Charting a Resilient Future: Climate Change as a Catalyst for Sustainable National Development
Proceedings of the 5th International Conference (FESCON 2025) at Chukwuemeka Odumegwu Ojukwu University, Uli Campus, Uli, Nigeria
18 - 20 June 2025

LEVERAGING CLIMATE-SMART AGRICULTURE AND INDIGENOUS KNOWLEDGE FOR SUSTAINABLE FOOD SECURITY IN SUB-SAHARAN AFRICA: POLICY AND PRACTICE INSIGHTS

Charles Chikodili Anukwonke[1] and Augustina Ukamaka Okonkwo[2]
[1,2] Department of Environmental Management, Chukwuemeka Odumegwu Ojukwu University, Uli Campus, Uli, Anambra State, Nigeria

E-mail: [1]charlesjohnbosco@gmail.com

Abstract

Food security has continued to pose significant barrier in Sub-Saharan Africa, intensified by the rising climate change challenges on agricultural yield and rural sustainability. Climate-Smart Agriculture (CSA) represents an integrated approach that combines sustainable agricultural productivity, climate adaptation, and mitigation to strengthen food security in Sub-Saharan Africa. However, despite global advocacy and relevance, the integration of indigenous knowledge systems with modern CSA practices remains underexplored in both policy and implementation contexts. This paper, critically examines the potential of combining indigenous agricultural knowledge with climate-smart practices to enhance food security in Sub-Saharan Africa, with a focused case study on Nigeria and its neighbouring countries including Niger, Chad, Cameroon, and Benin. This study drawing from a holistic desk-based thematic analysis of diverse frameworks, articulation of relevant FAO and IPCC reports, germane literature review from Scopus based journal comprising of peer review studies in related subjects, identified major thematic codes within policy gaps, challenges relating to integration, and typical types of local experience and implications in climate resilience: Findings demonstrate that while indigenous knowledge including traditional crop selection, water conservation, and seasonal forecasting offers valuable context-specific adaptive strategies, its integration with CSA technologies varies across Nigeria and neighbouring countries (Niger, Chad, Cameroon, Benin) due to differing institutional barriers, policy frameworks, and community engagement levels. This disparity highlights the need for tailored policy reforms and localized CSA interventions to address the unique socio-cultural and environmental conditions within each country. However, institutional barriers, lack of policy recognition, and limited collaboration between local communities and formal agricultural systems hinder this integration. This article contends for policy reform inclusivity which identifies local experience and cultural knowledge as an invaluable input in discussing climate adaptation and food access game plans. The study also advocates for the interconnectedness between all major stakeholders including peasant farmers, academics and policy analysts to synthesize context-specific CSA solutions that are viable and scalable. Such participatory involvement can build stronger capacity for climate adaptation, resilience, and equality in food supply within the inevitable climate crisis era, and lastly, the research contributes to sustainability science by bridging traditional wisdom and scientific innovation, offering a pathway to more effective and culturally sensitive climate-smart agriculture policies in Sub-Saharan Africa.

Keywords: Adaptation, Climate Change, Climate Smart Agriculture, Resilience

1. INTRODUCTION

1.1 Background

Sub-Saharan Africa (SSA) as a territory is challenged with a deepening catastrophe in sustainable food security, intricately tied to population related drivers and pressures, environmental degradation, and an increasingly volatile-climate system. Its human-population expected to double by 2050, accentuated by rural related agricultural activities, more so, the area's heavy reliance on rainfed smallholder agriculture creates a structural susceptibility (Mbow, 2020; Sithole & Olorunfemi, 2024). This farming culture which, which provides over two-third of the workforce and contributes approximately 23% to national GDPs, operates at the linkage of ecological sensitivity and socio-economic precarity (Ayanlade et al., 2022). The vulnerability of these rainfed systems to climatic drifts such as droughts, floods, and increasingly erratic precipitation renders food systems highly unstable and undermines macroeconomic resilience (Malhi et al., 2021).

A factor of note is the holistic vacuum between the degree of ecological factors and stressors and the SSA's techno-policy feedback. Despite the exponential demographic pressure, access to novel agricultural innovations remains limited, particularly in agrarian localities where core traditional practices persist without fundamental and logistical support (Kaba, 2020; Andrianarimanana & Yongjian, 2021). These communities are often caught in a feedback loop: land degradation reduces productivity, which in turn raises concerns of over cultivation and intensive use of agro-chemicals, that further deteriorates the natural ecosystem and its resources. The antecedental gap in the efficacious institutional reactions to the bandwagon effect of environmental destruction reflects the immense socio-governance failures and insufficiency in integrating core traditional knowledge systems to formalized development school of thought.

Climate-Smart Agriculture (CSA) is a universally approved option, proposed by the FAO and others as a tripartite strategy aiming to enhance productivity, foster climate adaptation, and mitigate greenhouse gas emissions (Kabato et al., 2025). The practices associated with CSA, ranging from conservation agriculture and agroforestry to drought-resistant crop varieties and optimized irrigation services, provides ample science oriented and formalized technicality to arriving at resilient communities in the rising agricultural development attempts. In line with CSA paradigm, methods such as no-till farming, intercropping, precision irrigation, and integrated nutrient management are valued for their potential to reconcile environmental sustainability with productivity imperatives (Tambe et al., 2023). However, despite its potentials and capabilities, CSA implementation across SSA remains odd and unnoticed due to socio-economic inequality and disparity, fragmented policy ecosystems, and a persistent disconnect between top-down development strategies and local agro-ecological realities (Olabanji & Chitakira, 2025).

A critical limitation lies in the epistemological marginalization of Indigenous Knowledge (IK), which despite its contextual richness and historical efficacy, is frequently excluded from CSA discourse and policy planning. IK encompasses a keynote consciousness of micro-climates, soil dynamics, traditional seed systems, and seasonal forecasting, skills accumulated through centuries of adaptation to Africa's environmental heterogeneity (Tume et al., 2019): Yet in many CSA attempts and score cards, IK is either superficially acknowledged or wholly neglected, dismissed as anecdotal or unscientific. This oversight is not merely technical but ideological, reflecting the legacy of colonial knowledge hierarchies and the privileging of Eurocentric scientific paradigms over endogenous African epistemologies.

Moreover, institutional structures often externally funded and donor-driven reproduce these exclusions by relying on standardized CSA templates that fail to engage with local social norms, land tenure systems, or gender dynamics. These system of response, lower the capacity and potentialities of CSA in context specific areas and restrict its scalability at the broader communal level.

For instance, while agroforestry may be promoted as a CSA strategy, in contexts where land inheritance systems marginalize women or youth, such interventions may exacerbate existing inequalities if not adapted to local governance structures and thus, without re-strategizing and reforming CSA to reflect the required concern through building of knowledge with local farming systems, its transformative agility remains compromised. The future of agricultural resilience in SSA, therefore, depends not only on technological innovation but on epistemological justice that places IK at the heart of CSA design and implementation.

