



DIGITIZING INDIGENOUS KNOWLEDGE: LEVERAGING DIGITAL LIBRARIES FOR SUSTAINABLE LAND AND WATER RESOURCE MANAGEMENT IN THE ANTHROPOCENE

By

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Abstract

Indigenous ecological knowledge (IEK) represents centuries of adaptive experimentation with land and water systems, yet remains critically underrepresented in digital repositories and mainstream environmental governance frameworks. This study investigates the perceptions, challenges, and aspirations of key stakeholders regarding the digitization of indigenous knowledge for sustainable land and water resource management in the Anthropocene era. Employing a convergent mixed-methods design with data collected from 15 purposively selected respondents, comprising indigenous knowledge custodians, teachers, ICT/library professionals, and farmers across Nigerian rainforest and savannah eco-zones, the study reveals that 93.3% of participants are willing to co-create digital repositories of indigenous knowledge, while 93.3% affirm that digital libraries can help protect indigenous heritage. Despite high digital library awareness (80.0%), a critical representational deficit persists: only 33.3% confirmed the existence of any digital platform containing indigenous knowledge from their communities. Lack of technology infrastructure (60.0%), language barriers (53.3%), and fear of cultural misappropriation (53.3%) emerged as the most pressing digitization challenges. The study introduces the Community-Anchored Indigenous Digital Ecosystem (CAIDE) framework, a novel participatory model integrating CARE and FAIR principles with mobile-first, multilingual, and community-governed digital repositories. Findings strongly affirm IEK's untapped potential in advancing SDG 6 (Clean Water and Sanitation, 66.7%), SDG 13 (Climate Action, 40.0%), and SDG 15 (Life on Land, 40.0%).

Keywords: Indigenous Ecological Knowledge; Digital Libraries; Knowledge Preservation; CAIDE Framework; CARE Principles; FAIR Principles; Water Resource Management; Climate Resilience; Sustainable Development Goals; Anthropocene

INTRODUCTION

The Anthropocene has thrust unprecedented environmental stresses upon communities whose livelihoods are intricately tied to the health of land and water systems. Paradoxically, these same communities, particularly indigenous peoples across Sub-Saharan Africa, possess sophisticated ecological knowledge developed over generations of direct engagement with local environments. Indigenous ecological knowledge (IEK) encompasses rotational farming systems, traditional irrigation techniques, sacred forest stewardship, and community-governed water harvesting practices that have sustained ecosystems long before the advent of formalized

science (Ajayi et al., 2021). Yet this knowledge is haemorrhaging at an alarming rate, threatened by urbanization, intergenerational disconnects, and the wholesale adoption of Western-dominated environmental paradigms (Munyua & Otiike, 2022).

Against this backdrop, digital libraries have emerged as promising infrastructural tools for archiving, organizing, and disseminating diverse knowledge forms. However, the existing literature reveals a striking paradox: while digital technology has dramatically expanded knowledge access globally, indigenous communities remain disproportionately absent from digital archives (UNESCO, 2021; Koya & Chowdhury, 2022). Where digital representations of

indigenous knowledge exist, they are frequently decontextualized, linguistically inaccessible, or stripped of the relational significance that renders such knowledge meaningful and actionable (George & Sankaran, 2023).

This study departs from prior scholarship in three critical ways: First, it foregrounds the voices of indigenous knowledge custodians as prospective architects of digital knowledge systems. Second, it moves beyond descriptive inventory of IEK toward empirical investigation of stakeholder readiness, institutional trust, and participatory governance preferences within a Nigerian context. Third, it proposes the Community-Anchored Indigenous Digital Ecosystem (CAIDE) framework, a novel conceptual model synthesizing CARE and FAIR principles with community-driven governance mechanisms calibrated to the realities of the Global South.

STATEMENT OF THE PROBLEM

Despite global acknowledgement of indigenous knowledge systems' contribution to environmental resilience, IEK remains critically underrepresented in digital repositories and mainstream scientific platforms (UNESCO, 2021; Koya & Chowdhury, 2022). The absence of systematic documentation, preservation, and digital dissemination mechanisms threatens the continuity of this ecological heritage, particularly as elder custodians decline and younger generations disengage from traditional practices (Munyua & Otiike, 2022).

