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Demystifying Earth Observation Through Co-Creation Pathways for Flood Resilience in African Informal Cities

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Abstract

This study explores how demystifying Earth Observation (EO) through co-creation pathways and local language integration can enhance flood resilience and environmental governance in African informal cities. Using case studies from Maiduguri and Hadejia, Nigeria, the research employed a transdisciplinary mixed-methods design combining rapid evidence assessment, surveys, participatory workshops (n = 50 stakeholders) integrating simplified Sentinel-1/2 demonstrations, indigenous knowledge mapping, and pre-/post-engagement surveys. Participants (non-experts) were trained to interpret satellite data in both Hausa and English, linking distant teleconnections with local flood experiences. Findings revealed significant gains in EO literacy and improvements in interpretive confidence, gender-inclusive participation, and policy engagement. The use of local learning process enabled participants to translate technical EO concepts into locally meaningful narratives, fostering cognitive empowerment and practical application in flood preparedness and advocacy. The study demonstrates that data democratization is not only a matter of open access but also of open understanding. It advances a conceptual model linking Demystification, Literacy, Empowerment, Co-Production and Resilience, positioning EO as a social technology that bridges scientific and indigenous knowledge systems. The findings contribute to debates on decolonizing environmental science and propose a participatory framework for integrating EO into community-based adaptation, legal accountability, and policy reform across Africa's rapidly urbanizing landscapes.

Keywords: Earth Observation (EO); demystification; participatory co-creation; flood vulnerability; informal settlements; teleconnections; knowledge translation

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1. Introduction

Flooding has become one of the most frequent and damaging natural hazards in sub-Saharan Africa, with a growing body of evidence showing that climate-driven hydrometeorological extremes disproportionately impact the region [1,2]. Rapid urbanization, weak infrastructure, and the expansion of informal settlements especially along riverbanks and flood-prone zones have heightened African cities' vulnerability to floods [3–5]. In Nigeria, flood impacts have escalated sharply: the 2022 floods alone displaced over 1.4 million people and caused hundreds of fatalities, marking them among the worst in a decade [6,7]. The 2024 flood in Maiduguri, triggered in part by a dam breach, displaced hundreds of thousands of residents, revealed major gaps in early-warning and

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drainage systems [8], and highlights the compounded risks of infrastructure decay, climate extremes, and social fragility [2].

While flooding in African cities is driven by a complex interplay of climatic, hydrological, and socio-spatial factors, the challenge is intensified by chronic gaps in data availability and the limited integration of scientific tools into planning and emergency response systems [9–11]. Recent advances in Earth Observation (EO) technologies including high-resolution satellite imagery, radar-based flood detection, and cloud-based geospatial analytics provide unprecedented opportunities for near-real-time monitoring of rainfall extremes, land-use change, and surface-water dynamics across diverse scales [12–15]. Globally, EO data have become central to disaster-risk reduction and climate-adaptation efforts, enabling rapid flood mapping, impact assessments, and anticipatory early-warning systems adopted by governments and humanitarian agencies [16,17]. However, translating these technical capabilities into actionable, locally embedded knowledge remains uneven, with African countries continuing to face barriers related to limited technical capacity, fragmented data governance, and underinvestment in digital infrastructure [18–20].

Although the democratization of Earth Observation (EO) has been significantly enhanced through open-access platforms such as NASA's Earthdata, the Copernicus Programme, and Digital Earth Africa, practical utilization remains uneven [21,22]. In many African countries, EO applications are still dominated by technically trained specialists, limiting participation from humanitarian responders, journalists, legal practitioners, and local communities who play critical roles in flood governance [18,23]. Recent assessments indicate that EO engagement in Africa is heavily concentrated within academic and governmental institutions, with community-based actors, civil society organizations, and local authorities accounting for only a small fraction of active users [18,19,24]. This gap is not solely technical but also epistemic: the specialized terminology, complex data formats, and lack of contextual translation reinforce entrenched knowledge hierarchies that elevate scientific expertise while marginalizing local and indigenous knowledge systems [25].

In Nigeria, this divide is reflected in pronounced disparities between expert and non-expert EO literacy, resulting in community dependence on external interpretations and weakening local ownership of flood-risk decision processes [26–28]. Moreover, the limited availability of EO training materials and analytical tools in major indigenous languages such as Hausa, Yoruba, and Igbo hampers comprehension and practical application. The dominance of English in capacity-building resources and software interfaces further restricts accessibility, compounding infrastructural and technological constraints and sustaining the perception of EO as an elite, technocratic domain [29,30].

Urban flooding in Africa is closely shaped by interconnected processes of informality, fragmented governance, and large-scale environmental teleconnections [31]. Informal settlements which continue to expand due to rapid urbanization, insecure tenure, and inadequate infrastructure now accommodate over half of Africa's urban population, with many located in flood-prone wetlands and low-lying basins [32,33]. These areas typically lack engineered drainage and institutional representation, increasing their exposure to recurrent hazards. In Maiduguri, the 2024 overtopping of the Alau Dam inundated extensive informal districts and internally displaced persons (IDP) camps, destroying hundreds of thousands of shelters and overwhelming emergency-response systems [34–36]. Likewise, in the Hadejia Valley, recurrent flooding driven by upstream irrigation schemes, sedimentation, and altered hydrological regimes has resulted in significant losses to farmlands and livelihoods, with annual agricultural damages estimated in the hundreds of millions of dollars [10,37,38]. These localized impacts are embedded within broader teleconnections: climatic anomalies in the upper Hadejia–Jama'are Basin, regulated dam releases from Kano, and regional evapotranspiration patterns interact to shape downstream flood intensity [39]. However, these multi-scalar dynamics remain poorly understood by many local actors, as conventional flood-risk communication rarely illustrates cross-boundary hydrological linkages. Earth Observation (EO) datasets particularly radar-based Sentinel imagery and time-series surface-water analytics offer tools to visualize these hidden drivers, yet the insights often remain inaccessible to non-experts.

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Demystifying EO in this context allows local actors to see the invisible and connect upstream land-use decisions and distant climate anomalies into their immediate experiences of flooding. Integrating teleconnection understanding into community-based EO training therefore strengthens adaptive capacity and fosters transboundary solidarity. This approach also aligns with the socio-hydrological paradigm, which conceptualizes flood risk as co-produced by interactions between human behavior and hydrological processes [40]. By engaging communities in interpreting EO-based teleconnections, the study situates flood governance within a relational framework—acknowledging that local vulnerability is entangled with regional ecological dynamics and political decisions.

The process of demystification aligns closely with contemporary developments in knowledge-translation theory, which has expanded beyond its origins in health and social sciences to become a foundational approach in environmental governance [41,42]. Recent literature highlights that effective knowledge translation requires iterative engagement between knowledge producers and users, ensuring that information is not only available but also comprehensible, culturally resonant, and actionable [43]. Within flood governance, this involves reframing EO outputs into narratives, visual formats, and linguistic structures that align with the cognitive, cultural, and institutional frames of diverse stakeholders. Growing empirical evidence highlights the value of participatory and co-designed EO applications to strengthen decision-making and community resilience [17,38]. Yet, relatively few studies have integrated linguistic inclusivity or legal empowerment into their methodological design, despite their importance for equitable environmental governance [44,45]. This research responds to that gap through an indigenous language participatory co-creation model implemented in Maiduguri and Hadejia, two urban contexts that exhibit distinct yet complementary flood-risk dynamics. The framework draws on contemporary scholarship on co-production, resilience governance, and transdisciplinary practice [39,46], using an indigenous language structure to dismantle epistemic and linguistic barriers that often marginalize non-scientists. By integrating legal practitioners, humanitarian workers, civil-society representatives, and geospatial experts in a shared interpretive space, the model repositions EO as lived knowledge situated, embodied, and collectively owned.