1.2 Indigenous Knowledge and Climate Adaptation

Indigenous Knowledge (IK) in Sub-Saharan Africa (SSA) constitutes a foundational epistemological resource, shaped through generations of ecological interaction, experimentation, and adaptation (Kom & Nthaduleni, 2024; Thothela et al., 2025). Far from being anecdotal or static, IK represents a dynamic and evolving body of knowledge that includes practical techniques such as traditional crop diversification, soil fertility restoration through organic amendments and fallowing, localized water conservation methods like zai pits and stone bunds, as well as the use of ecological indicators phenological cues, animal behavior, or atmospheric patterns for seasonal forecasting (Zougmoré et al., 2023). These practices, while deeply contextual and culturally ingrained, also demonstrate strategic ecological intelligence that aligns with contemporary goals of sustainability and resilience.

The increasing volatility of SSA's climate evident in erratic rainfall, frequent droughts, and shifting growing seasons has brought renewed attention to the potential of IK in strengthening community-level climate adaptation. Unlike many top-down, technologically driven interventions that often falter due to socio-cultural misalignment or logistical inaccessibility, IK is inherently accessible and trusted by rural communities. As Amare and Gacheno (2021) demonstrate, the integration of IK with Climate-Smart Agriculture (CSA) not only enhances resilience outcomes but also improves uptake and long-term sustainability of CSA practices. For instance, when conservation agriculture techniques are embedded within indigenous rotational cropping systems or when formal seasonal forecasting tools are co-developed with traditional prediction mechanisms, both credibility and adoption improve among farming households.

However, despite this demonstrated utility, IK remains structurally marginalized within national climate policy and agricultural extension frameworks. One significant barrier is the unresolved discourse around intellectual property many IK practices lack formal documentation or legal recognition, making their inclusion in formal systems both technically and politically contentious (Adade Williams et al., 2020). Additionally, the lack of collaboration between research institutions and indigenous custodians often results in extractive, one-directional knowledge flows rather than participatory co-production. This not only undermines the agency of local communities but perpetuates a neo-colonial dynamic in which knowledge is validated only through external scientific frameworks.

Moreover, the absence of institutional mechanisms for integrating IK such as bilingual agricultural extension models, community-led documentation initiatives, or transdisciplinary policy platforms further entrenches the separation between formal CSA programs and localized realities. Bridging this divide requires more than inclusionary rhetoric; it demands structural reforms that center indigenous actors as equal stakeholders in climate adaptation governance.

1.3 Problem Statement

Despite growing interest in Climate-Smart Agriculture (CSA) across Sub-Saharan Africa (SSA), a major policy-practice disconnect persists in integrating Indigenous Knowledge (IK) into CSA strategies, significantly weakening climate resilience outcomes across multiple national contexts (Ogisi & Begho, 2023). In Nigeria, although the National Policy on Climate Change (2021–2030) acknowledges the urgency of adaptation, it lacks mechanisms for integrating context-specific indigenous agricultural practices into CSA frameworks. This oversight disproportionately affects smallholder farmers whose traditional methods such as crop rotation, sacred forest preservation, and seasonal forecasting remain underutilized. Compounding this is the ecological diversity of Nigeria, ranging from humid tropics in the south to arid zones in the north, which necessitates region-specific CSA models. However, national adaptation plans like NASPA-CCN have yet to address these variations meaningfully (Chevallier, 2024; Ariom et al., 2022).

In Benin, while institutions like FAO, ICRISAT, and CIAT have promoted CSA initiatives such as agroforestry and improved seed varieties their implementation remains uneven due to low farmer awareness, financial inaccessibility, and poor institutional coordination (FAO, ICRISAT & CIAT, 2018). The vulnerability of northern Benin, where erratic rainfall and high temperatures are predicted to boost maize yields, contrasts with declining productivity in southern and central zones, highlighting the urgent need for climate-specific, locally grounded CSA policies (Dossa et al., 2025). Furthermore, even with increased cultivation areas over the past decades, cereal yields remain unstable due to climatic volatility and limited access to technologies and credit (Faye et al., 2020; Yegbemey et al., 2018).

In Senegal, initiatives such as PICSA and the introduction of seasonal forecasts have attempted to bridge knowledge gaps. However, their reach, especially among women and rural farmers, is constrained by lack of digital infrastructure and training. Agroforestry and water conservation practices promoted under CSA frameworks are inconsistently adopted across regions due to insufficient support and weak institutional cohesion (CIAT & BFS/USAID, 2016; Sow et al., 2020; Ariom et al., 2022). Similarly, in Chad, CSA strategies remain underdeveloped and largely detached from the socio-ecological realities of rural farmers in semi-arid and Sahelian zones. Though policies nominally support CSA, their execution fails to reflect the adaptive capacities embedded in indigenous strategies long used to manage drought and desertification (CIAT, ICRISAT & World Bank, 2021; Ariom et al., 2022).

Cameroon also suffers from uneven institutional capacity, especially in the arid north where traditional irrigation and soil management practices are disregarded in favor of modern techniques unsuited to local ecologies. Without formal recognition of IK in national CSA strategies, rural farmers are left unsupported in adapting to increasingly hostile climatic conditions (Marie Chimi et al., 2023; Ariom et al., 2022). Thus, across SSA, systemic exclusion of IK from CSA policymaking undermines tailored adaptation and poses a significant barrier to building localized resilience.

1.4 Objectives

This study targets to:

i. Identify thematic gaps and opportunities within policy frameworks for integrating indigenous knowledge and CSA in SSA.

ii. Examine the role of indigenous knowledge in climate resilience and food security enhancement, focusing on Nigeria and neighboring countries.

iii. Propose evidence-based policy and practice recommendations to bridge indigenous and scientific knowledge for sustainable food systems.

2. LITERATURE REVIEW

2.1 Climate-Smart Agriculture in Sub-Saharan Africa

The implementation of Climate-Smart Agriculture (CSA) across Sub-Saharan Africa (SSA) is marked by considerable variability in both uptake and outcomes, reflecting the heterogeneity of agro-ecological zones, institutional capacities, and socio-economic contexts. While CSA has been positioned as a transformative strategy capable of enhancing agricultural productivity, promoting adaptation, and reducing emissions (Bhatnagar et al., 2024), its deployment across SSA reveals systemic constraints that limit its full potential. These constraints are not merely technical but embedded in structural inequalities, knowledge gaps, and fragmented institutional arrangements.

