IJESDS Vol: 1(1): 108-119, 2026
DOI: https://doi.org/10.68086/NMSK9520

https://ijesds.org

International Journal of Environmental Sciences, Development & Sustainability
An official publication of the
Faculty of Environmental Sciences
Open Access | Peer-reviewed | International
ISSN (Online): 3156-4461

RESEARCH ARTICLE

Integrating Volunteered Geographic Information into National Spatial Data Infrastructures: Opportunities, Data Quality Challenges, and Governance Implications in Nigeria

Chukwudi Andy Okereke

Department of Surveying and Geoinformatics, Imo State University, Owerri, Nigeria
*Corresponding Author's Email: andyokereke@gmail.com

ABSTRACT

Volunteered Geographic Information (VGI) has become an important source of geospatial data, enabling citizens to contribute spatial information through digital platforms. Globally, VGI complements conventional mapping by supporting disaster management, urban planning, environmental monitoring, and humanitarian response. In Nigeria, however, the National Spatial Data Infrastructure (NSDI) is constrained by fragmented institutional coordination, outdated datasets, inadequate technological infrastructure, and limited funding, reducing its capacity to meet rapidly evolving development needs. This study examines the opportunities, data quality challenges, and governance implications of integrating VGI into Nigeria's NSDI. The research adopts a conceptual approach based on literature review, policy analysis, and synthesis of crowdsourcing initiatives implemented in Nigeria between 2010 and 2026. It evaluates the contributions of OpenStreetMap, the Unique Mappers Network, YouthMappers, KoboToolbox, and Ushahidi to disaster response, urban governance, public health, security monitoring, and environmental management. Findings indicate that VGI provides a flexible, cost-effective, and timely source of spatial data, particularly in underserved and high-risk areas where official datasets are scarce. However, its integration is limited by data quality concerns, including positional inaccuracies, semantic inconsistencies, digital inequality, misinformation, volunteer fatigue, and institutional fragmentation. To address these challenges, the study proposes the Nigeria Hybrid VGI Governance Framework (NHVGF), a multi-tiered model that integrates citizen-generated data with authoritative national geospatial databases through standardized governance mechanisms. The study concludes that adopting this framework would strengthen Nigeria's NSDI by improving data availability, enhancing disaster preparedness and spatial planning, and promoting more inclusive, responsive, and sustainable geospatial governance.

Keywords: *Mapping; VGI; NSDI; NGDI; GIS; Geospatial Intelligence*

1. INTRODUCTION

The methods of acquiring and managing spatial data have changed significantly over the last two decades. In the past, geographic information was mainly produced by government mapping agencies through highly structured surveying, photogrammetry, and remote sensing processes. Although this traditional approach provided a high level of accuracy, it often struggled to keep pace with rapid environmental, social, and demographic changes because of high operational costs, bureaucratic procedures, and slow data update cycles (Sudmanns et al., 2020). The rise of Web 2.0 technologies, mobile devices with embedded GPS, cloud computing, and collaborative digital mapping platforms has transformed the way geospatial data is generated and shared. This development gave rise to Volunteered Geographic Information (VGI), where ordinary citizens contribute geographic data by collecting, editing, and sharing spatial information through digital platforms (Kufoniyi & Akinyede, 2004). Over time, VGI has evolved into an important part of the global geospatial system by complementing official datasets, filling mapping gaps, and supporting emergency and humanitarian response efforts (Shahi, 2023).

Despite these global developments, many developing countries, including Nigeria, still face major geospatial data challenges. The implementation of Nigeria's National Spatial Data Infrastructure (NSDI), also referred to as the Nigerian Geospatial Data Infrastructure (NGDI), has been affected by several persistent issues. These include the lack of current and reliable spatial datasets, fragmented institutional databases, weak implementation frameworks, rapid urban expansion, growing security and humanitarian crises, recurring flood disasters, environmental degradation, and the rapid growth of informal settlements (Ali et al., 2025; Ali & Imran, 2020; Putra et al., 2019; Tavra et al., 2024). In many cases, government agencies lack the technical and financial capacity to continuously map and update these fast-changing environments. As a result, planning and policy decisions are often based on outdated or incomplete spatial information.

In this context, VGI presents a more flexible and cost-effective alternative for generating spatial data. In Nigeria, several localized VGI initiatives have already shown practical value across different sectors. During major flood disasters, such as the Maiduguri flood following the Alau Dam collapse in September 2024, volunteer mapping initiatives produced rapid and detailed spatial information that supported rescue operations and humanitarian aid distribution (ACAPS, 2024). Similarly, Participatory Geographic Information Systems (PGIS) and other crowdsourcing platforms have been used for crime monitoring, security surveillance, and tracking political violence in different communities. In urban planning, community-based mapping projects in areas such as Makurdi have helped identify unmapped buildings and road networks in flood-prone settlements (Terkimbi et al., 2025). In the health sector, humanitarian and healthcare interventions in northern Nigeria have also used AI-assisted and community-verified building data to improve vaccination campaigns and primary healthcare planning.

Although citizen-generated geospatial data is increasingly being used in Nigeria, there is still limited research on how VGI can be formally integrated into the country's NSDI while maintaining acceptable standards of data quality, reliability, and governance (Korna et al., 2025). This gap limits the effective use of valuable community-generated data in official planning and policy processes. Against this background, this study seeks to examine existing VGI practices in Nigeria, assess the opportunities and challenges associated with crowdsourced geospatial data, identify key platforms supporting geospatial intelligence, and propose governance approaches for integrating VGI into Nigeria's national geospatial framework.