Existing digital platforms are frequently ill-equipped to handle the contextual, oral, and relationally embedded nature of indigenous knowledge (George & Sankaran, 2023). Moreover, policies and digital architectures are routinely designed without meaningful community participation, generating ethical tensions around ownership, authenticity, and cultural misappropriation. This study addresses three interrelated knowledge gaps: (i) the empirical deficit regarding stakeholder perceptions of IEK digitization in Nigerian contexts; (ii) the absence of community-responsive conceptual frameworks for ethical indigenous digital library design; and (iii) the limited documentation of how IEK can be systematically linked to SDG implementation at the community level.

AIM AND OBJECTIVES

The overarching aim of this study is to examine stakeholder perceptions of digital libraries as tools for preserving and disseminating indigenous ecological knowledge for sustainable land and water resource management. The specific objectives are to:

1. Identify and categorize key indigenous ecological knowledge practices related to land use, agroforestry, and water conservation among respondents in Nigerian communities.
2. Assess current levels of digital library awareness and indigenous knowledge representation within existing digital platforms.
3. Analyze the challenges and ethical considerations in digitizing indigenous knowledge with attention to access, ownership, and cultural integrity.

4. Develop the CAIDE framework as a novel model for participatory, ethical, and inclusive indigenous knowledge archiving.
5. Evaluate community readiness, preferred participation roles, and trust-building features for indigenous digital repositories.
6. Propose strategic recommendations for co-creating inclusive digital infrastructures that amplify indigenous knowledge for climate resilience and SDG achievement.

LITERATURE REVIEW

4.1 Indigenous Ecological Knowledge and Environmental Sustainability

Indigenous Knowledge Systems (IKS) have long been recognized as vital to sustainable natural resource management. Rooted in centuries of experiential learning and community-based practice, IKS provides adaptable, resilient strategies for land use, agriculture, forestry, and water conservation. Practices such as rotational farming, sacred forest preservation, and traditional irrigation systems have sustained ecosystems and food security across African, Asian, and Latin American communities (Chanza & Mususa, 2020). Despite their efficacy, these knowledge systems are routinely marginalized in formal policy and academic frameworks, accelerating their erosion, particularly where Western-dominated development paradigms dominate (Nyantakyi-Frimpong et al., 2022).

Ajayi et al. (2021) argue that integrating traditional knowledge into modern environmental governance enhances the contextual relevance of policy interventions, particularly in climate-vulnerable regions. The concept of Traditional Ecological Knowledge (TEK) extends this understanding, recognizing the cumulative, adaptive, and place-based nature of ecological wisdom held by indigenous communities (Berkes, 2018).

4.2 Digital Libraries as Tools for Knowledge Preservation

The emergence of digital libraries has redefined the scope of knowledge preservation and access. Digital repositories are no longer static archives but dynamic platforms for community engagement, multimedia storytelling, and decentralized knowledge curation. As Wangari and Katembo (2023) assert, digital libraries in Africa hold potential as 'technological sanctuaries' where oral traditions, ecological observations, and indigenous histories can be stored and accessed across generations.

Efforts such as the Indigenous Knowledge Management System (IKMS) in South Africa and the Masakhane Project demonstrate how digital platforms can support indigenous language preservation and environmental knowledge sharing (Munyua & Otiike, 2022). When coupled with indigenous knowledge, digital technologies can foster hybrid systems of environmental governance that are both scientifically robust and culturally grounded.

4.3 Governance Frameworks: CARE, FAIR, and Data Sovereignty

The FAIR principles, Findable, Accessible, Interoperable, and Reusable, provide technical standards for data management that enhance discoverability (Wilkinson et al., 2022). The CARE principles, Collective Benefit, Authority to Control, Responsibility, and Ethics, address the power dimensions of indigenous data governance, centering community agency and relational accountability (Carroll et al., 2020; Global Indigenous Data Alliance, 2021). The integration of both frameworks represents a critical advance in designing repositories that are simultaneously technically functional and ethically grounded.

4.4 Identified Gaps

Several empirical gaps persist. First, many existing digital libraries lack indigenous content or fail to align with community linguistic diversity and cultural protocols (Wangari & Katembo, 2023). Second, there is limited empirical research from Nigeria on stakeholder perceptions of IEK digitization. Third, legal frameworks governing indigenous data exclude customary laws and traditional authority structures. This study addresses these gaps through primary data collection and the development of the CAIDE framework.

