

# ASSESSMENT OF GROUND SUBSIDENCE AND DEFORMATION IN LOKPAUKWU TOWN, UMUNNOCHI LOCAL GOVERNMENT AREA OF ABIA STATE, NIGERIA

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**Abstract:** Ground subsidence and surface deformation are major environmental and geotechnical challenges in mining regions due to continuous excavation and disturbance of subsurface geological formations. This study assessed the spatial and temporal characteristics of ground subsidence and deformation in Lokpaukwu town, Umunneochi Local Government Area of Abia State, Nigeria. The research employed satellite-based remote sensing and geospatial techniques to monitor surface displacement over a ten-year period (2014-2024). Multi-temporal Sentinel-1 Synthetic Aperture Radar (SAR) measurements were used for ground validation. Additional datasets such as Shuttle Radar Topography Mission (SRTM) digital elevation models were integrated within a Geographic Information System (GIS) environment for spatial analysis and deformation mapping. Results revealed significant ground deformation across the study area, with vertical displacements values ranging from a maximum subsidence of -11.4mm to an uplift of +2.1mm during the observation period. The most intense subsidence events were recorded between 2016-2017 and 2021-2022, corresponding with periods of increased quarrying and mining activities. Trend analysis indicated an average subsidence rate of approximately -6.6mm/year, confirming persistent downward ground movement in active mining zones. Spatial velocity analysis further revealed areas of simultaneous vertical and horizontal displacement, indicating heightened geotechnical risk in certain parts of the town. The findings demonstrate the effectiveness of integrating InSAR, GNSS, and GIS techniques for monitoring mining-induced ground deformation. The study provides valuable information for land-use planning, environmental management, and the development of mitigation strategies to reduce subsidence-related hazards in mining environments.

**Keywords:** Ground subsidence, Surface deformation, InSAR, GNSS, Remote sensing, Mining activities, Geospatial analysis, Lokpaukwu town, Nigeria.

## INTRODUCTION

### 1.1. BACKGROUND TO THE STUDY

Ground Subsidence and Deformation are Significant and geographical issues that affects Mining areas. Subsidence refers to the gradual sinking or sudden collapse of the earth's surface due to subsurface or underground activities such as; mining, while deformation describes any change in the shape or volume of the ground caused by stress factors. These processes can create serious environmental, economic and social problems (Bell *et al.*, 2000).

Mining operations often disrupt the natural balance of subsurface strata, leading to ground instability. This is particularly evident in areas rich in mineral deposits such as Lopaukwu Umuchieze in Umunneochi local government area, Abia state, Nigeria.

The consequences of ground subsidence can be extensive, damaging road, building and interfering with agriculture, and in extreme situations causing fatalities (Johnson, 2005). Additionally, subsidence reshapes the terrain, producing depressions and sinkholes that may collect water and intensify flooding hazards (Singh, 1992). Addressing these problems requires detailed assessments of ground deformation patterns and their underlying causes.

Lopaukwu's geology exacerbates its vulnerability to ground instability. The region's mining methods, which frequently involves large-scale blasting and excavation undermines rock layers and increases the likelihood of subsidence (Adeboye, 2011; Zhou *et al.*, 2020). These methods deliver high-precision data, supporting effective mitigation planning and the promotion of sustainable mining practices.

## METHODOLOGY

### 2.0. MATERIALS AND METHODS

This study employed a comprehensive satellite geodesy and geospatial analysis framework to investigate ground subsidence and surface deformation in the mining area of Lokpaukwu Umuchieze in Umunneochi local government area, Abia state, Nigeria. The methodological design integrated multi-temporal satellite observations, ground-based GNSS measurement advanced time-series modeling, statistical trend analysis, GIS-based zonation. Central to the approach was the utilization of sentinel-synthetic aperture radar (SAR) data, (Massonnet *et al.*, 1998; Ferretti *et al.*, 2001) which, in combination with ground control data and digital elevation models, facilitated a robust, high-resolution assessment of surface dynamics over a decade-long period (2014 - 2024).