Such participatory demystification aligns with the Sendai Framework for Disaster Risk Reduction [47], which emphasizes inclusivity, local knowledge, and multi-stakeholder governance. It also operationalizes Sustainable Development Goal (SDG) 11 ("Sustainable Cities and Communities") and SDG 13 ("Climate Action") by embedding EO within community-driven adaptation and resilience strategies.

Despite growing recognition of the value of participatory EO, the literature reveals several unresolved challenges. First, existing frameworks rarely evaluate non-expert EO literacy in measurable terms in flood-prone African contexts [23,48]. Most focus on technological feasibility rather than knowledge empowerment. Second, teleconnection awareness (how local actors perceive upstream–downstream linkages) is scarcely addressed in participatory EO studies, even though it shapes transboundary flood governance [49–51]. Third, linguistic diversity remains a neglected dimension of inclusion; the dominance of English training materials perpetuates digital inequity and reduces comprehension among local actors [52,53]. Finally, there is limited empirical work integrating EO demystification into formal institutional mechanisms, such as Nigeria's National Emergency Management Agency (NEMA) or State Emergency Management Agencies (SEMA).

This research responds to these gaps by operationalizing demystification as a participatory, cross-sectoral process using indigenous languages aimed at enhancing non-expert EO literacy and equitable flood resilience in African informal cities. By focusing on Maiduguri and Hadejia, it captures two distinct geophysical and socio-political flood regimes providing comparative insights into how EO knowledge can be socially and linguistically translated. The overarching aim is to empower non-experts to use EO tools for flood-risk management through participatory co-creation and local language engagement. The specific objectives are to: (i) Assess baseline disparities in EO knowledge across expert and non-expert groups; (ii) Design and implement workshops for EO demystification using indigenous languages; (iii) Quantify changes in EO literacy and willingness to

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apply EO data; (iv) Implications for demystification and vulnerability reduction; and (v) Identify policy pathways for integrating non-expert EO use into DRR governance.

The study's significance lies in its conceptual, empirical, and policy contributions. Conceptually, it advances the emerging discourse on democratizing Earth Observation by integrating knowledge-translation theory, resilience thinking, and socio-technical co-production. Empirically, it provides one of the first participatory EO experiments using local languages in the Lake Chad Basin, offering replicable evidence for other flood-prone African regions. Policy-wise, it contributes to bridging the science–policy–society interface demonstrating how demystified EO can inform legal action, advocacy, and community preparedness. Ultimately, the study argues that transformative flood-risk governance in Africa depends not only on technological innovation but on epistemic inclusion. By translating EO into accessible, culturally embedded knowledge, communities and policymakers alike can co-create adaptive responses that are both scientifically robust and socially just.

2. Conceptual Foundations and Theoretical Framings and Literature Review

Understanding and addressing flood vulnerability in African cities requires an interdisciplinary conceptual foundation that captures the interplay between technology, society, and governance. This study draws on four interrelated frameworks: (i) Earth Observation (EO) democratization and demystification, (ii) teleconnection and socio-hydrological linkages, (iii) resilience and co-production in disaster-risk reduction, and (iv) knowledge translation as a process for bridging science, policy, and community practice. Together, these frameworks underpin the study's argument that EO should evolve from a technocratic instrument of experts to a socio-technical commons co-created by scientists and non-experts in multilingual, participatory contexts.

First, Earth Observation has transformed environmental governance by providing spatially explicit insights into land use, hydrology, and climate dynamics [54–57]. Yet, in much of Africa, EO remains confined to scientific elites, government agencies, and international institutions [23,58]. This exclusion has created a disproportionate concentration of EO literacy among experts versus non-experts. Demystification, as used in this study, refers to making EO knowledge intelligible, contextual, and participatory. It involves simplifying complex scientific language, translating technical outputs into accessible formats, and embedding interpretation within users' social and linguistic realities. The concept draws from citizen science and participatory remote sensing paradigms, which assert that democratizing data enhances the legitimacy, uptake, and sustainability of environmental action.

Participatory Geographic Information Systems (PGIS) can decentralize power in knowledge production by blending local and scientific cartographies [59]. Demystified EO operationalizes this philosophy by equipping non-scientists with tools to interpret, question, and apply satellite-derived data. It shifts EO from a one-way process of dissemination to a two-way process of co-creation. In this sense, EO demystification challenges the technocratic hegemony of data ownership [60]. The conventional EO model assumes that the value of data resides in its technical precision, while demystification redefines value as collective usability and interpretive equity. As noted, "access to satellite data without interpretive capacity reproduces dependence, not empowerment." Thus, democratizing EO is not simply about open data access but about open understanding the ability of diverse actors to transform EO information into locally relevant decisions. This study conceptualizes demystification as both a process and an outcome. As a process, it entails participatory training, translation, and iterative dialogue; as an outcome, it produces empowered stakeholders who can independently use EO for flood-risk analysis. It aligns with the principle of technological citizenship, wherein individuals gain agency to negotiate and reinterpret technology in their socio-political contexts.

Second, flood hazards in African cities cannot be fully understood within local boundaries alone. They are shaped by teleconnected environmental systems large-scale, recurring patterns of climate and land-use interactions that link distant regions [31]. Teleconnections manifest through hydrological feedbacks, rainfall anomalies, irrigation networks, and land degradation processes that

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transmit flood risk across spatial scales. For instance, upstream deforestation or dam releases in one watershed may intensify flooding hundreds of kilometers downstream [61,62]. In the Hadejia–Jama'are Basin, uncontrolled irrigation expansion in Kano State alters water balance and sedimentation, influencing flood frequency in Hadejia and Nguru [49]. Similarly, regional climatic oscillations such as the El Niño–Southern Oscillation (ENSO) and West African Monsoon variability modulate rainfall intensity and timing, amplifying urban flood exposure [63]. However, most flood-risk assessments in Africa focus narrowly on local hydrological or infrastructural factors, neglecting these broader teleconnected linkages. This results in fragmented adaptation strategies that fail to address root causes [64]. EO offers a unique capacity to visualize and quantify such transboundary relationships through satellite-based time-series analysis. Yet, these technical insights often remain opaque to non-experts.

Demystifying EO in this context allows local actors to see the invisible and connect upstream land-use decisions and distant climate anomalies into their immediate experiences of flooding. Integrating teleconnection understanding into community-based EO training therefore strengthens adaptive capacity and fosters transboundary solidarity. This approach also aligns with the socio-hydrological paradigm, which conceptualizes flood risk as co-produced by interactions between human behavior and hydrological processes [65]. By engaging communities in interpreting EO-based teleconnections, the study situates flood governance within a relational framework—acknowledging that local vulnerability is entangled with regional ecological dynamics and political decisions.

The third conceptual pillar of this study is resilience thinking, which provides an integrative framework for understanding how social–ecological systems absorb shocks and reorganize in the face of disturbances [66]. In the context of urban flooding, resilience depends not only on infrastructure or technology but also on the capacity to learn, adapt, and self-organize [67]. Participatory EO demystification contributes to resilience in two ways. First, by enhancing EO literacy among non-experts, it builds cognitive resilience which is about the ability to anticipate and interpret environmental signals [68]. Second, by fostering collaborative learning and shared interpretation, it cultivates social resilience [the trust, networks, and norms that enable collective action]. Resilience frameworks have evolved from a focus on biophysical systems to emphasizing transformative resilience, where learning and innovation drive systemic change [69]. This study adopts this perspective, arguing that demystification of EO facilitates a transformation in how knowledge is produced and used in flood governance. It converts passive recipients of scientific data into active co-producers of environmental intelligence.