In Ghana, the integration of CSA practices such as crop rotation, intercropping, and the use of improved crop varieties has been associated with tangible improvements in productivity. With 75% of surveyed farmers reportedly adopting CSA measures, maize yields have increased by 15–25% over the past decade (Mutenje, 2021). Such high adoption rates suggest that when enabling conditions such as access to climate information, institutional support, and adaptive credit systems are present, CSA can deliver measurable benefits. However, this success is not mirrored uniformly across SSA. In Nigeria, particularly in the North Central and Northwest zones, CSA adoption is more fragmented. Although 87% of farmers have adopted at least one climate-resilient crop trait (e.g., drought tolerance or early maturation), broader adoption of CSA techniques like crop rotation or conservation tillage remains low, with only 56% of farmers utilizing such practices (Gabriel et al., 2023). This discrepancy underscores the role of access barriers especially to credit, inputs, and extension services in shaping adoption behavior.

Socio-economic factors significantly influence CSA adoption patterns across the region. Mogaka et al. (2021) emphasize that education level, gender, and landholding size are crucial determinants. Male-headed households and more educated farmers tend to have greater access to resources and are more likely to experiment with CSA innovations. Conversely, women farmers, despite often being central to food production, are marginalized in access to information, land, and credit, which restricts their participation in CSA initiatives. This gendered inequity creates an adoption gap that undermines inclusive climate resilience.

In Mali, the inconsistency in CSA uptake is stark. Practices such as intercropping and farmer-managed natural regeneration (FMNR) have adoption rates between 39% and 77%, indicating their resonance with traditional knowledge systems and low-cost requirements. In contrast, advanced technologies such as fertilizer micro-dosing and improved seed varieties register adoption rates of only 23–38%, due to lack of training, high input costs, and weak market linkages (Ouédraogo et al., 2019). These disparities suggest that CSA strategies aligned with indigenous practices enjoy greater traction, whereas more technologically-intensive solutions face adoption hurdles without complementary support systems.

In Niger, climate-smart interventions such as agroforestry and FMNR have demonstrated efficacy in restoring degraded landscapes and improving soil health, particularly in Sahelian zones prone to desertification (Badji et al., 2020). However, these successes are localized and often unsupported by national-level agricultural policies. Limited extension services, financial constraints, and infrastructural deficits inhibit broader uptake. The recurring theme here found also in Nigeria is the failure of state institutions to create enabling environments for CSA diffusion. Although practices like drought-resistant crops and water-efficient irrigation have shown potential, their effectiveness is bounded by the systemic inaccessibility of resources and lack of institutional incentives.

Olabanji and Chitakira (2025) point to fragmented policy coordination as a core institutional challenge inhibiting CSA scalability in SSA. Where CSA strategies exist, they often function in silos divorced from national adaptation plans, local governance structures, or agricultural financing frameworks. Moreover, weak climate information services impede farmers' ability to make informed, timely decisions, especially in regions experiencing growing climate variability.

Overall, while CSA demonstrates considerable promise as a framework for sustainable agriculture in SSA, its uneven uptake reflects entrenched socio-economic and institutional asymmetries. Bridging these gaps necessitates not only technical capacity building but also inclusive governance models that integrate local knowledge systems, expand equitable access to resources, and harmonize fragmented policy structures. Without such systemic transformation, CSA risks reproducing existing inequalities rather than addressing the core vulnerabilities of SSA's agricultural systems.

2.2 Indigenous Knowledge Systems and Agricultural Adaptation

Indigenous knowledge systems have long been central to agricultural adaptation across Sub-Saharan Africa, offering context-specific, sustainable practices developed over generations. These systems reflect a deep understanding of local ecosystems, often surpassing modern interventions in relevance and accessibility for rural communities. According to Melash et al. (2023), indigenous agricultural knowledge includes diverse techniques such as seed saving, mixed cropping, agroforestry, and natural pest control, all of which are ecologically harmonious and tailored to specific environmental conditions. These strategies enhance resilience by maintaining biodiversity, reducing dependency on external inputs, and ensuring continuity of food production in uncertain climatic conditions.

One of the most striking examples of indigenous adaptation is seasonal forecasting based on natural indicators. In northern Nigeria, for instance, farmers monitor bird migration patterns and the flowering of particular plant species to predict rainfall, reportedly with over 70% accuracy, a figure that rivals formal meteorological forecasts (Dillon et al., 2025). Such knowledge systems not only support timely planting and harvesting decisions but also reflect a deeply embedded ecological literacy passed down through generations.

Water scarcity is another major challenge in the region, and indigenous techniques have evolved to address this as well. The Zai pit system, widely used in the Sahel, exemplifies this ingenuity. As documented by Danjuma and Mohammed (2015), Zai pits significantly improve soil moisture retention and enhance crop yields by between 20–40%. These pits, typically filled with organic matter and spaced strategically, help rejuvenate degraded land. In Burkina Faso, the application of Zai pits has restored up to 300,000 hectares, leading to an annual increase of 80,000 tons of food production. The success extends to Niger, where the Tahoua Rural Development Project employed Zai pits and complementary methods to rehabilitate 125,000 hectares, improving both soil fertility and community food security.

Despite their proven effectiveness, these indigenous practices face threats. Youth migration, often driven by limited opportunities in rural areas, disrupts the intergenerational transfer of knowledge. Moreover, formal education systems frequently undervalue indigenous techniques, reinforcing a preference for externally developed solutions. Lastly, institutional recognition of indigenous knowledge remains minimal, further contributing to its gradual erosion.

Thus, while indigenous knowledge systems such as those documented by Melash et al. (2023), Dillon et al. (2025), and Danjuma and Mohammed (2015) are vital for climate adaptation and food security, their survival depends on conscious integration into formal agricultural planning and education systems.

2.3 Barriers to Integration of Indigenous Knowledge in CSA

Indigenous Knowledge (IK) systems have long supported sustainable agriculture in Sub-Saharan Africa. These knowledge forms developed through centuries of experience are locally adapted, cost-effective, and environmentally sustainable. However, despite their proven relevance in enhancing agricultural resilience, integrating IK into Climate-Smart Agriculture (CSA) faces significant barriers across the region.

One major obstacle is the lack of inclusion of IK in national policy frameworks. As Ajani et al. (2013) argue, IK remains largely unrecognized in formal agricultural and climate adaptation policies. Even when local farmers develop effective indigenous strategies, such as planting pits and rainwater harvesting in Niger, these methods are rarely incorporated into official planning. This policy oversight results in missed opportunities to institutionalize sustainable practices that are already functioning on the ground. The absence of formal recognition sidelines IK from extension services, subsidies, and research funding, reducing its visibility and undermining its credibility in policy circles.

Another significant barrier is the challenge of intellectual property rights and lack of documentation. Unlike conventional scientific knowledge, IK is typically communal, orally transmitted, and deeply embedded in culture. This makes it difficult to protect under existing intellectual property laws, which are designed for individually owned innovations. Moahi (2005) explains that because IK is undocumented and lacks legal protection, it is vulnerable to misappropriation. For example, pharmaceutical and agricultural industries have often benefited from indigenous knowledge—such as the medicinal or pest-resistant properties of local plants without compensating the communities that developed this understanding. Moreover, the lack of formal documentation hinders the integration of IK into scientific research, school curricula, and national databases. This creates a further disconnect between local wisdom and institutional systems.

