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Multi-Epoch Land Use And Land Cover Change Detection In Sand-Mining Communities Along Ase Creek, Delta State, Nigeria: A Remote Sensing and GIS Approach (2003–2023)

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ABSTRACT

The aim of this study is to unveil the multi-epoch land cover and land use changes which have occurred over time in the sand mining communities of the study area. To achieve this aim, the study outlined and investigated three (3) objectives: (i) To map and quantify the spatial differences in the LULC composition and distribution among Ashaka, Ivorogbo, and Asaba-Ase communities in the study area. (ii) to compute epoch-specific and cumulative area changes for each land cover class, distinguishing between positive trajectory classes (expanding area) and negative trajectory classes (declining area); and (iii) to interpret the observed changes in the context of documented sand mining activity-history in the area. The use of Multi-temporal Landsat 7 ETM+ and Landsat 8 OLI/TIRS imagery acquired from the USGS EarthExplorer portal was classified using a combined supervised and unsupervised classification protocol, trained on field-verified reference polygons and high-resolution Google Earth Pro imagery, across six land cover categories. Results for Ashaka (1,548.48 ha) reveal that vegetation declined from 334.26 ha (21.59%) in 2003 to 209.59 ha (13.97%) in 2023, a net reduction of 124.67 ha over 20 years, while built-up/bare land expanded from 727.29 ha (46.96%) to 830.40 ha (55.35%). Sand dump sites at Ashaka expanded from 50.77 ha in 2003 to a peak of 86.66 ha in 2013, subsequently declining to 80.23 ha in 2023 following documented enforcement activity. In Ivorogbo (793.48 ha), forest cover declined from 22.71% to 12.97% over the 20-year period, while in Asaba-Ase (338.98 ha), sand dump site extent increased nearly sevenfold from 0.60 ha to 4.00 ha between 2003 and 2023. These findings confirm that unregulated sand extraction is driving systematic deforestation, vegetation degradation, and landscape fragmentation across the Ase Creek riparian corridor, with the ecological and social consequences demanding urgent, evidence-based policy intervention.

Keywords: land use land cover change; LULC; remote sensing; GIS; sand mining; Ase Creek; Landsat; classification; deforestation; Niger Delta

INTRODUCTION

Anthropogenic activities within and around geographical areas of the globe are not without environmental changes. These include the Mississippi River Basin, rivers in India, the Nile River Basin, The Niger River, the Congo River, etc. all have their problems resulting from human activities (Singh, 2024; Liu et

al. 2023, and Eli, 2023). Investigating and understanding properly such environmental problems form an area of focus which most environmentalists are interested.

The complex and complicated nature of most fluvial systems, especially those poorly drained, have difficult terrains which are a result of man – nature interrelationship ranging from agricultural activities, to settlement development, logging, sand mining, etc. are human involvements that are capable of causing negative effects on human society which are capable of changing land uses and land cover.

Land cover change detection through multi-temporal remote sensing analysis has become an indispensable tool in environmental science, providing spatially explicit, historically traceable evidence of landscape transformation that cannot be obtained through field observation alone. In regions where extractive industries exert sustained pressure on natural ecosystems — as in the case of sand mining along tropical alluvial waterways — remote sensing change detection provides the empirical foundation for evaluating the rate, spatial extent, and trajectory of ecosystem degradation over time, informing both scientific understanding and policy design (Enaruvbe & Pontius, 2015; Makhtoumi et al., 2023).

Sand mining-induced land cover change encompasses several interconnected processes operating at multiple spatial scales. At the extraction site itself, the immediate conversion of vegetated riverbank to bare excavated surface represents the most direct and visible form of land cover transformation. Beyond the site boundary, however, extraction activities drive secondary landscape changes through bank erosion and lateral channel migration, which progressively convert riparian forest and farmland to river channel area; through the creation of access tracks and haul roads that fragment forest cover and create linear corridors of bare ground; and through the spillover of sand during transport and stockpiling operations that creates localised bare ground and sand dump features detectable in satellite imagery (Deguenon et al., 2022; Torres et al., 2017).

In the Ase Creek, riparian corridor of Delta State, Nigeria, the land cover consequences of three decades of commercial sand extraction have proceeded without systematic spatial monitoring. The absence of a multi-epoch LULC change baseline has represented a significant constraint on policy and management responses, depriving regulatory authorities of the quantitative landscape-scale evidence needed to define sustainable extraction limits, delineate environmentally sensitive areas requiring protection, and assess the cumulative impact of dispersed extraction operations on the regional ecosystem. The present study addresses this evidence gap through the production of a six-class LULC change detection analysis for three extraction-affected communities across three-time epochs, using freely available Landsat imagery and standard GIS analytical tools.

This study is structured around three analytical objectives: (i) To map and quantify the spatial differences in the LULC composition and distribution among Ashaka, Ivorogbo, and Asaba-Ase communities in the study area, (b) to compute epoch-specific and cumulative area changes for each land cover class, distinguishing between positive trajectory classes (expanding area) and negative trajectory classes (declining area); and (c) to interpret the observed changes in the context of documented sand mining activity-history, identifying extraction-driven change signals within the broader matrix of land cover transitions that reflect multiple anthropogenic and natural drivers.

The Drainage Basin Concept

The drainage basin also known as the river basin, is of the view that all solid superficial spaces on the earth's surface at precipitation drain to a destination which terminate at specific destinations or continue the same event in cyclic form (Iboaya, 1991; Eze & Abua, 2003; Eli, 2012).

The study area, which is in the geomorphological space of the Niger Delta is drained through many run-offs of various kinds. The lowland fluvial features as well as the equatorial high rainfall nature have resulted in so many drains of various types also in the study area. Considering the drainage basin as a concept is relevant to this study.

Study Area

The study area encompasses three riparian communities — Ashaka, Ivorogbo, and Asaba-Ase — situated along the principal sand-mined reaches of Ase Creek in Ndokwa East Local Government Area, Delta State, Nigeria. Ase Creek flows through a Quatenary alluvial plain characterised by Coastal Plain Sands

and Sombreiro-Warri Deltaic Plain deposits, supporting a riparian ecosystem mosaic of freshwater swamp forest, gallery woodland, and seasonally flooded agricultural terraces (Oseji & Ofomola, 2010). The total study area encompasses approximately 2,680 hectares across the three communities, with Ashaka covering the largest extent at 1,548.48 ha, Ivorogbo at 793.48 ha, and Asaba-Ase at 338.98 ha (See figure 1).

Commercial sand extraction has been ongoing along the Ase Creek corridor since the early 1990s, with extraction intensity increasing through the 2000s and 2010s in response to growing construction demand in regional urban centres. The period 2003–2023 therefore captures a substantial portion of the cumulative extraction history of the creek and the associated land cover trajectory, making it an analytically appropriate window for detecting extraction-induced landscape change signals above the background noise of natural and other anthropogenic land cover dynamics.