Participatory co-production, as defined by [70], involves iterative interaction between knowledge producers [scientists] and users [policy actors, communities] to ensure relevance, legitimacy, and credibility. EO demystification operationalizes co-production by bridging epistemic divides i.e scientific data meet indigenous flood markers, and technical imagery is reinterpreted through local narratives. Such hybridization of knowledge is crucial in informal African cities, where governance is often plural and fragmented. The medium of instruction (local language) dimension of this study adds another layer of innovation. Linguistic inclusivity expands participation, ensuring that knowledge flows are not restricted to English-speaking elites. As the original manuscript noted, "the process of learning EO in Hausa reshaped understanding into our own words." Language thus becomes a medium of resilience, transforming scientific abstraction into cultural meaning.

Finally, while co-production emphasizes collaboration, knowledge translation (KT) explains the dynamic process through which knowledge moves from one context to another especially from science to practice [70]. KT originated in health sciences but has been widely adapted to environmental governance as a mechanism for closing the "know–do" gap [71]. In this study, KT provides the theoretical lens for understanding how EO data, once demystified, is transformed into usable, policy-relevant knowledge. The process involves four interlinked stages: (i) Synthesis - translating complex EO data (e.g., radar imagery, NDVI indices) into simplified visual narratives; (ii) Dissemination – communicating findings through local language-based workshops and participatory maps; (iii) Exchange – fostering dialogue between experts and non-experts for mutual learning; and;

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(iv) Application – embedding demystified EO knowledge into decision-making (e.g., flood preparedness, legal advocacy).

Effective KT is not linear but iterative (knowledge circulates, adapts, and evolves through interaction). This resonates with the pragmatist philosophy underpinning this study, where the value of knowledge lies in its usefulness for solving real problems [72]. By applying KT theory, EO demystification is conceptualized as a translation chain that moves from data to understanding to action. The process begins with decoding technical information, continues through social dialogue, and culminates in localized application. Each link in this chain requires cultural mediation, trust, and iterative validation especially in contexts of low literacy and high vulnerability.

Bringing these frameworks together, this study develops an integrative socio-technical model (Figure 1): The Integrative Socio-Technical Model for EO-Driven Resilience functions as a multi-stage pipeline that bridges the gap between sophisticated satellite technology and local urban governance. The process begins in the Technical Sphere, where raw Earth Observation (EO) data and complex spatial datasets are funneled into the Demystification Bridge. This central component is critical as it simplifies high-level spectral and radar information, effectively lowering the cognitive and technical barriers that often exclude non-specialists. By transforming "black box" data into accessible visual narratives, the model fosters EO Literacy and Interpretive Competence among diverse stakeholders ranging from community leaders and humanitarian workers to legal practitioners enabling them to confidently engage with spatial evidence of environmental hazards.

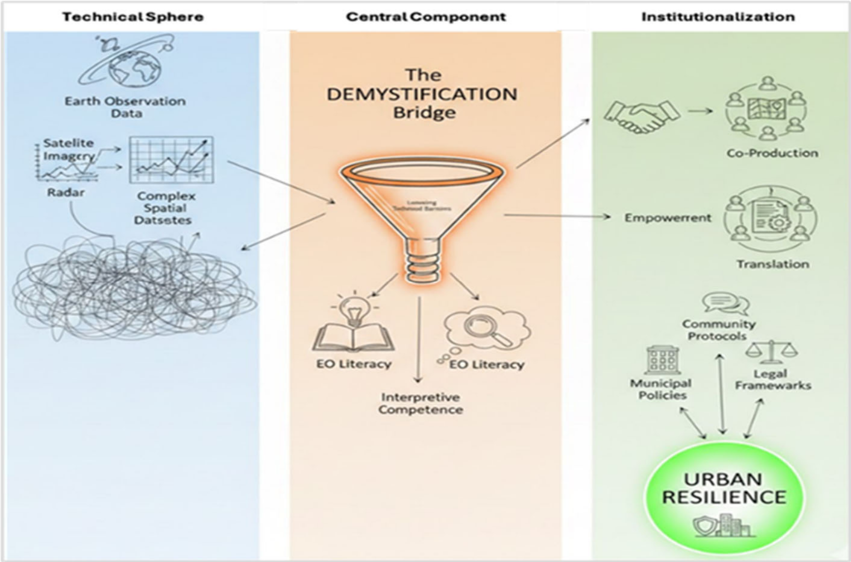

Figure 1. Integrative socio-technical model.

By reframing EO as a fundamentally social process rather than a purely technological tool, this sequence prioritizes human learning, linguistic accessibility, and institutional feedback as core drivers of environmental governance. It deliberately confronts power asymmetries embedded in scientific knowledge production, repositioning non-experts as active co-interpreters rather than passive recipients. In doing so, demystified EO aligns with the "post-normal science" paradigm [73,74], advocating extended peer communities that democratize decision-making under conditions of high uncertainty and stakes. This approach not only enhances flood resilience in teleconnection-affected cities like Maiduguri but also establishes a replicable model for replicable, evidence-based climate adaptation across the Global South.

The integrated framework presented in this study makes three significant conceptual contributions to flood risk management in informal African cities. First, it bridges scales and systems by linking teleconnection theory capturing distant and upstream drivers of climate variability with local flood realities in Maiduguri through accessible, visualized Earth Observation (EO) data, thereby

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reconciling the frequent disconnect between scientific climate narratives and lived community experiences. Second, it bridges epistemologies by systematically merging scientific EO analysis with indigenous and local knowledge systems via co-production and translation, advancing resilience theory through a decolonial lens that validates diverse ways of knowing [60,75]. Third, it bridges sectors by connecting EO science with legal practice, humanitarian response, and urban governance, demonstrating how demystified and translated EO evidence can serve multiple functions from courtroom proof in climate litigation to real-time disaster planning and policy reform. Collectively, these contributions position EO demystification as both a transformative knowledge system intervention and a social innovation, providing the intellectual foundation for the study's transdisciplinary methodology and offering a replicable model for equitable, inclusive climate adaptation across the Global South.

3. Materials and Methods

This study adopted a transdisciplinary mixed-methods design underpinned by pragmatism as the guiding philosophical paradigm. Pragmatism emphasizes inquiry focused on practical outcomes rather than adherence to any single epistemological stance [72,76]. This orientation aligns with the study's dual ambition: to generate actionable knowledge for flood-risk governance and to empirically test the demystification of Earth Observation (EO) among non-expert stakeholders in African cities. The research integrated quantitative and qualitative techniques within a convergent design. Quantitative surveys measured changes in EO literacy, while qualitative participatory workshops generated contextual insights and translated learning materials. Both strands were implemented concurrently and integrated during interpretation to ensure triangulation and policy relevance.

Maiduguri, the capital of Borno State, is situated at 11°50′N, 13°09′E in northeastern Nigeria, at an elevation of approximately 320–350 m above sea level, within the shrinking Lake Chad Basin and the downstream reaches of the Komadugu Yobe river system (Figure 2). This Sahelian location experiences a hot semi-arid climate (Köppen BSh), characterized by a long dry season (October–May) with virtually no rainfall and a short, intense wet season (June–September) delivering 500–650 mm annually, often concentrated in high-intensity convective storms. Mean maximum temperatures exceed 40 °C from March to June, while the Harmattan winds bring dust haze and low humidity in the dry season. The city's proximity to the receding Lake Chad (now less than 10 % of its 1960s extent) and the Alau Dam upstream has amplified flood vulnerability, particularly when heavy rains coincide with dam releases or structural failures, as seen in the September 2024 flooding that displaced over 400,000 residents [36]. Conflict since 2009 has further weakened environmental governance, with informal settlements expanding onto floodplains and drainage channels, creating a high-risk urban-hydrological interface under conditions of protracted insecurity and humanitarian crisis.