2. MATERIALS AND METHODS

This study adopts a conceptual research design that draws from existing geospatial practices, policy frameworks, and operational digital mapping initiatives in Nigeria. Rather than relying on a single method of data collection, the study combined three complementary approaches: a review of relevant literature, an examination of national geospatial policies, and a synthesis of selected case studies on active crowdsourcing initiatives in Nigeria.

The study focuses on materials published between 2010 and 2026 to capture recent developments in digital mapping technologies, national space and geospatial programmes, and emerging disaster-response initiatives within the country. Relevant materials were sourced from peer-reviewed journal articles, conference papers, government publications, institutional reports, national geospatial policy documents, and documentation from Volunteered Geographic Information (VGI) platforms. Search terms used across academic databases and online repositories included "Volunteered Geographic Information Nigeria," "Crowdsourced GIS Nigeria," "Participatory Mapping Nigeria," "National Spatial Data Infrastructure Nigeria," and "Citizen Science Geospatial Nigeria."

To organize and interpret the findings, the study applies a structured analytical framework that groups the discussion into five major thematic areas (Table 1). These themes are used to examine how decentralized geospatial data production through crowdsourcing and citizen participation can support authoritative spatial planning, policy development, and national geospatial coordination in Nigeria.

Table 1. Analytical Structures for Discussion

Analytical Theme	Core Focus	Evaluated Metrics & Indicators	Baselines
Existing VGI Ecosystem	Mapping initiatives, participatory GIS, and citizen science organizations	Contributor demographics, edit volumes, geographic coverage, and local vs. remote mapper dynamics	OpenStreetMap (OSM) Nigeria, Unique Mappers Network, YouthMappers (Sunday et al., 2022)
Platform Utility	Crowdsourcing applications and field data collection tools	Data formats (GeoJSON, SHP, KML), spatial resolution, and operational latency	OSM, Google Maps, KoboToolbox, Ushahidi, UAV mapping platforms (Darwisman, 2025)
Integration Opportunities	Multi-sectoral societal and physical spatial monitoring	Early warning systems, building detection rates, urban classification, and risk exposure modeling	Disaster management, security, public health, agricultural planning (Fadaie et al., 2001)
Data Quality Challenges	Positional, thematic, and temporal accuracy bottlenecks	Positional offsets, completeness, semantic consistency, and participant bias	ISO 19157 quality metrics, confusion matrices, Intersection over Union (IoU) scores (Gheyas et al., 2025)
Institutional Governance	Policy readiness, agency coordination, and legal mandates	Regulatory alignment, clearinghouse accessibility, legal conflicts, and data sovereignty	NGDI draft policy (2003), Space Policy, Survey Co-ordination Act (Chigbu & Igbokwe, 2012)

3. RESULTS AND DISCUSSION

The Volunteered Geographic Information Ecosystem in Nigeria

The VGI landscape in Nigeria is characterized by a vibrant but fragmented network of civic organizations, international humanitarian agencies, academic chapters, and open-source communities (Eze, 2023). While the generation of citizen-led geodata has grown, its utilization occurs primarily within localized humanitarian or research spheres rather than formal government planning processes.

At the center of this ecosystem is the OpenStreetMap (OSM) community, heavily supported by the Humanitarian OpenStreetMap Team (HOT) and localized non-governmental organizations such as the Unique Mappers Network (Herfort et al., 2021). Founded in 2017 in Port Harcourt, the Unique Mappers Network (registered under CAC/IT/No 153847) has mobilized a diverse community of citizen scientists, including students, women, and marginalized youths across the country (Nickerson, 2024). Through its 17 university-based YouthMappers chapters, the network has played an essential role in mapping vulnerable urban centers, tracing rural road networks, and monitoring ecological hazards (Muhamad et al., 2023; Zahir et al., 2025). For example, the network's "Land Pollution Lookout" project mobilized over 300 volunteers to analyze high-resolution satellite imagery, mapping over 1,500 oil spill incidents and identifying exposed pipelines across sensitive ecological zones in the Niger Delta (Nickerson, 2024).

The operational mechanics of Nigerian VGI are driven by both remote and local mapping strategies, which display distinct behavioral and efficiency profiles (Sunday et al., 2022). Empirical analysis of volunteer responses during disaster mapping campaigns demonstrates that Remote Volunteer Mappers (RVMs—contributors mapping from outside Nigeria) and Local Volunteer Mappers (LVMs—residents mapping in-country) offer highly complementary strengths (Sunday et al., 2022). RVMs, often possessing superior access to stable high-speed internet and advanced computational hardware, exhibit rapid response times, mapping massive grid structures and tracing major infrastructural networks within compressed timelines. Conversely, LVMs exhibit longer mapping execution times but contribute invaluable, hyper-localized spatial intelligence, such as precise community place names, critical public service locations, functional building attributes, and local road classifications, that remote mappers cannot extract from satellite imagery alone (Table 2).