METHODOLOGY

5.1 Research Design

This study adopts a convergent mixed-methods research design, integrating quantitative survey data with qualitative open-ended responses to generate a comprehensive understanding of stakeholder perceptions. The convergent design enables triangulation of findings, enhancing credibility and analytical depth (Creswell & Creswell, 2018).

5.2 Study Area and Target Population

The study focuses on indigenous knowledge custodians, practitioners, educators, and digital information professionals in Nigeria, with emphasis on communities in rainforest and southwestern ecological zones. The target population included indigenous knowledge custodians (elders, farmers, herbalists), teachers engaged in environmental education, ICT and library professionals, and community leaders with governance roles over traditional knowledge.

5.3 Sampling and Sample Size

A purposive sampling technique was employed to select respondents with demonstrable knowledge of indigenous ecological practices and/or involvement in digital knowledge systems. This approach is appropriate given the specialized nature of the subject matter (Palys, 2008). A total of 15 respondents participated, including seven (46.7%) aged 45–54, five (33.3%) aged 35–44, and three (20.0%) aged 54 and above.

5.4 Data Collection Instrument

A structured questionnaire comprising thirty (30) items across six (6) thematic sections was administered digitally. Section A captured demographic information; Section B documented IEK practices and transmission; Section C assessed digital

library awareness; Section D explored digitization challenges; Section E examined participatory preferences; Section F evaluated sustainability impacts and SDG alignment.

5.5 Data Analysis

Quantitative data were analyzed using descriptive statistics, frequency distributions and percentage scores, computed with Python (pandas library). Multi-select items were disaggregated to count individual response options. Qualitative open-ended responses were subjected to thematic content analysis, identifying recurring themes around digitization advocacy, institutional support, and community empowerment.

5.6 Ethical Considerations

The study adhered to informed consent, anonymity, and respect for traditional authority structures, consistent with the Nagoya Protocol on Access and Benefit-Sharing and the CARE Principles (Carroll et al., 2020). Ethical approval was obtained from the institutional review board prior to data collection.

RESULTS AND DISCUSSION

6.1 Demographic Profile of Respondents

Figure 1 and Table 1 present the demographic characteristics of the 15 respondents. The sample was predominantly male (80.0%) and in the 45–54 age bracket (46.7%), suggesting that older, experienced community members are the primary custodians of IEK. Teachers constituted the largest occupational group (46.7%), followed by ICT/library workers (26.7%), farmers (13.3%), and others (13.3%). All respondents held tertiary-level education, indicating a literate, digitally aware population capable of bridging indigenous and modern knowledge systems.

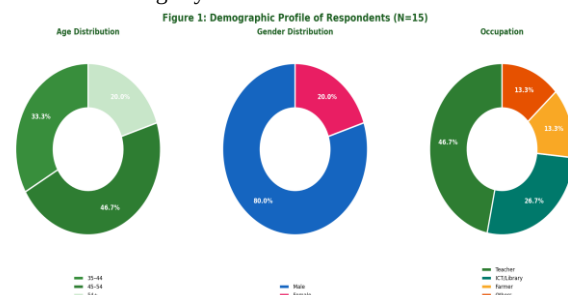


Figure 1: Demographic Profile of Respondents (N=15)

Table 1: Demographic Characteristics of Respondents (N = 15)

Variable	Category	n	%
Age	35–44	5	33.3
	45–54	7	46.7
	54 and above	3	20.0
Gender	Male	12	80.0
	Female	3	20.0

Variable	Category	n	%
Occupation	Teacher	7	46.7
	ICT/Library Worker	4	26.7
	Farmer	2	13.3
	Others	2	13.3
Community Role	Community Elder	3	20.0
	Community Leader	3	20.0
	Political Figure	1	6.7
	Others	8	53.3

Source: Author's Field Survey Data, 2025

6.2 Indigenous Ecological Knowledge Practices and Transmission

Figure 2 reveals that rotational farming was the most prevalent practice, reported by 10 respondents (66.7%), followed by traditional irrigation (46.7%) and the use of indigenous plants for soil and water preservation (46.7%). Rainwater harvesting was practiced by 40.0% of respondents. Knowledge transmission remains anchored in informal, community-centred mechanisms: community elders (66.7%) and oral storytelling (60.0%) are the primary conduits (Figure 3a), while formal institutions such as local schools were cited by only 33.3%, underscoring the non-institutionalized character of IEK and the attendant risk of discontinuity.

