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Review

Geospatial Technologies In Environmental Risk Mapping And Monitoring In Nigeria

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Abstract: Geospatial technologies (Global Navigation Satellite System - GNSS, Geographic Information Systems - GIS, Cartography and Remote Sensing - RS) have become fundamental to environmental risk mapping and assessment in Nigeria, a country of over 220 million people covering approximately 923,768 km² and spanning ecosystems from the mangroves of the Niger Delta to the semi-arid Sahel. This paper assesses the scope, performance, and constraints of Geospatial technologies applications in managing land-use/land-cover (LULC) change, coastal erosion, flooding, desertification, wetland loss, oil pollution, and rapid urbanisation. Multi-temporal satellite analyses indicate that Nigeria's urban built-up area expanded by more than 150% between 1996 and 2026, while forest cover declined by 7-10% in several southern states. Shoreline retreat rates of 2-30 m per year have been recorded along parts of the coast, and flood-risk mapping shows that approximately 20-25% of the population resides in flood-prone zones. In northern frontline states, desertification advances at an estimated 0.6 km annually. Institutional review highlights the growing role of the National Space Research and Development Agency and over 40 universities offering geospatial training; however, fewer than half of state environmental agencies operate functional GIS units. The study identifies progress in data availability and technical capacity but underscores persistent gaps in funding, data integration, and policy uptake, proposing a strategic roadmap for strengthened geospatial governance.

Keywords: GIS, Remote Sensing, Environmental risk, Monitoring, Landuse/Landcover, NASRDA

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1. Introduction

Environmental risks in Nigeria emanate from multiple, interacting challenges: rapid urbanisation, agricultural expansion, coastal erosion and sea-level rise impacts on the Niger Delta, seasonal and catastrophic flooding, expanding desertification in the north (Bello & Abdulrahman, 2023), and pollution from oil and solid waste. Empirical studies demonstrate that these pressures are intensifying under climate variability and socio-economic growth trends (Twumasi & Merem, 2006; Nkeki et al., 2022).

Modern geospatial technologies, including remote sensing (satellite and aerial imagery) combined with GIS analytic frameworks, provide cost-effective, repeatable, and scalable means to observe, monitor, model, and support decision-making across various environmental problems. Recent applications demonstrate that multi-temporal satellite data (e.g., Landsat, Sentinel) and spatial modelling techniques have significantly improved environmental assessment accuracy in Nigeria (Ologunde et al., 2025; Abu & Ibebuchi, 2025).

Globally, the integration of remote sensing (RS) and geographic information systems (GIS) has matured into standard practice for environmental monitoring and risk analysis. In Nigeria, institutional capacity has expanded through agencies such as the National Space Research and Development Agency (NASRDA) and university-based geospatial research centres, which support satellite data acquisition and applied research (Bello, 2024).

This paper critically appraises these applications, focusing on their impacts, evidence from Nigerian case studies, and systemic barriers to greater uptake (Dike et al., 2024; Ibrahim et al., 2022). Figure 1 illustrates Nigeria as the study area.

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Figure 1. Political Map of Nigeria

2. Materials and Methods

The Google Earth Pro web-mapping and GIS platform served as a source of satellite images for mapping and assessing environmental changes in the landscape of Nigeria over different time periods (1996-2026). In addition, the study adopted a narrative review and synthesis combining (a) peer-reviewed studies addressing geospatial technology applications in Nigeria across environmental themes, (b) institutional materials and reports on national space and remote sensing capacity, such as those produced by the National Space Research and Development Agency (NASRDA), and (c) recent case studies demonstrating applied outcomes in coastal monitoring, flood modelling, desertification assessment, and land-use change analysis (Bello & Abdulrahman, 2023). Previous research demonstrates that multi-temporal satellite datasets, such as Landsat, Sentinel, MODIS, and SRTM, have been widely applied to environmental monitoring in Nigeria and have significantly improved spatial accuracy and temporal change detection (Twumasi & Merem, 2006; Nkeki et al., 2022; Ologunde et al., 2025).

Sources were identified through targeted literature searches of peer-reviewed journals, institutional repositories, and geospatial databases to capture representative work from approximately 2010 to 2025. Priority was given to studies that (1) used multi-temporal satellite data, (2) linked remote sensing observations to environmental indicators or models such as flood inundation mapping, the Coastal Vulnerability Index (CVI), and MEDALUS desertification models (Dike et al., 2024; Ibrahim et al., 2022), and

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(3) reported direct policy or environmental risk assessment implications. Key studies are cited throughout the text.

In other words, this paper synthesises peer-reviewed studies, institutional descriptions, and targeted case studies found in the open literature to appraise the applications of geospatial technologies in Nigeria. For readers seeking operational data (e.g., national datasets, satellite archives, or NASRDA product lines), GRID3, NASRDA's portals, and recent MDPI, ScienceDirect, and PMC articles cited are good starting points.

3. Results and Discussion: Major Application Areas in Nigeria

3.1 Land Use/Land Cover (LULC) Monitoring and Urban Growth

Figure 2 shows the trends in land cover and environmental changes over the last thirty years (1996, 2001, 2006, 2011, 2016, 2021, and 2026). It presents an interval of five years, revealing a steady decline in vegetation cover and a corresponding increase in urban development. Multi-temporal satellite analyses indicate that Nigeria’s urban built-up area expanded by more than 150% between 1996 and 2026, while forest cover declined by 7-10% in several southern states. Thus, mapping changes in the environment helps to track, monitor, and make informed decisions regarding proper risk management. As population and temperature increase, it is abundantly clear that they will have an effect on the biophysical and ecological environment.