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2.1. STUDY AREA

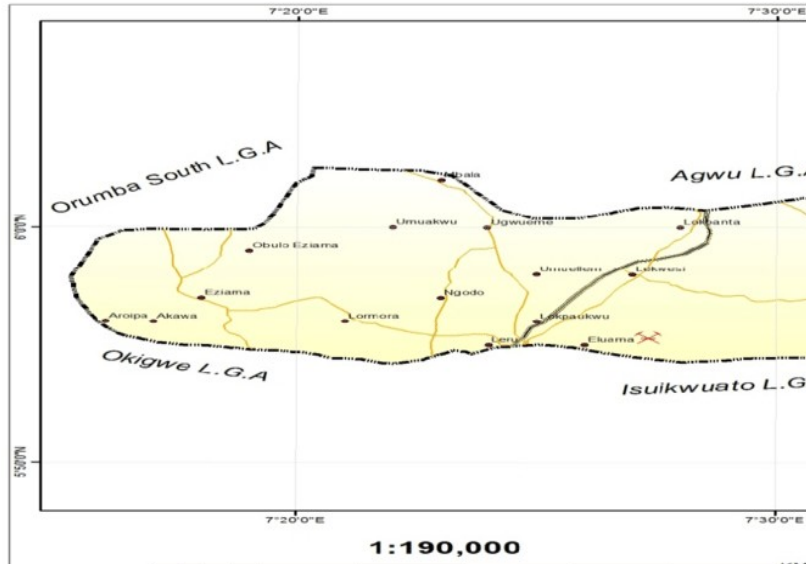


Fig 1: MAP OF THE STUDY AREA, LOKPAUKWU TOWN

2.1.1. LOCATION

Lokpaukwu town in Umunneochi local government area is situated in the north-most part of Abia state, Nigeria. It lies between the latitudes of 5°51'N and 5°56'N and longitudes 7°21'E and 7°26'E.

Lokpaukwu town is bordered Awg town in Enugu state to north, Isiagu in Ebonyi state to the east. Isuochi to the west and Uturu to the south. Lokpaukwu covers an approximate area of 3.5square kilometers.