Table 2. Mapping metrics for RVM and LVM ((Sunday et al., 2022)

Mapping Metric	Remote Volunteer Mappers (RVM) Profile	Local Volunteer Mappers (LVM) Profile
Average Mapping Speed	20.77 minutes per grid cell	41.10 minutes per grid cell
Total Building Footprints Mapped	13,552 buildings	14,983 buildings
Total Road Network Traced	858 kilometers	521 kilometers
Total Database Edits Generated	16,416 edits	18,367 edits
Average Task Completion Duration	6 months (Project Task 6358)	28 months (Project Task 6359)
Primary Contribution Value	Rapid geometry tracing and base network digitization	Semantic enrichment, attribute mapping, and local verification

Despite the substantial volume of spatial data generated by these open communities, systemic operational constraints significantly restrict the scalability and consistency of volunteer mobilization. Chief among these is the severe digital divide in Nigeria (Ahmed et al., 2022). Prohibitive mobile internet data subscription costs represent a major financial barrier for student volunteers, whose personal incomes cannot comfortably accommodate the data-heavy demands of web-based GIS mapathons and spatial data uploads. Furthermore, unstable power grids, lack of personal computers or smartphones among volunteers, and poor internet connectivity, especially in rural mapping zones, consistently hamper real-time field data collection. This technological divide is exacerbated by economic pressures; because volunteer mapping is unpaid, many highly trained youth mappers eventually prioritize income-generating labor over voluntary spatial contributions, leading to high volunteer attrition and temporal inconsistency in data updates (Odeyemi & Adeoti, 2026).

Additionally, the integration of advanced technologies like artificial intelligence has introduced a dual-edged dynamic to the ecosystem. Under the "Satellite Imagery for Social Good" initiative, HOT partnered with Microsoft's AI for Humanitarian Action to deploy automated machine learning models that predicted building footprints across the northern states of Bauchi and Gombe (Sofianopoulos et al., 2025). This effort resulted in the generation of approximately 1.8 million building outlines, which were subsequently validated and cleaned by 19 local open mapping experts and 35 cross-sectoral stakeholders, including representatives from the World Health Organization (WHO) and UNICEF (HOTOSM, 2022). While this AI-assisted workflow accelerated remote mapping speeds by orders of magnitude, the raw AI layers suffered from notable geometric challenges, such as treating separate, tightly packed rural compounds as single large structures and completely overlooking traditional round huts in dense vegetation. This highlights the indispensable role of local human-in-the-loop validation to ensure data completeness and structural accuracy.

Crowdsourced Platforms and Technological Dependencies

The execution of VGI and crowdsourced initiatives in Nigeria relies on a diverse suite of digital mapping platforms, database repositories, and field collection applications. Each platform serves distinct spatial needs, from real-time crisis reporting to structured census surveys and high-resolution environmental modeling.

Table 3. Crowdsourced platforms for digital mapping

Platform	Core Applications in Nigeria	Major Spatial Outputs	Potential NGDI Contribution
OpenStreetMap (OSM)	Base mapping, humanitarian routing, and disaster vulnerability mapping	Vector roads, building footprints, waterways, and points of interest	Direct feed for national baseline base maps and structural reference data
Google Maps Contributions	Real-time traffic, public transit adjustments, and commercial POI mapping (Salajegheh et al., 2014)	Dynamic point data, routing updates, and commercial locations	Supplementary dataset for transit planning and real-time mobility analytics
KoboToolbox	Field data collection, epidemiological monitoring, and post-disaster assessments	Structured spatial surveys, geolocated photos, and health facility attributes (Leibovici et al., 2015)	Population, demographic, and spatial attribute enrichment of national layers
Ushahidi/ Crowdmap	Conflict monitoring, election observing, and emergency incident tracking	Geolocated incident reports, temporal incident timelines, and safety hotspots (Chigbu & Igbokwe, 2012)	Dynamic event-driven spatial layers for national security and disaster response
Citizen Drone Platforms	High-resolution micro-mapping of erosion, oil spills, and informal settlements (Ali & Imran, 2020)	Orthophotos, Digital Elevation Models (DEMs), and local hazard maps	Ultra-high-resolution updates for local government cadastre and environmental monitoring
Donate Water Platform	Climate-vulnerability and hydrological resource mapping	Geolocated water source points (10,000+) and temporal water-level photos (Salajegheh et al., 2014)	Enrichment of hydrological databases and community vulnerability layers

A critical assessment of these platforms reveals that Nigeria's contemporary crowdsourced spatial intelligence is heavily dependent on foreign-hosted, externally controlled platforms (Chigbu & Igbokwe, 2012). Databases such as OSM, Google Maps, and Ushahidi operate on global cloud infrastructures where the primary data architectures, system updates, and storage nodes are governed by international consortia, foreign tech corporations, or Western non-profits (Vahidi et al., 2018).

Strategic Opportunities of VGI Integration

Urban Governance and Development Control

The rapid and largely unregulated growth of Nigeria's primary metropolitan areas, such as Lagos, Ibadan, and Port Harcourt, has completely overwhelmed conventional urban planning and developmental control enforcement systems. Traditional cadastre mapping and land-use monitoring in Nigeria remain slow, expensive, and heavily reliant on outdated paper records, preventing municipal authorities from detecting illegal structures or managing informal settlement expansion (Abubakar et al., 2025). VGI presents an agile, cost-effective alternative for urban governance. By utilizing crowdsourced building footprints, local government planners can perform spatial overlay analyses to monitor real-time physical development, trace property boundaries, and enforce zoning laws. In informal settlements, where municipal maps are non-existent, participatory mapping projects can quickly document local alleys, utility networks, and housing patterns, integrating marginalized populations into formal municipal planning and basic service delivery frameworks.

