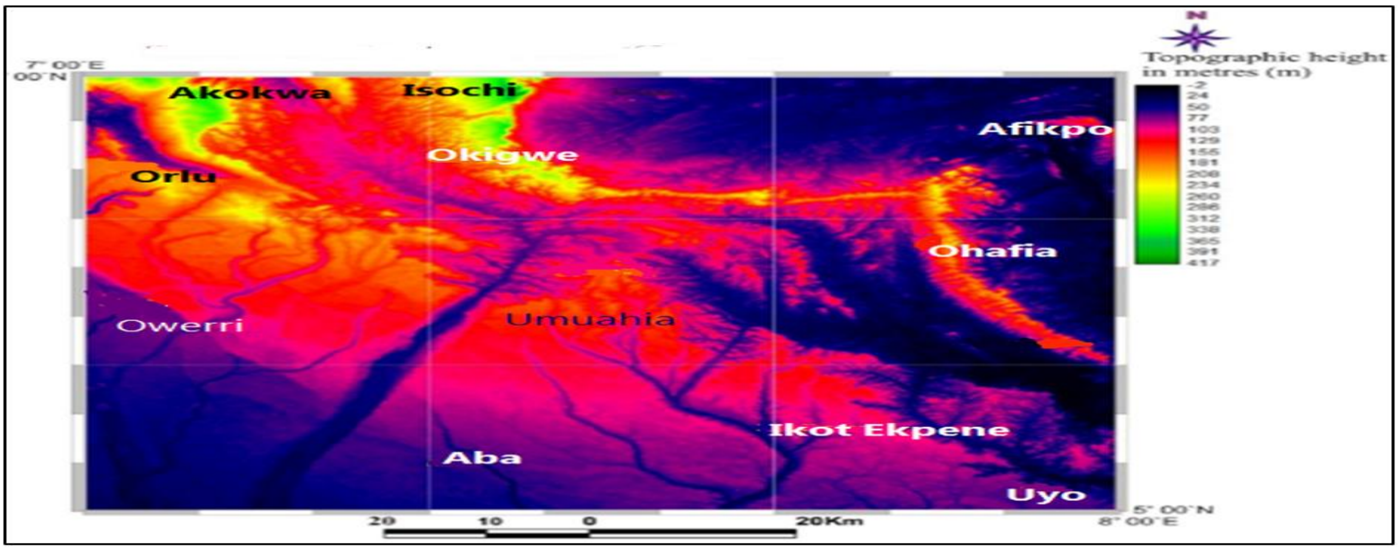

Fig 2 Digital Terrain Model (DTM) of the Study Area

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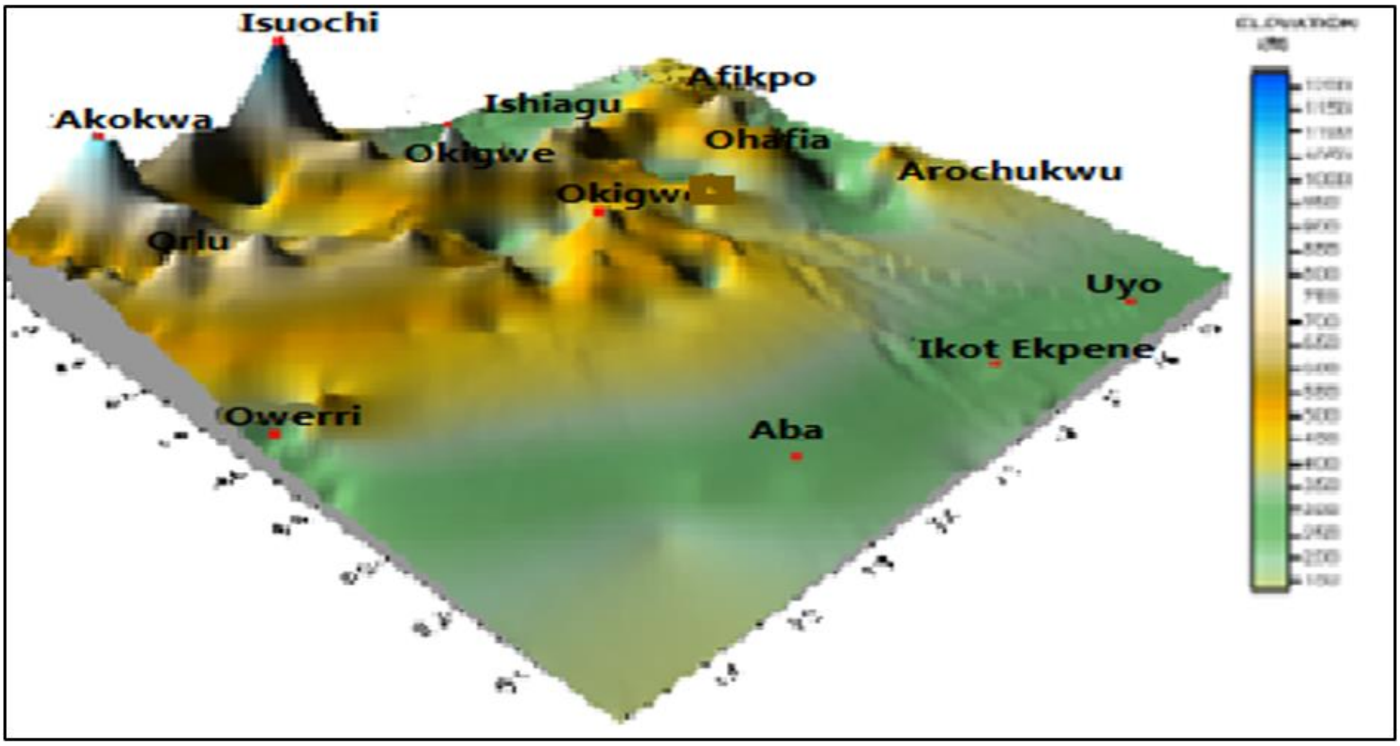

Fig 3 Elevation Model of the Area Showing Height Above Sea Level in feet

➢ *Normalized Difference Vegetation Index (NDVI)*

Digital image processing techniques enhanced vegetation assessment through NDVI analysis, identifying areas of varying vegetative density. Lower vegetation density was noted in Afikpo, Ohafia, and Ishiagu in the northeast, while greater density was found in the southwestern areas, including Akokwa, Orlu, Aba, and Umuahia, indicating a disparity in vegetation health and coverage, Figure 4.