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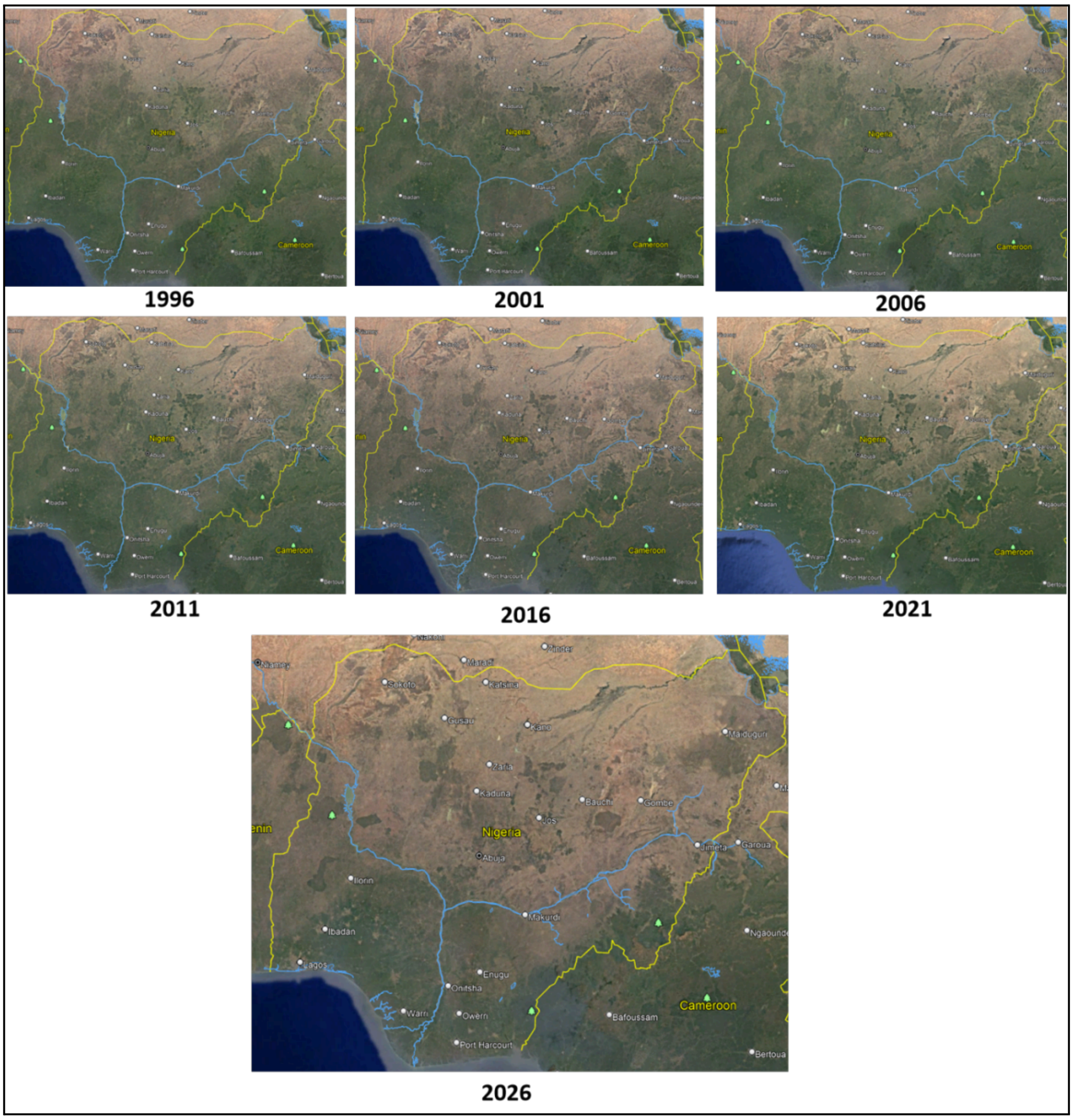

Figure 2. Land cover changes in Nigeria (1996, 2001, 2006, 2011, 2016, 2021, and 2026).

These findings are similar to what other scholars have discovered in their respective studies using different satellite images. In fact, several Nigerian studies have applied Landsat and Sentinel imagery using supervised and unsupervised classification techniques to quantify urban expansion, vegetation loss, and agricultural land conversion. These analyses demonstrate measurable growth in built-up areas around major urban centres such as Abuja and rapidly expanding coastal cities, where population growth, peri-urban sprawl, and informal settlements drive land use change (Ologunde et al., 2025; Fashae, 2022).

Multi-year land use and land cover (LULC) mapping studies conducted in southwestern Nigeria and other ecological zones show that the integration of ArcGIS, ENVI, and open-source classifiers improves spatial accuracy and change detection over time (Twumasi & Merem, 2006; Ologunde et al., 2025). These LULC products provide

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critical inputs for land-use planning, infrastructure siting, urban development control, and environmental impact assessments.

3.2 Flood Mapping, Flood Risk Assessment, and Disaster Response

Flooding is an acute problem in Nigeria, as evidenced by the national floods of 2012 and 2022. Remote sensing techniques, including MODIS, Sentinel-1 SAR for cloudy and wet conditions, and Landsat, along with hydraulic modelling using HEC-RAS and SRTM-derived DEMs, and GIS-based risk frameworks, have been employed to delineate inundation extent, map floodplains, and identify vulnerable infrastructure and populations (Nkeki et al., 2022; see Figure 3). These maps have informed post-event assessments and have the potential to enhance early warning systems when coupled with rainfall forecasts and hydrological models. Case studies conducted after the 2022 event demonstrate the capacity of geospatial technologies to quantify affected areas and support relief prioritisation (Nkeki et al., 2022). This is similar to the extreme flood risk zones in Nigeria (see Figures 4 and 5).

