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INDIGENOUS KNOWLEDGE SYSTEMS AND CLIMATE SMART AGRICULTURE IN AFRICA: FROM LOCAL PRACTICES TO CONTEMPORARY RELEVANCE

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Abstract

Indigenous Knowledge Systems (IKS) have long supported agricultural production in Africa by providing locally adapted approaches to natural resource management, food production, and environmental stewardship. With climate change increasing the frequency of droughts, floods, erratic rainfall, and land degradation, indigenous knowledge is receiving renewed attention as a key component of sustainable and Climate-Smart Agriculture (CSA). This review examines indigenous practices such as crop rotation, intercropping, agroforestry, mixed farming, mulching, indigenous seed conservation, soil and water conservation, and traditional weather forecasting. It highlights their contributions to climate resilience, biodiversity conservation, ecosystem sustainability, and rural livelihoods. Drawing on empirical evidence from several African countries, the review demonstrates that Indigenous Knowledge Systems remain essential for strengthening adaptive capacity and achieving the goals of Climate-Smart Agriculture. It concludes that integrating scientifically validated indigenous knowledge with modern agricultural innovations, climate information services, and supportive policies offers a practical pathway to improving food security, environmental sustainability, and climate resilience across Africa.

Keywords: Indigenous Knowledge Systems, Climate-Smart Agriculture, Sustainable Agriculture, Climate Resilience, Indigenous Agricultural Practices

Introduction

Agriculture remains the backbone of most African economies, providing livelihoods, employment, and food for millions of people. However, the sector is increasingly threatened by climate change, manifested through rising temperatures, erratic rainfall, prolonged droughts, floods, land degradation, and biodiversity loss, all of which have adversely affected agricultural productivity and food security. Since over 95% of agriculture in sub-Saharan Africa is rain-fed, smallholder farmers remain particularly vulnerable to climate variability and extreme weather events (Amare & Gacheno, 2021). These challenges have intensified the search for sustainable and locally adaptable agricultural approaches capable of strengthening resilience while ensuring environmental sustainability. Consequently, Indigenous Knowledge

Systems (IKS) have received renewed attention as practical, cost-effective, and environmentally sound approaches for addressing contemporary agricultural and climate challenges (Chavula, 2021). Indigenous Knowledge Systems comprise the cumulative knowledge, skills, beliefs, and practices developed by indigenous communities through generations of interaction with their environment. In African agriculture, IKS encompasses practices such as crop rotation, intercropping, agroforestry, mixed farming, mulching, terracing, contour ploughing, indigenous weather forecasting, water conservation, soil fertility management, and the preservation of indigenous seed varieties. These practices have enabled farming communities to sustainably utilize natural resources, conserve biodiversity, improve soil fertility, enhance water-use efficiency, and adapt to changing climatic conditions long before modern climate adaptation strategies emerged (Amare & Gacheno, 2021; Rosati *et al*., 2021). Today, many of these indigenous practices are recognized as integral components of Climate-Smart Agriculture (CSA), which seeks to improve agricultural productivity, enhance resilience, and reduce greenhouse gas emissions where possible (Chavula, 2021).

Despite their proven effectiveness, Indigenous Knowledge Systems remain underutilized within formal agricultural research, extension services, and climate policies due to inadequate documentation, rapid modernization, and declining intergenerational knowledge transfer. Nevertheless, increasing empirical evidence from countries such as Ethiopia, Kenya, Nigeria, Ghana, Tanzania, Zimbabwe, Malawi, and South Africa demonstrates that integrating indigenous knowledge with scientific innovations can significantly strengthen sustainable agriculture and climate resilience (Belachew *et al*., 2020; Chavula &Turyasingura, 2022). Against this background, this review examines the contribution of Indigenous Knowledge Systems to sustainable agriculture and Climate-Smart Agriculture and explores their relevance in enhancing climate resilience in contemporary Africa.

Indigenous Agricultural Practices in Nigeria

Traditional Crop Cultivation

Traditional crop cultivation in Nigeria is marked by techniques refined over generations to optimize yield, ensure sustainability, and maintain soil fertility.

Yam Mounds in Igbo Farming

The Igbo people of southeastern Nigeria have mastered yam cultivation using mounds, a method involving raised heaps of soil for planting yam setts. These mounds improve drainage, reduce soil erosion, and enhance root aeration, contributing to healthier yam tubers. This approach also supports intercropping, allowing crops like maize and beans to grow alongside yams, which optimizes land use and enhances biodiversity.

Terrace Farming among the Berom People

On the Jos Plateau, the Berom people employ terrace farming, a technique that involves constructing stepped levels on slopes. These terraces effectively mitigate soil erosion, conserve water, and foster

micro-environments conducive to a variety of crops. By converting hilly terrain into productive farmland, the Berom have successfully cultivated sustainable crops like millet, sorghum, and vegetables (Olaniyan & Govender, 2023).

Soil and Water Conservation Techniques

Preserving soil and water is fundamental to indigenous agricultural methods, and essential for maintaining sustainable productivity and ecological harmony.

Mulching

Mulching is a common practice throughout Nigeria, where organic materials such as leaves, straw, and crop residues are applied to the soil surface (Ojo *et al*., 2021). This technique helps to retain soil moisture, suppress weeds, and improve soil fertility as the organic matter decomposes. It is especially valuable in arid and semi-arid regions where water conservation is essential.