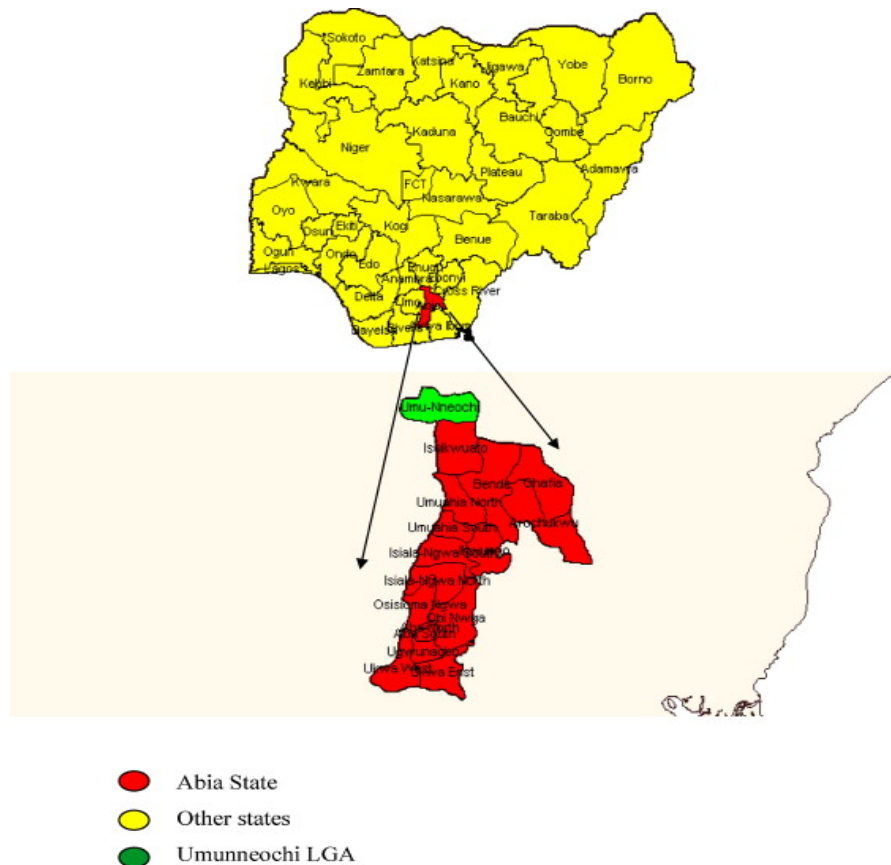


Fig 2: MAP OF UMUNNEOCHI LOCAL GOVERNMENT

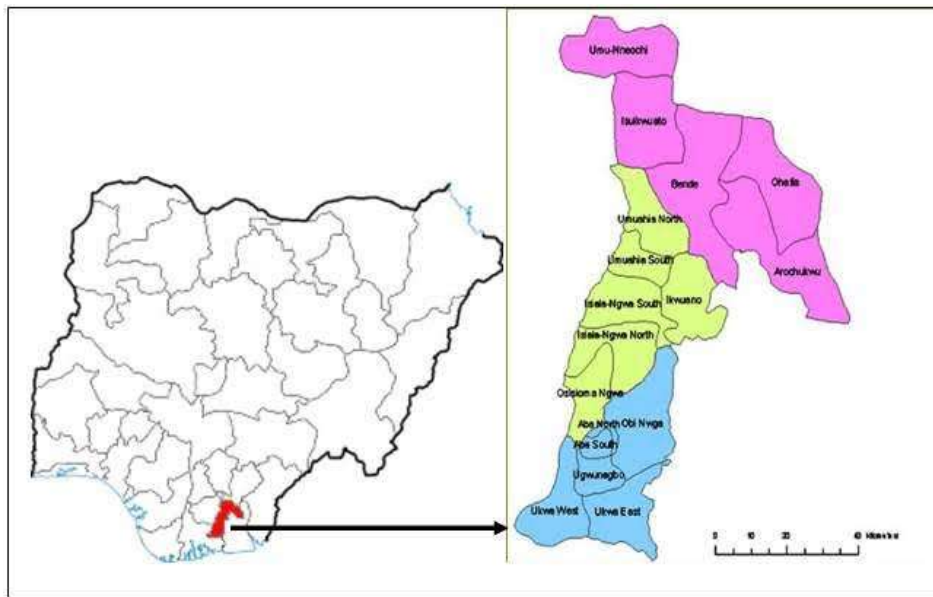


Fig 3: MAP OF ABIA STATE

### 2.1.2. GEOGRAPHY

This topography of Lokpaukwu town is characterized by low lying valleys and flat plains. The area is dominated by tropical rainforest vegetation, with seasonal water ways dominating the landscape. Lokpaukwu town is rich in mineral resources, particularly hard-core stone quarry granite. The climatic condition is typically humid tropical with an annual rainfall ranging from 2,000mm to 3,500mm and temperatures averaging between 25 degree Celsius and 30 degree Celsius. The area's diverse ecosystem supports a variety of flora and fauna, some of which are unique to the study area.