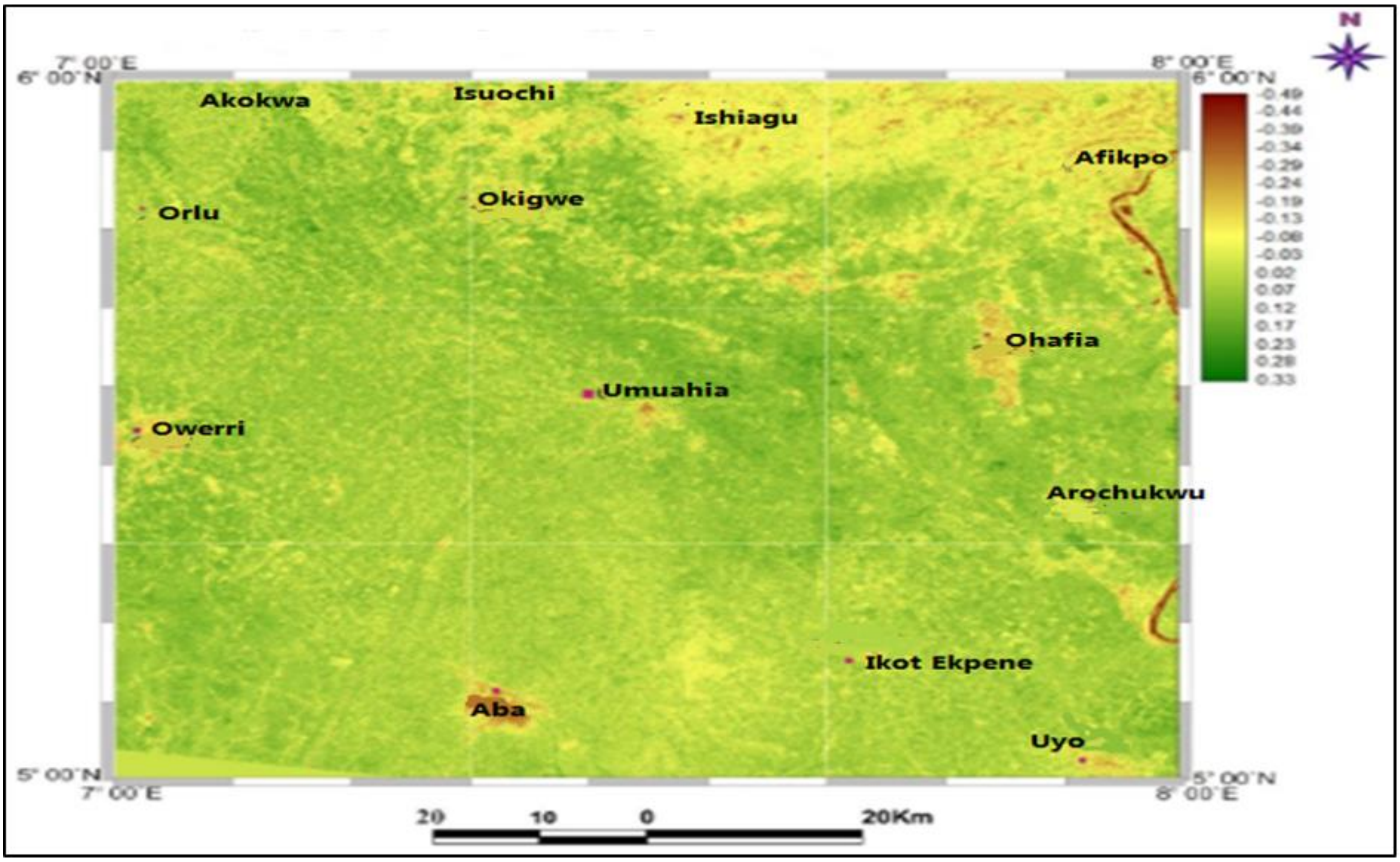

Fig 4 Normalized Difference Vegetation Index (NDVI) of the area

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➢ *Lineament Draped On Edge Enhancement Bands*

The integration of lineament analysis with edge enhancement techniques showed a distribution of lineaments overlaid on enhanced band images, Figure 5. The analysis highlighted that light gray areas indicate higher lineament concentrations in the northeastern part compared to the southwestern region, suggesting more geological features and potential structural complexities in the north.