Notably, 73.3% of respondents indicated that indigenous practices are still used regularly (Figure 3b). A combined 86.7% rated their practices as very effective or moderately effective in promoting land and water sustainability, a powerful affirmation of IEK's continued ecological relevance.

Figure 2: Indigenous Ecological Knowledge (IEK) Practices Identified by Respondents (N=15, Multiple Response)

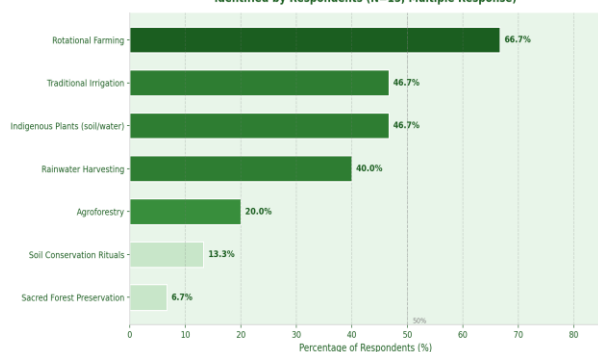


Figure 2: IEK Practices Identified by Respondents (N=15, Multiple Response)

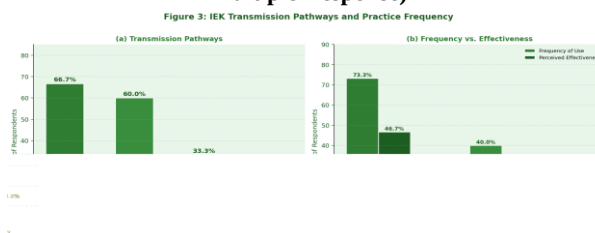


Figure 3: (a) IEK Transmission Pathways and (b) Frequency vs. Effectiveness of Practice

Table 2: IEK Practices, Transmission Pathways, Frequency, and Effectiveness

Variable	Category	N	%
IEK Practices	Rotational Farming	10	66.7
	Traditional Irrigation	7	46.7
	Indigenous Plants (soil/water)	7	46.7
	Rainwater Harvesting	6	40.0
	Agroforestry	3	20.0
	Soil Conservation Rituals	2	13.3
	Sacred Forest Preservation	1	6.7
Transmission	Community Elders	10	66.7
	Oral Storytelling	9	60.0
	Local School	5	33.3
	Family Rituals	1	6.7
Frequency	Regularly	11	73.3
	Rarely	3	20.0
	Not Anymore	1	6.7
Effectiveness	Very Effective	7	46.7

Variable	Category	N	%
	Moderately Effective	6	40.0
	Slightly Effective	2	13.3

Source: Author's Field Survey Data, 2025. Practices and transmission are multiple-response; percentages based on N=15.

6.3 Digital Library Awareness and Indigenous Knowledge Representation

Figure 4 illustrates the digital library awareness, representation, and trust profile across four key indicators. A majority (80.0%) reported awareness of or prior interaction with a digital library. However, only 33.3% confirmed that any digital library contained indigenous knowledge from their communities, while 46.7% said no, exposing a critical representational gap. Mobile phones are the dominant access device (66.7%), mandating mobile-first digital library design. Trust in digitized IK was broadly positive at 73.3% (agree/strongly agree), though perceived quality of existing representation was mixed: 46.7% rated archives as fairly good, 33.3% as poor, and only 20.0% as very good.

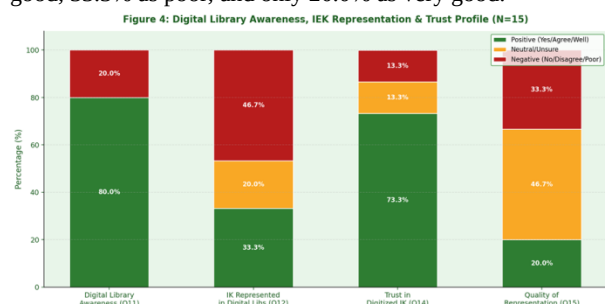


Figure 4: Digital Library Awareness, IEK Representation and Trust Profile (N=15)

Table 3: Digital Library Awareness and IEK Representation

Variable	Category	n	%
Digital Library Awareness	Yes	12	80.0
	No	3	20.0
IK in Digital Libraries	No	7	46.7
	Yes	5	33.3
	Not Sure	3	20.0
Access Device	Mobile Phone	10	66.7
	Computer	3	20.0