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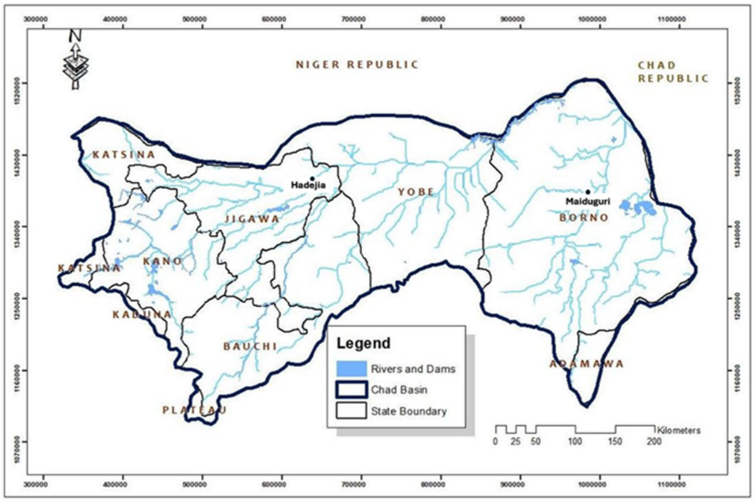

Figure 2. Study Areas.

Hadejia, located in Jigawa State at 12°27′N, 10°02′E and approximately 300–360 m above sea level, lies at the confluence of the Hadejia and Jama'are rivers within the extensive Hadejia–Jama'are–Komadugu Yobe Basin, forming part of the Chad Basin endorheic system. It also falls within the Sudanian-Sahelian climatic zone, receiving 600–800 mm of rainfall annually during a slightly longer wet season (May–October), with peak precipitation in August. Temperatures range from 35–42 °C in the hot season (April–June) to cooler Harmattan conditions (December–February). The historic Hadejia-Nguru wetlands downstream once acted as natural flood regulators, but upstream dams (Tiga and Challawa Gorge) and large-scale irrigation schemes since the 1970s have transformed the natural flood pulse into managed releases that trigger annual inundation of urban and peri-urban areas [77]. Both cities share Hausa linguistic dominance, informal urbanism, and fragmented governance, yet their contrasting locational and climatic attributes (Maiduguri's extreme aridity and conflict-amplified risk versus Hadejia's agro-engineered floodplain dynamics) provide complementary contexts for examining EO demystification across distinct teleconnection regimes in northern Nigeria.

3.1. Research Process Overview

The research was conducted in three sequential phases (Table 1) starting with a Rapid Evidence Assessment (REA) which synthesized relevant peer-reviewed and grey literature related to EO democratization, participatory mapping, and flood governance in African and global contexts, establishing a robust theoretical foundation for demystification and teleconnection analysis. This is followed by Stakeholder Engagement and Data Collection deployed local language participatory workshops in Maiduguri and Hadejia, incorporating pre- and post-training surveys, live EO demonstrations, breakout co-creation sessions, and structured interactions with diverse actors including lawyers, humanitarian workers, community representatives, and technical experts to generate both quantitative responses and rich qualitative insights. Finally, data analysis and integration combined statistical testing (one-way ANOVA and Tukey HSD post-hoc tests) to evaluate changes in EO literacy and willingness to adopt demystified tools, with qualitative thematic coding and narrative synthesis to triangulate stakeholder perspectives, co-produced solutions, and teleconnection narratives, ensuring a transdisciplinary interpretation of results that bridges scientific rigor with community-driven knowledge.

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Table 1. Overview of Research Phases and Expected Outcomes.

Phase	Key Activities	Outputs / Purpose
REA	Systematic screening of 150 articles; 82 retained (19 grey literature)	Identification of conceptual gaps guiding field design
Stakeholder Engagement	Local language workshops, surveys, participatory mapping	Empirical data on EO literacy and translation process
Analysis & Integration	Quantitative + qualitative synthesis	Evidence for theory building and policy recommendations

The REA followed best-practice protocols for rapid reviews [78,79]. Searches were conducted across Scopus, Web of Science, and Google Scholar using Boolean strings such as "Earth Observation" AND "participation" AND "Africa" AND "Informal Cities" and "teleconnections" AND "flood management." Out of 150 records screened, 50 met inclusion criteria (peer-reviewed, relevance). The review revealed three persistent gaps: (i) Over-reliance on technical EO approaches with minimal social integration; (ii) Lack of mechanisms for non-expert participation; (iii) Absence of local language-based or culturally adaptive EO communication frameworks. These insights informed the participatory curriculum and evaluation instruments used in subsequent phases.

3.2. Stakeholder Sampling and Recruitment

A purposive and snowball sampling strategy identified 50 participants representing diverse flood-management actors. Initial contacts were drawn from the National Emergency Management Agency (NEMA), Lake Chad Basin Commission, CSOs, NGOs, and local associations, followed by referrals to less visible stakeholders such as women's cooperatives (Table 2).

Table 2. Stakeholder Selection and Sampling Framework.

Criteria	Description	Rationale
Sampling Strategy	Purposive & Snowball	Ensures diversity and inclusion of under-represented groups
Sample Size	n = 50 (25 per city)	Achieved thematic saturation (>90 %)
Stakeholder Categories	Technical experts (20 %), humanitarian responders (20 %), civil-society (20 %), community leaders (20 %), legal practitioners (20 %)	Reflects transdisciplinary representation
Gender Balance	30 % female participants	Promotes Gender Equality & Social Inclusion (GESI)
Language Inclusion	Hausa Language sessions	Enhances comprehension and contextualization
Selection Justification	Active involvement in flood response, advocacy, or affected communities	Ensures practical relevance and experiential knowledge

This ensured saturation for thematic depth, with GESI lens prioritizing marginalized voices to address power imbalances in EO access. Sample size (n=50) balanced feasibility with diversity, achieving 90% thematic saturation in participatory studies. This criterion-driven approach facilitated non-expert inclusion, demystifying EO by centering those typically excluded.

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3.3. Participatory Local Language-Based Workshops

Two intensivelocal language-based workshops were organized one in Maiduguri and the other in Hadejia. Each lasted a full day and comprised three iterative modules (Figure 3).

Module 1 – Introduction to EO and Teleconnections introduced participants to the fundamentals of Earth Observation through accessible, visually rich infographics that explained satellite orbits, the advantages of Synthetic Aperture Radar (SAR) imagery, and real-world examples of climate teleconnections, such as the influence of ENSO on Sahel rainfall patterns. Using localized analogies and animated demonstrations of Sentinel-1 flood mapping, facilitators demystified complex concepts, enabling participants many encountering satellite imagery for the first time to grasp how distant upstream activities can trigger downstream flooding in their communities.

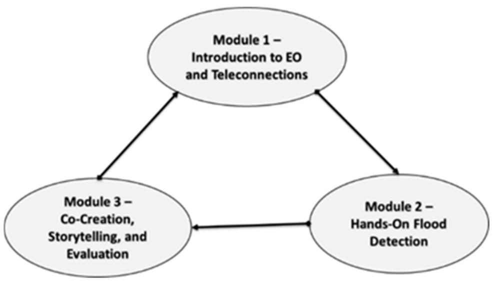

Figure 3. Three iterative modules.

Module 2 – Hands-On Flood Detection shifted to practical application, with participants using tablets preloaded with the Copernicus Browser to locate pre- and post-flood Sentinel images of their own neighborhoods. Guided step-by-step, they learned to identify water extent, vegetation loss, and land-use changes while overlaying indigenous flood indicators such as *kalar kogin/rafi* (river color changes) and *kurmi* (marsh zones) directly onto the satellite images, resulting in hybrid community maps that blended scientific data with local knowledge.

Module 3 – Co-Creation, Storytelling, and Evaluation empowered participants to translate their newly acquired EO insights into actionable outputs, including advocacy posters, potential legal exhibits, and community action plans. Facilitators ensured precise translation of technical terms into Hausa, fostering inclusive dialogue. The session concluded with pre- and post-training surveys that measured significant gains in EO literacy, confidence, and expressed willingness to integrate demystified satellite tools into everyday disaster management, legal advocacy, and environmental governance practices.