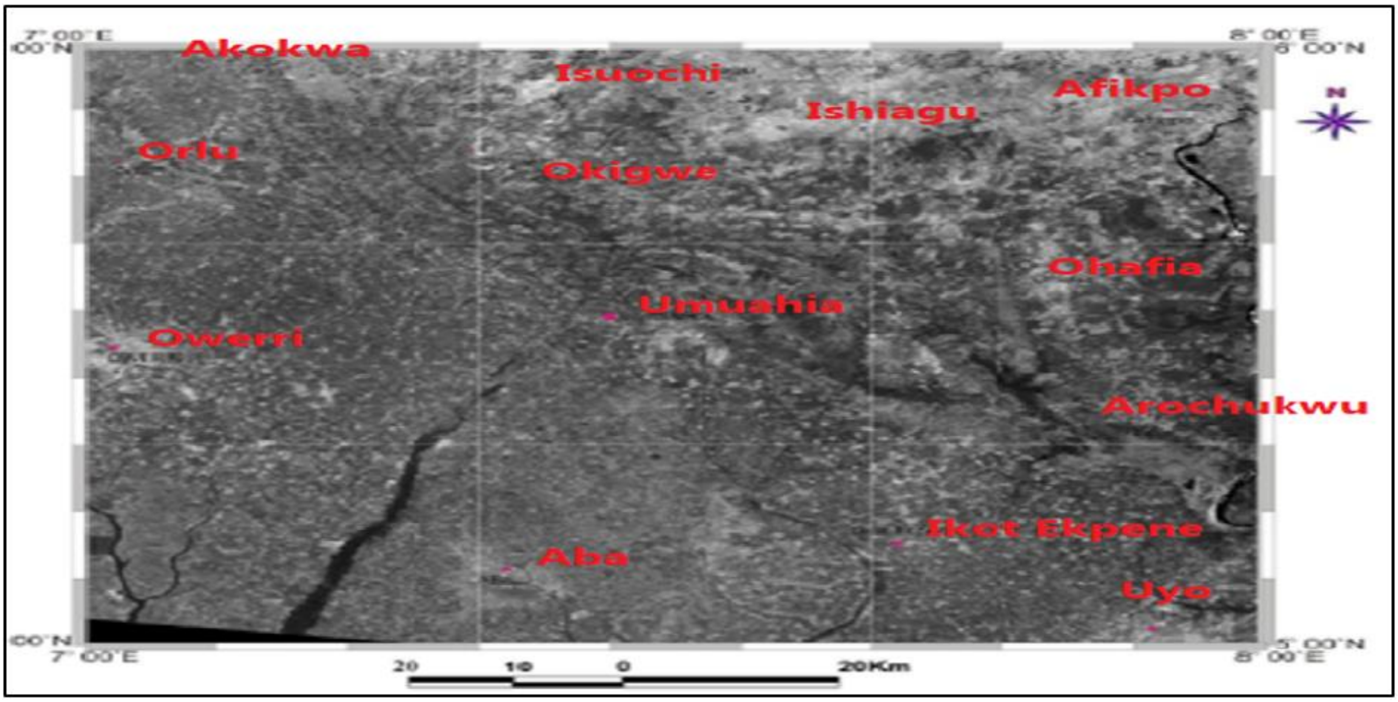

Fig 5 Lineament Draped On Edge Enhancement Bands of the area

➢ *Lineament Analysis (Fracture Analysis) and Drainage Pattern*

Fracture analysis utilized digital imaging to delineate linear features, resulting in numerous observed fractures predominantly in the northeastern section. Common orientations included N-S, NW-SE, NE-SW, and E-W, with a notable prevalence of NE-SW trends. Towns most impacted by these fractures (e.g., Afikpo, Ishiagu, Ohafia) experienced significant structural influences, while regions along the diagonal NW-SE showed no fractures, Figure 6. The analysis of drainage patterns identified a predominantly dendritic drainage configuration, digitized from Landsat TM imagery. Major drainage sources were traced to three significant highlands, with rivers predominantly flowing parallel to or away from these features. The drainage textures varied, exhibiting coarse characteristics in southern regions, indicative of less runoff, while finer drainage textures in areas like Leru, Okigwe and Umuahia areas suggested higher runoff and impervious soils. This pattern reflects the underlying lithology and soil types, emphasizing the hydrological dynamics within the study area, Figure 6.