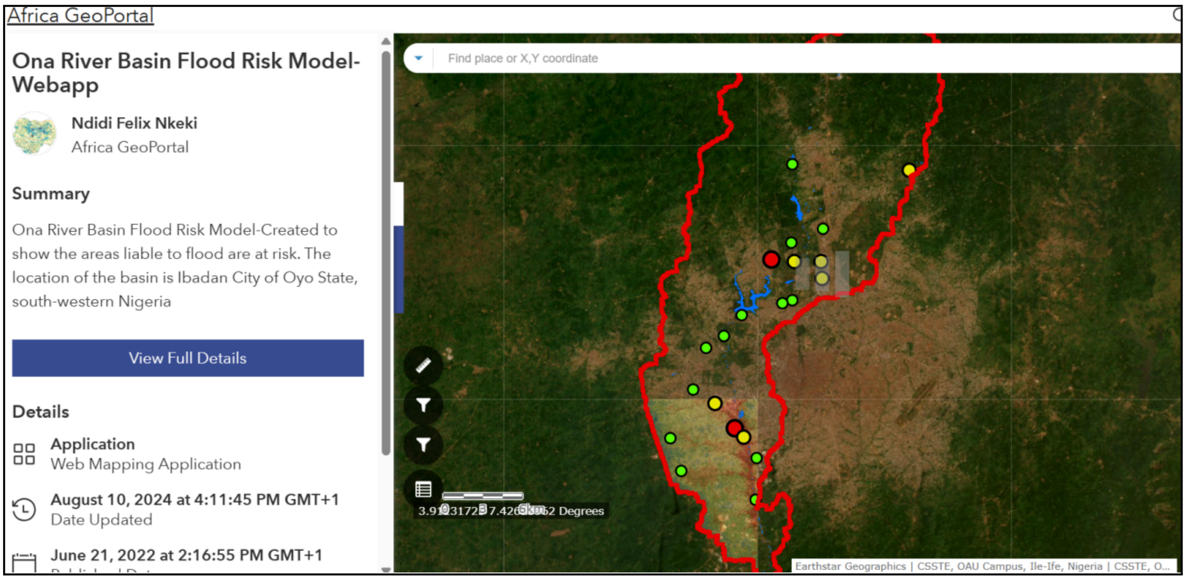

Figure 3. A flood risk model of the Ona River Basin (Nkeki, Bello, & Agbaje, 2022).

Source:

https://africageoportal.hub.arcgis.com/apps/37b3c2ba2b0d4a3cbbfb3bbb57f7e1b8/explore

NOTE: The Ona River Basin Flood Risk Model was created to identify areas at risk of flooding. The location of the basin is in Ibadan, a city in Oyo State, south-western Nigeria.

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3.3 Coastal Monitoring, Shoreline Change, and Niger Delta Dynamics

The low-lying Niger Delta coastline exhibits significant spatially variable patterns of flooding, erosion, and accretion (Figure 4), as corroborated by Amangabara and Obenade (2015). In fact, coastal areas and riverbanks in Nigeria are at risk of flooding, as shown in Figure 5. Coastal vulnerability assessments that integrate satellite-derived shoreline extraction, Coastal Vulnerability Index (CVI) modelling, and GIS overlay analysis have identified hotspots of high erosion and zones highly exposed to sea-level rise and anthropogenic pressures (Dike et al., 2024; Twumasi & Merem, 2006). These spatial outputs provide critical evidence for coastal protection planning, ecosystem restoration, and community adaptation or relocation strategies.

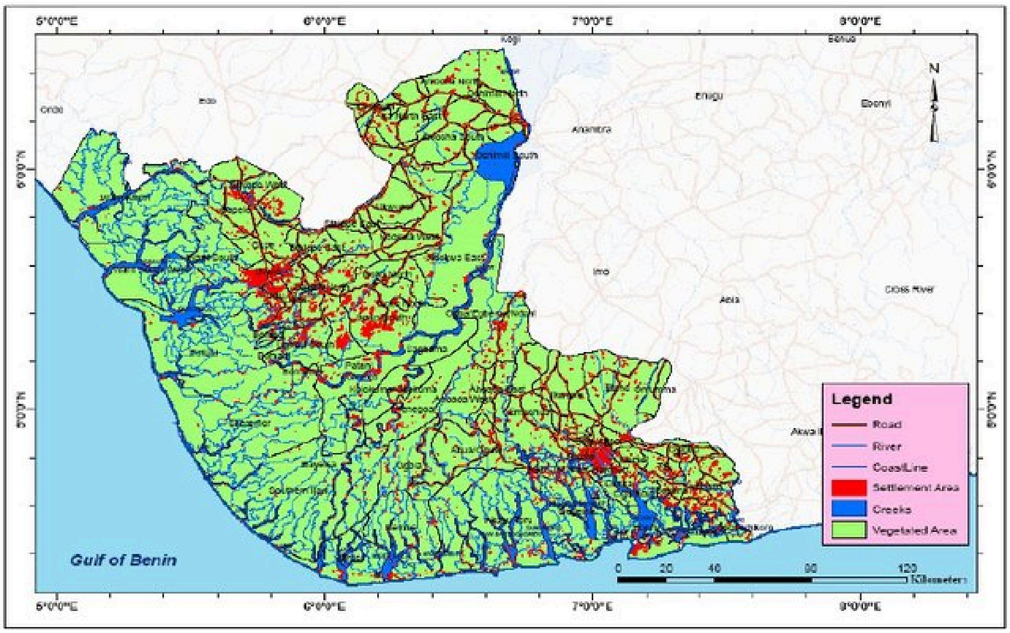

Figure 4. Networks of drainage systems, road networks, and settlements in the Niger Delta.

Source: Amangabara and Obenade (2015)

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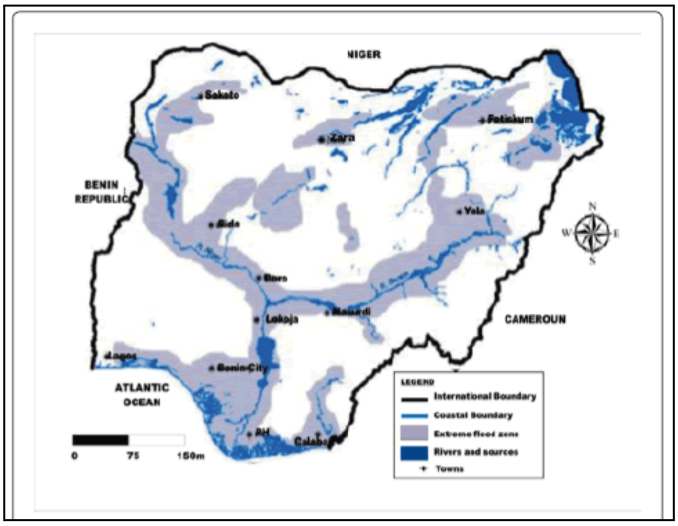

Figure 5. Areas Liable to Extreme Flooding in Nigeria (Ministry of the Environment)

Recent studies have integrated DEM-derived topographic indices (elevation, slope, flow accumulation, flow length) with land use/land cover data in GIS to delineate soil and erosion risk zones classified as having high, medium, and low susceptibility for targeted hazard assessment and land management (Ojo et al., 2018; Lasisi et al., 2020; Aslam et al., 2021). For example, quantitative assessments in the Niger Delta indicate that approximately 26% of analysed areas fall within high-risk zones, 43% within medium-risk zones, and 31% within low-risk zones, highlighting substantial exposure to coastal degradation processes (Dike et al., 2024; Fashae, 2022). Such spatial modelling supports planners and environmental managers in identifying vulnerable areas and prioritising mitigation measures such as vegetation restoration and soil stabilisation.

