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Spatio-Temporal Assessment Of Vegetation Cover Changes In Selected Agricultural Areas Of Ahaba Imenyi, Isuikwuato Local Government Area, Abia State, Nigeria (2000–2025)

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Abstract

This study assessed spatio-temporal changes in vegetation cover and their implications for agricultural land affected by gully erosion in Ahaba Imenyi, Isuikwuato Local Government Area, Abia State, Nigeria, between 2000 and 2025. Geographic information systems (GIS) and remotely sensed imagery were used to examine Normalized Difference Vegetation Index (NDVI) patterns for the two observation years. The reported analysis involved NDVI raster differencing, threshold-based reclassification of vegetated/agricultural land using NDVI ≥ 0.15, zonal statistics within site polygons and computation of area change in ArcGIS 10.8. The mapped results describe a greater presence of low-NDVI areas in parts of the southern and southwestern study area in 2025 than in 2000. Quantitative values reported for three locations indicate reductions in the mapped vegetated/agricultural area: Amiyi Ahaba decreased from 839,713 m² to 587,419 m² (30.0%); Ihie Ahaba decreased from 685,927 m² to 495,183 m² (27.8%); and Ahaba Ehuma decreased from 233,217 m² to 171,839 m² (26.3%). These results indicate a decline in NDVI-defined vegetated area at the three reported locations. The spatial correspondence between these changes and areas described as affected by gully erosion suggests an association

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between erosion-affected terrain and vegetation loss. However, NDVI change alone does not prove that gully erosion caused all observed vegetation changes. The study provides geospatial evidence relevant to agricultural land monitoring and identifies the need for field-based erosion measurements and validated land-cover classification in future work.

Keywords: Normalized Difference Vegetation Index, Vegetation Change, Gully Erosion, Agricultural Land, Remote Sensing, GIS, Ahaba Imenyi, Nigeria

1. INTRODUCTION

1.1 Background to the Study

Vegetation cover is an important component of agricultural and environmental systems. It provides an indication of land-surface condition and is associated with soil protection, moisture regulation, habitat quality and agricultural productivity. Changes in vegetation cover may reflect several interacting processes, including cultivation, fallow cycles, settlement expansion, vegetation clearance, climatic variability and land degradation.

Gully erosion is a form of land degradation that removes soil through concentrated surface runoff. As gullies expand, they may dissect agricultural plots, remove productive topsoil, expose bare surfaces and restrict access to farmland. In humid southeastern Nigeria, high rainfall, terrain characteristics, erodible surface materials and human activities can contribute to runoff concentration and erosion development (Umo, Ibanga and Ike, 2018; Akanwa and Ezeomedo, 2018/2019).

Satellite remote sensing provides a means of observing vegetation conditions over large areas and comparing land-surface patterns across different dates. The Normalized Difference Vegetation Index (NDVI), derived from near-infrared and red reflectance, is commonly used to indicate relative vegetation greenness. Higher positive values generally correspond to greater photosynthetically active vegetation, while lower values may indicate sparse vegetation, bare ground, built-up surfaces or water. NDVI is therefore useful for monitoring vegetation change, but it is not a direct measurement of soil moisture and cannot, by itself, establish the cause of vegetation loss.

This study consequently focuses on the vegetation-change evidence contained in the available NDVI maps and area calculations for Ahaba Imenyi between 2000 and 2025. Soil-moisture estimation is outside the scope of the analysis presented because the available manuscript does not report Soil Water Index outputs or numerical field soil-moisture measurements.

1.2 Statement of the Problem

Agricultural land in Ahaba Imenyi is exposed to environmental pressures that may reduce vegetation cover and affect the continuity and productivity of cultivated areas. Gully erosion can remove or fragment agricultural land, while other land-use and seasonal processes can also alter vegetation patterns. Despite these concerns, spatially explicit comparisons of vegetation condition across the study area and over time are limited in the material presented.