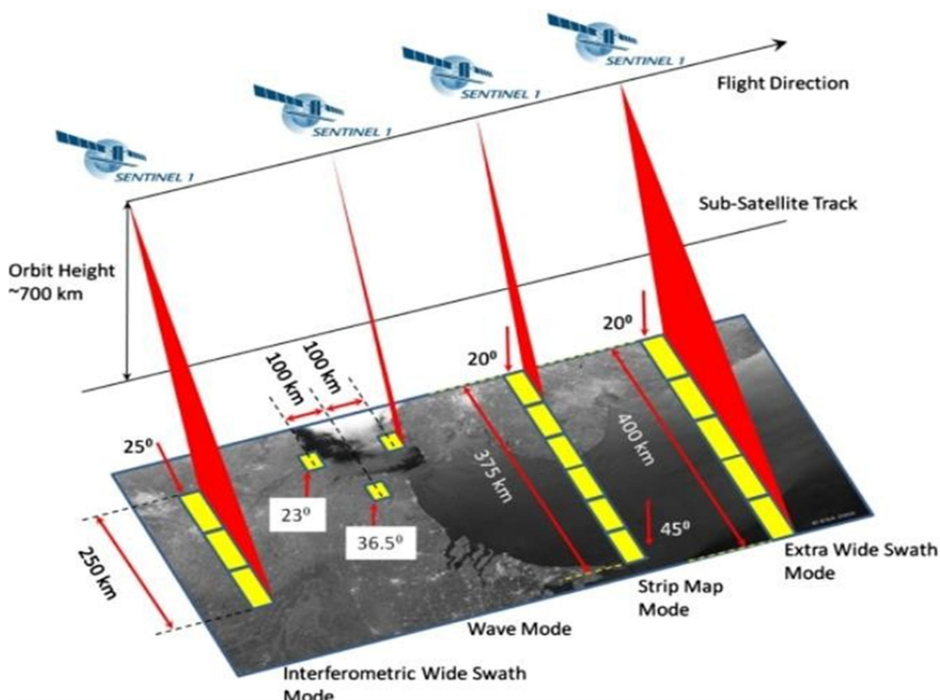
### 2.1.3 ECONOMY

The economy of Lokpaukwu town is heavily reliant on natural resources, particularly mining and agriculture. The area is

renowned for its limestone and granite quarries, which supplies raw materials for construction and industrial activities within and beyond Abia state. Agriculture also plays a significant role, with crops like, yam, cassava; maize and plantain are widely cultivated. Additionally, the timber industry contributes to local economy, although concern about deforestation and environmental degradation persists. Lokpaukwu faces challenges such as; inadequate infrastructure, poor regulation of mining activities, and environmental risks; including ground subsidence and erosion. It is common to see broken walls on foundation of buildings over public and private infrastructure.

### 2.2. DATA REQUIREMENT

The data was used includes; Sentinel-1A SLC time-series data, SRTM and GNSS ground data validation.



### 2.3. DATA ACQUISITION

Ground validation data were obtained through targeted GNSS (Global navigation satellite system) (Hofmann-Wellenhof *et al.*, 2008). Field campaign conducted in selected mining locations. These campaigns provided high-accuracy reference point that were critical for calibrating satellite-derived displacements, estimating horizontal motion components, and improving overall precision.

Primary remote sensing data were derived from sentinel-1 C-band SAR imagery, acquired through the Copernicus open access hub. Both ascending and descending track datasets were used to ensure optimal spatial coverage and enable decomposition of vertical and horizontal displacement vector.

#### 2.3.1 HARDWARE AND SOFTWARE

The hardware component includes the equipments that was used for the execution of the study and they includes:

- I. A Computer (Laptop) system with the following configuration – Hewlett Packard Elitebook, processor Intel® core i7 CPU T6570@ 3.50Ghz

The following software packages were used for this study:

1. SNAP (Sentinel application platform): used for SAR image preprocessing, co – registration, and interferogram generation.
2. STAMPS (Stanford method for persistent scatterers: applied for advance time-series analysis or displacement.
3. QGIS: Utilized for spatial data visualization, the motion, mapping, and zonation analysis.

4. Python (Numpy – pandas, matplotlib, and generation of graphic outputs.
5. Microsoft excel and word: Employed for tabular data summarization, charting and report documentation.