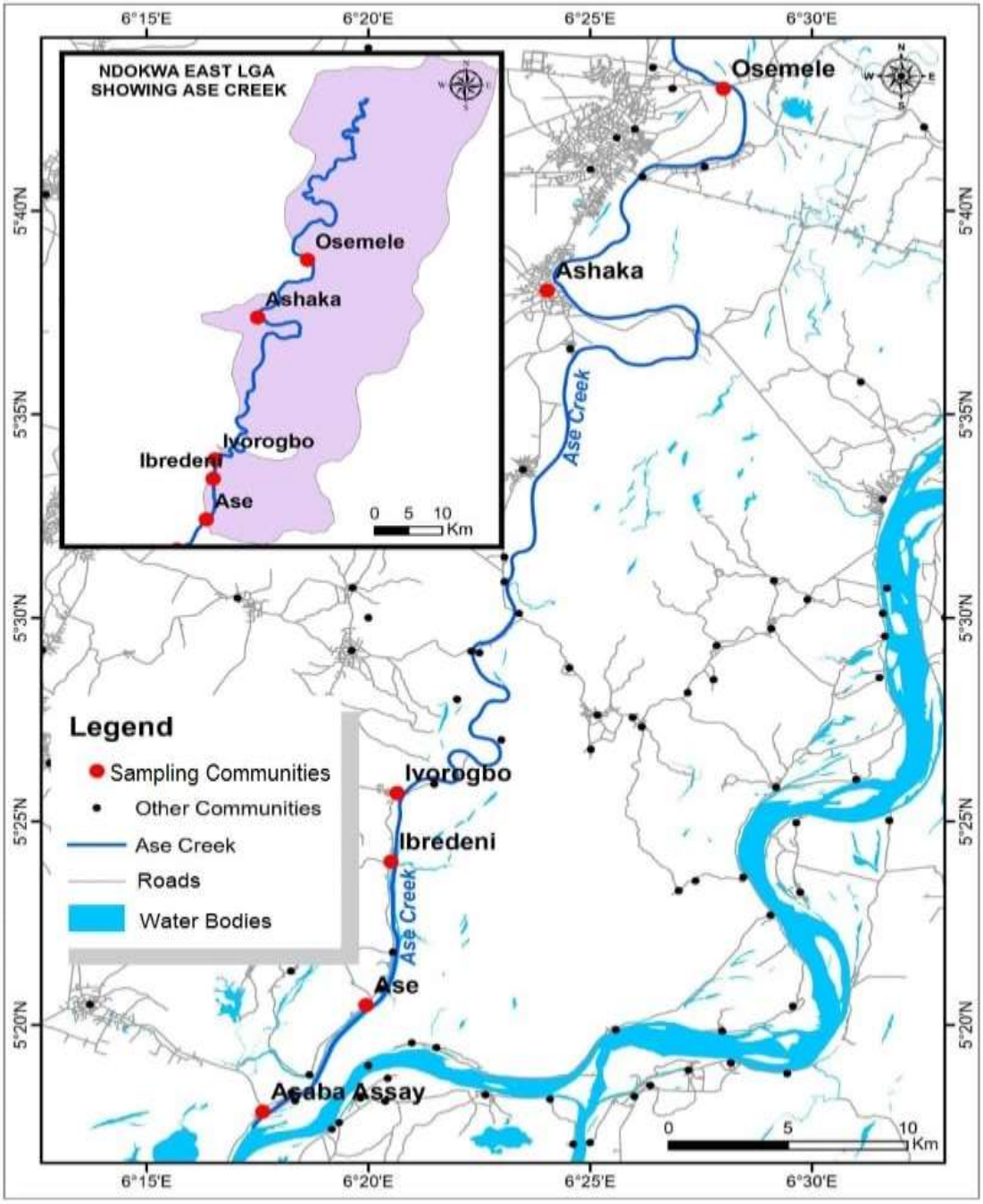

Figure 1: Study Area and its settlement
Source: Authors' field work, 2025.

METHOD

Image Acquisition and Pre-Processing

Multi-temporal satellite imagery was acquired from the USGS EarthExplorer portal for three target years: 2003 (Landsat 7 ETM+, path/row 190/56 and 57, cloud cover 6.64%), 2013 (Landsat 8 OLI/TIRS L2SP, cloud cover 6.63%), and 2023 (Landsat 8 OLI/TIRS L2SP, cloud cover 6.63%). All images were acquired as Level-2 surface reflectance products, minimising the need for atmospheric correction. Images were selected for the dry season to maintain spectral consistency across epochs and to ensure that seasonal flooding patterns did not confound interpretation of land cover boundaries, particularly the river-floodplain interface.

Pre-processing steps included geometric registration to the WGS 1984 geographic coordinate system and layer stacking of multi-band images in ESRI ArcGIS v10.8. All classified rasters were produced at the native 30-metre Landsat spatial resolution. Accuracy assessment of classified images was conducted through comparison with field-verified reference points collected using a Garmin GPS 76 device during field campaigns in 2025, supplemented by high-resolution Google Earth Pro imagery at locations with documented land cover history.

Classification Protocol

A combined supervised and unsupervised classification methodology was applied to each epoch image. Unsupervised clustering using the ISODATA algorithm provided an initial spectral grouping of pixels into candidate classes, which were then merged and refined through supervised classification using training samples derived from field-verified sites. Ten training polygon samples were established per land cover class per image epoch, providing a minimum of 60 training polygons per epoch across the six classification categories. The classification workflow comprised: (a) delineation of training polygons; (b) extraction of spectral statistics for training samples; (c) training of a random forest classifier on the spectral data from each epoch image; and (d) application of the trained classifier to produce wall-to-wall land cover maps for 2003, 2013, and 2023. Post-classification change detection was performed by comparing classified maps between successive epochs using the change detection function in ArcGIS, generating class-by-class transition matrices and net change statistics.

Six land cover classes were defined and mapped: river (open water body of the creek and its backwaters); built-up/bare land (residential, commercial, and industrial surfaces including roads, cleared ground, and recently excavated areas); forest land (closed-canopy native and secondary forest); vegetation (open savanna-woodland, herbaceous grassland, and shrubland); agricultural land (smallholder crops, orchards, and fallow areas identifiable by spectral texture); and sand dump sites (active or recent sand stockpiling and dredge spoil areas identifiable by high reflectance sand signature).

RESULTS

Land Cover Change in Ashaka Community

Ashaka community encompasses the largest study area (1,548.48 ha) and the most extensive documented sand extraction history among the three communities. Analysis of the 2003 baseline classification reveals that built-up/bare land was already the dominant land cover at 727.29 ha (46.96%), reflecting the community's established settlement pattern and the significant area of cleared ground associated with the long-established extraction industry. Vegetation was the second most extensive class at 334.26 ha (21.59%), followed by forest land at 270.80 ha (17.49%), agricultural land at 118.32 ha (7.64%), sand dump sites at 50.77 ha (3.28%), and river area at 47.04 ha (3.04%).

Over the first decade (2003–2013), the most significant changes were the expansion of built-up/bare land by 50.72 ha, the growth of sand dump sites by 35.89 ha — representing a 70.7% increase in extraction footprint — and simultaneous declines in vegetation (−59.73 ha) and forest land (−34.47 ha). These trajectory patterns reflect the documented intensification of extraction activity during this period and the clearing of riparian vegetation to facilitate access and expansion of dredging operations. In the second decade (2013–2023), built-up/bare land continued to expand by 52.39 ha, and vegetation continued to decline by 64.94 ha, while sand dump site area decreased slightly by 6.43 ha — consistent with the

documented enforcement action that curtailed licensed operations. Forest land decline decelerated markedly, from 34.47 ha in the first decade to 3.17 ha in the second, suggesting that the most accessible and extraction-proximate forest cover had already been converted during the earlier period. Table 1 presents the complete LCLU change statistics for Ashaka.