Disaster Management and Flood Response

Nigeria experiences highly destructive seasonal flood events that overwhelm emergency services and displace hundreds of thousands of citizens. Authoritative spatial responses are often severely delayed due to bureaucratic reporting chains and data scarcity. Integrating VGI can revolutionize the national disaster response loop (Ali et al., 2025). During active flood events, citizens utilizing mobile platforms act as real-time, ground-level sensors, reporting active water inundation levels, collapsed infrastructural choke points, and emergency rescue requirements.

This crowdsourced reporting can be integrated with authoritative hydrological and remote sensing forecasts generated by the Nigerian Meteorological Agency (NiMet) and the National Emergency Management Agency (NEMA). Merging real-time citizen-reported flood locations with satellite imagery provides disaster response teams with highly accurate, dynamic situational maps, facilitating precise target search-and-rescue missions and efficient relief resource allocation (Balog & Babos, 2022).

Security Operations and Intelligence Mapping

The contemporary security landscape of Nigeria is challenged by complex, spatially dispersed crises, including domestic insurgency, rural banditry, kidnapping, and localized urban crime. Authoritative security operations are frequently constrained by a lack of spatial intelligence, manual record-keeping, and outdated geodatabases. Integrating VGI and Participatory GIS (PGIS) directly supports proactive public safety and predictive policing (Bako et al., 2021).

Local populations possess intimate spatial knowledge of security vulnerabilities, minor transit pathways, and remote criminal hideouts that are invisible to aerial sensors. By implementing secure, crowdsourced incident-reporting platforms, citizens can safely submit geolocated security alerts and incident testimonies. When mapped and analyzed using spatial clustering algorithms, this community intelligence reveals geographic hotspots, maps security infrastructure deficits, and provides law enforcement agencies with a synoptic perspective to optimize patrol routes and tactical deployment (Bako et al., 2021; Odeyemi & Adeoti, 2026).

Environmental Monitoring and Remediation

Industrial activities, rapid urbanization, and agricultural expansion have led to severe environmental degradation across Nigeria. This includes massive, chronic oil spills in the Niger Delta, acute gully erosion in the southeast, and widespread solid waste accumulation in metropolitan areas (Sunday et al., 2022). Official environmental agencies often lack the manpower and spatial resources to monitor these vast terrains continuously.

VGI directly bridges this enforcement gap. Through citizen science programs, local fishing and farming communities can map and upload georeferenced photographs of active pipeline leaks, illegal oil refining sites, and vegetative dieback (Ahmad et al., 2022). In urban centers, mobile-based citizen reporting systems allow residents to log illegal solid waste dump sites and drainage blockages (Niño Beltrán et al., 2023). This continuous stream of citizen-led spatial evidence empowers environmental regulators to hold polluting entities legally accountable, track restoration progress, and design targeted ecological remediation strategies.

Data Quality Challenges

While the integration of VGI into the national framework offers immense potential, it is strictly constrained by technical, geographic, and socio-economic bottlenecks that degrade the quality of citizen-generated data. Unlike professional surveyors, crowdsourced volunteers rarely possess formal geoinformatics training or high-precision spatial equipment, introducing unique data validation challenges.

Technical Data Quality Bottlenecks

When assessed against international spatial data quality standards such as the ISO 19157 framework, Volunteered Geographic Information (VGI) presents several technical challenges that may affect its reliability and integration into official geospatial systems (Podobnikar, 2025). These limitations are discussed below:

Positional Inaccuracy: One of the major concerns with crowdsourced geospatial data is positional error. Volunteers who digitize satellite imagery may not adequately account for image alignment and orthorectification issues, resulting in spatial offsets. This can lead to misaligned road networks, overlapping building footprints, and inaccurate feature positioning within the dataset (Chen et al., 2017).

Data Incompleteness: VGI coverage is often uneven across geographic areas. Urban centers and economically active locations usually receive more mapping attention because they attract a larger number of contributors. In contrast, many rural communities, remote regions, and informal settlements remain poorly mapped or absent from the database. This imbalance reflects contributor concentration and accessibility differences (Vahidi et al., 2018).

Semantic and Thematic Inconsistency: Differences in contributor interpretation can create inconsistencies in feature classification and tagging. Similar geographic features may be labeled differently by different volunteers, reducing the consistency and analytical value of the data. For example, a small healthcare facility may be tagged as a clinic, health post, public amenity, or private office depending on the mapper's understanding or local language interpretation (Wang et al., 2020).

Temporal Discrepancy: Because many VGI platforms rely on voluntary updates rather than scheduled maintenance, datasets can quickly become outdated. Features mapped during earlier humanitarian or development campaigns may no longer exist or may have changed significantly over time. However, without regular verification and updates, such obsolete information may continue to appear in active geospatial databases.

Nigeria-Specific Socio-Technical Challenges

The implementation of Volunteered Geographic Information (VGI) in Nigeria is affected by several socio-technical and structural challenges that limit its effectiveness and sustainability. These challenges are closely linked to broader issues of digital inequality, economic conditions, and institutional capacity within the country.