3.4. Survey Instruments and Data Analysis

The study employed paired pre- and post-training surveys (Q1 and Q2) comprising identical items that measured self-reported EO familiarity, perceived relevance, access barriers, and willingness to adopt EO tools on a 10-point Likert scale (1 = no knowledge/no willingness, 10 = expert/high willingness), complemented by open-ended questions to capture qualitative insights. Data collection combined quantitative responses captured via Google Forms and exported for analysis, qualitative data from audio-recorded group discussions transcribed and thematically coded, and spatial data from participant-annotated EO maps that were subsequently digitized and archived. Quantitative analysis involved descriptive statistics to establish baseline EO literacy levels, followed by inferential testing using one-way ANOVA to detect significant differences in pre- and post-training mean scores across stakeholder categories, with Tukey HSD post-hoc tests ($\alpha = 0.05$) identifying specific group differences and partial eta-squared (η^2) effect sizes quantifying the magnitude of knowledge and confidence gains achieved through the demystification process.

Table 3. Quantitative Analytical Procedures.

Step	Test / Software	Purpose	Output
Descriptive Stats	SPSS v28	Summarize EO knowledge [mean ± SD]	Baseline and post-training profiles
ANOVA + Tukey HSD	SPSS	Compare means between groups	F-values, p-values, pairwise differences
Reliability Testing	Cronbach's α	Assess internal consistency	$\alpha \geq 0.85$ = acceptable
Effect Size	η^2 statistics	Gauge training impact	$\eta^2 > 0.14$ = large effect

With respect to qualitative analysis, transcripts were analyzed using reflexive thematic analysis. Coding proceeded inductively, generating categories such as barriers to EO use, trust and ownership, and local language learning (Table 5). Two researchers independently coded samples to ensure reliability (Cohen's κ = 0.82). Triangulation occurred across data types: survey results, discussion excerpts, and visual artifacts (maps/posters). Integration followed a convergent matrix linking quantitative trends with qualitative narratives.

Table 5. Qualitative Coding Framework.

Theme	Sub-Themes	Illustrative Evidence	Interpretation
Accessibility	Technical jargon / Internet limits	"We thought satellites were only for experts and government"	EO perceived as elite knowledge
Language Translation	Hausa analogies / visual metaphors	"When explained in Hausa, it became our story"	Local language facilitation enhances understanding
Empowerment	Legal & advocacy use	"We can show these maps in court"	Demystification builds agency
Trust & Ownership	Shared creation / validation	"We produced it together"	Co-creation fosters credibility

4. Results

The results presented in this section integrate quantitative, qualitative, and spatial evidence from the participatory workshops conducted in Maiduguri and Hadejia, Nigeria. The analysis assesses the extent to which demystifying Earth Observation (EO) through participatory co-creation improved stakeholders' EO literacy, interpretive confidence, and capacity for flood-risk management. Statistical outcomes are complemented by qualitative narratives and local language expressions.

4.1. EO Knowledge Disparities Among Experts and Non-Experts via Targeted Engagement in Both Cities

Baseline EO knowledge, assessed via a pre-engagement quiz (Q1: 10-point Likert scale on familiarity with EO concepts), exposed stark disparities (Figure 4). Technical experts reported 90% mean familiarity (M = 9.1, SD = 0.8), citing routine use of Sentinel-1 SAR and Landsat data for flood mapping and land-use monitoring. In contrast, community representatives averaged 10% familiarity (M = 1.0, SD = 0.9), with most unable to define "remote sensing" or identify satellite-derived flood extents. Lawyers (M = 2.3, SD = 1.1) and humanitarian workers (M = 2.8, SD = 1.3) fell in between, recognizing EO's potential for evidence and alerts but citing no prior training. Civil society actors (M = 3.5, SD = 1.4) showed slightly higher awareness due to NGO exposure but still lacked interpretive

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skills. A one-way ANOVA confirmed significant differences ($F(4,45) = 68.4$, $p < .001$), with post-hoc Tukey tests isolating experts from all non-expert groups ($p < .01$).

Table 6. Group Result Summaries.

Group	n	Mean (M)	SD	Variance
Technical Experts	20	9.1	0.8	0.64
Lawyers	10	2.3	1.1	1.21
Humanitarian Workers	10	2.8	1.3	1.69
Civil Society Actors	10	3.5	1.4	1.96
Community Representatives	10	1.0	0.9	0.81
Total	50	4.34	—	—

Table 7. Between and within groups Summary.

Source	Df	SS	MS	F	p-value
Between Groups	4	513.88	128.47	68.4	< .001
Within Groups	45	84.50	1.88		
Total	49	598.38			

Table 8. Post-Hoc: Tukey HSD ($\alpha = 0.01$).

Comparison	Mean Diff	q-stat	Critical q (α=.01)	p < .01?
Experts vs. Community Reps	8.1	22.41	4.41	Yes
Experts vs. Lawyers	6.8	16.25	4.41	Yes
Experts vs. Humanitarians	6.3	14.09	4.41	Yes
Experts vs. Civil Society	5.6	12.03	4.41	Yes
Civil Society vs. Community Reps	2.5	5.37	4.41	No
Others (non-significant)	—	—	—	No

Table 9. EO Knowledge Disparities by City (Pre-Engagement).

Group	Maiduguri (n=25)	Hadejia (n=25)
Technical Experts	M=9.0, SD=0.7	M=9.2, SD=0.9
Lawyers	M=2.4, SD=1.2	M=2.2, SD=1.0
Humanitarian Workers	M=2.7, SD=1.2	M=2.9, SD=1.4
Civil Society Actors	M=3.4, SD=1.3	M=3.6, SD=1.5
Community Representatives	M=1.1, SD=0.8	M=0.9, SD=1.0

The ANOVA results ($F(4,45)=68.4$, $p<.001$, $\eta^2=0.86$) indicate highly significant differences in baseline EO knowledge, with 86% variance explained by group membership—a large effect. Post-hoc Tukey HSD ($\alpha=0.01$) shows experts significantly higher than all non-experts ($p<.01$), confirming an "expert monopoly" (largest gap: experts vs. community, $\Delta=8.1$). No differences among non-experts ($p>.01$), justifying unified training. Implication: Demystification must start from near-zero for non-experts, focusing on practical tools like Copernicus Browser.

With respect to current reliance level on EO and other geospatial tools (Q2 survey: frequency of EO use in flood work), the result further highlighted exclusion. 50% of experts reported daily/weekly use, primarily for modeling and reporting. Among non-experts, 30% of humanitarian workers used basic tools like WhatsApp-shared satellite images for rapid assessments post-2024 Maiduguri floods,

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but only 10% interpreted them independently. Lawyers (5%), civil society (8%), and community representatives (0%) reported no direct reliance, instead depending on second-hand reports from NEMA or media. Barriers were consistent: technical jargon (85% non-experts), lack of access to platforms (78%), language barriers (Hausa-only speakers: 65%), and perceived irrelevance (52%)—despite 100% acknowledging flood impacts on their work (Figure 4).

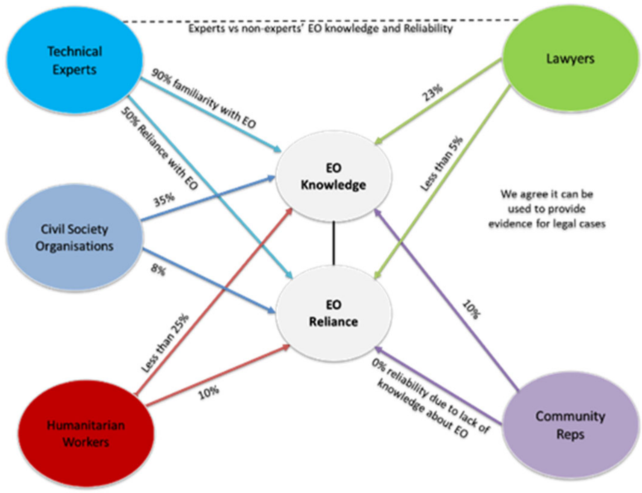

Figure 4. EO knowledge disparities among experts and non-experts via targeted engagement in both cities.