A third challenge is institutional mistrust and limited participatory engagement. Many rural communities in Sub-Saharan Africa have a long-standing distrust of government agencies and scientific bodies, often rooted in a history of top-down interventions. Warner et al. (2022) emphasize that this mistrust, combined with the lack of participatory platforms, prevents meaningful collaboration between local farmers and formal institutions. Farmers frequently do not engage with climate information services because they view them as irrelevant or disconnected from their lived realities. This weakens the potential for co-producing knowledge between indigenous and scientific systems. Without inclusive spaces where both forms of knowledge are equally valued, integration becomes tokenistic or one-sided.

Resource constraints and gender inequality also pose critical barriers. Many indigenous communities practicing traditional agriculture face infrastructural limitations, low financial investment, and weak access to markets and training. Bryan et al. (2024) highlight how gender dynamics further marginalize IK. Women often hold valuable agricultural knowledge especially related to seed selection, pest control, and soil management but are underrepresented in policy decisions and development programs. With male outmigration increasing due to economic pressures, women now lead many agricultural tasks, yet receive little support. Their knowledge is frequently overlooked in mainstream CSA approaches, further perpetuating exclusion.

Finally, the regional variability of institutional support affects IK integration. As Kimengsi et al. (2022) show in Cameroon, colonial histories have shaped local governance systems, which in turn influence the place of IK. In Kilum-Ijim, where British colonial administration supported traditional institutions, community-based natural resource management remains relatively effective. Conversely, in Santchou, influenced by French governance models, fragmented institutions and overlapping authorities have weakened community trust and compliance. This regional disparity reveals that the success of IK integration depends not only on the knowledge itself but also on the institutional environment in which it operates.

In conclusion, while IK has enormous potential to complement CSA in Sub-Saharan Africa, its integration is obstructed by policy exclusion, lack of legal protections, institutional mistrust, gender inequities, and regional governance challenges. Addressing these barriers will require deliberate reforms that elevate IK to equal standing with scientific knowledge, protect communal intellectual property, promote participatory decision-making, and recognize the socio-political contexts in which these systems exist (Ajani et al., 2013; Moahi, 2005; Warner et al., 2022; Bryan et al., 2024; Kimengsi et al., 2022).

3. METHODOLOGY

This study employed a qualitative, desk-based thematic analysis to investigate the integration of Indigenous Knowledge (IK) into Climate-Smart Agriculture (CSA) frameworks within Sub-Saharan Africa, with an emphasis on Nigeria and its neighboring countries Niger, Chad, Cameroon, and Benin. The analysis was designed to be systematic, transparent, and replicable, focusing exclusively on secondary data sources that are authoritative and policy-relevant.

Data collection involved three primary streams. First, national and regional policy documents were gathered directly from the official websites of agriculture, environment, and climate change ministries across the selected countries. These documents included national agricultural investment plans, adaptation frameworks, and food security strategies published between 2010 and 2024. Only documents with clear references to indigenous practices, climate resilience, or rural development were selected. Second, institutional reports from the Food and Agriculture Organization (FAO) and the Intergovernmental Panel on Climate Change (IPCC) were included. These reports were obtained from the FAO's CSA knowledge platform and the IPCC official archives, specifically targeting content from the FAO CSA Sourcebooks (2013 and 2017 editions) and the Fifth and Sixth IPCC Assessment Reports. Relevant sections discussing traditional practices, adaptation in Sub-Saharan Africa, and community-based approaches were extracted for analysis.

Third, a structured literature search was conducted using Scopus, Web of Science, and Google Scholar databases. Search terms included "Indigenous Knowledge," "Climate-Smart Agriculture," "Sub-Saharan Africa," "policy integration," and "adaptation practices." Articles published in English between 2005 and 2024 were screened for inclusion, with priority given to empirical studies and policy analyses focused on IK and CSA interactions. The abstracts of all retrieved documents were reviewed to ensure thematic alignment and the themes under discussion were refined iteratively to capture policy trends, institutional barriers, and region-specific practices, ensuring that thematic analysis remained grounded in the context of Sub-Saharan Africa's diverse institutional and environmental realities.

Analytical Procedure

The analytical procedure followed the six-phase thematic analysis model proposed by Naeem et al. (2023), which supports a structured and in-depth examination of qualitative data. This method is particularly effective for synthesizing diverse policy documents, reports, and academic literature, allowing the researcher to identify context-dependent patterns relevant to Indigenous Knowledge (IK) integration in Climate-Smart Agriculture (CSA).

The process began with an immersive familiarization phase involving repeated reading of all collected texts to develop a deep understanding of content related to IK, CSA, and adaptation policy. Initial themes were manually generated to capture references to IK recognition, CSA implementation strategies, and institutional or structural barriers. These themes were then grouped into broader candidate themes such as "Policy and Institutional Barriers" by identifying conceptual similarities.

Themes were reviewed and refined for coherence, ensuring consistency within and across data sources. Clear definitions and descriptive names were assigned to finalized themes, including: Recognition of Indigenous Knowledge in CSA Policies, Application of Indigenous Knowledge in Climate Adaptation, Barriers to Integration, and Policy and Practice Recommendations. This process was guided by the principles of transparency and reproducibility in qualitative research, in line with standards emphasized by Ahmed et al. (2025).

4. FINDINGS AND DISCUSSION

4.1 Policy Recognition of Indigenous Knowledge in CSA Frameworks

The integration of Indigenous Knowledge (IK) into Climate-Smart Agriculture (CSA) frameworks remains inconsistent and underdeveloped across Sub-Saharan Africa, despite the increasing prominence of CSA within national agricultural and climate policies. While countries such as Nigeria, Cameroon, and the Democratic Republic of Congo (DRC) have embraced CSA as a guiding framework for agricultural development and climate adaptation, the institutional recognition of IK within these frameworks remains limited, often treated as an ancillary rather than a central component of adaptive strategies. This fragmented recognition impedes the effective integration of traditional knowledge systems that are essential for localized, sustainable, and resilient agricultural practices (Nwajiuba et al., 2015).

In Nigeria, the Agricultural Transformation Agenda (ATA) acknowledges traditional agricultural practices primarily for their role in biodiversity conservation rather than as a dynamic source of climate-resilient innovation. The ATA emphasizes increasing food security and promoting sustainable farming but does not incorporate IK into its operational CSA framework. This omission is particularly problematic, given Nigeria's ecological diversity and the long-standing reliance of farming communities on local forecasting, water harvesting, and seed-saving practices. In failing to institutionalize these practices within its CSA programming, Nigeria overlooks a valuable reservoir of adaptive strategies. As Nwajiuba et al. (2015) argue, this selective engagement with IK where it is symbolically recognized but not embedded in CSA implementation represents a critical policy gap. Moreover, the Federal Ministry of Agriculture and Rural Development (2014) reinforces this point by emphasizing environmental protection and productivity while neglecting the operational pathways to embed IK in climate policy planning.