3.4 Desertification and Land Degradation in Northern Nigeria

The Sahelian and Sudanian zones in northern Nigeria experience persistent desert encroachment, land degradation, and declining vegetation productivity, which invariably affect the land cover dynamics (Figure 6). Remote sensing approaches, including Normalised Difference Vegetation Index (NDVI) time-series analysis, the MEDALUS model, and long-term trend analysis of vegetation indices, have been widely applied to map desertification sensitivity and monitor changes in vegetation cover over decadal scales (Ibrahim et al., 2022; Ogbue et al., 2024).

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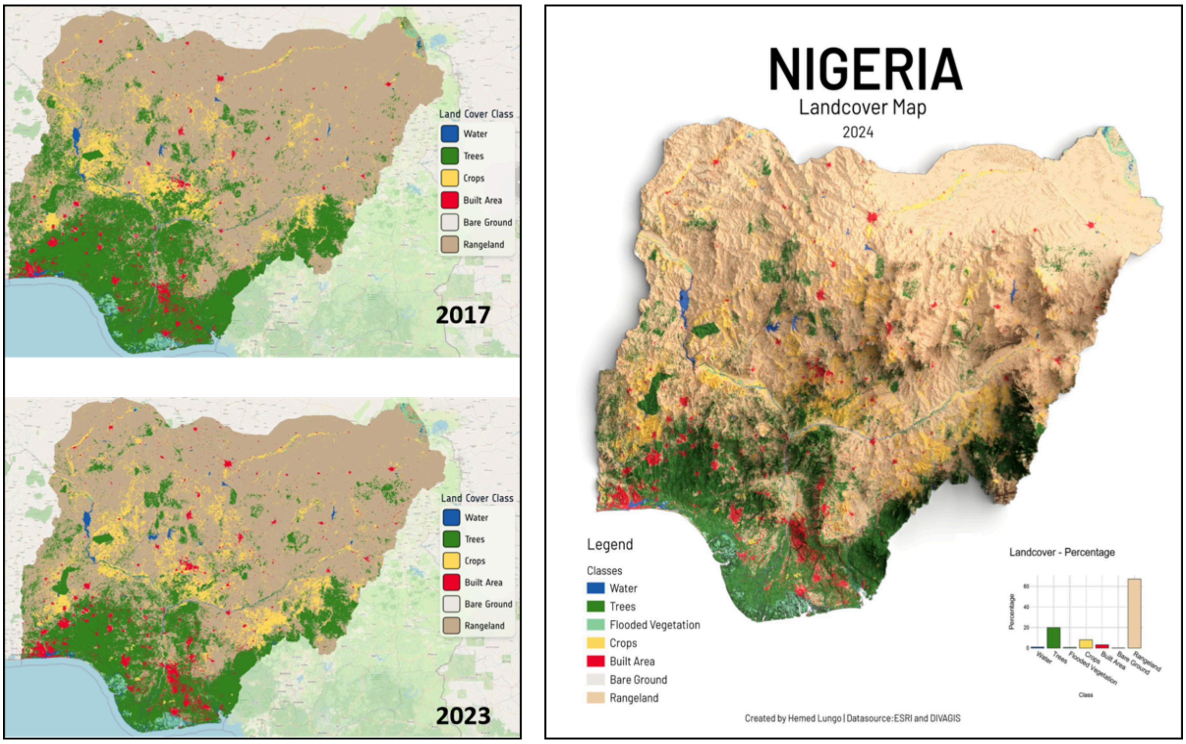

Figure 6. Land cover degradation in Nigeria.

These geospatial assessments provide quantitative evidence to support targeted interventions such as reforestation, sustainable grazing management, soil conservation strategies, and ecosystem restoration, while also strengthening national reporting obligations under the United Nations Convention to Combat Desertification (UNCCD) framework (Ibrahim et al., 2022). The findings of Bello and Abdulrahman (2023) in their study on the integration of geospatial technologies in assessing the National Great Green Wall woodlots/orchards in Katagum LGA, Bauchi State, Nigeria, are also worthy of note. This is similar to the work of Bello, Irabor, and Bello (2017).

3.5 Wetlands, Biodiversity, and Mangrove Monitoring

Mangroves and wetlands in the Niger Delta are ecologically critical for fisheries productivity, blue carbon sequestration, shoreline stabilisation, and coastal protection. However, these ecosystems are increasingly threatened by oil pollution, land conversion, urban expansion, and infrastructure development. High-resolution satellite imagery combined with change-detection techniques enables the mapping of mangrove extent, fragmentation patterns, and ecosystem recovery following oil spill remediation or restoration interventions. Such geospatial analyses provide quantitative evidence for conservation planning and environmental impact assessment of development projects.

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Recent studies applying geospatial technologies to the Niger Delta coastal zone reveal significant declines in water bodies and mangrove forests, alongside increases in human settlements, cropland expansion, and disturbed or mixed-forest land cover classes (Bello & Rilwani, 2016). Multi-temporal classified satellite imagery demonstrates clear spatial and temporal degradation trends, offering strong visual and analytical decision-support tools for coastal and resource managers (Ayanlade et al., 2020; Akinyemi et al., 2022). These mapping products support the monitoring of ecosystem loss, restoration progress, and policy compliance in fragile deltaic environments.