The research problem addressed here is the lack of a clearly documented comparison of vegetation cover for the 2000 and 2025 observation years at locations identified as being affected by gully erosion. The study uses NDVI mapping and reported zonal area statistics to describe the extent and spatial distribution of vegetation change. It treats the relationship with gully erosion as a spatial association rather than a proven causal effect.

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1.3 Aim and Objectives

The aim of the study was to assess spatio-temporal changes in vegetation cover and examine their implications for agricultural land in gully-erosion-affected locations of Ahaba Imenyi, Isuikwuato Local Government Area, Abia State, between 2000 and 2025.

The specific objectives were to:

1. map the spatial distribution of NDVI in the study area for 2000 and 2025;
2. identify areas showing relative vegetation persistence, gain or decline between the two observation years;
3. quantify changes in NDVI-defined vegetated/agricultural area within the site polygons for which numerical results were reported; and
4. discuss the implications of the observed vegetation changes for agricultural land monitoring and erosion management.

1.4 Significance of the Study

The study provides a spatial comparison of vegetation conditions at two observation dates and identifies locations where the mapped vegetated/agricultural area declined. Such information can support preliminary agricultural land monitoring, prioritisation of field inspections and the identification of areas requiring erosion-control attention. The findings should be interpreted as NDVI-based evidence and not as direct measurements of soil moisture, crop yield or the physical volume of soil lost.

2. LITERATURE REVIEW

2.1 NDVI and Vegetation Monitoring

NDVI is calculated from the contrast between near-infrared (NIR) and red (Red) reflectance. Healthy green vegetation typically absorbs red light for photosynthesis and reflects a relatively large proportion of near-infrared energy. NDVI provides a dimensionless indicator that can be mapped and compared across locations and dates when imagery acquisition and processing are sufficiently consistent.

NDVI has limitations. Values may be influenced by vegetation type and density, soil background, atmospheric conditions, cloud and shadow contamination, sensor differences, image season and phenological stage. A decline in NDVI-defined area therefore indicates a change in the mapped vegetation signal; additional evidence is needed to attribute that change specifically to gully erosion.

2.2 Gully Erosion and Agricultural Land

Previous geospatial studies in southern Nigeria have examined the relationship between gully erosion, rainfall, terrain and human activities. Umo, Ibanga and Ike (2018) used geospatial techniques to assess gully erosion in the humid tropics and discussed the influence of rainfall, surface configuration and anthropogenic activities. Akanwa and Ezeomedo (2018/2019) examined gully erosion and its effects on farmers in Akpo, Anambra State, using field survey, remote sensing and GIS. These studies demonstrate the relevance of spatial analysis for identifying erosion-affected land and informing mitigation.

The present study contributes a two-date NDVI comparison for selected locations in Ahaba Imenyi. Its contribution is limited to the vegetation patterns and area statistics reported in the available analysis.

3. STUDY AREA

The study area is Ahaba Imenyi in Isuikwuato Local Government Area of Abia State, southeastern Nigeria. The analysis focuses on the locations identified in the source maps and numerical results: Amiyi Ahaba, Ihie Ahaba and Ahaba Ehuma. The administrative location is retained from the source manuscript.

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Precise study-boundary coordinates, total study-area size, climatic normals and detailed geological descriptions are not reproduced here because the source manuscript did not provide a verifiable map reference or supporting authoritative data for independently checking those particulars.

The precise geographic extent and physical-environment descriptions should be confirmed against the study-area boundary file, an authoritative administrative map and appropriate meteorological or geological sources. Accordingly, unverified coordinate limits, area estimates and detailed climate/geology claims are not treated as established facts in this study.

4. MATERIALS AND METHODS

4.1 Research Design

The study adopted a comparative remote-sensing and GIS approach to assess vegetation conditions in 2000 and 2025. The analysis focused on NDVI maps and the reported area statistics for selected site polygons in Ahaba Imenyi.