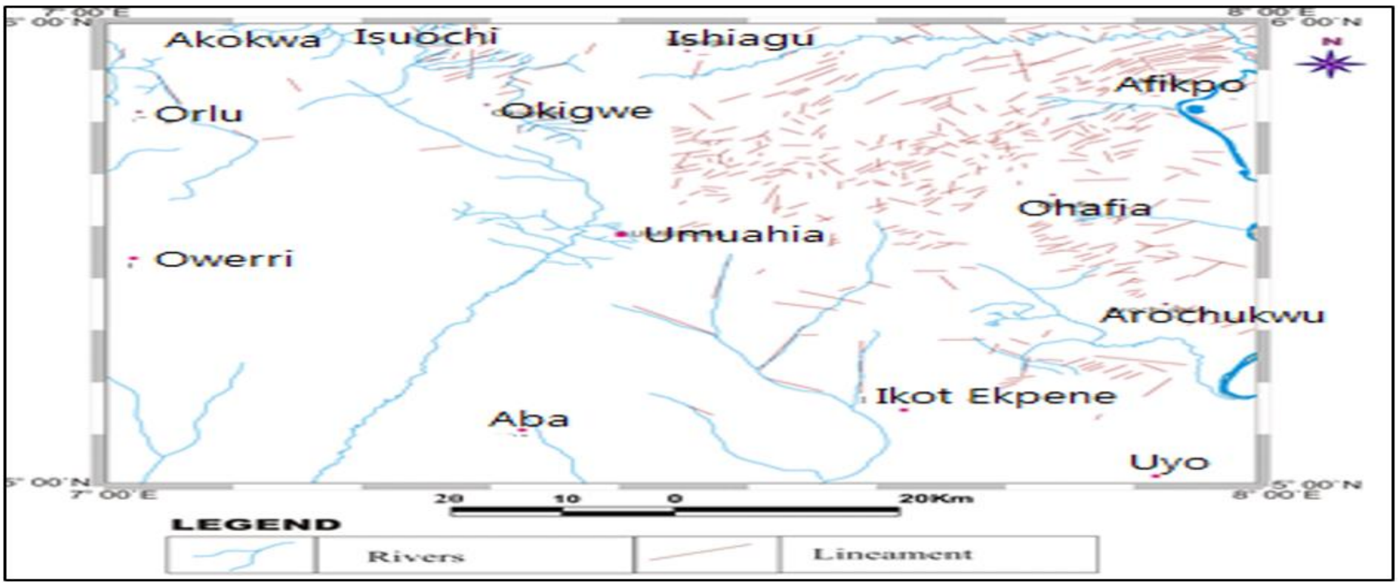

Fig 6 Lineament on drainage map of the area

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➤ *Lineament Density Map*

Lineament features were digitized, resulting in a lineament density map with a pixel resolution of 2 km. The density distribution highlighted a concentration of fractures primarily in the northeastern area, with prevailing structural trends of NE-SW, NW-SE, and N-S observed, reflecting the geological complexity of the landscape, Figures (7a and 7b).