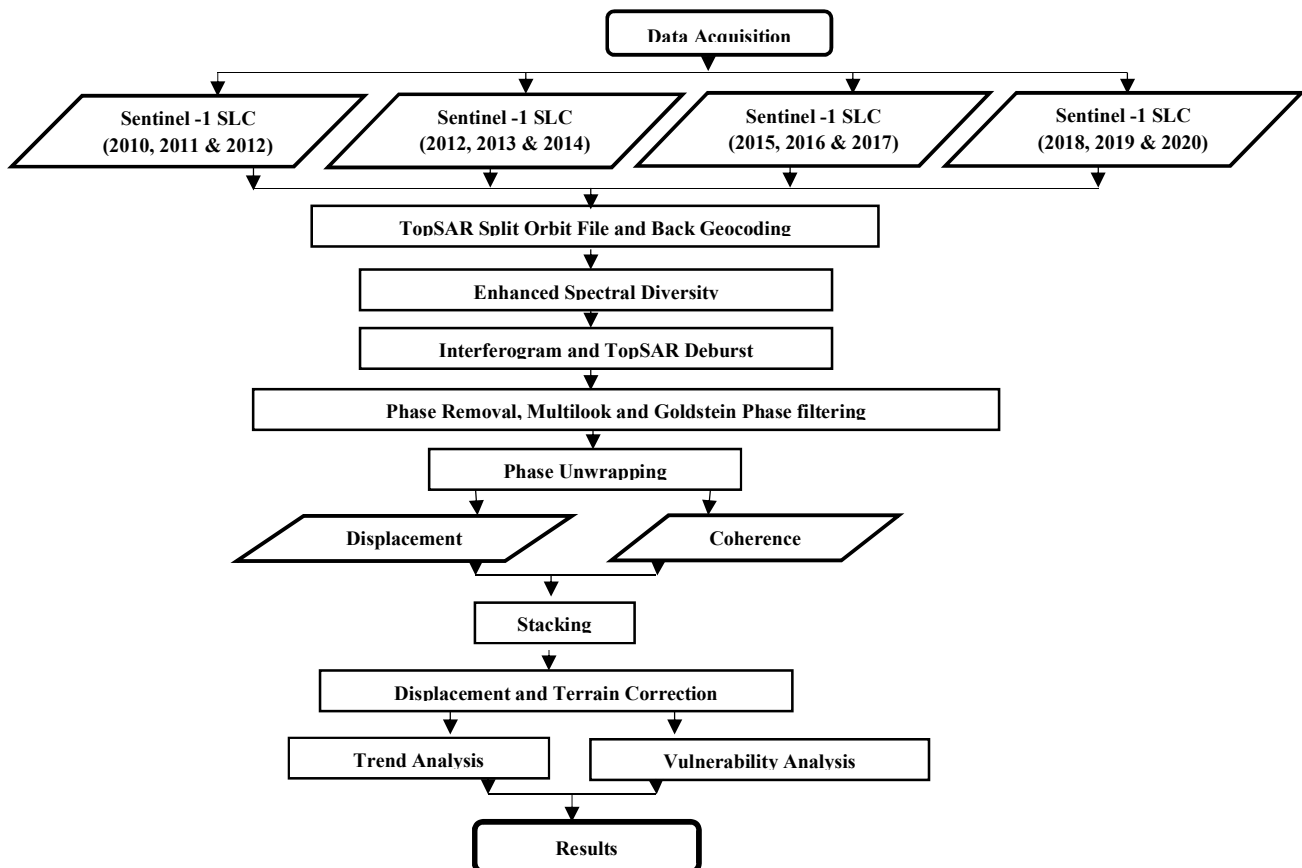
#### 2.3.2 VISUALIZATION AND INTERPRETATION

A suite of visual analytic was developed to communicate findings effectively and facilitate interpretation. Maps, velocity vector fields and temporal displacement plots, were produced using QGIS, Python( utilized libraries such as matplotlib and seaborn ), and Microsoft excel, These visual tool enabled the identification of spartial patterns, highlighted hotspots of deformation, and clarified directional trends were possible, remotely sened findings were corroborated through ground truthing, including field inspections of mining pits, haul road, and other disturbed features indicative of subsidence or surface instability.

## RESULTS

### 3.0. RESULTS AND DISCUSSION

Ground displacement in the mining areas of Lokpaukwu town umunnuchi local government area of Abia state was modeled in time – series format over a period of year. The analysis was segmented into annual epochs to better capture the temporal evolution of surface movements associated with mining activities. These displacements were derived using time – series InSAR data (Ferretti *et al.*, 2001; Berardino *et al.*, 2002), were expressed in terms of minimum and maximum values for each epoch. A negative displacement value indicates ground subsidence, while positive values represent uplift within the terrain.



**TIME – DEPENDENT GROUND DISPLACEMENT**

During the epoch of 2014 to 2015, the modeled vertical ground displacement ranged from -5.2 millimeters to +1.2 millimeters, reflecting the baseline geodynamic condition of area prior to heightened mining activities. From 2015 to 2016, subsidence deepened to a millimium value of -6.8 millimeters, whereas uplift was recorded at a maximum of +2.1 millimeters. Indicating the presence of ground instability triggered by increased excavation.