Variable	Category	n	%
	Radio/TV	2	13.3
Trust in Digitized IK	Agree / Strongly Agree	11	73.3
	Neutral	2	13.3
	Disagree / Strongly Disagree	2	13.3
Quality of Representation	Fairly Well	7	46.7
	Poorly	5	33.3
	Very Well	3	20.0

Source: Author's Field Survey Data, 2025

6.4 Challenges and Ethical Considerations

Figure 5 presents a radar diagram of the four digitization barriers and community data sovereignty conviction. Lack of technology infrastructure (60.0%) was the most cited barrier, followed by language barriers (53.3%), fear of misuse or misinterpretation (53.3%), and cultural secrecy/sacredness (46.7%). Critically, 73.3% affirmed that communities should have the right to control how their knowledge is shared online, aligning with the CARE principle of Authority to Control.

A significant majority (66.7%) disagreed or strongly disagreed that digital documentation necessarily leads to loss of cultural essence, challenging a common techno-pessimist assumption in the literature. Only 20.0% expressed agreement with this concern, suggesting communities are not categorically opposed to digitization but demand culturally informed terms of engagement.

Figure 5: Challenges & Ethical Dimensions of IEK Digitization (%)

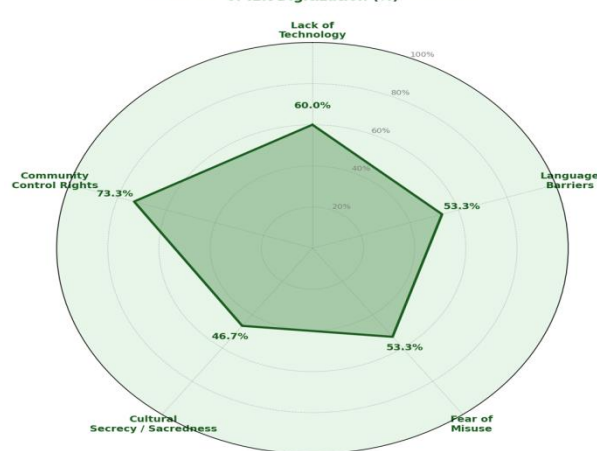


Figure 5: Radar Profile of IEK Digitization Challenges and Ethical Dimensions (N=15)

Table 4: Challenges and Ethical Dimensions of IEK Digitization

Challenge / Ethical Dimension	n	%
Lack of Technology Infrastructure	9	60.0
Language Barriers	8	53.3
Fear of Misuse or Misinterpretation	8	53.3
Cultural Secrecy / Sacredness	7	46.7
Community should control online sharing (Yes)	11	73.3
Digitization causes cultural essence loss (Agree/Strongly)	3	20.0
Digitization does NOT cause cultural loss (Disagree/Strongly)	10	66.7

Source: Author's Field Survey Data, 2025. Challenges are multiple-response items.

6.5 Participatory Models, Inclusion, and Trust Features

Figure 6 presents community participation readiness and preferred roles. An exceptional 93.3% of respondents indicated willingness to participate in creating a digital repository, a near-unanimous mandate for co-creation. Community Reviewer (53.3%) and Knowledge Provider (46.7%) were the most preferred roles, reflecting communities' desire to retain editorial authority over archived content. Figure 7 shows the trust-building features ranked by preference: local endorsement (53.3%), offline access (46.7%), multilingual support (46.7%), copyright controls (40.0%), and community login systems (33.3%). The prominence of offline access reveals a critical infrastructural reality for digital library design in underserved communities.

Figure 6: Community Participation Readiness and Preferred Roles

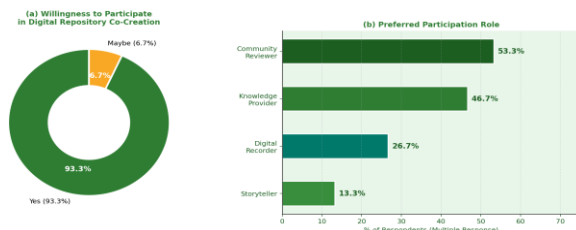


Figure 6: Community Participation Readiness and Preferred Roles in Digital Repository Co-Creation

Figure 7: Trust-Building Features Preferred for Indigenous Digital Libraries (N=15)