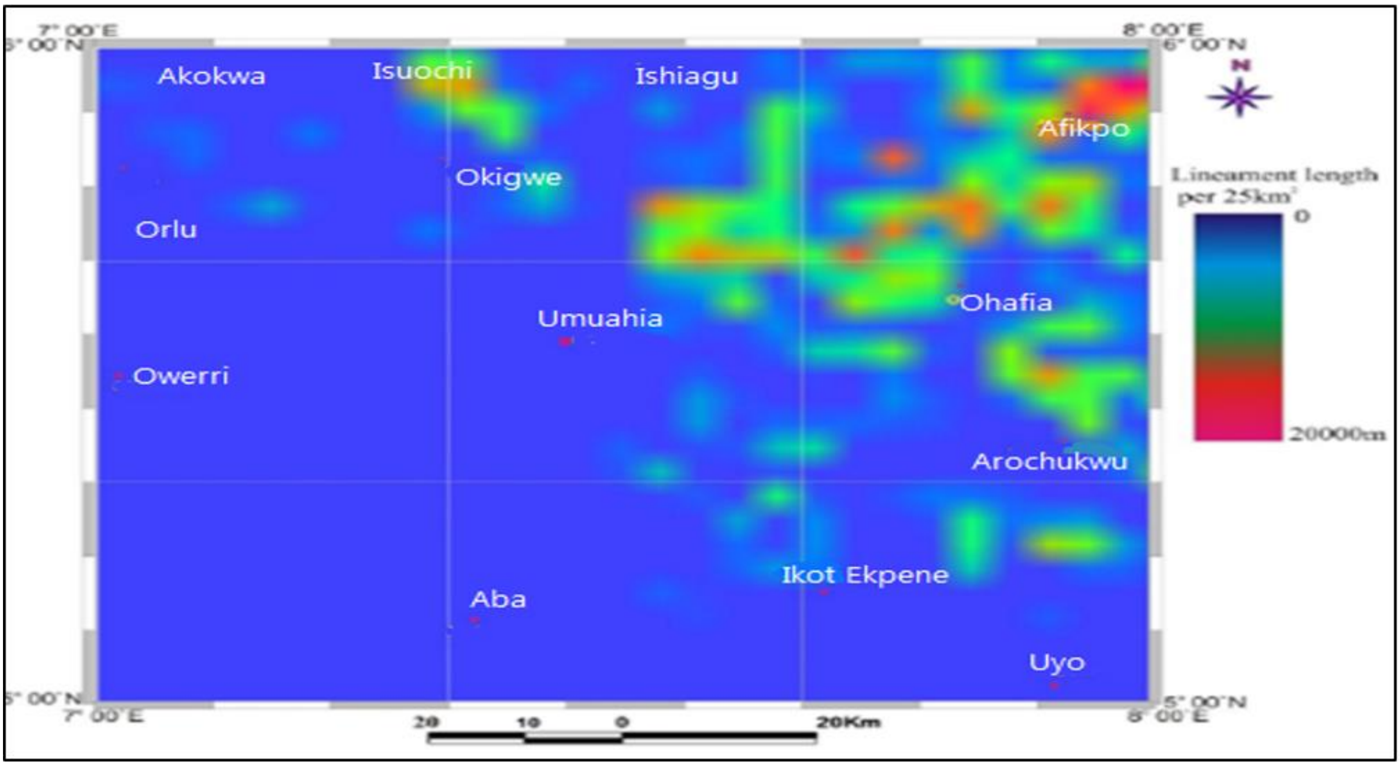

Fig 7 A Lineament density map of the area

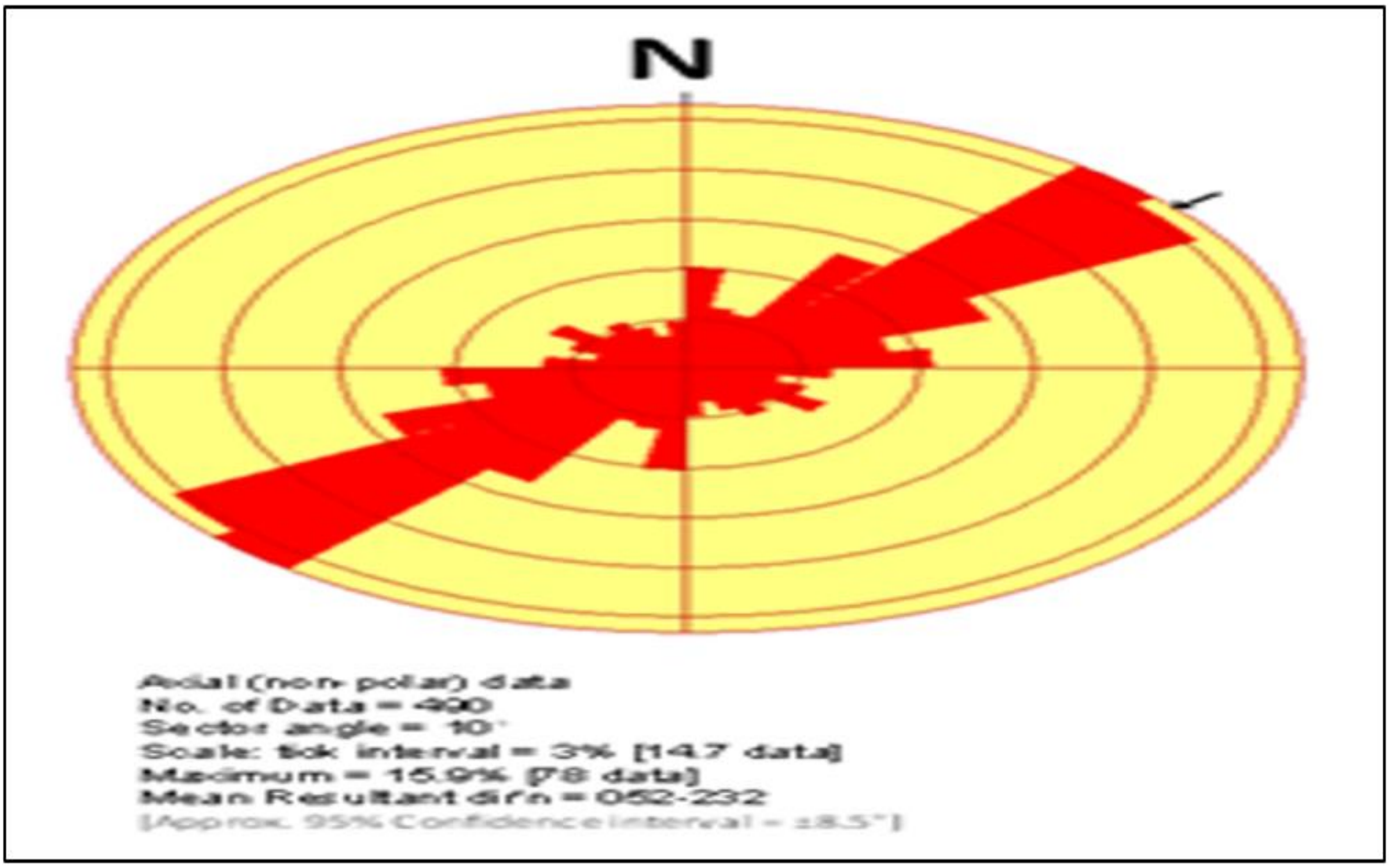

Fig 7 B Lineament Trend map of the area

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V. DISCUSSION

This study highlights the importance of integrating GPS data and high-resolution satellite imagery for analyzing landform dynamics in Southeastern Nigeria. Through the application of Digital Elevation Models (DEMs), distinct geomorphic features such as ridges, valleys, and drainage systems have been identified, confirming the influence of geological processes such as erosion and sedimentation over time (Bishop et al., 2021; Schowengerdt, 2021). The analysis's change detection component demonstrates a dynamic landscape, particularly concerning erosion patterns exacerbated by human activities and climate variability (Miller et al., 2022). This underscores the necessity for ongoing monitoring to guide effective land-use planning and environmental management (Gomez et al., 2021).

Furthermore, the lineament analysis revealed the presence of significant NE-SW trending fractures, indicating crucial structural influences on hydrology and drainage patterns (Bolstad, 2022). These findings can inform risk assessments related to landslides and other geological hazards, particularly concerning agricultural viability (Nguyen et al., 2023). The assessment of vegetation density through the Normalized Difference Vegetation Index (NDVI) showed considerable variation across the landscape, suggesting areas of ecological degradation that may result from unsustainable agricultural practices (Ali et al., 2020). This highlights the need for integrating ecological considerations into land-management strategies, reinforcing the importance of vegetation cover for soil stability and water quality (Tarolli & Sofia, 2021).

Moreover, recent studies conducted in Nigeria have underscored the necessity of utilizing remote sensing for land use and land cover mapping, demonstrating its effectiveness in identifying land degradation hotspots (Adebayo et al., 2021). Local research indicates that integrating local knowledge with remote sensing data can enhance decision-making processes for sustainable land management (Adeyemi & Alabi, 2022). The methodologies employed in this study, combining GPS, satellite imagery, and analytical techniques, proved effective for high-precision geomorphic analysis, with successful validation efforts affirming the reliability of the data (Bhusal et al., 2022). Future research could be enhanced by incorporating additional datasets, such as geological surveys, to deepen the understanding of landform dynamics. Additionally, a multidisciplinary approach integrating social and economic data will be vital in addressing the challenges faced by local communities in managing their landscapes effectively.

VI. CONCLUSION

This research underscores the utility of high-precision geospatial analysis in comprehending landform dynamics and geomorphic processes in Southeastern Nigeria. The insights gained can inform environmental management, disaster preparedness, and sustainable land-use practices, laying the groundwork for further studies that promote resilience against environmental challenges.

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