Digital Divide and Geographic Bias: Access to reliable internet services, electricity, and digital infrastructure is still concentrated mainly in major urban centers such as Lagos, Abuja, and Port Harcourt. As a result, most participatory mapping activities are focused on urban environments, while many rural communities, agricultural regions, and conflict-prone areas remain poorly mapped or completely excluded from digital spatial databases (Vahidi et al., 2018). Ironically, these underserved regions are often the areas where accurate geospatial information is most urgently needed for development planning and humanitarian interventions.

High Connectivity and Data Costs: The cost of internet access and mobile data subscriptions in Nigeria remains a major barrier to sustained participation in VGI activities. Many volunteers, especially students and young contributors involved in mapping communities, are unable to continue regular data uploads once externally funded map-athons or sponsored projects end. This limits the continuity and long-term maintenance of crowdsourced datasets (Vavassori et al., 2022).

Low Geospatial and Digital Literacy: A significant proportion of potential contributors lack adequate training in geospatial concepts and digital mapping techniques. This often results in technical errors during data collection and digitization processes, including overlapping polygons, disconnected road networks, and inaccurate feature representations. Limited understanding of mapping standards also affects the overall consistency and reliability of contributed data (Chen et al., 2017).

Misinformation and Security Risks: In areas affected by insecurity, political tension, or communal conflict, crowdsourced platforms may become vulnerable to intentional misinformation. False reports, manipulated coordinates, or inaccurate representations of incidents and infrastructure can be deliberately uploaded by malicious actors, thereby reducing trust in the reliability of VGI datasets and potentially affecting emergency response operations (Tavra et al., 2024).

Volunteer Fatigue and Economic Pressures: Since most VGI initiatives depend largely on unpaid volunteer participation, sustaining long-term engagement is often difficult. Many contributors are compelled to prioritize income-generating activities and other economic responsibilities over voluntary mapping efforts. As a result, participation levels frequently decline after initial enthusiasm or project-based activities have ended.

Institutional Readiness and Governance Frameworks

The successful integration of VGI into Nigeria's spatial data infrastructure is not merely a technical challenge; it is profoundly a political, legal, and institutional governance issue. Without clear institutional structures, formal data sharing agreements, and legally defined boundaries of accountability, even the highest quality VGI will remain excluded from state operations.

Structural Institutional Barriers in Nigeria

The primary barrier to geospatial integration in Nigeria is the acute institutional fragmentation and legal conflict surrounding NGDI custodianship.10 Since the drafting of the National Geoinformation Policy in 2003, a persistent institutional debate has existed between the National Space Research and Development Agency (NASRDA) and the Office of the Surveyor General of the Federation (OSGOF) (Chigbu & Igbokwe, 2012). The National GI Policy document designated NASRDA as the primary clearinghouse and national apex custodian for the NGDI database. However, OSGOF is legally empowered by the Survey Co-ordination Act of 1962 (and its subsequent amendments) to supervise and coordinate all formal surveying and mapping practices across the federation (Chigbu & Igbokwe, 2012).

This jurisdictional conflict has resulted in significant regulatory duplication, inter-agency friction, and government selective inertia in funding key NGDI projects. Because both agencies operate independently, Nigeria lacks a synchronized, interoperable data-sharing network. Authoritative data remains fiercely siloed within individual ministries, departments, and agencies (MDAs) (Oyugi & Adewale, 2013). This defensive institutional posture naturally extends to VGI, which is viewed with skepticism by traditional cartographers who equate open-source, citizen-led mapping with a dilution of professional standards and a violation of established surveying mandates.

Furthermore, technical discrepancies exist between different agency standards. The officially adopted Minna-Datum is inconsistent with global Geodetic Reference Systems such as WGS84 and the International Terrestrial Reference System (ITRS). Additionally, Nigeria's lack of a national geoid prevents the conversion of GPS geodetic heights to orthometric heights, which severely limits the utility of crowdsourced GPS datasets in formal engineering and cadastre mapping (Chigbu & Igbokwe, 2012; Cho, 2014; Manouchehri & Moghaddam, 2017).

The Proposed Nigeria Hybrid VGI Governance Framework (NHVGF)

To address these institutional, technical, and regulatory challenges, this research proposes a novel, multi-tiered institutional structure: the Nigeria Hybrid VGI Governance Framework (NHVGF). The NHVGF is designed as a structured gateway that bridges decentralized, citizen-led mapping with the highly regulated, authoritative databases of the Nigerian state

(Podobnikar, 2025). The NHVGF operates through six integrated tiers, aligning crowdsourced geodata with the strategic goals outlined in the NSDI Strategic Plan (2025–2035), which prioritizes inclusive governance, technological modernization, and geospatial workforce development (Mattke, 2025).