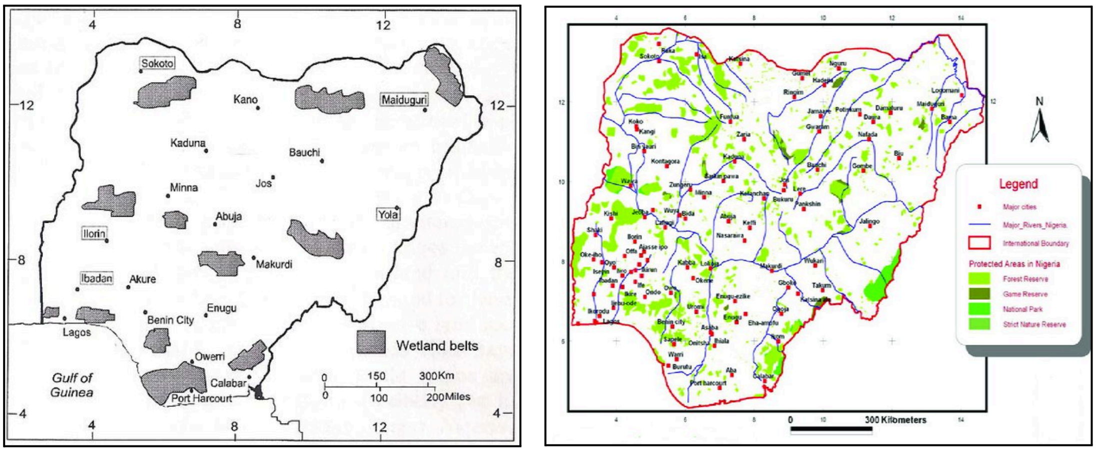

Figure 7. (a) Wetland Regions of Nigeria (b) Protected Areas for Biodiversity in Nigeria.

3.6 Pollution and Oil-Spill Monitoring

Remote sensing using multispectral imagery and hyperspectral data, where available, has been widely applied to detect oil spills, surface contamination, and land degradation in hydrocarbon-producing regions such as the Niger Delta. Satellite-based change detection combined with spectral anomaly analysis enables the identification of spill extents and impacted land cover classes (Giri et al., 2011; Okolie et al., 2023). Oil spills significantly affect rural livelihoods by reducing crop productivity, contaminating water sources, degrading soil quality, and increasing poverty among farming communities in impacted regions (Figure 8).

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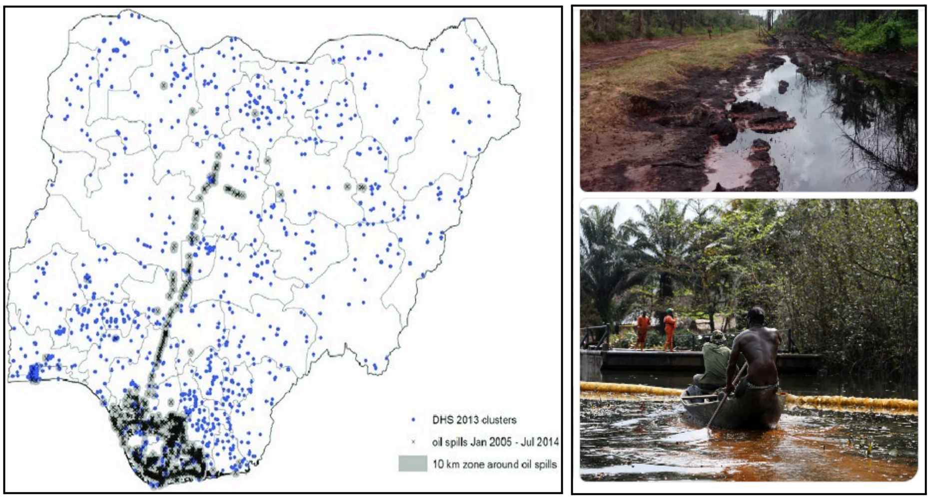

Figure 8. Oil Spill Mapping and Monitoring in Nigeria

Note: This map shows the locations of all oil spills in our records and all clusters of the Nigeria DHS 2013. The shaded areas represent the union of all circles with a 10-km radius around each of the oil spills.

Geographic Information Systems (GIS) further integrate these spatial observations with socio-economic datasets to estimate affected communities, assess agricultural losses, and prioritise remediation efforts (Twumasi & Merem, 2006). However, operational near-real-time oil spill monitoring remains constrained by limitations in data revisit frequency, persistent cloud cover in tropical environments, restricted access to high-resolution radar or hyperspectral sensors, and limited institutional capacity for continuous monitoring (Akinyemi et al., 2022).

3.7 Solid Waste and Urban Environmental Risk Assessment

Geospatial technologies have been widely applied to map landfill sites, detect illegal dump locations, and evaluate municipal solid waste distribution trends in rapidly urbanising cities. Spatial analyses using satellite imagery and GIS-based overlay modelling support routing optimisation for waste collection, identification of environmental contamination risks, and improved urban sanitation planning (Singh, 2019; Aderoju et al., 2021). Broader waste management studies integrate remote sensing outputs with field surveys and socio-economic datasets to strengthen evidence-based municipal decision-making and infrastructure planning. Proper land management through productive agricultural land use that benefits humanity in terms of food security and reduction of poverty requires technology-driven precision agriculture practices.

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Figure 9. Soil Waste Management Practices through Sustainable Agricultural Practices

Source:
https://cdn.punchng.com/wp-content/uploads/2024/12/23175223/Irrigation-farmland.jpg

As shown in Figure 9, sustainable soil management practices in Nigeria include:

Farmland under cover crops, mulching systems, and crop rotation practices aims to preserve soil fertility, improve organic matter content, and reduce erosion. Remote sensing and GIS-based soil monitoring support the spatial identification of degraded lands and areas requiring restoration (Lal, 2015; Akinyemi et al., 2022).

Contour farming and soil-conservation layouts on sloped land are designed to reduce surface runoff and soil loss. Geospatial analysis using DEM-derived slope modelling and erosion risk mapping helps identify high-risk zones in erosion-prone regions of Nigeria and supports targeted intervention planning (Fashae, 2022).

Agroforestry and mixed-cropping systems, where trees are integrated with agricultural crops, represent sustainable land management strategies that improve carbon sequestration, soil stability, and ecosystem resilience. Spatial monitoring tools assist in mapping agroforestry expansion and evaluating land-use transitions towards sustainable production systems (Twumasi & Merem, 2006).

Soil-fertility mapping and data-driven soil-health assessment, using spatial interpolation and remote sensing indicators, enable the monitoring of soil nutrient variability across the ecological zones of Nigeria and guide precision agriculture and land rehabilitation efforts (Ologunde et al., 2025).