4.2 Satellite Image Acquisition and Data Sources

Satellite imagery covering Ahaba Imenyi, Isuikwuato Local Government Area, Abia State, was obtained from the United States Geological Survey (USGS) EarthExplorer platform for two observation periods, 2000 and 2025. Landsat imagery was used for the 2000 observation period, while Sentinel-2 imagery was used for 2025. The Sentinel-2 imagery was acquired using the MultiSpectral Instrument (MSI), which provides multispectral data suitable for vegetation monitoring and land-cover assessment.

The downloaded satellite images were processed and analysed using ArcGIS 10.8. The red and near-infrared spectral bands were used to derive the Normalized Difference Vegetation Index (NDVI). For Sentinel-2 imagery, Band 4 (Red) and Band 8 (Near-Infrared) correspond to the 10-metre spatial-resolution bands used in NDVI calculation. The exact Landsat sensor and band identifiers for the 2000 imagery could not be established because the original image metadata were unavailable.

The exact acquisition dates, Landsat product identifier, Sentinel-2 product level, cloud-cover percentage and image-processing metadata were not available for verification. These details are therefore acknowledged as limitations of the available image records.

4.3 NDVI Derivation

The Normalized Difference Vegetation Index (NDVI) was used to assess vegetation conditions within the study area. NDVI was calculated using the standard equation:

$$NDVI = (NIR - Red) / (NIR + Red)$$

Where NIR represents the near-infrared spectral band and Red represents the red spectral band. The index measures the difference between vegetation reflectance in the near-infrared and red portions of the electromagnetic spectrum. Higher positive values generally indicate greener vegetation, while lower values may indicate sparse vegetation, bare surfaces or non-vegetated land.

4.4 Image Processing and Change Detection

The satellite images for 2000 and 2025 were processed using ArcGIS 10.8. NDVI was derived from the corresponding red and near-infrared bands, and the resulting NDVI layers were used to examine vegetation-cover conditions for the two observation periods.

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Raster differencing was applied to examine spatial changes in NDVI between 2000 and 2025. An NDVI threshold of 0.15 and above was applied to identify vegetated areas for the area calculations reported in the study. Zonal statistics were subsequently used to estimate the areas within the selected locations.

The areas identified for the two observation periods were compared to determine the magnitude and percentage change in NDVI-defined vegetated areas. Percentage change was calculated as:

$$\text{Percentage Change (\%)} = [(A_{2000} - A_{2025}) / A_{2000}] \times 100$$

Where A_{2000} represents the mapped vegetated area in 2000 and A_{2025} represents the mapped vegetated area in 2025. Positive values indicate a reduction in NDVI-defined vegetated area between the two observation periods.

4.5 Field Sampling and Soil-Moisture Information

Five soil samples were collected from selected locations within the study area as part of the field investigation. The sampling was intended to support the assessment of soil-moisture conditions. However, the detailed sampling coordinates, collection dates and corresponding soil-moisture measurements were unavailable for quantitative analysis.

Consequently, the five soil samples were not used for statistical validation of the NDVI results. The reported vegetation-cover changes are based on the remotely sensed NDVI analysis and the area statistics available for the selected locations. The absence of corresponding soil-moisture measurements is recognised as a limitation of the study.

5. RESULTS

5.1 NDVI Pattern in 2000

The 2000 NDVI map is described in the source analysis as showing relatively high NDVI values across much of the study area, with scattered low-NDVI patches in peripheral or disturbed locations. The source text reports values approaching 0.28 in areas of stronger vegetation signal and values approaching −0.27 in lower-NDVI patches. These values are retained as reported; the underlying raster was not available for independent inspection.