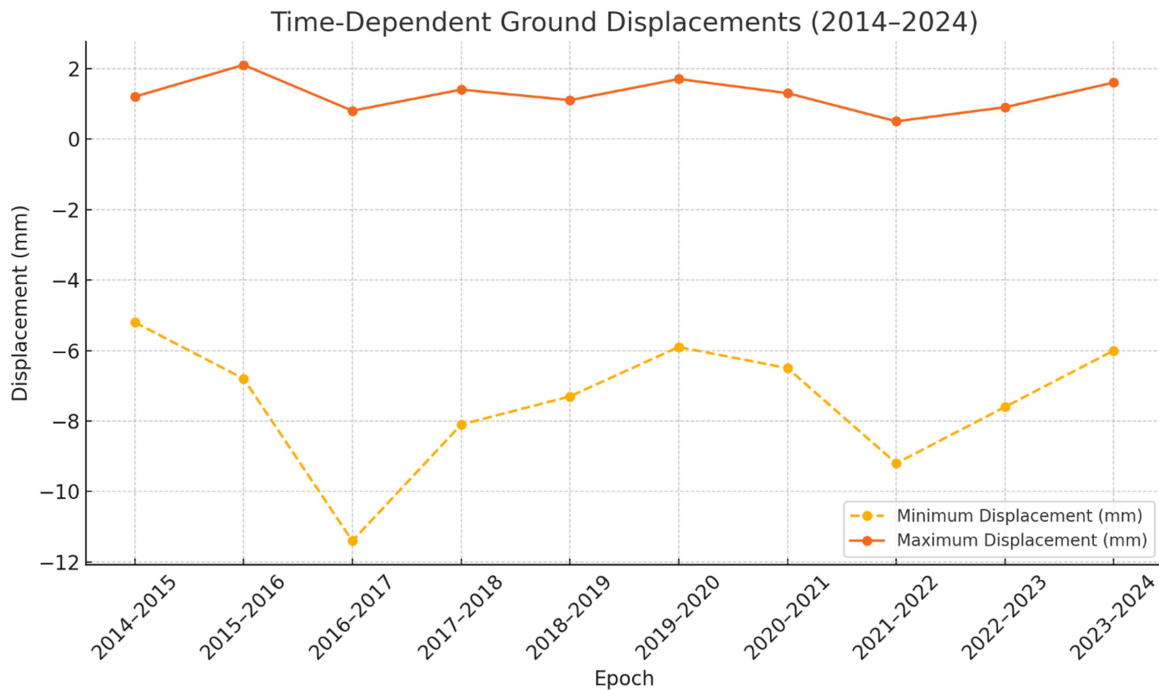
The epoch spanning 2016 to 2017 recorded the highest rate of subsidence over the period. With a minimum displacement of -11.4 millimeters. The maximum uplift was only +0.8 millimeters, indicating a strong dominance of downward movement in the timeframe between 2017 to 2018, significant subsidence continued, reaching -8.millimeters, while uplift increased slighted to +1.4millimeters, possibly influenced by limited ground recovery in les active zones.

In the following epoch of 2018 to 2019, displacement trends showed a minor reduction in intensity with subsidence reaching -7.3 millimeters and uplift measured at +1.1 millimeters. A further decline in deformation activity was observed between 2019 to 2020, as subsidence reduced to -5.9 millimeters and uplift rose to +1.7 millimeters. However, this pattern changed again in 2020 to 2021, where subsidence increased to -6.5 millimeters and uplift

dropped slightly to +1.3 millimeters, potentially due to seasonal rainfall contributing to shop saturation and further soil compaction.

From 2021 to 2022, the area experience and other notable peak in the ground deformation, with subsidence reaching -9.2 millimeters and uplift barely rising to +0.5 millimeters. This trend indicated resurgence in mining intensity or expansion into new extraction zones. The epoch of 2022 to 2023 reflected a moderate deformation pattern with the ground subsiding to a minimum of -7.6 millimeters and uplift reaching +0.9 millimeters, indicating a possible showing down of subsurface movement in areas with declining mining activities. Finally, during the most recent epoch of 2023 to 2024, subsidence was modeled at +6.0 millimeters, while uplift rose to +1.6 millimeters the second highest uplift recorded across the decade implying localized terrain rebound possibly linked to site reclamation or the end of extraction activities.