Table 1: Multi-Epoch Land Cover and Land Use Change Analysis for Ashaka Community, 2003–2023

Land Cover Class	2003 (ha)	2003 %	2013 (ha)	2013 %	2023 (ha)	2023 %	Change 2003–2013 (ha)	%	Change 2013–2023 (ha)	%
River	47.04	3.04	54.48	3.52	65.25	4.35	+7.44	+0.48	+10.77	+0.70
Built-up/Bare Land	727.29	46.96	778.01	50.24	830.40	55.35	+50.72	+3.28	+52.39	+3.38
Forest Land	270.80	17.49	236.33	15.26	239.50	12.03	−34.47	−2.23	−3.17	−0.20
Vegetation	334.26	21.59	274.53	17.73	209.59	13.97	−59.73	−3.86	−64.94	−4.19
Agricultural Land	118.32	7.64	118.47	7.91	122.99	14.24	+0.15	+0.01	+4.52	+0.29
Sand Dump Sites	50.77	3.28	86.66	5.85	80.23	0.07	+35.89	+2.32	−6.43	−0.42
TOTAL	**1,548.48**	**100.00**	**1,548.48**	**100.00**	**1,548.48**	**100.00**	—	—	—	—

Note: Areas in hectares. Positive change values indicate class expansion; negative values indicate class contraction.

Source: Authors' remote sensing classification and GIS analysis, 2025.

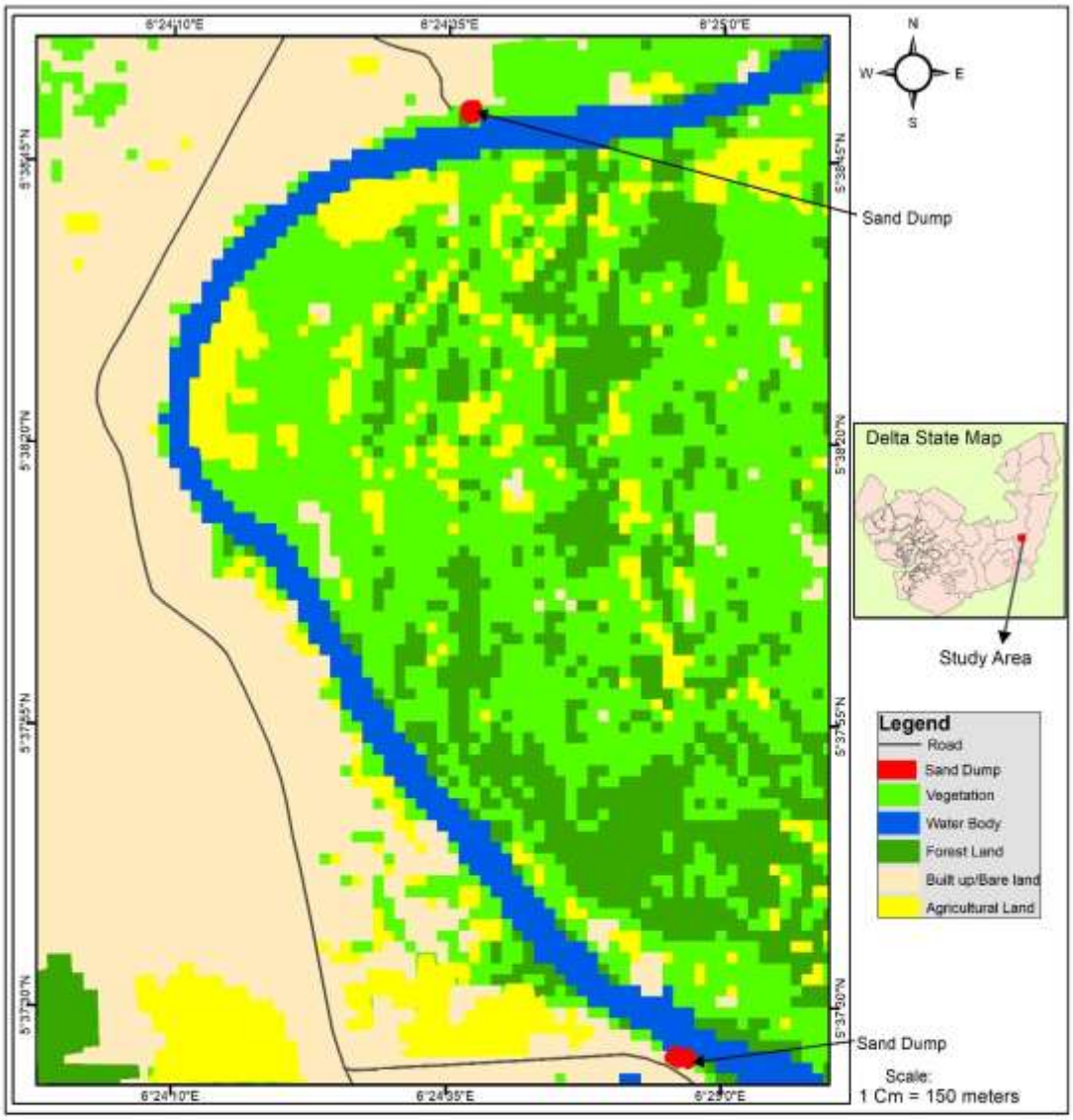

Figure 2: Land Cover and Land Use Classification Map for Ashaka Community, 2003.
Source. Authors' remote sensing analysis, 2025.