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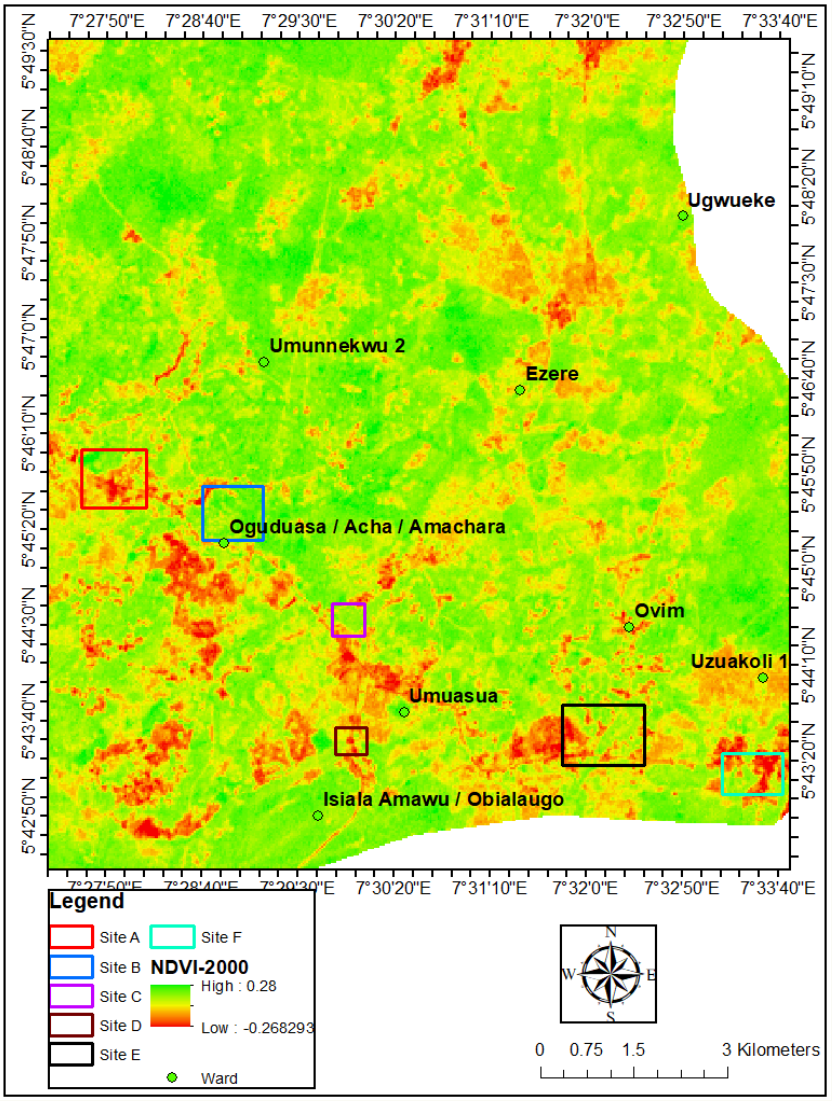


Figure 1. NDVI distribution in Ahaba Imenyi, 2000 (source map supplied in the original manuscript).

5.2 NDVI Pattern in 2025

The 2025 NDVI map is described as showing an expansion of low-NDVI zones towards the southern and southwestern parts of the study area. The source analysis identifies locations around Amiyi Ahaba, Ihie Ahaba and Ahaba Ehuma among the areas where lower vegetation signals were observed. Higher NDVI values were reported to persist in some northern and northeastern sectors, although vegetation signals in central areas were described as fragmented.