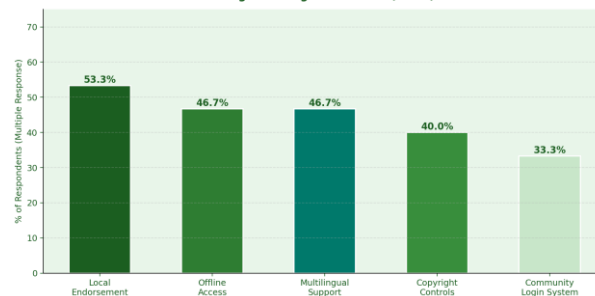


Figure 7: Trust-Building Features Preferred for Indigenous Digital Libraries (N=15, Multiple Response)

Table 5: Community Participation Preferences and Trust Features

Variable	Category	n	%
Willingness to Participate	Yes	14	93.3
	Maybe	1	6.7
Preferred Role	Community Reviewer	8	53.3
	Knowledge Provider	7	46.7
	Digital Recorder	4	26.7
	Storyteller	2	13.3
Language Preference	Both (Local + International)	13	86.7
	Local Language Only	1	6.7
Trust Features	Local Endorsement	8	53.3
	Offline Access	7	46.7
	Multilingual Support	7	46.7
	Copyright Controls	6	40.0
	Community Login System	5	33.3

Source: Author's Field Survey Data, 2025. Roles and trust features are multiple-response items.

6.6 Sustainability Impact and SDG Alignment

Figure 8 presents sustainability impact perceptions and SDG alignment. Digital knowledge tools have helped improve environmental practices for 66.7% of respondents, with 33.3% indicating 'maybe', zero outright negative responses. A remarkable 93.3% agreed or strongly agreed that digital libraries can help protect the future of indigenous heritage. SDG 6 (Clean Water and Sanitation) ranked highest at 66.7%, followed by SDG 13 (Climate Action) and SDG 15 (Life on Land) each at 40.0%, directly reflecting the water-intensive nature of IEK practices documented in Section 6.2 and confirming the strategic relevance of indigenous knowledge to global water security.

Figure 8: SDG Alignment and Sustainability Impact Perceptions

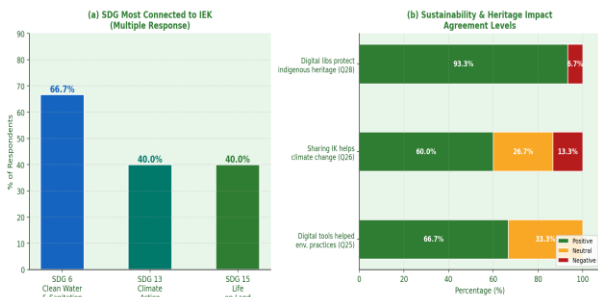


Figure 8: SDG Alignment and Sustainability Impact Perceptions (N=15)

Table 6: Sustainability Perceptions and SDG Alignment

Variable	Category	n	%
Digital Tools Helped Env. Practices	Yes	10	66.7
	Maybe	5	33.3
Sharing IK Helps Climate Change	Agree / Strongly Agree	9	60.0
	Neutral	4	26.7
	Disagree / Strongly Disagree	2	13.3
SDG Alignment	SDG 6 – Clean Water & Sanitation	10	66.7
	SDG 13 – Climate Action	6	40.0
	SDG 15 – Life on Land	6	40.0
Digital Lib Protects	Agree / Strongly	14	93.3

Variable	Category	n	%
Heritage	Agree		
	Strongly Disagree	1	6.7

Source: Author's Field Survey Data, 2025. SDG alignment is multiple-response.

The CAIDE Framework

Figure 9 presents the Community-Anchored Indigenous Digital Ecosystem (CAIDE) framework, the study's central theoretical and operational contribution. Drawing from empirical findings and grounded in the complementary logic of CARE and FAIR principles, CAIDE provides a novel conceptual architecture for designing, implementing, and governing indigenous digital libraries in the Global South. The framework is structured around five interconnected pillars that flow from IEK sources and diverse stakeholders through a community-governed digital repository to produce measurable sustainability outcomes.