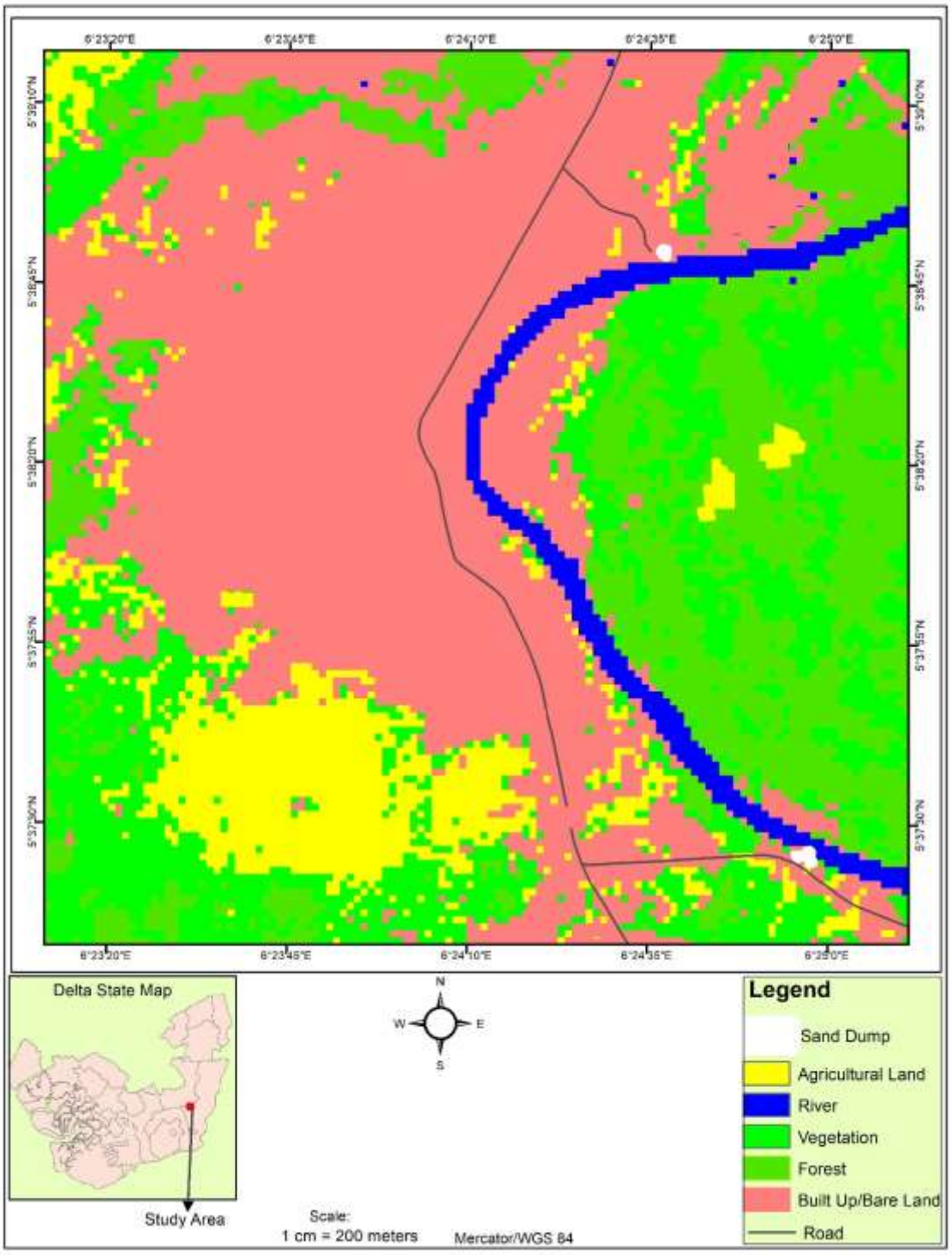

Figure 3: Land Cover and Land Use Classification Map for Ashaka Community, 2013, Showing the Marked Expansion of Sand Dump Sites and Built-Up/Bare Land.
Source. Authors' remote sensing analysis, 2025.

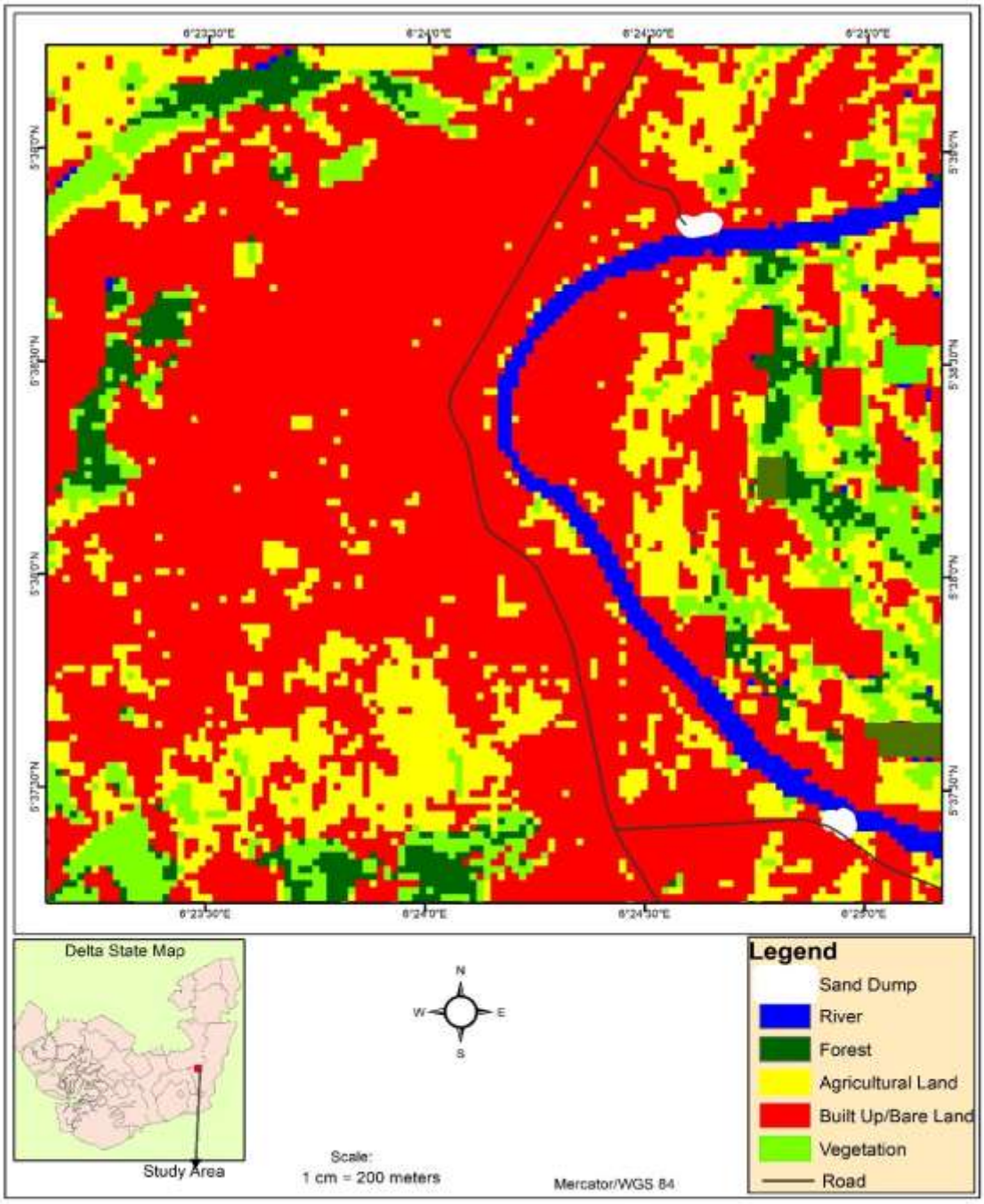

Figure 4: Land Cover and Land Use Classification Map for Ashaka Community, 2023, Documenting Continued Vegetation Decline and Landscape Fragmentation.
Source: Authors' remote sensing analysis, 2025.

Land Cover Change in Ivorogbo Community

Ivorogbo community covers 793.48 ha across the second monitored reach of Ase Creek. The 2003 baseline shows a relatively more balanced land cover distribution than Ashaka, with agricultural land as the near-dominant class at 203.60 ha (25.00%), followed by built-up/bare land at 260.80 ha (32.85%), forest land at 180.20 ha (22.71%), vegetation at 127.98 ha (16.13%), river at 21.00 ha (2.64%), and sand dump sites at only 0.50 ha (0.06%), reflecting the relatively limited extraction footprint at this community in the baseline year.

The 20-year change pattern at Ivorogbo is distinguished from Ashaka by two features: the sustained expansion of agricultural land — from 203.60 ha to 248.73 ha over the full period — alongside the continued decline of forest land and vegetation; and the comparatively modest but steady expansion of sand dump sites from 0.50 ha to 1.96 ha. The agricultural expansion appears paradoxical in the context of overall land degradation; however, it is interpreted as reflecting the conversion of degraded forest and shrubland margins to low-intensity crop cultivation as riparian woodland cover retreats under extraction pressure, effectively representing a land degradation transition rather than genuine agricultural intensification. Table 2 presents the complete statistics.

Table 2: Multi-Epoch Land Cover and Land Use Change Analysis for Ivorogbo Community, 2003–2023

Land Cover Class	2003 (ha)	2003 %	2013 (ha)	2013 %	2023 (ha)	2023 %	Change 2003–2013 (ha)	%	Change 2013–2023 (ha)	%
River	21.00	2.64	31.30	3.94	37.30	4.70	+10.30	+1.30	+6.00	+0.76
Built-up/Bare Land	260.80	32.85	290.40	36.60	320.40	40.38	+29.60	+3.73	+30.00	+3.78
Forest Land	180.20	22.71	130.20	16.41	102.90	12.97	−50.00	−6.30	−27.30	−3.44
Vegetation	127.98	16.13	112.80	14.22	82.80	10.43	−15.18	−1.91	−30.00	−3.78
Agricultural Land	203.60	25.00	227.93	28.73	248.73	31.35	+24.33	+3.07	+20.80	+2.62
Sand Dump Sites	0.50	0.06	1.46	0.18	1.96	0.25	+0.96	+0.12	+0.50	+0.06
TOTAL	**793.48**	**100.00**	**793.49**	**100.00**	**793.49**	**100.00**	—	—	—	—

Note: Areas in hectares.