Cameroon presents a similar case of partial inclusion. Its National Adaptation Plan recognizes the role of community knowledge in natural resource management, suggesting a general awareness of IK's relevance. However, the policy lacks specific mechanisms for incorporating IK into CSA methodologies, particularly across diverse agro-ecological zones. The plan stops short of delineating how traditional practices such as local crop rotation systems or customary land use regulations can be integrated into climate-resilient agriculture. As noted by the African Development Bank (2009), while the adaptation narrative in Cameroon acknowledges community-based adaptation, it is not adequately translated into operational CSA guidelines. This disconnect between acknowledgement and action limits the policy's effectiveness and undermines its capacity to engage rural farming communities who already rely on traditional knowledge systems for survival.

In contrast, countries such as Niger and Chad face even more significant challenges in formal policy recognition of IK. Despite widespread use of traditional agricultural practices at the local level including techniques like planting pits and traditional pest management these countries lack institutional structures to support the translation of local knowledge into policy action. As the International Institute for Environment and Development (IIED, 2008) notes, institutional fragility, resource limitations, and the absence of participatory policy frameworks in these countries hinder the formal engagement with IK.

This not only marginalizes local knowledge holders but also deprives national CSA strategies of proven, community-embedded tools for coping with climate variability. The result is a top-down policy orientation that lacks contextual grounding and risks implementation failure due to its detachment from the lived realities of rural farmers.

What emerges across these national contexts is a pattern of symbolic recognition of Indigenous Knowledge without substantive integration into the design, implementation, or evaluation of CSA programs. This institutional hesitancy reflects deeper issues of epistemological bias, where scientific or externally developed knowledge systems are prioritized over experiential, community-derived approaches. Bridging this gap requires not merely rhetorical inclusion of IK but structural reforms that embed indigenous practices into CSA policy frameworks supported by clear operational mechanisms, participatory governance models, and targeted capacity-building. Without this, CSA policies will continue to underutilize a critical resource for achieving resilience in the face of climate change (Nwajiuba et al., 2015; Federal Ministry of Agriculture and Rural Development, 2014; African Development Bank, 2009; IIED, 2008).

4.2 Indigenous Knowledge as a Vital Component of Climate Adaptation

Indigenous Knowledge (IK) remains a cornerstone of agricultural adaptation, particularly in ecologically fragile and resource-constrained environments. In regions with marginal agro-ecologies, such as northern Nigeria and the Sahel, local communities continue to rely on traditional systems that have evolved to manage climatic uncertainties. These practices are not only context-specific but also provide practical and tested strategies for resilience. For instance, Shiferaw et al. (2014) highlight the use of traditional seed banks in Nigeria, where farmers preserve millet and sorghum landraces. These varieties are genetically diverse and drought-tolerant, allowing farmers to maintain crop yields even under prolonged dry conditions. The preservation of these seeds is not merely a cultural act; it is a deliberate adaptive strategy that ensures food security and biodiversity conservation.

In the Sahelian regions of Niger, traditional zai pits represent a proven indigenous method of improving water retention and soil fertility. These pits, dug manually and filled with compost, enable water to infiltrate and be stored around plant roots, significantly increasing water availability by 30–50% during dry spells (Moussa et al., 2016). This technique not only boosts productivity on degraded lands but also allows communities to reclaim otherwise abandoned farmland, contributing to both adaptation and land restoration.

Another key component of IK is seasonal forecasting using environmental indicators such as wind patterns, cloud formation, animal behavior, and plant phenology. In many rural areas, where access to meteorological services is limited or unreliable, these indigenous forecasting systems guide planting and harvesting decisions. According to Hansen (2022), such methods offer reliable, localized predictions that farmers trust and act upon. When combined with modern CSA technologies like improved irrigation or early maturing seed varieties indigenous forecasting improves yield stability and reduces exposure to climate risks.

Together, these practices demonstrate that IK is not supplementary but fundamental to climate adaptation strategies in many Sub-Saharan agricultural systems.

4.3 Barriers to Effective Integration and Regional Variation

The integration of Indigenous Knowledge (IK) into Climate-Smart Agriculture (CSA) across Sub-Saharan Africa (SSA) continues to be hindered by deeply embedded socio-political, epistemological, and institutional challenges. A primary barrier is the systemic marginalization of IK, rooted in the dominance of Western scientific epistemologies that often devalue local knowledge as unscientific or outdated. This epistemological bias, described by Makondo and Thomas (2018) and Fair (2018), manifests in national agricultural and climate policies that prioritize technological innovations while overlooking context-specific, community-derived solutions. In Nigeria, this dynamic is evident in the erosion of Yoruba sacred ecological practices, where urban expansion and policy neglect have led to the decline of sacred groves and associated biodiversity (Leal Filho et al., 2025). Similarly, in Kenya and Tanzania, Maasai pastoralism, which relies on rotational grazing to maintain rangeland health, is increasingly undermined by land insecurity and modernization pressures.

Colonial legacies and globalization have further accelerated the erosion of IK through the suppression of indigenous languages and the weakening of oral knowledge transmission systems. Ngoepe and Bhebhe (2024) and Derhemi and Moseley (2023) emphasize that the loss of linguistic diversity is inseparable from the loss of ecological knowledge, as many adaptive practices are encoded in local languages and narratives. This cultural erosion is compounded by donor-driven adaptation projects, which often impose externally designed solutions without consulting indigenous communities, reinforcing feelings of mistrust and alienation. As McNamara et al. (2020) observe, the exclusion of indigenous voices in project design undermines both legitimacy and effectiveness, creating a gap between scientific institutions and local actors.

Despite these challenges, there are promising models that demonstrate the value of integrating IK with scientific approaches. For instance, Farmer-Managed Natural Regeneration (FMNR) in Niger and rainwater harvesting systems in Ethiopia have successfully combined local practices with scientific validation to enhance resilience and productivity. These successes underline the potential for co-production of knowledge, but such integration remains rare without institutional support. Barriers like the absence of intellectual property protections, gendered exclusion, and youth disinterest further threaten the sustainability of IK transmission (Lwamba et al., 2022). Meaningful integration thus requires inclusive governance frameworks, reform in educational systems that recognize IK as legitimate knowledge, and platforms that elevate indigenous actors as equal stakeholders in CSA design and implementation.