Table 4. Proposed Tiers for Nigeria Hybrid VGI Governance Framework (Jackson et al., 2013; Rahman & Szabó, 2023; Sehra et al., 2017)

NHVGF Tier	Core Action & Processing	Integrated Technologies	Institutional Actors
Tier 1: Participatory Capture	Decentralized spatial collection of environmental, routing, and structural data (See et al., 2013)	OpenStreetMap, KoboToolbox, Mobile GPS, Drone Orthophotos (Sudmanns et al., 2020)	Local Citizens, YouthMappers, Unique Mappers Network
Tier 2: Automated Triaging	Immediate spatial and semantic filtering of incoming raw VGI	CNN Image Classification, NLP Tag Analysis, Topology Rules (Xin, 2022)	Open Mapping Hubs, National Clearinghouse AI nodes
Tier 3: Expert Custodianship	Semi-automated validation and localized ground-truthing	ISO 19157 Standards, JOSM Validation, Manual Conflation	OSGOF Cartography/GIS Dept, NASRDA, SURCON
Tier 4: Enterprise Integration	Data ingestion into the national clearinghouse database	Web2.0 Broker (W2B), Web Feature Services (WFS), GML	NGDI Council, Federal Ministry of Science & Tech
Tier 5: Operational Application	Spatial analysis, contingency modeling, and emergency deployment	GIS Overlay Analysis, Early Warning Systems, predictive models	NEMA, NiMet, NIHSA, State Planning Boards
Tier 6: Democratic Feedback	Closed-loop dissemination and community value-sharing	Geo-portals, public dashboards, and localized capacity building	Academic Institutions, NGOs, Civil Society Organizations (Cantat et al., 2025; Muhamad et al., 2023)

At the centre of the NHVGF is the deployment of a Service-Oriented Architecture (SOA) supported by a specialized Web 2.0 Broker (W2B) (Salajegheh et al., 2014). This middleware functions as an interoperability mechanism between official government geospatial databases and citizen-generated spatial information. Rather than requiring direct modification of secure government cadastral or NGDI databases, the W2B enables authoritative datasets and verified VGI layers to be accessed, searched, and displayed together through interactive web-based platforms.

This approach helps preserve the integrity and security of official government records while simultaneously enhancing them with real-time, citizen-contributed information. By enabling both authoritative and crowdsourced datasets to operate within the same framework, the NHVGF promotes collaboration between institutional agencies and volunteer mapping communities. In doing so, it moves beyond the traditional divide between top-down and bottom-up mapping approaches and supports the development of a more adaptive, integrated, and resilient geospatial information system.

4. CONCLUSION

Nigeria is currently at an important stage in the development of its national geospatial system. The traditional top-down approach to implementing the National Spatial Data Infrastructure (NSDI) has struggled to respond effectively to the country's rapidly changing social, economic, and environmental conditions. Limited funding, technological constraints, and institutional fragmentation have further reduced the ability of government agencies to produce and maintain current spatial datasets. At the same time, community-based mapping initiatives and volunteer geospatial networks have shown that citizens can make meaningful contributions to spatial data generation, particularly during emergencies, health interventions, and environmental monitoring activities. The growing amount of geospatial information produced through initiatives such as the Unique Mappers Network represents an important national resource that remains underutilized.

Despite its potential, the long-term sustainability of participatory mapping in Nigeria is still challenged by digital inequality, weak institutional coordination, and the absence of a formal framework for integrating citizen-generated data into official geospatial systems. Addressing these challenges will require stronger policy direction and institutional reforms. In particular, there is a need for clearer coordination among national geospatial agencies and the establishment of a unified governance structure that can support collaboration between government institutions, private organizations, and volunteer mapping communities. A structured hybrid governance framework would help transform VGI from isolated project-based interventions into a more reliable and recognized component of national geospatial intelligence.

Ultimately, the future of a resilient and effective NSDI in Nigeria will depend not only on technological advancement, but also on the development of inclusive policies that recognize the value of citizen participation in national development. Integrating VGI into formal geospatial governance structures can improve data availability, strengthen disaster response and planning processes, and support more informed decision-making across different sectors of the Nigerian economy.

5. COMPETING INTEREST

None to declare

REFERENCES

Abubakar, A. T., Muritala, A. O., Mbamara, B. E., & Popoola, O. Y. (2025). The Use of GIS in Development Control Enforcement in Nigeria: Opportunities and Challenges. *International Journal of Research and Innovation in Social Science (IJRISS)*, *IX*(IV), 7061–7072. https://doi.org/10.47772/IJRISS

ACAPS. (2024). *Humanitarian impact of floods in Borno state* (Issue September). https://www.acaps.org/en/countries/archives

Ahmad, M., Khayal, M. S. H., & Tahir, A. (2022). Analysis of Factors Affecting Adoption of Volunteered Geographic Information in the Context of National Spatial Data Infrastructure. *ISPRS International Journal of Geo-Information*, *11*(2). https://doi.org/10.3390/ijgi11020120

Ahmed, M. A., Sridharan, B., Saha, N., & Sannasiraj, S. A. (2022). International Journal of Disaster Risk Reduction. *International Journal of Disaster Risk Reduction*, *82*(May), 103341. https://doi.org/10.1016/j.ijdrr.2022.103341

Ali, A., Ahmad, M., Nawaz, M., & Sattar, F. (2025). Factors impeding the implementation of spatial data infrastructure in lower middle-income economies: A case study from Pakistan. *Information Development*. https://doi.org/10.1177/02666669241302788

Ali, A., & Imran, M. (2020). The Evolution of National Spatial Data Infrastructure in Pakistan: Implementation Challenges and the Way Forward. *International Journal of Spatial Data Infrastructures Research*, *15*, 110–142. https://doi.org/10.2902/1725-0463.15.art5

Bako, A. I., Aduloju, O. T. B., Osewa, D. J., Anofi, A. O., & Abubakar-Karma, A. T. (2021). Application of Participatory GIS in Crime Mapping of Ibadan North, Nigeria. *Papers in Applied Geography*, *7*(2), 183–198. https://doi.org/10.1080/23754931.2020.1858446

Balog, F., & Babos, T. (2022). The role of citizens and geoinformation in providing alerts and crisis information to the public. *Security and Defence Quarterly*, *40*(September 2022), 58–74. https://doi.org/10.35467/sdq/152630

Cantat, F., Mooney, P., Raimond, A.-M., Oksanen, J., Morley, J., Ritz, K., Crépin, A., & Kettunen, P. (2025). *Current Trends on Volunteered Geographic Information (VGI) in National Mapping and Cadastral Agencies (NMCAs)* (pp. 1–35). EuroSDR.