Source: Authors' remote sensing classification and GIS analysis, 2025.

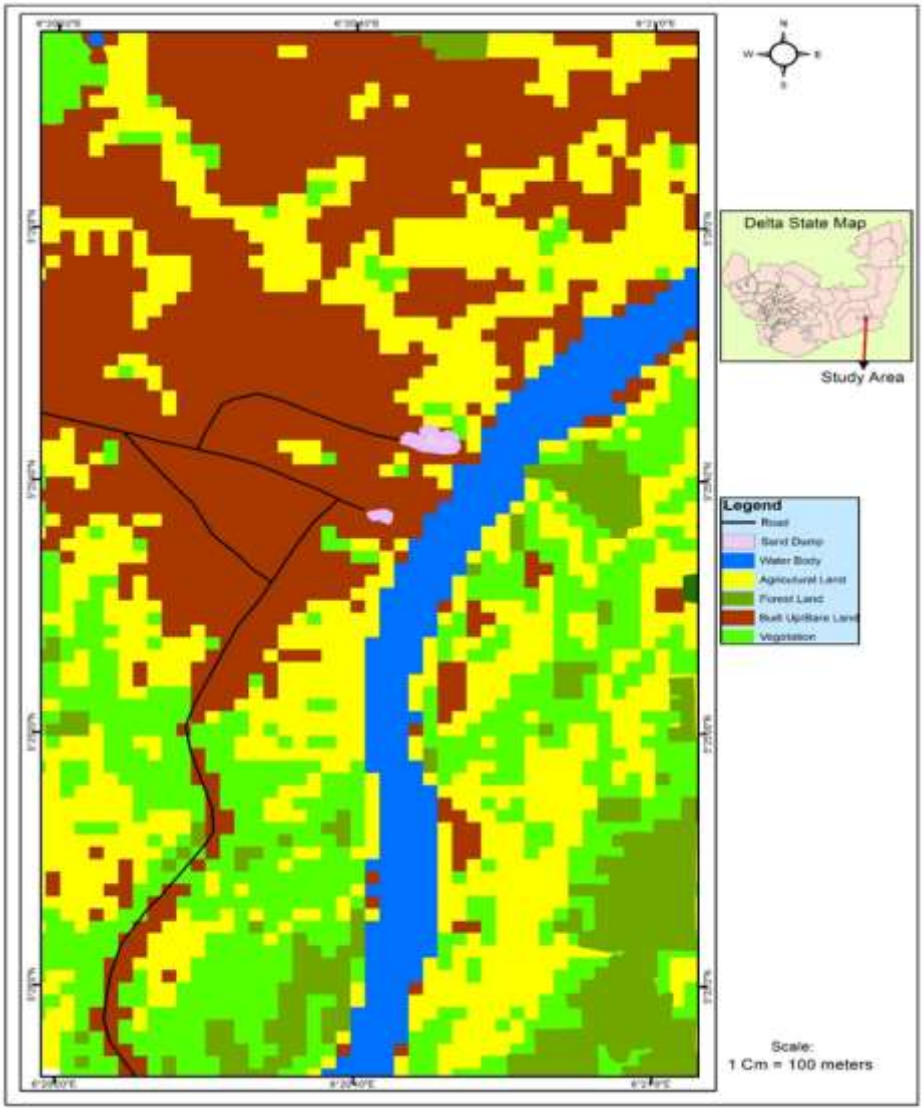

Figure 5: Land Cover and Land Use Classification Map for Ivorogbo Community, 2003, Establishing the Baseline Distribution of Land Cover Classes.
Source: Authors' remote sensing analysis, 2025.

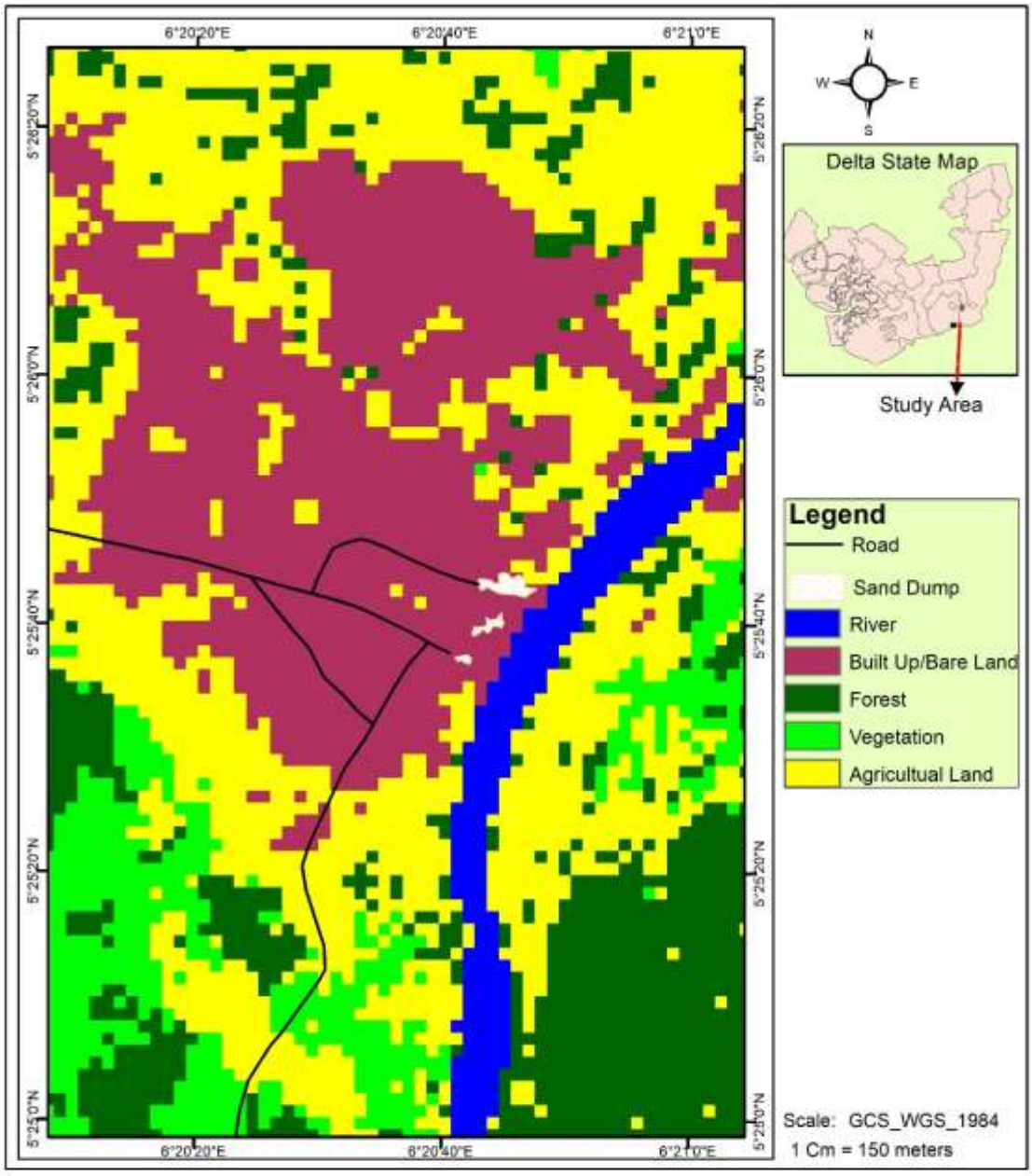

Figure 6: Land Cover and Land Use Classification Map for Ivorogbo Community, 2013, Documenting Decade-One Landscape Transitions.