4.4 Policy and Practice Recommendations

Despite the critical role Indigenous Knowledge (IK) plays in enhancing the climate resilience of agricultural systems in Sub-Saharan Africa, it remains significantly underutilized in Climate-Smart Agriculture (CSA) policies and practices. Effective integration demands a paradigm shift that values IK not as an auxiliary component but as a foundational pillar of agricultural adaptation. Given the socio-ecological diversity of countries like Nigeria, Niger, Chad, Cameroon, and Benin, these recommendations aim to establish frameworks that bridge traditional practices with modern CSA interventions in equitable, inclusive, and practical ways.

i. Formalize Indigenous Knowledge

To fully harness the potential of IK, national policies must explicitly recognize and protect it as a formal knowledge system within CSA frameworks. This involves creating legal structures that ensure intellectual property rights, acknowledging IK holders as rightful custodians of their knowledge. Drawing on lessons from the health and biotechnology sectors, where traditional knowledge has been protected and documented, such protections must be extended to agricultural practices (Bhattacharya & Saha, 2011). This formalization should include establishing community-led registries, ethical access protocols, and benefit-sharing mechanisms, ensuring IK is preserved and respected.

ii. Promote Participatory Approaches

Effective CSA must be co-designed through inclusive, participatory processes that involve indigenous communities from the outset. Rather than top-down models, governments and development agencies should prioritize frameworks where farmers, IK holders, scientists, and policymakers collaborate to design, test, and refine CSA solutions. Participatory action research and community-led innovation platforms have shown high potential in enhancing both adoption and local ownership of CSA practices (Kangogo et al., 2021). This approach ensures interventions align with local values, practices, and realities.

iii. Strengthen Institutional Capacities

Integrating IK into CSA requires robust institutional support. Governments must invest in building the capacities of extension services, community-based organizations, and local research institutes to act as intermediaries for knowledge exchange. Institutions must be equipped to document, validate, and disseminate IK alongside scientific knowledge (Kountios et al., 2024). Training programs for extension officers should include cultural competence and participatory facilitation to strengthen trust and cooperation with local communities.

iv. Contextualize CSA Solutions

CSA technologies should be tailored to local cultural and ecological contexts rather than imposed uniformly. This means adapting interventions to reflect indigenous preferences, practices, and farming systems. Respecting traditional land-use patterns, seasonal calendars, and agro-ecological indicators ensures better integration and long-term sustainability (Mustonen et al., 2022). Localized CSA design enhances not only resilience but also cultural relevance and community acceptance.

v. Foster Regional Collaboration

Finally, fostering regional collaboration is essential. Climate change impacts in the Sahel and West African region do not respect national borders. Collaborative platforms involving Nigeria, Niger, Chad, Cameroon, and Benin can facilitate knowledge sharing, joint research, and policy harmonization. Transboundary learning exchanges will help scale successful IK-based CSA innovations and address common challenges through collective action and shared best practices.

Collectively, these strategies aim to reposition Indigenous Knowledge at the heart of climate adaptation policy, ensuring its survival and its role in shaping equitable, sustainable agricultural futures.

5. CONCLUSION

This study highlights that the marginalization of Indigenous Knowledge (IK) in Climate-Smart Agriculture (CSA) frameworks across Sub-Saharan Africa constitutes not merely a policy oversight, but a structural limitation that constrains the scalability and contextual relevance of adaptation strategies. Through thematic analysis of policy documents, institutional reports, and empirical literature, the study affirms that CSA's fragmented implementation reflects epistemological asymmetries privileging technocratic solutions over place-based knowledge. The failure to embed IK in CSA programming perpetuates systemic exclusion, eroding adaptive capacities, especially among smallholder farmers. However, where co-production models and participatory governance have been initiated, as in select agroforestry and FMNR initiatives, outcomes are demonstrably more resilient and locally anchored. To reposition CSA as both socially legitimate and ecologically effective, IK must be reconstituted as a core epistemic asset, protected, formalized, and institutionally mainstreamed. Bridging this gap demands recalibrated governance that shifts from extractive knowledge flows to reciprocal, embedded collaborations. Ultimately, only through structural reform that institutionalizes IK as a co-equal pillar in CSA design can Sub-Saharan Africa transcend its current policy inertia and realize climate-resilient food systems that are both culturally consonant and scientifically robust.

REFERENCES

Adade Williams, P., Sikutshwa, L., & Shackleton, S. (2020). Acknowledging Indigenous and Local Knowledge to Facilitate Collaboration in Landscape Approaches—Lessons from a Systematic Review. *Land*, *9*(9), 331. https://doi.org/10.3390/land9090331

African Development Bank. (2009). Lake Chad Sustainable Development Support Program (PRQDEBALT). African Development Bank: Tunis.

Ahmed, S. K., Mohammed, R. A., Nashwan, A. J., Ibrahim, R. H., Abdalla, A. Q., Ameen, B. M. M., & Khidhir, R. M. (2025). Using thematic analysis in qualitative research. *Journal of Medicine, Surgery, and Public Health*, *6*(6), 100198. https://doi.org/10.1016/j.glmedi.2025.100198

Ajani, E. N., Mgbenka, R. N., & Okeke, M. N. (2013). Use of indigenous knowledge as a strategy for climate change adaptation among farmers in Sub-Saharan Africa: Implications for policy. *Asian Journal of Agricultural Extension, Economics & Sociology, 2*(1), 23-40. https://doi.org/10.9790/2380-08210104

Amare, G., & Gacheno, D. (2021). Indigenous knowledge for climate smart agriculture—A review. *International Journal of Food Science and Agriculture, 5*(2), 332–338. https://doi.org/10.26855/ijfsa.2021.06.019

Andrianarimanana, M. H., & Yongjian, P. (2021). Importance of the Improvement in the Agricultural Technology of Sub-Saharan Africa on Local Economic Development and International Trade. *Sustainability*, *13*(5), 2555. https://doi.org/10.3390/su13052555

Ariom, T. O., Dimon, E., Nambeye, E., Diouf, N. S., Adelusi, O. O., & Boudalia, S. (2022). Climate-smart agriculture in African countries: A review of strategies and impacts on smallholder farmers. *Sustainability, 14*(11), 11370. https://doi.org/10.3390/su14111370

Ayanlade, A., Oluwaranti, A., Ayanlade, O. S., Borderon, M., Sterly, H., Sakdapolrak, P., Jegede, M. O., Weldemariam, L. F., & Ayinde, A. F. O. (2022). Extreme climate events in sub-Saharan Africa: A call for improving agricultural technology transfer to enhance adaptive capacity. *Climate Services*, *27*, 100311. https://doi.org/10.1016/j.cliser.2022.100311

Badji, A., Binam, J. N., & Reij, C. (2020). Regreening Niger: Climate-Smart Agriculture practices in the Sahel. *Frontiers in Global Change, 3*, 571679. https://doi.org/10.3389/ffgc.2020.571679.

Bhattacharya, S., & Saha, C. N. (2011). Intellectual Property rights: an Overview and Implications in Pharmaceutical Industry. *Journal of Advanced Pharmaceutical Technology & Research*, *2*(2), 88. ncbi.