On the other hand, soil and waste management strategies aim to reclaim degraded land, enhance soil quality, and ensure nutrient replenishment to sustain agricultural productivity and food security. Spatial technologies help identify areas affected by contamination, erosion, or improper waste disposal and support remediation planning and sustainable land management decisions. Thus, Figure 10 showcases urban waste management challenges and interventions, which include:

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a) Urban waste collection trucks servicing Nigerian cities.
b) Households and streets are accumulating waste due to inadequate disposal infrastructure.
c) Informal waste-picking and sorting activities are a common but often hazardous component of Nigeria’s waste economy.
d) Overfilled drains and waste accumulation in waterways contribute to flood risk and environmental health hazards.
e) Community clean-up initiatives and organised waste management efforts demonstrate institutional and grassroots responses to sanitation challenges.

Figure 10. Waste and Environmental Health Management in Nigeria

4. Technical Advances Enabling Nigerian Applications

Several technological advances have significantly improved the applicability and scalability of Remote Sensing (RS) and Geographic Information Systems (GIS) in Nigeria. These include:

Access to free multi-spectral satellite datasets: Long-term data archives such as Landsat, Sentinel-1 (Synthetic Aperture Radar), Sentinel-2 (optical), and NigeriaSat missions (NigeriaSat-1, -2, and NigeriaSat-X) provide dense temporal coverage for long-term environmental monitoring and change detection (Figure 11). The availability of open-access satellite data has enhanced land-use mapping, flood monitoring, and vegetation analysis across Nigeria (Gorelick et al., 2017; Ologunde et al., 2025).

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Figure 11. Satellite remote sensing image map covering Nigeria and neighbouring countries for environmental mapping and monitoring.

ii. Affordable computing and open-source geospatial tools: Platforms such as QGIS and cloud-based systems like Google Earth Engine (GEE) enable large-scale, multi-temporal spatial analysis without requiring extensive local computing infrastructure. Cloud-based geospatial processing significantly reduces cost barriers and improves accessibility for researchers and government agencies in developing countries (Gorelick et al., 2017; Akinyemi et al., 2022).

Technological and methodological advances have further enhanced the performance of geospatial modelling in Nigeria in the following ways:

a) Improved Digital Elevation Models (DEMs) and radar data: Satellite-derived elevation datasets, such as the Shuttle Radar Topography Mission (SRTM), Sentinel-1 Synthetic Aperture Radar (SAR), and other emerging radar-based products, improve flood modelling, terrain analysis, and topographic characterisation in flat coastal and basin environments. These datasets enhance hydrological modelling accuracy and support flood-risk assessment in vulnerable regions (Tarolli, 2014; Ologunde et al., 2025).

b) Methodological progress: Advances in machine learning classifiers, object-based image analysis (OBIA), and the integration of SAR-optical time-series data have significantly improved classification accuracy for vegetation mapping, urban growth detection, and flood extent delineation (Maxwell et al., 2018; Ologunde et al., 2025). Such approaches increase automation and analytical precision in land use studies.

c) The application of remote sensing in land use/land cover (LULC) mapping in Southern Nigeria is well documented in recent literature (Figure 12), demonstrating

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improved spatial resolution, multi-temporal monitoring, and the integration of advanced classification algorithms for environmental change detection.

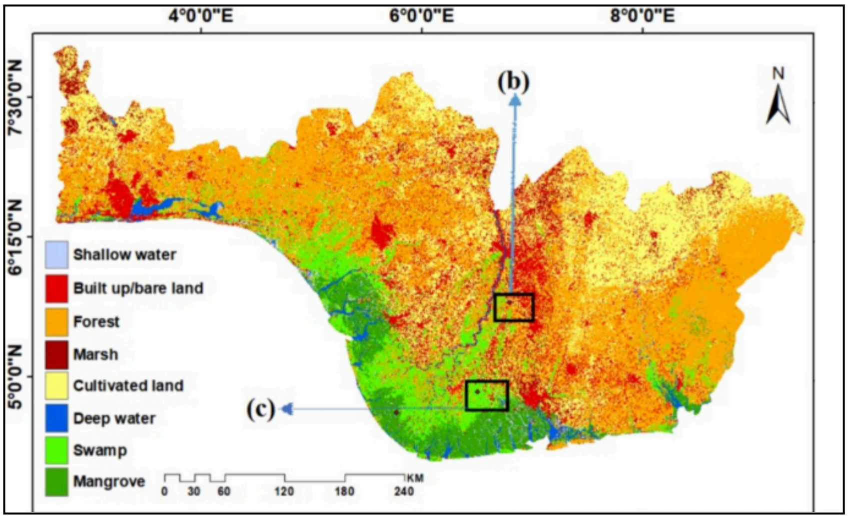

Figure 12. Application of Remote Sensing Images in Land Use/Land Cover Mapping in Southern Nigeria.

Source:
https://media.springernature.com/lw685/springer-static/image/art%3A10.1007%2Fs11273-023-09919-2/MediaObjects/11273_2023_9919_Fig6_HTML.png

In general, geospatial technologies, especially satellite remote sensing, provide consistent, repeatable, and large-scale environmental coverage, an essential advantage for a vast and ecologically diverse country such as Nigeria, where ground-based surveys are costly and logistically challenging. Remote sensing enables the monitoring of agriculture, deforestation, urban expansion, soil health, wetlands, and water bodies, thereby supporting evidence-based decision-making in agriculture, environmental risk assessment, urban planning, and disaster risk reduction (Gorelick et al., 2017; Ologunde et al., 2025). The availability of freely accessible satellite datasets such as Landsat and Sentinel-1/2 allows researchers and policymakers to conduct long-term historical analyses of land cover change and environmental dynamics over several decades.

5. Institutional Capacity and Initiatives in Nigeria

The National Space Research and Development Agency (NASRDA), headquartered at the Obasanjo Space Centre, serves as the national focal institution for satellite data management, space research, and geospatial capacity development in Nigeria. NASRDA supports satellite data access, technical training, and research partnerships across sectors (Bello, 2024). Universities and research institutions, including engineering faculties and geospatial research centres, contribute significantly to applied geospatial technologies

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research. The establishment of the Institute of Space Science and Engineering (ISSE), affiliated with the African University of Science and Technology (AUST) in Abuja, has further strengthened institutional capacity development.