Source: Authors' remote sensing analysis, 2025.

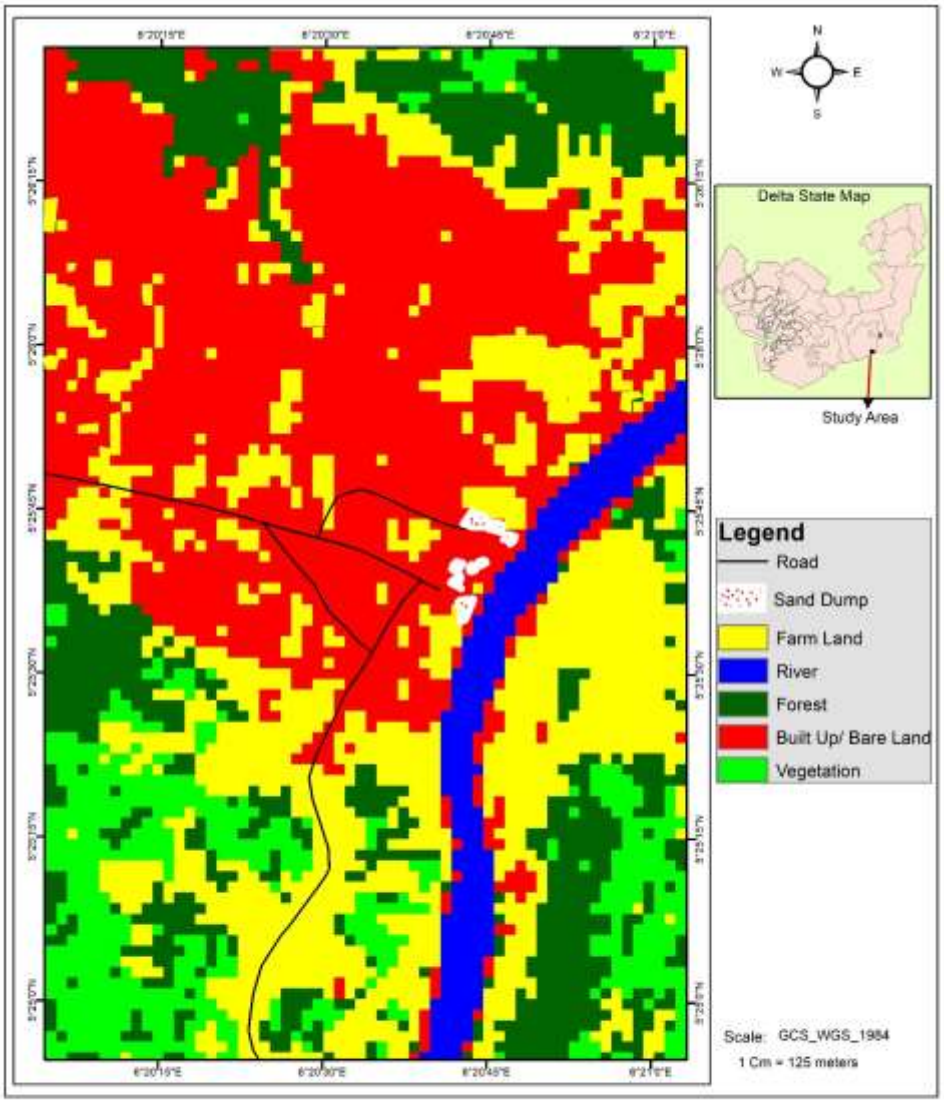

Figure 7: Land Cover and Land Use Classification Map for Ivorogbo Community, 2023, Showing Continued Forest Decline and Expanding Built-Up/Bare Land.
Source: Authors' remote sensing analysis, 2025.

Land Cover Change in Asaba-Ase Community

Asaba-Ase covers 338.98 ha, the smallest of the three study areas, and exhibits the most pronounced relative land cover change signals over the 20-year period. The 2003 baseline reveals that vegetation was the dominant land cover class at 158.69 ha (43.84%), followed by forest land at 115.45 ha (31.89%), agricultural land at 26.31 ha (7.27%), built-up/bare land at 40.01 ha (11.05%), river at 20.92 ha (5.78%), and sand dump sites at 0.60 ha (0.17%). The relatively large proportion of natural land cover classes (vegetation and forest combined = 75.73%) in 2003 indicates that Asaba-Ase was in a less degraded

condition than Ashaka at the study baseline, consistent with its lower extraction intensity during the earlier period.

By 2023, the landscape of Asaba-Ase had transformed substantially. Vegetation had declined from 158.69 ha to 105.48 ha (−53.21 ha, −33.5%), while forest land had contracted from 115.45 ha to 50.40 ha (−65.05 ha, −56.3%). Together, the two natural land cover classes lost over 118 ha in 20 years — more than a third of the entire community land area. Sand dump sites expanded from 0.60 ha to 4.00 ha, a nearly sevenfold increase that reflects the documented intensification of extraction activity at Asaba-Ase during the second epoch. Built-up/bare land grew from 40.01 ha to 78.02 ha, while agricultural land expanded from 26.31 ha to 60.98 ha, again reflecting conversion of degraded natural cover to low-intensity agricultural use rather than genuine improvement in agricultural conditions. Table 3 presents the full change statistics.

Table 3: Multi-Epoch Land Cover and Land Use Change Analysis for Asaba-Ase Community, 2003–2023

Land Cover Class	2003 (ha)	2003 %	2013 (ha)	2013 %	2023 (ha)	2023 %	Change 2003–2013 (ha)	%	Change 2013–2023 (ha)	%
River	20.92	5.78	33.19	9.17	40.10	11.83	+12.27	+3.39	+7.00	+1.93
Built-up/Bare Land	40.01	11.05	61.02	16.86	78.02	23.02	+21.01	+5.80	+17.00	+4.70
Forest Land	115.45	31.89	76.48	21.13	50.40	14.87	−39.05	−10.79	−26.00	−7.18
Vegetation	158.69	43.84	140.60	38.84	105.48	31.12	−18.09	−4.99	−35.00	−9.67
Agricultural Land	26.31	7.27	49.29	13.62	60.98	17.99	+22.89	+6.32	+13.00	+3.83
Sand Dump Sites	0.60	0.17	1.40	0.39	4.00	1.18	+0.80	+0.22	+2.60	+0.72
TOTAL	**338.98**	**100.00**	**338.98**	**100.00**	**338.98**	**100.00**	—	—	—	—

Note: Areas in hectares.

Source: Authors' remote sensing classification and GIS analysis, 2025.