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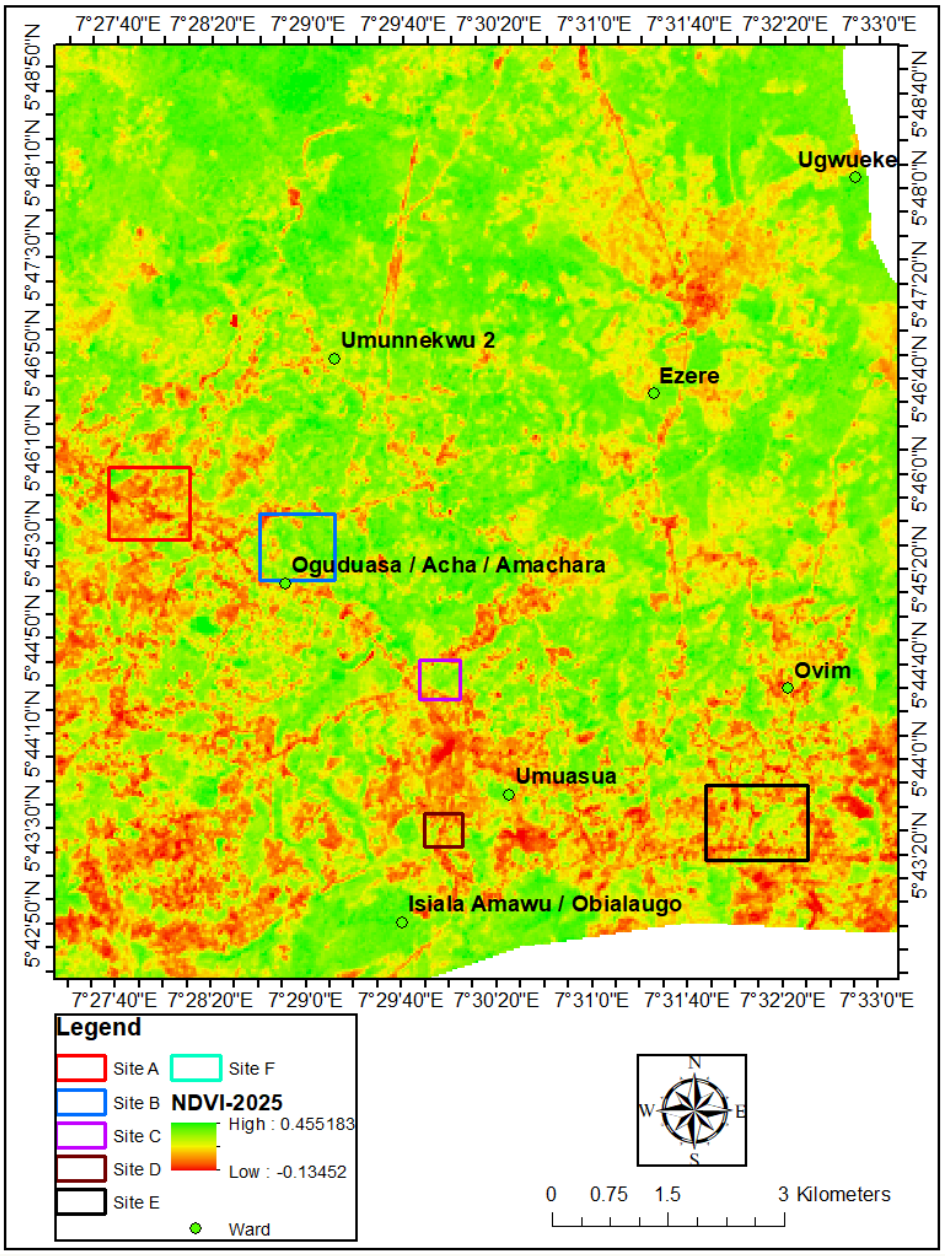


Figure 2. NDVI distribution in Ahaba Imenyi, 2025 (source map supplied in the original manuscript).

5.3 Change in NDVI-Defined Vegetated/Agricultural Area

Numerical area statistics were supplied for three locations: Amiyi Ahaba, Ihie Ahaba and Ahaba Ehuma. The reported areas and recalculated percentage changes are presented in Table 1.

Location	Area 2000 (m²)	Area 2025 (m²)	Change (m²)	Change (%)
Amiyi Ahaba	839,713	587,419	−252,294	−30.0
Ihie Ahaba	685,927	495,183	−190,744	−27.8
Ahaba Ehuma	233,217	171,839	−61,378	−26.3

Source: Author's analysis as reported in the original manuscript: ArcGIS 10.8, NDVI raster differencing, NDVI ≥ 0.15 reclassification and zonal statistics. Percentage changes were recalculated from the area values in the table.