Despite progress, coordination among federal agencies, state governments, and local institutions remains inconsistent, limiting the operational integration of geospatial technology outputs (geospatial layers) into routine environmental governance (Bello, 2024).

6. Constraints and Remaining Gaps

Despite their clear utility, several systemic constraints limit the broader adoption and operationalisation of geospatial technologies in environmental risk assessment in Nigeria.

Data-sharing and access policies. Although satellite data are largely free, institutional datasets remain fragmented and siloed, limiting integrated analysis. This challenge has led to the development of the National Geospatial Data Infrastructure (NGDI) initiative to reduce duplication and promote standardised geospatial data sharing (Bello, 2024). National geoinformation policies and enabling legislation have been developed through stakeholder consultations and are progressing towards federal approval and implementation (Bello, 2024).

Ground truthing and validation: Limited field data collection and sparse in situ monitoring networks reduce classification accuracy and model calibration, particularly for pollution mapping and small-scale coastal processes.

c) Human capacity and retention. Although training programmes exist, geospatial expertise is unevenly distributed across states. Brain drain to the private sector and international labour markets remains a challenge to sustained capacity development.

d) Funding and Operationalisation Many geospatial technology initiatives remain academic or project-based rather than fully operational systems. Long-term sustainability requires recurring funding and institutional mandates for systems such as national flood early warning dashboards.

e) Integration into Policy and Planning Cycles Geospatial outputs are not consistently integrated into environmental impact assessments, urban planning frameworks, or policy implementation mechanisms.

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Persistent cloud cover in tropical and coastal zones, limited hyperspectral coverage, and temporal gaps in very high-resolution imagery constrain certain monitoring applications (Zhu & Woodcock, 2014).

7. Case Study Syntheses (Selected Examples)

7.1 2022 National Floods: Remote Sensing for Damage Assessment

The 2022 floods in Nigeria were among the most severe hydrometeorological disasters in recent decades. National assessments indicate that over 3.2 million people were affected, approximately 600 fatalities were recorded, and more than 1.4 million hectares of farmland were inundated, resulting in widespread infrastructure damage and disruptions to food security (National Emergency Management Agency [NEMA], 2022; Abu & Ibebuchi, 2025).

Studies applying Sentinel-1 SAR, Sentinel-2 optical imagery, and MODIS time-series data, integrated with rainfall, soil moisture, and hydrological modelling, quantified inundation extents and detected anomalies in precipitation patterns. Remote sensing analyses showed that large flood peaks were partially influenced by extreme rainfall conditions combined with upstream reservoir releases, including operations from the Lagdo Dam in Cameroon (Nkeki et al., 2022; Abu & Ibebuchi, 2025).

These geospatial assessments provided rapid damage mapping, exposed flood-prone settlements, and supported state-level emergency response and relief allocation. The integration of geospatial technologies with hydrological modelling demonstrates a strong capacity for near-real-time disaster impact evaluation and population exposure estimation.

7.2 Niger Delta Coastal Vulnerability and Shoreline Trends

Shoreline trend analyses using satellite-derived coastlines and the Coastal Vulnerability Index (CVI) modelling indicate that a significant proportion of the Niger Delta coastline is highly vulnerable to erosion, sea-level rise, subsidence, and anthropogenic pressures.

Quantitative studies show shoreline retreat rates ranging from 2 to 30 metres per year in highly exposed sections, with approximately 25-35% of assessed coastal zones classified as high vulnerability areas, depending on geomorphology and land-use pressure (Dike et al., 2024; Fashae, 2022). Mangrove degradation and land reclamation further accelerate shoreline instability.

These findings support the prioritisation of erosion-control structures, mangrove restoration, and community-level adaptation strategies. Incorporating local sediment

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dynamics, tidal processes, and human land conversion into management frameworks improves predictive accuracy and coastal resilience planning.

7.3 Desertification Monitoring in Northern Nigeria

Remote sensing approaches using NDVI time-series analysis and the MEDALUS regional desertification model have been widely applied to map desertification sensitivity zones in northern Nigeria and parts of the Niger Basin. Studies show that vegetation cover in frontline Sahel states has declined in some areas by 10-20% over multi-decadal periods, with measurable southward shifts in high desertification-risk zones at approximately 0.5-0.7 km per year in vulnerable ecological belts (Ibrahim et al., 2022; Ogbue et al., 2024).

These geospatial outputs support targeted afforestation programmes, sustainable grazing management, soil conservation strategies, and national reporting obligations under the United Nations Convention to Combat Desertification (UNCCD). The integration of spatial modelling with policy frameworks strengthens environmental monitoring and land restoration planning (Nkeki et al., 2022).

8. Discussion of Findings: Impact, Limitations, and Evidence of Effectiveness

Geospatial technologies are now central tools for environmental risk assessment worldwide, supported by global satellite data repositories such as Landsat (USGS), Sentinel (ESA), and global land-cover products distributed through NASA and FAO data portals. In Nigeria, a country of over 220 million people spanning approximately 923,768 km² and characterised by ecosystems ranging from coastal mangroves in the Niger Delta to Sahelian drylands in the north, the applications of geospatial technologies have expanded significantly over the past two decades. Global environmental monitoring datasets indicate that satellite-derived information is now routinely incorporated into environmental impact assessments in developing countries, including major Nigerian urban regions such as Lagos, Abuja, and Port Harcourt (United Nations Environment Programme [UNEP], 2022; World Bank, 2023b).

Quantitative evidence from global land-cover products, such as the Global Forest Watch dataset and MODIS/Landsat-derived land-cover maps, indicates that Nigeria experienced significant urban expansion, with built-up areas increasing substantially between 1990 and 2020, while forest cover declined by measurable percentages in southern ecological zones (Hansen et al., 2013; Song et al., 2018). Coastal remote sensing analyses show shoreline retreat rates of approximately 2-30 metres per year in vulnerable sections of

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the Niger Delta, contributing to mangrove degradation and ecosystem fragmentation (IPCC, 2022; Murray et al., 2019).

Flood risk modelling based on global Digital Elevation Models (e.g., SRTM, NASADEM) suggests that approximately 20-25% of Nigeria's population resides in flood-prone zones, with extreme flood events in 2012 and 2022 impacting over 30 states and displacing millions (EM-DAT, 2023; Abu & Ibebuchi, 2025). In northern drylands, NDVI-based global vegetation monitoring products indicate recurring drought stress, with desertification processes advancing southward in vulnerable agro-ecological zones at measurable annual rates in certain frontline states (FAO, 2021).