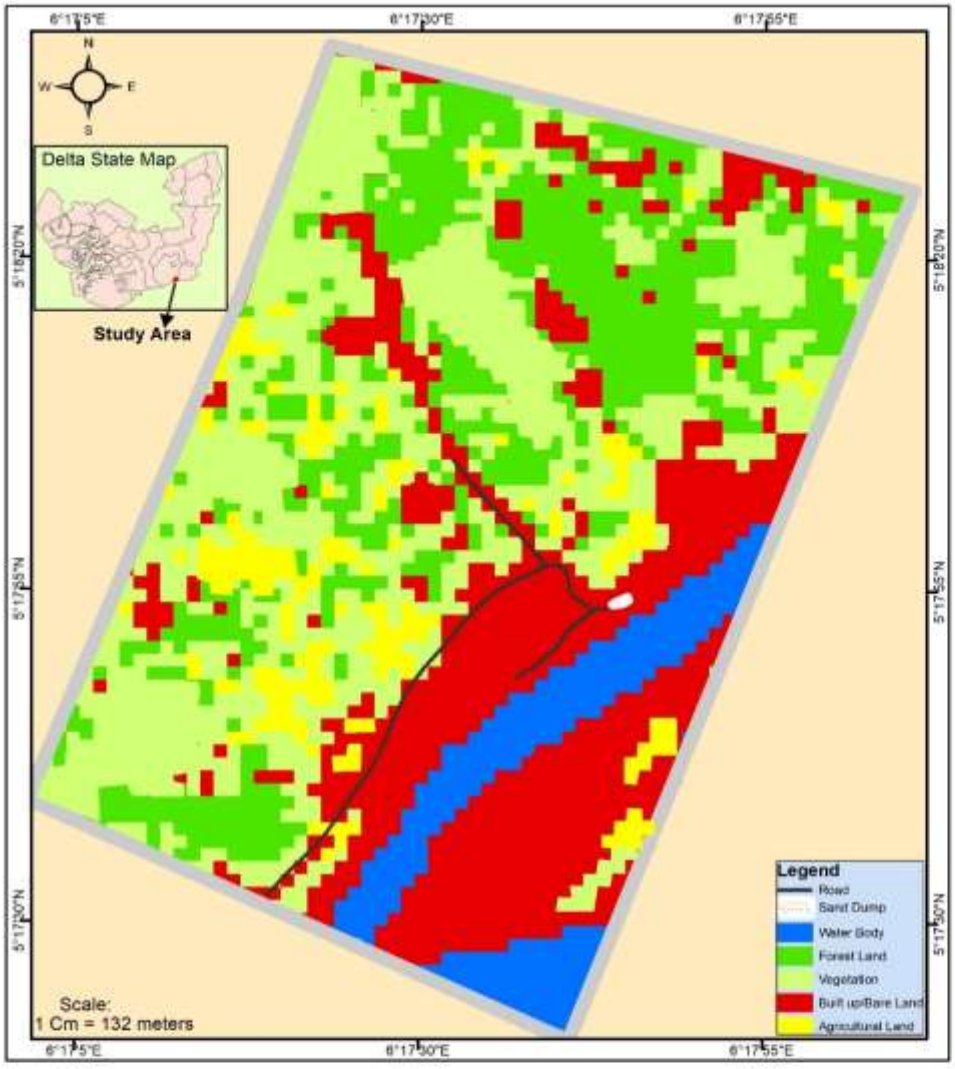

Figure 8: Land Cover and Land Use Classification Map for Asaba-Ase Community, 2003, Showing the Relatively Intact Natural Cover Baseline.
Source: Authors' remote sensing analysis, 2025.

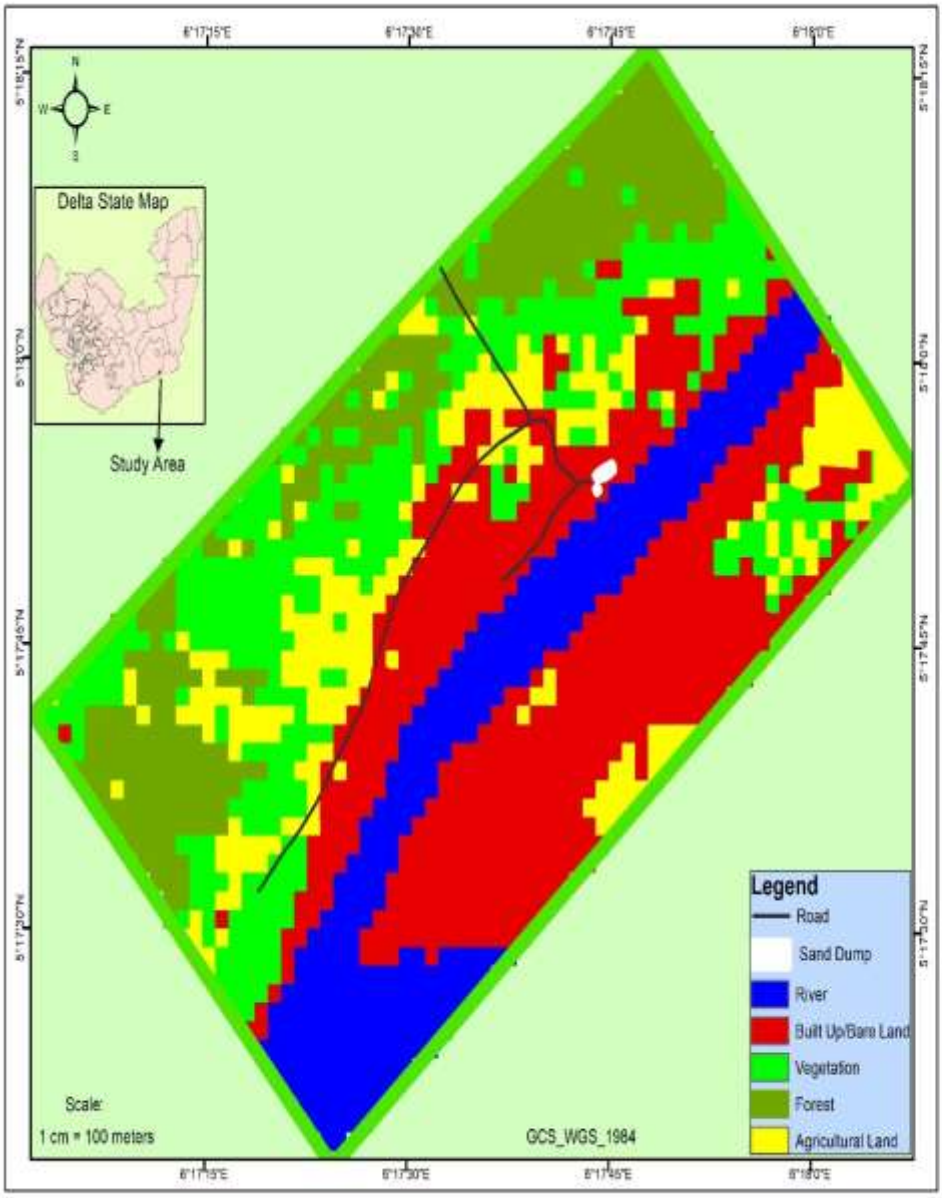

Figure 9: Land Cover and Land Use Classification Map for Asaba-Ase Community, 2013, Documenting Early Landscape Transformation Under Expanding Extraction Pressure.
Source: Authors' remote sensing analysis, 2025.