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All three reported locations recorded a decline in NDVI-defined vegetated/agricultural area between 2000 and 2025. Amiyi Ahaba had the largest absolute reduction (252,294 m^2) and the largest percentage reduction (30.0%). Ihie Ahaba declined by 190,744 m^2 (27.8%), while Ahaba Ehuma declined by 61,378 m^2 (26.3%). These values describe the area classified above the stated NDVI threshold; they should not be interpreted as direct measurements of total agricultural land lost or soil removed by erosion.

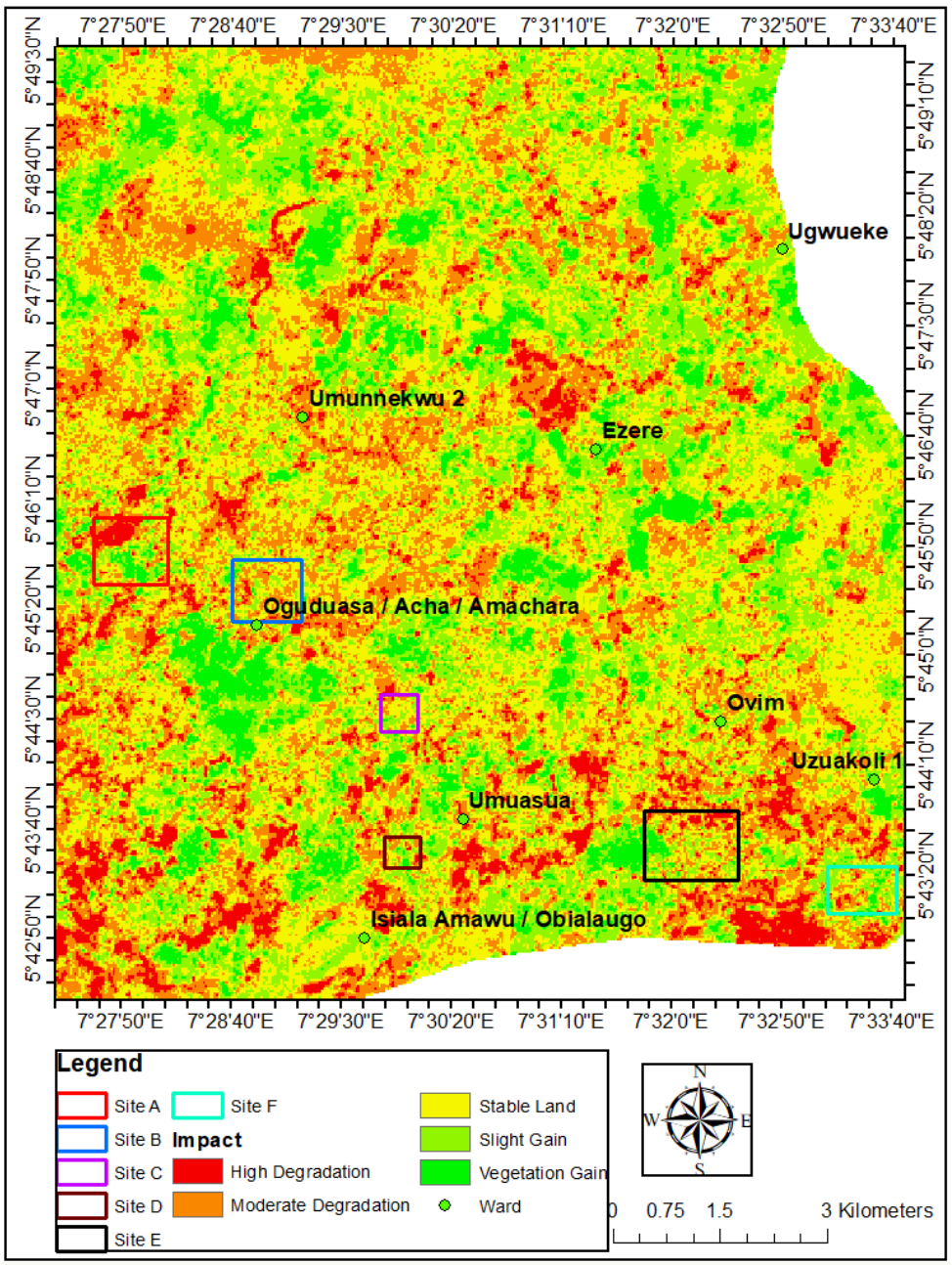


Figure 3. Spatial distribution of NDVI-defined vegetation changes in selected agricultural areas of Ahaba Imenyi between 2000 and 2025.

6. DISCUSSION

The two-date NDVI comparison indicates a reduction in the area classified as vegetated/agricultural at the three locations for which numerical results were reported. The largest proportional reduction occurred at Amiyi Ahaba, followed by Ihie Ahaba and Ahaba Ehuma. The mapped expansion of lower-NDVI areas towards parts of the southern and southwestern study area is consistent with the reported pattern of vegetation decline in those sectors.

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The spatial pattern is relevant to agricultural land management because vegetation cover can help protect soil surfaces from raindrop impact and runoff. Where vegetation is removed or fragmented, exposed soil may become more susceptible to erosion. Conversely, active gully erosion can remove vegetation and make cultivation difficult. The relationship can therefore be mutually reinforcing. Nevertheless, the NDVI results alone do not establish the direction or magnitude of causation. Seasonal differences, crop rotations, fallowing, land clearing, settlement growth, fire, image conditions and sensor differences may also influence NDVI.

The results should be treated as a preliminary spatial assessment. A stronger causal assessment of gully erosion impacts would require mapped gully boundaries for both dates, measurements of gully length, width and expansion, field verification of affected agricultural plots, consistent image acquisition seasons and a formal accuracy assessment of the vegetation classification. The original draft's qualitative six-site table also conflicts with the three-site quantitative area table; only the three locations with numerical values have been retained in the quantitative results.