Overall, the time – dependent displacement analysis, shows that the study area underwent a recurring pattern of subsidence, the most severe movement recorded during the 2016 – 2017 and 2021 – 2022 epochs. While uplift occurred in all epochs the magnitude remained considerably lower than subsidence, indicating that downward movement was the dominant mode of deformation.

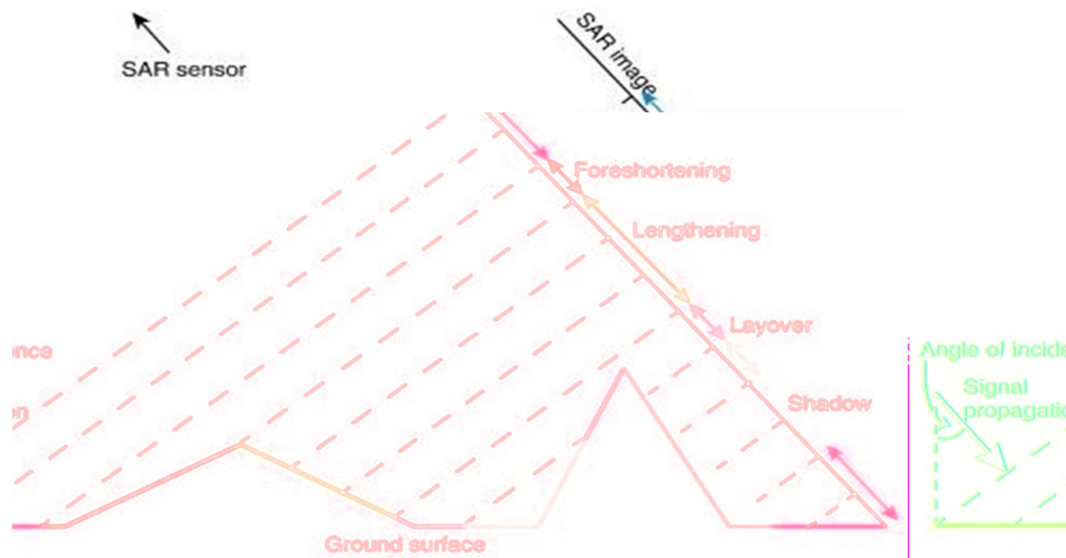


**TREND AND CHARACTERISTICS OF GROUND DISPLACEMENT IN LOKPAUKWU TOWN**

To understand the evolving nature of ground deformation across the study area, a trend analysis was conducted using the displacement data obtained from satellite – based InSAR time – series. The analysis focused on evaluating the direction and temporal characteristics of ground movement particularly subsidence from 2014 to 2024. The deformation patterns were subjected to statistical trend detections and the rate of displacement

were calculated using linear regression and moving average smoothing techniques, while non-parametric testing (Mann-Kendall) was applied to confirm significance (Mann, 1945; Kendall 1975).

The computed vertical displacement rate for the area showed a mean value of -6.7 millimeters per year, confirming a persistent downward movement. Spatial variability was also observed, as some location experienced much higher deformation intensities.



At a final point, the trend and characteristics of ground displacement in lokpaukwu town over the past decades indicates that subsidence is the prevailing deformation mode derived largely by anthropogenic activities related to mining. Patterns are complex involving both steady and episodic change with some evidence with some partial terrain recovery in abandoned mining zones. The observed spatial and temporal deformation dynamics underscore the needs for geodetic and geotechnical monitoring, especially in areas where settlements, infrastructure, or ecological assets may be exposed to structural risks due to persistent movement.

The integration of vertical and horizontal velocity data provides a comprehensive view of how the ground surface in lokpaukwu town has responded to long-term mining activities. Regions with simultaneous high subsidence and lateral movement present significant geotechnical risks and required targeted monitoring. This area should be prioritized for mitigation strategies, especially where infrastructure, residential buildings, or transport corridors are present.