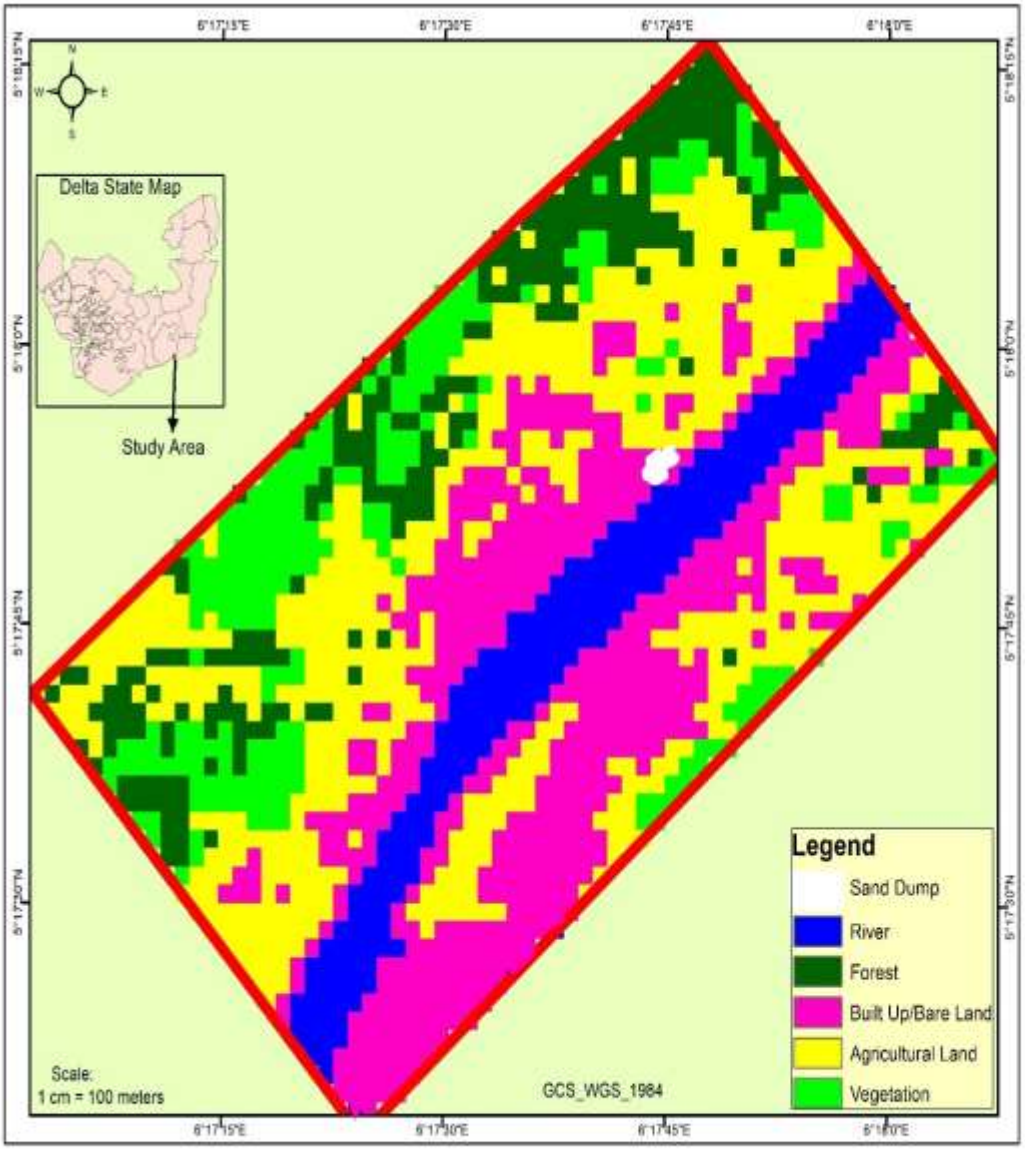

Figure 10: Land Cover and Land Use Classification Map for Asaba-Ase Community, 2023, Revealing Advanced Deforestation and Expansion of Sand Dump and Built-Up Classes.
Source: Authors' remote sensing analysis, 2025.

DISCUSSION

The multi-epoch LULC change patterns documented in this study reveal a consistent and spatially coherent landscape transformation trajectory across all three study communities, characterised by the progressive conversion of natural land cover classes (forest and vegetation) to extractive and anthropogenic land uses (built-up/bare land and sand dump sites), with agricultural land occupying an intermediate position that expands as natural cover degrades but does not compensate for ecosystem

service losses associated with forest and riparian vegetation decline. This trajectory is consistent with the theoretical predictions of the ecosystem services framework applied to extractive industry impacts: the exploitation of provisioning services (sand as construction raw material) systematically undermines regulating and supporting services (carbon sequestration, erosion control, biodiversity habitat) in ways that are spatially evident in satellite-classified land cover maps (Millennium Ecosystem Assessment, 2005).

The most analytically significant land cover change signal across all three communities is the sustained, accelerating decline of vegetation and forest land over the 20-year study period. At Ashaka, combined vegetation and forest loss reached 124.67 ha (vegetation) and 31.30 ha (forest) — a combined 155.97 ha of natural cover loss within a community whose total area is 1,548.48 ha, representing 10.1% of total community land area lost from natural cover classes. At Asaba-Ase, where the natural cover baseline was proportionally higher, the relative loss is even more dramatic: combined vegetation and forest decline of 118.26 ha from a total community area of 338.98 ha represents 34.9% of the entire land area transitioning from natural to non-natural classes in 20 years — a rate of landscape change that places this community among the more severely affected riparian zones in documented West African sand mining case studies (Lawal, 2011; Akanwa, 2021).

The temporal dynamics of sand dump site expansion are particularly informative regarding the responsiveness of extraction footprint to governance interventions. The marked increase in sand dump area at Ashaka between 2003 and 2013 (from 50.77 to 86.66 ha, +35.89 ha) followed by a modest decrease between 2013 and 2023 (−6.43 ha) directly mirrors the documented trajectory of extraction intensity: peak expansion during the unregulated boom period of the 2000s, followed by partial contraction in response to enforcement activity by the local government authority. This correspondence between LCLU change signals and documented governance actions demonstrates that satellite-based change detection can function as an effective, independent monitoring tool for assessing the spatial impact of regulatory interventions — a finding with direct operational relevance for the Delta State Ministry of Environment and NIWA.

The expansion of agricultural land across all three communities — at Ashaka, Ivorogbo, and Asaba-Ase — requires careful interpretive framing. On the surface, increases in agricultural land area might appear to indicate a positive land use trajectory; however, field observation and community interview data from the companion socioeconomic study indicate that the expansion of classified agricultural area reflects the encroachment of low-productivity smallholder cultivation onto degraded former forest and riparian vegetation margins rather than intensification of existing agricultural systems. This interpretation is consistent with the documented decline in per-household agricultural yields and crop diversity reported by community members in the study area, which points to agricultural expansion driven by land degradation displacement rather than genuine agricultural development (Enaruvbe & Pontius, 2015; FAO, 1999).

CONCLUSION

This study delivers the first systematic, multi-epoch LCLU change detection record for three sand-mining communities along Ase Creek, Nigeria, providing a satellite-based evidence base for the environmental monitoring and governance of sand extraction in the Niger Delta. Key findings establish that: (a) all three communities have experienced sustained, statistically significant declines in natural land cover (forest and vegetation) concurrent with expansion of extraction-associated land uses; (b) combined vegetation and forest cover losses over 20 years range from approximately 10% of total community land area at Ashaka to nearly 35% at Asaba-Ase; (c) sand dump site expansion mirrors documented extraction intensity trajectories, confirming the validity of satellite-based change detection as a governance monitoring tool; and (d) agricultural land area expands as natural cover declines, reflecting land degradation displacement rather than genuine agricultural development. It is recommended that the Delta State Ministry of Environment institute a mandatory annual satellite-based land cover monitoring programme for all creek

communities with active sand extraction operations, with classified change maps incorporated into annual permit review processes.

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