Bhatnagar, S., Chaudhary, R., Sharma, S., Janjhua, Y., Thakur, P., Sharma, P., & Keprate, A. (2024). Exploring the dynamics of climate-smart agricultural practices for sustainable resilience in a changing climate. *Environmental and Sustainability Indicators*, *24*, 100535. https://doi.org/10.1016/j.indic.2024.100535

Bryan, E., Alvi, M. F., Huyer, S., & Ringler, C. (2024). Addressing gender inequalities and strengthening women's agency to create more climate-resilient and sustainable food systems. *Global Food Security*, *40*, 100731–100731. https://doi.org/10.1016/j.gfs.2023.100731

Chevallier, R. (2024). Strengthening Africa's climate-smart agriculture and food systems through enhanced policy coherence and coordinated action. *South African Journal of International*

Affairs/the South African Journal of International Affairs, 1–24. https://doi.org/10.1080/10220461.2024.2318712

CIAT, ICRISAT, & World Bank. (2021). *Climate-smart agriculture in Chad: CSA country profiles for Africa*. International Center for Tropical Agriculture (CIAT); International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); World Bank. https://doi.org/10.2499/9780896292048

CIAT, & BFS/USAID. (2016). *Climate-smart agriculture in Senegal: CSA country profiles for Africa series*. International Center for Tropical Agriculture (CIAT); Bureau for Food Security, United States Agency for International Development (BFS/USAID). https://doi.org/10.2499/9780896292048

Danjuma, M. N., & Mohammed, S. (2015). Zai pits system: A catalyst for restoration in the drylands. *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS), 8*(2), 1-4. https://doi.org/10.9790/2380-08210104

Derhemi, E., & Moseley, C. (2023). *Endangered languages in the 21st century*. Routledge

Dillon, A., Mueller, V., & Salau, S. (2025). *Migratory responses to agricultural risk in Northern Nigeria*. Cgiar.org; International Food Policy Research Institute. https://cgspace.cgiar.org/items/0c983267-9340-4972-865c-a5c23fd7f2a4

Dossa, K. F., Bissonnette, J.-F., Barrette, N., Bah, I., & Miassi, Y. E. (2025). Projecting climate change impacts on Benin's cereal production by 2050: A SARIMA and PLS-SEM analysis of FAO data. *Climate, 13*(1), 19. https://doi.org/10.3390/cli13010019

Fair, H. (2018). Three stories of Noah: Navigating religious climate change narratives in the Pacific Island region. *Geo: Geography and Environment*, 5(2), e00068. https://doi.org/10.1002/geo2.68

FAO, ICRISAT, & CIAT. (2018). *Climate-smart agriculture in Benin: CSA country profiles for Africa series*. International Center for Tropical Agriculture (CIAT); International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/3/i9396e/i9396e.pdf

Faye, A., Niang, I., & Faye, D. (2020). Climate change and cereal production in sub-Saharan Africa: A focus on Benin. *Climate*, 13(1), 19. https://doi.org/10.3390/cli13010019

Federal Ministry of Agriculture and Rural Development (FMARD). (2014). *Nigeria's Agricultural Transformation Agenda* (ATA). Nigerian Government Publications.

Gabriel, I., Olajuwon, F., Klauser, D., Michael, B., & Renn, M. (2023). State of climate-smart agriculture (CSA) practices in the North Central and Northwest zones of Nigeria. *CABI Agriculture and Bioscience, 4*(33). https://doi.org/10.1186/s43170-023-00156-4

Hansen, J. W. (2002). Applying seasonal climate prediction to agricultural production. *Agricultural Systems*, *74*(3), 305–307. https://doi.org/10.1016/s0308-521x(02)00042-2

IIED. (2008). *Community management of natural resources in Africa*. Natural Resource Issues No. 18. International Institute for Environment and Development.

Kaba, A. J. (2020). Explaining Africa's Rapid Population Growth, 1950 to 2020: Trends, Factors, Implications, and Recommendations. *Sociology Mind*, *10*(04), 226–268. https://doi.org/10.4236/sm.2020.104015

Kabato, W. S., Getnet, G. T., Sinore, T., Nemeth, A., & Molnár, Z. (2025). Towards climate-smart agriculture: Strategies for sustainable agricultural production, food security, and greenhouse gas reduction. *Agronomy, 15*(3), 565. https://doi.org/10.3390/agronomy15030565

Kangogo, D., Dentoni, D., & Bijman, J. (2021). Adoption of climate-smart agriculture among smallholder farmers: Does farmer entrepreneurship matter? *Land Use Policy*, *109*, 105666. https://doi.org/10.1016/j.landusepol.2021.105666

Kimengsi, J. N., Ndikebeng, K. R., & Mukong, A. K. (2022). Community-based forest management institutions in Cameroon: Dynamics and compliance determinants. *Journal of Land Use Science, 17*(1), 629-647. https://doi.org/10.1080/1747423X.2022.2136277.

Kom, Z., & Nthaduleni S. N. (2024). Indigenous and Local Knowledge: Instruments towards Achieving SDG2: A Review in an African Context. *Sustainability*, *16*(20), 9137–9137. https://doi.org/10.3390/su16209137

Kountios, G., Kanakaris, S., Moulogianni, C., & Bournaris, T. (2024). Strengthening AKIS for Sustainable Agricultural Features: Insights and Innovations from the European Union: A Literature Review. *Sustainability*, *16*(16), 7068. https://doi.org/10.3390/su16167068

Leal Filho, W., Lütz, J. M., Totin, E., Ayal, D., & Mendy, E. (2025). Obstacles to implementing indigenous knowledge in climate change adaptation in Africa. *Journal of Environmental Management*, 373, 123678. https://doi.org/10.1016/j.jenvman.2024.123678

Lwamba, E., Shisler, S., Ridlehoover, W., Kupfer, M., Tshabalala, N., Nduku, P., Langer, L., Grant, S., Sonnenfeld, A., Anda, D., Eyers, J., & Snilstveit, B. (2022). Strengthening women's empowerment and gender equality in fragile contexts towards peaceful and inclusive societies: A systematic review and meta-analysis. *Campbell Systematic Reviews*, *18*(1), 1–264. https://doi.org/10.1002/cl2.1214

Makondo, C. C., & Thomas, D. S. G. (2018). Climate change adaptation: Linking indigenous knowledge with Western science for effective adaptation. *Environmental Science & Policy*, 88, 83–91. https://doi.org/10.1016/j.envsci.2018.06.014

Marie Chimi, P., Armand Mala, W., Manga Essouma, F., Karimou Ngamsou, A., Hermann Matick, J., Louis Fobane, J., Preasious Funwi, F., Kouoguem Kamdem, M. E., Feunang Nganmegni, L. F., & Martin Bell, J. (2023). Family Farming Systems in Northern Central Cameroon: Challenges and Prospects for Food Security. *European Scientific Journal, ESJ*, *19*(6), 115. https://doi.org/10.19044/esj.2023.v19n6p115

Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability, 13*(3), 1318. https://doi.org/10.3390/su13031318