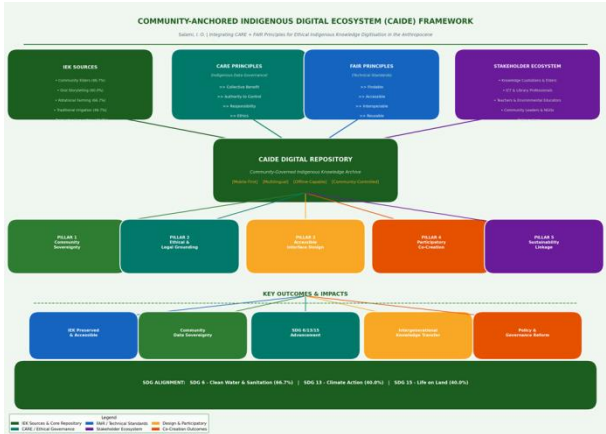


Figure 9: The Community-Anchored Indigenous Digital Ecosystem (CAIDE) Framework

Pillar 1: Community Sovereignty and Cultural Gatekeeping

IEK digitization must begin with, and remain accountable to, the communities that generate and steward knowledge. Community elders and designated reviewers hold editorial authority over what is archived, how it is described, and who may access it. Community login systems, tiered access controls, and elder endorsement protocols operationalize this pillar digitally.

Pillar 2: Ethical and Legal Grounding

All digital archiving activities must be governed by informed consent, intellectual property protections aligned with the Nagoya Protocol on ABS, and metadata schemas that include provenance, custodianship, and access conditions reflecting customary law. CARE principles, particularly Responsibility and Ethics, guide inter-institutional data-sharing agreements.

Pillar 3: Accessible and Inclusive Interface Design

Digital libraries must be mobile-first, low-bandwidth optimized, and multilingual. Offline functionality is non-negotiable in underserved Nigerian communities where 66.7%

of respondents access digital information via mobile phones. Interfaces should incorporate audio, video, visual symbols, and local language text to accommodate varying literacy levels.

Pillar 4: Participatory Co-Creation and Capacity Building

Communities are not passive contributors but active architects of digital repositories. Structured roles, knowledge provider, storyteller, digital recorder, community reviewer, empower diverse community members meaningfully. Partnerships with universities, NGOs, and ICT institutions provide technical capacity building without displacing community agency.

Pillar 5: Sustainability Impact Linkage

Digital repositories must be explicitly connected to environmental governance processes and SDG implementation mechanisms. Indigenous knowledge archived through CAIDE should be retrievable by environmental planners, climate adaptation practitioners, and water resource managers, creating a bidirectional flow between community knowledge and policy impact, particularly for SDG 6, 13, and 15.

CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

This study has illuminated both the urgent vulnerability and the transformative potential of indigenous ecological knowledge in Nigeria. It demonstrates empirically that IEK communities are ready, willing, and capable partners in co-creating inclusive digital knowledge systems, provided those systems are designed with genuine cultural respect, community sovereignty, and technological accessibility at their core. The fundamental paradox this research addresses is captured in a single statistic: 93.3% of respondents affirm that digital libraries can protect indigenous heritage, yet fewer than one in three communities can point to a digital platform containing their knowledge.

The CAIDE framework proposed herein offers a novel, empirically grounded, and operationally actionable roadmap for bridging this gap, integrating the technical rigour of FAIR principles with the ethical accountability of CARE governance, within the mobile-first, multilingual, offline-capable realities of the Nigerian community context.

8.2 RECOMMENDATIONS

For Policymakers

1. Enact legislative protections for indigenous digital intellectual property aligned with the Nagoya Protocol and CARE Principles;
2. Mainstream indigenous ecological knowledge into national climate action plans, water resource management frameworks, and educational curricula; and
3. Fund Community Digital Knowledge Hubs as nodes in a national Indigenous Knowledge Digital Network, coordinated through LASUED and partner universities.

For Digital Librarians and Information Scientists

1. Design mobile-first, multilingual, offline-capable platforms that meet communities where they are technologically;
2. Incorporate community login systems, elder endorsement protocols, and tiered access controls to operationalize data sovereignty; and
3. Collaborate with NLP and AI developers to build translation tools bridging indigenous languages and global platforms without decontextualizing knowledge.

For Academic Institutions

1. Conduct longitudinal studies tracking environmental sustainability impacts of IEK digitization beyond perceptions to measurable outcomes;
2. Develop certification programs for community knowledge brokers as culturally informed intermediaries; and
3. Partner with UNESCO, African Union, and ECOWAS to scale the CAIDE framework regionally across West Africa.

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