To cap it all, the spatial analysis of deformation velocity in lokpaukwu town revealed the marked differences in both vertical and horizontal movement across the study area. These differences are closely tied to the intensity and extent of mining operations. The findings affirms that ground deformation in mining environments is not the only matter of vertical settlement but also involves substantial shifts, both of which must be accounted for in land use planning and hazard mitigation efforts

## SUMMARY OF FINDINGS AND CONCLUSION

### 5.1. SUMMARY OF FINDINGS

This study investigated the spatial temporal characteristics of ground subsidence and deformation across selected mining regions in lokpaukwu town in umunnochilocal government area, Abia state, Nigeria. Using the remote sensing and geospatial analysis techniques. The findings derived from InSAR time-series analysis, GNSS measurements, and velocity field modeling, are summarized.

The analysis of time-dependent ground displacement over a long period, revealed significant ground measurement, with a dominance of subsidence patterns across actively mined areas.

Cumulative displacement values across different epochs ranged from minimum of -11.4mm to a maximum uplift of +2.1mm. The period 2016 to 2017 and 2021 to 2022 recorded the most intense subsidence events, which coincided with known quick quarrying activities, indicating a strong correlation between mining intensity and surface deformation.

Trend analysis confirmed that the subsidence behavior was not uniform but exhibited both linear and episodic characteristics. The overall average vertical displacement rate across the study area was -6.6mm/year with standard deviations of Kendall trend test showed statistically significantly negative trend in displacements.

The study established that mining-induced ground deformation in Lokpaukwu town is a serious and spatially dynamic phenomenon, characterized by significant subsidence and lateral ground displacement. The combination of InSAR, GNSS and GIS-based analytics proved effective in quantifying, monitoring, and mapping these changes thereby offering actionable insight for land-use planning, hazard mitigation, and sustainable mining practices in the study area.

### CONCLUSION

The research has demonstrated that mining activities in Lokpaukwu town in umunnochilocal government area Abia state, Nigeria, have led to significant ground deformation over the past decades through the integration of satellite-based InSAR time-series analysis, GNSS measurements, and geospatial modeling techniques, the study effectively qualified and visualized the extent, trend and spatial distribution of both vertical and horizontal ground displacements in the study area.

Displacement trends over a long period which showed both linear and episodic subsidence behavior, with deformation rates peaking during years of increased mining intensity. Additionally, the analysis of horizontal movement vectors revealed that terrain is undergoing directional shifts primarily toward the southwest and southeast, consistent with the slope and structural layout area.

The spatial variation in velocity field highlighted the heterogeneity of ground movement, with high-risk subsidence zones clearly delineated through zonation mapping. These critical

zones, if left unmanaged, pose potential risk to infrastructure, ecological systems, and human settlements.

The study overall, validates the importance of remote sensing and geospatial techniques as effective tools for monitoring land surface dynamics in mining environments. The result provides a scientific foundation for stakeholders including, policymaking environmental managers, and mining operators to develop and implement informed mitigation strategies. Moreover, the methodological framework adopted in this study can serve as a blueprint for a similar assessment in other mining prone regions.

## RECOMMENDATIONS

Based on the findings of the study, the following recommendations are made, which are;

1. It is recommended that a continuous and institutionalized monitoring framework should be established using remote sensing, GNSS stations, and periodic field surveys. This program will enable the early detection of abnormal ground movement and inform timely intervention in high risk zones.
2. In locations where subsidence rates are high early warning systems including ground sensors tilt meters, and satellite-triggered alerts should be deployed to safeguard life and property particularly in and around residential and industrial zones.
3. Future studies should expand the current approach by integrating soil geotechnical properties hydrological modeling, and 3D subsurface imaging to better understand the deformation mechanisms. Calibration with higher-resolution datasets such as LIDAR and UAV photogrammetric is also recommended.
4. The results of this study are strongly recommended to serve as a decision-support tool for ongoing subsidence monitoring and land-use management within lokpaukwu town. The insights gained can guide policy formulation, infrastructure planning, and environmental risk mitigation efforts.

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