7. CONCLUSION AND RECOMMENDATIONS

This study assessed vegetation-cover change in Ahaba Imenyi using NDVI mapping for 2000 and 2025. The reported maps indicate a greater presence of low-NDVI areas in parts of the southern and southwestern study area in 2025. Quantitative results for Amiyi Ahaba, Ihie Ahaba and Ahaba Ehuma show reductions of approximately 30.0%, 27.8% and 26.3%, respectively, in the area classified as vegetated/agricultural using the NDVI ≥ 0.15 threshold. The findings provide evidence of NDVI-defined vegetation decline at these locations and identify areas that merit closer agricultural and erosion-management attention.

The study does not establish soil-moisture conditions, nor does it demonstrate that gully erosion alone caused the observed vegetation changes. Recommendations are therefore directed towards monitoring and field verification:

1. Undertake field inspections at the three locations with reported vegetation decline to verify current land cover and identify the extent of active gully encroachment;
2. Map and measure gully boundaries and dimensions, and compare them with the 2000 and 2025 vegetation-change layers;
3. Prioritise appropriate runoff management, drainage maintenance and vegetative soil-conservation measures in verified erosion-prone locations;
4. Repeat NDVI monitoring using imagery acquired in comparable seasons and document sensor, preprocessing and classification procedures; and
5. Conduct an accuracy assessment using field reference points before using the mapped areas for detailed agricultural planning or policy decisions.

8. LIMITATIONS OF THE STUDY

The analysis is constrained by the information documented in the source manuscript. Exact satellite sensors, acquisition dates, image preprocessing details and classification accuracy statistics were not reported. Numerical area statistics were available for only three locations, although the original qualitative table referred to six sites. No field validation dataset for vegetation classification or measured gully dimensions was supplied. In addition, the soil-core samples mentioned in the original draft were not

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accompanied by soil-moisture readings and were not used in this NDVI-focused study. These limitations restrict the strength of causal conclusions and should be addressed before publication.

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