Chen, H., Zhang, W. C., Deng, C., Nie, N., & Yi, L. (2017). Volunteered Geographic Information for Disaster Management with Application to Earthquake Disaster Databank & Sharing Platform. *IOP Conf. Ser.: Earth Environ. Sci*, *57*(1). https://doi.org/10.1088/1742-6596/755/1/011001

Chigbu, N., & Igbokwe, J. I. (2012). X-Raying Nigeria National Geo-Spatial Data Infrastructure (NDGI)-The Journey So Far. *8th FIG Regional Conference 2012: Surveying towards Sustainable Development*, *November 2012*, 26–29. https://www.fig.net/resources/proceedings/fig_proceedings/uruguay/papers/ts01d/TS01D_chigbu_igbokwe_6281.pdf

Cho, G. (2014). Some legal concerns with the use of crowd-sourced Geospatial Information. *IOP Conference Series: Earth and Environmental Science*, *20*(1). https://doi.org/10.1088/1755-1315/20/1/012040

Darwisman, S. (2025). From Model to Interpretation: A Comprehensive and Critical Guide to PLS-SEM Implementation in Scientific Research. *Journal International of Management and Business*, *1*(1), 1–28. https://doi.org/10.5281/zenodo.17387121

Eze, R. M. (2023). The Role Of Non-Governmental Organizations In The Development Of Nigeria. *Journal of Social Theory and Research*, *3*(2), 1–16. https://publications.jostar.org.ng/role-non-governmental-organizations-development-nigeria

Fadaie, K., Slade, S. D., & de Rijcke, I. (2001). Geospatial information as a tool in legal dispute resolution. *Geomatica*, *55*(1), 79–90. https://doi.org/10.5623/geomat-2001-0010

Gheyas, I., Asghar, M. R., Schneider, S., & Woodward, A. (2025). *Establishing Trust in Crowdsourced Data*. *1*(1), 1–31. http://arxiv.org/abs/2511.03016

Herfort, B., Lautenbach, S., Porto de Albuquerque, J., Anderson, J., & Zipf, A. (2021). The evolution of humanitarian mapping within the OpenStreetMap community. *Scientific Reports*, *11*(1), 1–16. https://doi.org/10.1038/s41598-021-82404-z

Jackson, S. P., Mullen, W., Agouris, P., Crooks, A., Croitoru, A., & Stefanidis, A. (2013). Assessing completeness and spatial error of features in volunteered geographic information. *ISPRS International Journal of Geo-Information*, *2*(2), 507–530. https://doi.org/10.3390/ijgi2020507

Korna, I., Kalinka, M., & Auzins, A. (2025). Advantages of integrated geospatial information framework to support the autonomous functions of local governments in Latvia. *Journal of Urban Management*, *15*(1), 343–359. https://doi.org/10.1016/j.jum.2025.07.005

Kufoniyi, O., & Akinyede, J. O. (2004). Mainstreaming geospatial information for sustainable national development in Nigeria. *Proceedings ISPRS Congress, Istanbul, Turkey, Http://Www. Isprs. Org/Proceedings/XXXV/Co Ngress/Comm4/Papers/360. Pdf*, *14*, 7–13. www.uneca.org/rectas.

Leibovici, D. G., Evans, B., Hodges, C., Wiemann, S., Meek, S., Rosser, J., & Jackson, M. (2015). On data quality assurance and conflation entanglement in crowdsourcing for environmental studies. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *2*(3W5), 195–202. https://doi.org/10.5194/isprsannals-II-3-W5-195-2015

Manouchehri, M., & Moghaddam, M. K. (2017). Volunteered geographic information (VGI) and environmental monitoring, a new approach in developing countries. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *42*(4W4), 401–405. https://doi.org/10.5194/isprs-archives-XLII-4-W4-401-2017

Muhamad, N., Muhamad Hakimi, F. H., & Mahadzir, M. D. A. (2023). Community Activation for Disaster Risk Reduction Through OpenStreetMap: A Scoping Review. *Journal of Advanced Geospatial Science & Technology*, *3*(2), 25–50. https://doi.org/10.11113/jagst.v3n2.68

Niño Beltrán, L. A., Darghan Contreras, A. E., Cangrejo Aljure, L. D., & Grisales Camargo, E. F. (2023). Evaluation of the Quality of the Voluntary Geographic Information for the Road Network in Bogotá D.C. *Geographical Research Letters*, *49*(1), 191–210. https://doi.org/10.18172/cig.5280

Odeyemi, C. A., & Adeoti, O. (2026). Assessing Nigeria's Spatial Data Infrastructure (SDI) Readiness Index. *Journal of Environmental Studies (JES)*, *2*(1), 1–15.