Oil spill monitoring in the Niger Delta using high-resolution satellite imagery and synthetic aperture radar (SAR) data enables the detection of spill incidents through global monitoring platforms such as Sentinel Hub and NASA Earthdata, improving response coordination while revealing persistent patterns of environmental degradation (European Space Agency [ESA], 2023). Wetland mapping based on global datasets suggests that Nigeria has lost a substantial fraction (an estimated 30-35% in some basins) of freshwater wetlands due to urban expansion and agricultural encroachment, consistent with global wetland loss trends documented by international conservation monitoring systems (Ramsar Convention Secretariat, 2021).

Institutionally, agencies such as the National Space Research and Development Agency (NASRDA) and university-based geospatial laboratories have strengthened national technical capacity. Nigeria now operates indigenous Earth observation satellites, including NigeriaSat-2, which improves access to multi-temporal imagery. Over 40 universities offer geospatial technologies-related programmes, contributing to a growing professional workforce. However, budget allocation for environmental monitoring remains limited relative to national expenditure, and less than half of state environmental agencies maintain fully functional GIS units. Data-sharing systems remain fragmented, and systematic ground-truthing campaigns are limited.

Overall, global satellite repositories and international environmental monitoring frameworks demonstrate measurable progress in geospatial capacity. However, the integration of geospatial technology outputs into environmental governance in Nigeria remains inconsistent. This paper, therefore, appraises geospatial technology applications in Nigerian environmental risk assessment using global datasets, case studies, and institutional analysis. It identifies strengths, including improved access to multi-temporal satellite data

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and expanding technical expertise, as well as constraints such as limited funding, weak inter-agency data harmonisation, and insufficient operational decision-support systems. Finally, it proposes strengthening national spatial data infrastructure, expanding capacity development, improving field validation systems, and institutionalising policy-driven geospatial analytics to enhance sustainable environmental governance.

Collectively, the reviewed studies demonstrate that Geospatial Technologies (RS) generate actionable environmental intelligence by mapping vulnerable coastlines, delineating flood extents, monitoring urban expansion, and identifying desertification hotspots. When geospatial outputs are integrated into operational decision-making, such as flood response mapping, coastal hazard prioritisation, and land-use regulation, outcomes include improved targeting of relief resources, enhanced infrastructure protection, and evidence-based environmental planning (Nkeki et al., 2022; Dike et al., 2024).

However, a persistent implementation gap remains between research outputs and institutional adoption. Although many studies provide policy recommendations, these are often not systematically translated into action due to limited institutional mandates, funding constraints, weak inter-agency coordination, and political inertia. Bridging this gap requires coupling Geospatial Technologies research with targeted capacity building for managers and policymakers, strengthening data governance frameworks, and developing pilot operational systems that demonstrate direct public value, such as state-level flood early-warning dashboards integrated with emergency response systems (Bello, 2024; Abu & Ibebuchi, 2025).

9. Conclusion and Recommendations

Geospatial technologies have demonstrably advanced land and environmental assessment, playing a clear role in sustainable management across Nigeria's varied ecosystems. Technical readiness, in terms of data availability and analytical methods, is strong and improving. The primary challenges are institutional: data governance, operational funding, ground validation, and the institutionalisation of geospatial services into routine environmental governance. By addressing these challenges through targeted investments, policy reforms, and cross-sector capacity building, geospatial technologies can be transformed from episodic research outputs into core components of resilient environmental risk assessment in Nigeria.

The following strategies are recommended as a roadmap for strengthening geospatial technology capacity in Nigeria to improve environmental risk assessment:

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Create an interoperable National Geospatial Data Infrastructure (NGDI).

Develop clear data standards, centralised metadata discovery systems, and formalised data-sharing agreements across federal, state, and local government institutions to enable effective reuse of in-situ and remotely sensed data (Bello, 2024). The National Space Research and Development Agency (NASRDA), in collaboration with line ministries, should co-lead implementation to align with global Spatial Data Infrastructure (SDI) best practices and open data governance frameworks (Rajabifard & Williamson, 2001; Federal Government of Nigeria, 2020).

Invest in operational near-real-time environmental services.

Prioritise scalable systems for flood early warning (integrating synthetic aperture radar, rainfall data, and hydrological models), coastal erosion alerts, and land-use change monitoring dashboards for urban planning. The operationalisation of near-real-time geospatial services increases disaster preparedness and institutional responsiveness (Hochschild et al., 2021; World Bank, 2023a). Demonstration pilots at the state level can enhance trust and adoption.

Strengthen ground-truth networks and citizen science.

Support the expansion of in-situ monitoring infrastructure, such as river gauges, tide gauges, water-quality sensors, and structured citizen reporting platforms, to improve the validation of satellite-derived products and enhance model calibration accuracy. Integrating ground observations with satellite data improves the reliability of environmental monitoring systems (UN-GGIM, 2022).

Capacity building linked to decision makers.

Move beyond purely technical GIS training towards cross-disciplinary capacity development that equips policymakers and planners to interpret geospatial outputs for budgeting, procurement, environmental assessment, and infrastructure planning. Strengthening institutional capacity improves the policy uptake of spatial analytics (UNEP, 2022).

Promote open-source workflows and cloud processing.

Encourage the adoption of platforms such as Google Earth Engine (GEE), QGIS, and reproducible scripting environments to reduce computational barriers and improve transparency. Cloud-based geospatial analytics significantly lowers infrastructure costs and increases scalability (Gorelick et al., 2017).

Secure sustainable funding models.

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Adopt blended financing strategies that combine national budget allocations, development partner funding, and cost-recovery services (e.g., customised geospatial products for the private sector and industry). Sustainable financing is critical for maintaining operational geospatial services beyond project-based funding cycles (World Bank, 2023a).

Foster cross-border hydrological cooperation.

For transboundary river basins such as the Niger and Benue rivers, it is essential to strengthen data-sharing agreements and coordinated flood management mechanisms to reduce downstream flood risks and improve basin-scale water governance (UN-Water, 2021; IPCC, 2022).

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The authors declare that there are no conflicts of interest in this research.

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