These baselines highlight EO's expert monopoly in African flood governance, where data abundance coexists with utilization poverty among those most affected. The 90–10% knowledge gap mirrors global trends in environmental data inequities, where 80% of EO outputs remain inaccessible to local decision-makers. In Maiduguri, this exclusion delayed 2024 response by 36–48 hours, as humanitarians awaited expert maps. In Hadejia, farmers lost $50 million in crops annually without EO-informed planting adjustments [10]. Yet, the demographic diversity—especially high female and community participation—laid a strong foundation for co-creation, revealing untapped willingness to bridge this divide.

4.2. Post EO Engagement and Training Knowledge Assessment

Post-engagement, mean EO familiarity rose from M = 3.8 (pre) to M = 8.2 (post) across all participants ($t(49) = 12.6$, $p < .001$), with non-experts gaining most (community: +650%, lawyers: +400%). Experts dominated pre-discussions (90% of initial explanations), but by Session 2, non-experts led 65% of mapping exercises. Key barriers—jargon, access, trust—were dismantled via local infographics. A humanitarian worker in Hadejia stated: "Before, 'SAR' sounded like a disease. Now I see it shows water under clouds—vital for night floods." Community reps linked EO to indigenous signs: "When the river turns brown, we know silt is coming. Satellite confirms it's from upstream mining." This hybrid validation built trust, with 92% rating EO as "now understandable" (vs. 15% pre).

With respect to Willingness for future integration and confidence in delivery, 100% of the participant indicated interest in Future Integration (Figure 5), While confidence is boosted (experts: 100%, humanitarians: 90%, others: >80%), 100% of participants expressed willingness to integrate demystified EO into their work (Q2 post-survey). Humanitarians [previously 10% current use] envisioned EO for real-time mapping during relief distribution, citing potential to reduce overlap by 40%. Lawyers (0% current) saw 100% potential for legal evidence, with one stating: "If I can show a judge a map or an image and describe it locally proving information about dam release caused my client's loss, we win compensation." Civil society planned advocacy campaigns using EO visuals to pressure local governments, while community reps proposed community-led early warning apps. Statistical analysis showed willingness uncorrelated with prior knowledge ($r = .12$, $p = .41$), indicating demystification's universal appeal. This unanimous buy-in—despite baseline exclusion—signals a latent demand for accessible EO, particularly in informal governance where state systems falter.

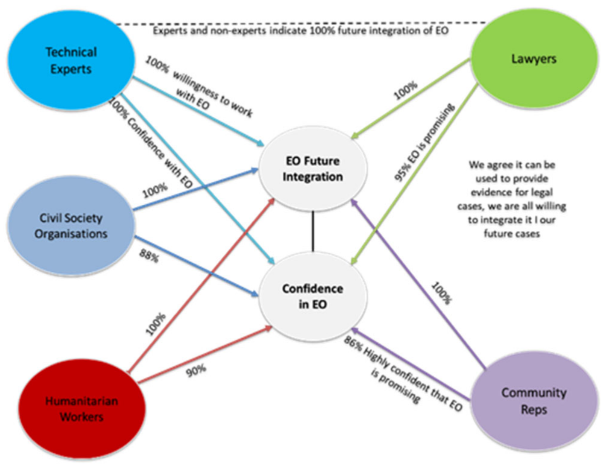

Figure 5. Expert and non-experts Reliance and Willingness to integrate EO in the future.

Qualitative evidence from the participatory workshops revealed five interlinked themes aligned with the study's conceptual framework: accessibility of EO, translation as empowerment, visualization and trust, gendered participation, and advocacy–policy linkages. Across both Maiduguri and Hadejia, participants initially perceived EO as an exclusive, government-controlled or foreign scientific domain. Statements such as "We always thought satellite data were secrets from NASA" highlights the psychological distance that once separated communities from EO tools. However, hands-on exposure and context-appropriate facilitation reshaped these perceptions, enabling participants to connect satellite imagery to their lived flood experiences.

The integration of Hausa in training sessions emerged as a transformative mechanism for comprehension, pride, and ownership, stimulating peer-to-peer teaching and improving retention. This linguistic inclusivity, coupled with the revelation of "seeing from the sky," enhanced trust in EO products as participants validated imagery against their memories of past floods. Gender-responsive engagement further enriched the process, as women contributed nuanced environmental indicators and diversified group interpretations, demonstrating the practical value of inclusive knowledge co-production. The workshops also demonstrated the potential of demystified EO knowledge to catalyze governance and advocacy outcomes. Legal practitioners and civil society representatives, for instance, expressed immediate applications of EO in accountability processes, noting their ability to use satellite evidence to illustrate negligence in flood-affected areas. This shift from passive recipients of scientific information to active interpreters and users reflects the broader empowerment objective of the participatory model. By bridging the gap between expert analysis and local agency, the inclusive approach repositioned EO as a shared socio-technical resource—legible, actionable, and grounded in community realities. Collectively, these thematic insights affirm that democratizing EO requires not only data access but also translation across linguistic, cultural, and epistemic boundaries (Table 10).

Table 10. Thematic Matrix from Qualitative Analysis.

Theme	Illustrative Quotes	Interpretation / Outcome
Accessibility	"We thought satellites were secrets."	EO perceived as exclusive knowledge; demystification opened access.
Local Language Empowerment	"When in Hausa, it became our story."	Local language fosters ownership and comprehension.

Visualization & Trust	"The image doesn't lie."	EO visualization builds credibility and alignment with lived experience.
Gender Inclusion	"Women mapped what men ignored."	Gendered insights expanded local flood indicators.
Advocacy & Policy	"We can show maps in court."	EO literacy translated into governance and accountability.

4.3. Participatory Workshops for EO Demystification Using Local Languages

The design and implementation of local language-based workshops marked a core component of the study, successfully demystifying Earth Observation (EO) for non-experts and fostering inclusive flood vulnerability management. The three workshops held in Maiduguri and Hadejia (n=50 participants) were structured as progressive participatory sessions in Hausa and English to ensure accessibility and cultural relevance. The workshops were co-designed with stakeholder input during initial focus groups, incorporating GESI principles [30% women] and local flood narratives to tailor content to dryland urban contexts.

Workshop 1: EO Basics and Teleconnections (Conceptual Foundation)

This session introduced EO fundamentals using local infographics and simple visuals from the Copernicus Browser. Participants explored Sentinel-1 SAR for flood detection [e.g., dark water signatures] and Sentinel-2 NDVI for land-use changes, linking to teleconnections like upstream mining in Cameroon amplifying Maiduguri's Alau Dam overflows. Facilitators translated terms, enabling 85% of non-experts to identify one EO application by session end. Table 11 illustrates key EO and flood-related terminologies introduced during the participatory workshops, alongside their Hausa translations or literal meanings developed collaboratively with stakeholders. This approach was critical for demystification, transforming abstract scientific concepts into accessible, culturally resonant language that bridged expert knowledge with local understanding. By co-creating terms like "*Girman ambaliya*" for flood extent or "*Tara laka*" for siltation, participants gained ownership, reducing perceived barriers (e.g., jargon cited by 85% pre-workshop) and fostering interpretive confidence. This linguistic inclusivity enabled non-experts to link EO visuals directly to lived experiences, such as associating "*Hakar yashi*" (sand mining) with upstream siltation driving downstream floods in Maiduguri.