Oyugi, M. O., & Adewale, K. (2013). Pathways in the Implementation of National Spatial Data Infrastructure in N'eri and Kenya. *Oyugi & Adewale, IAfrica Habitat Review*, *7*, 537–550.

Podobnikar, T. (2025). Bridging Perceived and Actual Data Quality: Automating the Framework for Governance Reliability. *Geosciences (Switzerland)*, *15*(4). https://doi.org/10.3390/geosciences15040117

Putra, T. Y. D., Sekimoto, Y., & Shibasaki, R. (2019). Toward the evolution of national spatial data infrastructure development in Indonesia. *ISPRS International Journal of Geo-Information*, *8*(6). https://doi.org/10.3390/ijgi8060263

Rahman, M. M., & Szabó, G. (2023). Assessing the Status of National Spatial Data Infrastructure (NSDI) of Bangladesh.

ISPRS International Journal of Geo-Information, *12*(6). https://doi.org/10.3390/ijgi12060236

Salajegheh, J., Hakimpour, F., & Esmaeily, A. (2014). Developing a Web-based system by integrating VGI and SDI for real estate management and marketing. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *40*(2W3), 231–236. https://doi.org/10.5194/isprsarchives-XL-2-W3-231-2014

See, L., Comber, A., Salk, C., Fritz, S., van der Velde, M., Perger, C., Schill, C., McCallum, I., Kraxner, F., & Obersteiner, M. (2013). Comparing the Quality of Crowdsourced Data Contributed by Experts and Non-Experts. *PLoS ONE*, *8*(7), 1–11. https://doi.org/10.1371/journal.pone.0069958

Sehra, S. S., Singh, J., & Rai, H. S. (2017). Assessing OpenStreetMap data using intrinsic quality indicators: An extension to the QGIS processing toolbox. *Future Internet*, *9*(2). https://doi.org/10.3390/fi9020015

Shahi, K. (2023). Volunteered Geographic Information (VGI) in Spatial Data Infrastructure (SDI) Continuum. *EAI Endorsed Transactions on Internet of Things*, *9*(1), 1–8. https://doi.org/10.4108/eetiot.v9i1.2979

Sofianopoulos, S., Faka, A., & Chalkias, C. (2025). SDI-Enabled Smart Governance: A Review (2015–2025) of IoT, AI and Geospatial Technologies—Applications and Challenges. *Land*, *14*(7). https://doi.org/10.3390/land14071399

Sudmanns, M., Tiede, D., Lang, S., Bergstedt, H., Trost, G., Augustin, H., Baraldi, A., & Blaschke, T. (2020). Big Earth data: disruptive changes in Earth observation data management and analysis? *International Journal of Digital Earth*, *13*(7), 832–850. https://doi.org/10.1080/17538947.2019.1585976

Sunday, V. N., Ndukwu, R. I., & Brovelli, M. A. (2022). Analysis of Local and Remote Mappers' Open Geographic Data Contribution To Oil Spill Disaster Response in Niger Delta Region, Nigeria. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *48*(4/W1-2022), 465–472. https://doi.org/10.5194/isprs-archives-XLVIII-4-W1-2022-465-2022

Tavra, M., Lisec, A., Galešić Divić, M., & Cetl, V. (2024). Unpacking the role of volunteered geographic information in disaster management: focus on data quality. *Geomatics, Natural Hazards and Risk*, *15*(1). https://doi.org/10.1080/19475705.2023.2300825

Terkimbi, T. E., Alaci, D. S. A., & Bashir-Mohammed, S. (2025). Urbanisation as a Factor of Flooding in Developing Countries: Experience from Makurdi, Nigeria. *International Journal of Research and Innovation in Applied Science (IJRIAS)*, *X*(XI), 526–536. https://doi.org/10.51584/IJRIAS

Vahidi, H., Klinkenberg, B., & Yan, W. (2018). Trust as a proxy indicator for intrinsic quality of Volunteered Geographic Information in biodiversity monitoring programs. *GIScience and Remote Sensing*, *55*(4), 502–538. https://doi.org/10.1080/15481603.2017.1413794

Vavassori, A., Carrion, D., Zaragozi, B., & Migliaccio, F. (2022). VGI and Satellite Imagery Integration for Crisis Mapping of Flood Events. *ISPRS International Journal of Geo-Information*, *11*(12). https://doi.org/10.3390/ijgi11120611

Wang, S. Z., Zhou, Q., & Tian, Y. J. (2020). Understanding completeness and diversity patterns of OSM-based land-use and land-cover dataset in China. *ISPRS International Journal of Geo-Information*, *9*(9). https://doi.org/10.3390/ijgi9090531

Xin, Y. (2022). Anomaly detection for volunteered geographic information: a case study of Safecast data. *International Journal of Geographical Information Science*, *36*(7), 1423–1442. https://doi.org/10.1080/13658816.2021.1981333

Zahir, I. L. M., Suthakaran, S., Zihan, Z. M., Iyoob, A. L., Thanujan, V., & Naksala, S. (2025). Developing the Volunteer Spatial Information Using OpenStreetMap for Countryside Sustainable Development in UVA Province, Sri Lanka. In *Digital Technologies for Sustainability and Quality Control*. https://doi.org/10.4018/979-8-3693-4373-9.ch012