Mbow, C. (2020). Use It Sustainably or Lose It! The Land Stakes in SDGs for Sub-Saharan Africa. *Land*, *9*(3), 63. https://doi.org/10.3390/land9030063

McNamara, K. E., Clissold, R., Westoby, R., Piggott-McKellar, A. E., Kumar, R., Clarke, T., Namoumou, F., Areki, F., Joseph, E., Warrick, O., & Nunn, P. D. (2020). An assessment of community-based adaptation initiatives in the Pacific Islands. *Nature Climate Change*, 10(7), 628–639. https://doi.org/10.1038/s41558-020-0813-1

Melash, A. A., Bogale, A. A., Migbaru, A. T., Chakilu, G. G., Percze, A., Ábrahám, É. B., & Mengistu, D. K. (2023). Indigenous agricultural knowledge: A neglected human based resource for sustainable crop protection and production. *Heliyon*, *9*(1), e12978. https://doi.org/10.1016/j.heliyon.2023.e12978

Moahi, K. H. (2005). Documenting indigenous knowledge systems in Africa: Prospects and challenges. *ESARBICA Journal, 24*, 63-73.

Mogaka, B. O., Bett, H. K., & Ng'ang'a, S. K. (2021). Socioeconomic factors influencing the choice of climate-smart soil practices among farmers in western Kenya. *Journal of Agriculture and Food Research*, *5*, 100168. https://doi.org/10.1016/j.jafr.2021.100168

Moussa, B. M., Diouf, A., Abdourahamane, S. I., Axelsen, J. A., Karimou J. M. Ambouta, & Mahamane, A. (2016). Combined Traditional Water Harvesting (Zai) and Mulching Techniques Increase Available Soil Phosphorus Content and Millet Yield. *Journal of Agricultural Science*, *8*(4), 126–126. https://doi.org/10.5539/jas.v8n4p126

Mustonen, T., Harper, S., Pecl, G., Castán Broto, V., Lansbury, N., Okem, A., Ayanlade, A., Dawson, J., Harris, P., & Feodoroff, P. (2022). *The role of indigenous knowledge and local knowledge in understanding and adapting to climate change*. In IPCC, Climate Resilient Development Pathways, Chapter 18. Retrieved from https://www.researchgate.net/publication/362432216

Mutenje, M. J. (2021). *Assessment of the evidence base on adaptation benefits of CSA options across timescales and geographies in West Africa*. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://ccafs.cgiar.org/donors

Ngoepe, M. S., & Bhebhe, S. (2024). *Indigenous archives in postcolonial contexts: Recalling the pasts*. Routledge. https://doi.org/10.4324/9781003277989

Naeem, M., Ozuem, W., Howell, K. E., & Ranfagni, S. (2023). A step-by-step Process of Thematic Analysis to Develop a Conceptual Model in Qualitative Research. *International Journal of Qualitative Methods*, *22*(1), 1–18. Sagepub. https://doi.org/10.1177/16094069231205789

Nwajiuba, C., Tambi, E. N., & Bangali, S. (2015). *State of knowledge on CSA in Africa: Case studies from Nigeria, Cameroon, and the Democratic Republic of Congo*. Forum for Agricultural Research in Africa. [ISBN: 978-9988-2-3782-9]

Ouédraogo, M., Houessionon, P., Zougmoré, R. B., & Partey, S. T. (2019). Uptake of climate-smart agricultural technologies and practices: Actual and potential adoption rates in the climate-smart village site of Mali. *Sustainability, 11*(17), 4710. https://doi.org/10.3390/su11174710

Ogisi, O. D., & Begho, T. (2023). Adoption of climate-smart agricultural practices in sub-Saharan Africa: A review of the progress, barriers, gender differences and recommendations. *Farming System*, *1*(2), 100019. https://doi.org/10.1016/j.farsys.2023.100019

Olabanji, M. F., & Chitakira, M. (2025). The Adoption and Scaling of Climate-Smart Agriculture Innovation by Smallholder Farmers in South Africa: A Review of Institutional Mechanisms, Policy Frameworks and Market Dynamics. *World*, *6*(2), 51. https://doi.org/10.3390/world6020051

Shiferaw, B., Tesfaye, K., Kassie, M., Abate, T., Prasanna, B. M., & Menkir, A. (2014). Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options. *Weather and Climate Extremes*, *3*, 67–79. https://doi.org/10.1016/j.wace.2014.04.004

Sithole, A. & Olorunfemi, O. A. (2024). Sustainable Agricultural Practices in Sub-Saharan Africa: A Review of Adoption Trends, Impacts, and Challenges Among Smallholder Farmers. *Sustainability*, *16*(22), 9766–9766. https://doi.org/10.3390/su16229766

Sow, B. L., Bah, A., Sow, P., & Yaffa, S. (2020). Farmers' awareness and adaptation to climate change in Kaffrine region of Senegal. *Journal of Environment and Earth Science, 8*(4), 51-59. https://doi.org/10.7176/jees/8-4-08

Tambe, E. B., Anukwonke, C. C., Mbuka-Nwosu, I. E., & Abazu, C. I. (2023). Changes in the agriculture sector that are essential to mitigate and adapt to climate changes. In S. A. Bandh (Ed.), *Strategizing agricultural management for climate change mitigation and adaptation* (pp. 89–112). Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-031-32789-6_6

Thompson, H. E., Berrang-Ford, L., & Ford, J. D. (2010). Climate Change and Food Security in Sub-Saharan Africa: A Systematic Literature Review. *Sustainability*, *2*(8), 2719–2733. https://doi.org/10.3390/su2082719

Thothela, S. N. S., Kola, E., Dalu, M. T. B., & Ndhlovu, P. T. (2025). Indigenous knowledge and utilisation of *Strychnos spinosa* Lam. in Sub-Saharan Africa: A systematic review of its medicinal, nutritional, and cultural significance. *Diversity, 17*(4), 228. https://doi.org/10.3390/d17040228

Tume, S. J. P., Kimengsi, J. N., & Fogwe, Z. N. (2019). Indigenous Knowledge and Farmer Perceptions of Climate and Ecological Changes in the Bamenda Highlands of Cameroon: Insights from the Bui Plateau. *Climate*, *7*(12), 138. https://doi.org/10.3390/cli7120138

Warner, D., Moonsammy, S., & Joseph, J. (2022). Factors that influence the use of climate information services for agriculture: A systematic review. *Climate Services, 28*, 100336. https://doi.org/10.1016/j.cliser.2022.100336

Yegbemey, R., et al. (2018). Impacts of climate change on cereal crop production in Benin. *Journal of Climate Adaptation*, 12(2), 334-348. https://doi.org/10.1007/jclimate120233

Zougmoré, R., Segnon, A. C., & Thornton, P. (2023). Harnessing indigenous knowledge and practices for effective adaptation in the Sahel. *Current Opinion in Environmental Sustainability*, *65*, 101389. https://doi.org/10.1016/j.cosust.2023.101389