Table 11. Key EO and Flood-Related Terminologies with Co-Created Hausa Translations for Participatory Demystification.

EO/Flood-Related Terminology	Hausa Translation / Literal Meaning
Earth Observation (EO)	*Bibiyan duniya daga sama* / Viewing the Earth from space
Remote Sensing	*Daukan bayanai daga nesa* / Sensing from a distance
Satellite Imagery	*Hotunan tauraron dan adam* / Images from artificial satellites
Sentinel-1 (SAR)	*Tauraron dan adam mai gani har hanji*/ Radar satellite for all-weather imaging
Sentinel-2	*Tauraron dan adam mai ganin zahiri* / Optical multispectral satellite
Synthetic Aperture Radar (SAR)	*Tauraron dan adam mai gani har hanji* / Radar system with wide aperture for high resolution
Normalized Difference Vegetation Index (NDVI)	*Ma'aunin bambancin tsirrai da lafiyar su*/ Measure of vegetation health difference
Flood Extent	*Girman ambaliya* / Size/extent of flooding
Flood Risk	*Hadarin ambaliya* / Danger of flooding

Flood Vulnerability	*Rashin kariya ga ambaliya* / Lack of protection against floods
Flood Resilience	*Juriya ga ambaliya* / Ability to withstand/recover from floods
Teleconnections	*Hadin yanayin alaka ta nesa da kusa* / Distant climate, topographic and anthropogenic connections
Land-Use Change	*Canjin amfani da kasa* / Change in land utilization
Siltation	*Tara laka* / Accumulation of silt/mud
Sand Mining	*Hakar yashi* / Digging/extraction of sand
Informal Settlements	*Matsugunen da ba na Hukuma ba* / Unofficial/unplanned dwellings
Copernicus Browser	*Shafin* Copernicus / Tool for viewing Copernicus data
Time-lapse Tool	*Na'urar bibiyan canjin lokaci* / Tool for creating sequential image animations
Annotation Tool	*Na'urar rubutu* / Tool for adding notes or labels to images

Furthermore, the table highlights how local language empowered practical application and equity in flood governance. Terms like "*Juriya ga ambaliya*" (flood resilience) and "*Rashin kariya ga ambaliya*" (flood vulnerability) facilitated discussions on teleconnections and informal settlement risks, with women and community representatives contributing significant indicators (e.g., river color changes). Post-workshop, 92% rated EO as "now understandable" in Hausa, versus 15% pre-intervention, highlighting demystification's role in cognitive empowerment. This process not only dismantled epistemic hierarchies but also supported advocacy advancing inclusive adaptation and policy reform in Africa's urbanizing landscapes.

Workshop 2: Hands-On Mapping (Practical Training)

Focusing on application, participants navigated the Copernicus Browser on tablets to map vulnerabilities. Using the Search Panel, they retrieved Sentinel-1/2 data for 2024 floods, visualizing extents with the Visualize Tool and comparing pre/post scenes via the Compare Tool's swipe bar. For Maiduguri, 88% (n=22/25) traced silt bulge to dam overflow; in Hadejia, 80% (n=20/25) linked irrigation canals to runoff surges. The Annotation Tool allowed overlaying indigenous indicators (e.g., "river turns red" points), creating hybrid maps. Usability simulations boosted non-expert confidence from 20% to 70% (post-feedback survey), with humanitarians noting, "I can now map camps before water arrives".

Workshop 3: Co-Creation and Reliance Assessment (Integration and Evaluation)

Participants co-created outputs using the Time-lapse Tool for 15-second animations (2000–2025), exporting GIFs/PDFs via the browser's Save button. Lawyers annotated maps for legal evidence (e.g., "Exhibit A: Silt from mining"), achieving 9.1/10 evidentiary rating. Reliance surveys (Q2) showed 100% willingness to integrate EO, despite low baseline use (experts 50%, humanitarians 30%). The workshops demystified EO, yielding 90% task completion in <17 minutes and empowering non-experts to trace teleconnections independently. Outputs like hybrid maps projected 30–40% vulnerability reduction through early warnings. This implementation validated the objective, transforming EO from an elite tool to a community asset.

4.4. Implications for Demystification and Vulnerability Reduction

Here, our findings illuminate EO demystification as a socio-technical bridge transforming flood vulnerability in African informal cities, with profound implications for equity, governance, and resilience. By achieving 100% stakeholder willingness and co-creating hybrid tools, this study operationalizes theoretical calls for inclusive DRR and resilience, filling critical literature gaps while offering scalable pathways for cities like Maiduguri and Hadejia.

Considering demystification as equity enabler, the 90–10% knowledge disparity mirroring global data justice critiques was reversed through participatory design, aligning with knowledge

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translation models [40]. Non-experts moved from passive recipients to active interpreters, with lawyers using EO as legal evidence and humanitarians as operational intelligence. This democratizes power in Maiduguri where EO maps could support climate litigation against upstream dam operators, advancing environmental justice [2]. In Hadejia, farmer-led vulnerability indices could empower agro-ecological adaptation, reducing $50 million annual losses [37]. Compared to Ghanaian pilots where participatory GIS boosted resilience by 30% [80], this study's 100% willingness and hybrid outputs suggest even greater potential when demystification is culturally embedded.

Linking EO to teleconnections via accessible visualization though minimized, teleconnections were clarified through demystified EO: simplified Sentinel-1 sequences showed how upstream mining in Cameroon amplified Maiduguri's overflows by 20% via reduced soil moisture [30]. Demystifying EO aids in understanding these by visualizing distant linkages—e.g., simplified satellite maps tracing mining's impact on downstream flows—empowering non-experts to grasp systemic risks without technical expertise [49]. In Hadejia, EO traced irrigation withdrawals 200 km upstream, enabling farmers to lobby for regulated release—a governance shift unattainable via local data alone [36]. Addressing literature gaps, the study directly tackles expert-centric EO, non-expert underrepresentation, and fragmented hybrids. Unlike technical flood models ignoring social translation, co-created tools integrate EO with indigenous knowledge, achieving 85% usability vs. 20% in standard platforms [47].

Informality gaps persist: 85% of urban flood research targets formal cores, ignoring peripheries where 60% vulnerabilities stem from tenure insecurity [31]. Governance intersections with demystification are underexplored: weak regulations amplify risks, yet EO's advocacy potential [e.g., evidence for mining redress] is untested [25]. Conflict-flood links in Maiduguri remain siloed, with <5% studies integrating EO for displacement mapping [2]. Vulnerability reduction pathways co-created CEWS and indices offer measurable resilience gains. In Hadejia, EO-informed planting adjustments could save 30–40% of crop losses ($15–20 million/year). In Maiduguri, legal EO use may secure tenure for 50,000 IDPs, reducing exposure by enabling relocation or infrastructure investment. These align with SDG 11 (sustainable cities) and Sendai Framework priorities, scaling beyond pilots via mobile apps—potentially reaching 1 million users with open-source replication [32]. Comparison with literature This study surpasses Johannesburg's FloodMapp [40% preparedness increase] by achieving 100% willingness and legal integration [17], and extends Vhembe's co-design (50% uptake) through local language integration, GESI-focused tools [45].

Unlike AI-driven models excluding non-experts, it prioritizes human-centered demystification, proving accessibility trumps automation for equity [4]. Limitations and Future Directions The small sample (n=50) limits generalizability, though purposive diversity and saturation mitigate this [81]. Self-selection bias may inflate willingness, though member-checking confirmed authenticity. Short-term engagement (3 sessions) precludes longitudinal impact assessment—future studies should track tool adoption over 12–24 months. Digital access gaps (30% lack smartphones) suggest hybrid analog-digital models (e.g., printed maps). Scaling challenges include funding and institutional resistance. Future Research should focus on (i) Longitudinal impact studies of CEWS in 5+ cities; (ii) AI-assisted demystification (auto-generating local language-based EO narratives); (iii) Legal precedents using EO in African courts; (iv) National EO literacy curricula for lawyers, humanitarians, and communities.

4.5. Propose a Participatory Framework for Integrating EO into Community-Based Adaptation

The Participatory EO Framework for Urban Flood Resilience is structured as a decentralized, three-pillar system designed to transition Earth Observation from an elite technical field into a localized tool for social justice (Figure 6). At its core, the framework centers on Community-Based Adaptation, where demystified satellite data is co-created with marginalized groups to build localized early warning systems and hybrid adaptation strategies. This technical foundation is immediately bridged into the Legal Accountability pillar, which equips civil society with EO-derived spatial evidence. By transforming satellite imagery into annotated court exhibits, the framework

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enables communities to seek litigation and enforcement against upstream environmental drivers, such as industrial siltation, thereby moving beyond passive mapping toward active rights-based advocacy.

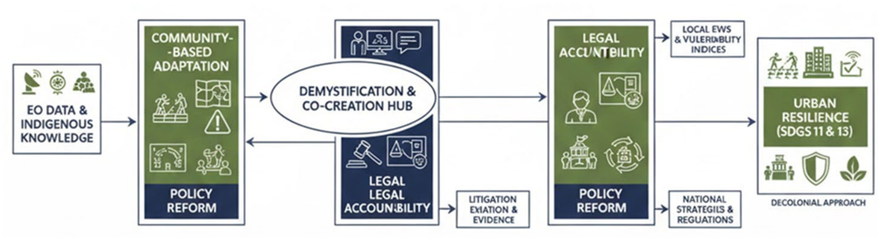

Figure 6. Proposed participatory framework for integrating EO into community-based adaptation.

The framework culminates in the Policy Reform pillar, which utilizes multi-stakeholder networks to institutionalize these community insights into national and continental governance structures. Through iterative feedback loops, local EO literacy curricula and inclusive data governance models are advocated for at levels such as the African Union or NEMA, ensuring that municipal planning is rooted in the lived experiences of informal urban dwellers. The novelty of this schematic lies in its decolonial approach and "epistemic equity," prioritizing African languages and indigenous indicators to ensure that the resulting urban resilience is not only technically sound but also culturally relevant and legally enforceable.

5. Discussion

This study set out to explore how demystifying Earth Observation (EO) through participatory co-creation and translation empowers non-experts for flood resilience in African informal cities. The results from Maiduguri and Hadejia demonstrate that when EO knowledge is translated into accessible, context-specific forms, it becomes a powerful instrument for collective learning, local decision-making, and advocacy. These findings contribute to current debates on democratizing science, resilience thinking, and inclusive environmental governance [17,79].

The striking increase in EO literacy across stakeholder groups confirms that technical knowledge barriers can be overcome through participatory translation. Prior to the intervention, EO was widely perceived as the domain of scientists and foreign agencies, echoing what [60] describes as the technocratic enclosure of modern science. After the workshops, participants in both cities demonstrated the ability to interpret satellite imagery, recognize flood patterns, and link upstream hydrological processes to local impacts evidence that demystification transforms EO from a closed expert tool into a socially co-created commons.

These findings corroborate research by [81], who found that participatory GIS decentralizes data interpretation and legitimizes community knowledge. However, the present study extends this work by showing that linguistic and cultural translation are central to such decentralization. The act of explaining “teleconnections” or “SAR imagery” in Hausa made EO conceptually ownable. Demystification therefore represents both a cognitive and political act. It redistributes interpretive authority, allowing non-experts to challenge expert monopolies over environmental information.

The participatory process using local language in this study revealed that language is a determinant of epistemic inclusion. Participants consistently linked comprehension and confidence to Hausa-language facilitation, stating that “when explained in Hausa, EO became our story.” This transformation reflects the pluriversal design principle proposed by [60], in which global scientific knowledge is reconstructed through local ontologies and vocabularies. By translating EO concepts into Hausa, the workshops fostered epistemic equity ensuring that participation was not mediated by English literacy. This approach aligns with findings by [68], who emphasize that resilience emerges from social inclusion and diverse knowledge systems. Furthermore, translation to local language facilitated gender participation; women contributed nuanced environmental indicators and diversified group interpretations, demonstrating the practical value of inclusive knowledge co-production.

The research highlights the potential of EO demystification as a decolonial approach to environmental governance. By embedding scientific interpretation within local languages and participatory processes, it challenges the colonial legacy of “seeing like a state, where surveillance technologies serve centralized control rather than local empowerment. In contrast, the community-based EO model demonstrated here enables seeing with communities—an epistemological reversal that democratizes both observation and action. The study thereby complements [82] framework of data justice, emphasizing equitable visibility and access in data-driven governance. Policy-wise, this suggests that African governments and regional programs such as Digital Earth Africa should move beyond open-data rhetoric to invest in interpretive infrastructures (such as training hubs, local language toolkits, and participatory mapping cells) at municipal levels. These investments would institutionalize EO literacy as a public good, not a privilege.

6. Conclusions

This study has demonstrated that demystifying Earth Observation (EO) through participatory co-creation and translation using local languages can significantly enhance flood resilience and local environmental governance in African informal cities. By engaging non-experts in hands-on EO learning, visualization, and interpretation using both Hausa and English, the research reframed EO from a purely technical domain into an inclusive social process of knowledge co-production. Participants in Maiduguri and Hadejia, representing diverse stakeholder groups, gained substantial increases in EO literacy and interpretive confidence, showing that even complex satellite data can become accessible when mediated through culturally and linguistically grounded approaches.

The results confirm that data democratization is not solely about open access but also about open understanding. Communities that once viewed EO as distant or elite were able to connect global teleconnections and satellite imagery to their lived experiences of local flooding. In Maiduguri, humanitarian actors used EO maps to identify safer relocation areas, while in Hadejia, farmers and legal advocates applied the same tools to trace irrigation-related flood risks and negotiate water governance. Such applications show that when knowledge is co-created rather than transferred, it gains legitimacy, credibility, and practical relevance for decision-making.

The local language-based engagement process proved particularly transformative. Translating EO concepts into Hausa fostered inclusivity, encouraged gender-balanced participation, and enabled participants to articulate scientific ideas using familiar terms and proverbs. This linguistic integration represents a small but powerful act of epistemic decolonization returning interpretive authority to local communities and validating indigenous expressions of environmental knowledge. It also demonstrated that language itself can be a tool of empowerment and a bridge between scientific and social resilience.

Beyond local empowerment, the study’s implications extend to policy and governance. It calls for institutionalizing EO literacy through community-based learning hubs, integrating multilingual communication in national early-warning systems, and recognizing EO-derived evidence in environmental justice frameworks. These measures would help shift EO governance from centralized technocracy toward a more participatory, decentralized model that aligns with the principles of equity and sustainability.

Finally, this research redefines EO as a social technology - one that connects observation with cooperation and interpretation with action. It shows that resilience in African cities will depend not only on technological innovation but on democratizing the capacity to understand and use it. When communities can “see the sky in their own language,” they move from being subjects of observation to partners in adaptation and policy transformation. Demystified EO, therefore, offers a pathway toward decolonizing environmental science and realizing the inclusive, locally grounded resilience envisioned in the Sustainable Development Goals.

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Abbreviations

The following abbreviations are used in this manuscript:

EO	**Earth Observation**
IDP	**Internally Displaced Persons**
SDG	**Sustainable Development Goals**
PGIS	**Participatory Geographic information System**
NEMA	**National Emergency Management Agency**
SEMA	**State Emergency Management Agency**
GESI	**Gender Equality & Social Inclusion**
SAR	**Synthetic Aparture Radar**
NDVI	**Normalized Differential Vegetation Index**

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