Contour Bunding

Contour bunding is a method used in northern Nigeria, where embankments are built along the contour lines of slopes to minimize water runoff and soil erosion. This approach slows down water flow, enabling it to infiltrate the soil and replenish groundwater. It is particularly beneficial in regions with irregular and scarce rainfall patterns.

Use of Organic Materials

In Nigeria, farmers frequently enhance soil fertility through traditional methods involving organic materials like compost and animal manure (Obinna, 2019). They create compost heaps by layering plant residues, kitchen scraps, and animal manure, which decompose to produce nutrient-rich humus. This practice enriches the soil with vital nutrients, enhances soil structure, and supports robust crop growth.

Livestock Management

Livestock management practices in Nigeria are diverse and tailored to different ecological zones, aiming to sustainably utilize resources and support community livelihoods.

Traditional Herding Practices

Nomadic and semi-nomadic pastoralists, like the Fulani in Nigeria, employ traditional herding methods that include seasonal migrations to find pasture and water. These practices rely on indigenous knowledge of grazing patterns, animal behavior, and environmental signals. By practicing rotational grazing and controlled movement, they mitigate overgrazing, facilitate vegetation regeneration, and maintain the health of their livestock (Olutumise *et al*., 2023).

Fodder Preservation Methods

In various regions of Nigeria, farmers utilize traditional methods to preserve fodder, ensuring livestock feed availability during the dry season. Techniques such as haymaking and silage preparation involve drying or fermenting green forage for storage as fodder. These practices are crucial for sustaining livestock nutrition and productivity throughout the year, especially in areas with distinct wet and dry seasons.

Indigenous Post-Harvest Management and Storage Systems

Post-harvest management is a vital component of Indigenous Knowledge Systems (IKS), ensuring that agricultural produce is preserved, protected, and made available for consumption and exchange beyond the harvesting period. Indigenous

storage and preservation practices in Nigeria reflect a deep understanding of local environmental conditions, pest dynamics, and material use. These practices complement production systems and contribute significantly to food security, sustainability, and rural livelihoods (Radcliffe *et al.*, 2020; Negi *et al*., 2021).

Traditional Grain Storage Structures

In many parts of northern Nigeria, farmers utilize traditional granaries constructed from mud, clay, and plant materials such as grasses and reeds. These structures are often elevated to minimize moisture intrusion and rodent attacks, while their design allows for natural aeration, thereby reducing the risk of mold development and pest infestation. The use of botanical materials such as neem leaves and ash as grain protectants demonstrates indigenous innovation in pest management and aligns with environmentally sustainable practices (Ojo *et al*., 2021; Tahat *et al*., 2020).

Yam Barns and Root Crop Storage

Among southern Nigerian communities, particularly the Igbo, yam barns are widely used for the storage of yam tubers. These structures promote adequate ventilation and reduce spoilage, thereby preserving the quality of the produce over extended periods. Similarly, root crops such as cassava are often processed into more durable forms like garri or flour to enhance shelf life and reduce post-harvest losses. These practices illustrate the integration of post-harvest strategies into indigenous farming systems, ensuring efficient resource utilization and reduced waste (Olaniyan and Govender, 2023).

Drying and Smoking Techniques

Drying and smoking are common preservation methods used across Nigeria, particularly in coastal and riverine communities. These techniques reduce the moisture content of agricultural produce, thereby inhibiting microbial growth and extending shelf life. For example, the smoking of fish and drying of crops are widely practiced and serve both subsistence and commercial purposes. Such methods demonstrate how indigenous practices enhance value addition and reduce post-harvest losses, contributing to household income and food availability (Sharma *et al*., 2020; Khan *et al*., 2021).

Use of Indigenous Materials and Botanical Preservatives

Traditional storage systems frequently rely on locally available materials such as clay pots, gourds, woven baskets, and calabashes. These materials help regulate temperature and humidity, thereby creating favorable storage conditions. Additionally, the use of botanical preservatives, such as neem leaves, pepper, and wood ash, helps protect stored produce from pests without the adverse environmental effects associated with synthetic chemicals. This reflects the ecological sustainability embedded in Indigenous Knowledge Systems (Tahat *et al*., 2020; Radcliffe *et al*., 2020).

Socio-Economic Importance of Indigenous Storage Systems

Indigenous post-harvest storage practices play a crucial role in enhancing household food security by minimizing losses and ensuring the availability of food during off-season periods. They also enable farmers to store produce and sell when market conditions are favorable, thereby improving income levels. Furthermore, these practices are embedded in cultural traditions and knowledge-sharing systems,

supporting community resilience and intergenerational transfer of knowledge (Phiri *et al*., 2022).

Critical Evaluation of Indigenous and Modern Post-Harvest Storage Systems

Indigenous post-harvest storage systems are cost-effective, environmentally sustainable, and well adapted to local conditions, making them suitable for smallholder farmers with limited resources (Tahat *et al*., 2020; Radcliffe *et al*., 2020). However, their effectiveness may be reduced by pest infestation, high humidity, prolonged storage periods, and the absence of standardized construction practices, particularly under changing climatic conditions (Negi *et al*., 2021). Modern storage technologies, such as hermetic storage systems and improved silos, provide better protection against pests and environmental factors, thereby reducing post-harvest losses, although they often require substantial financial investment, technical expertise, and supporting infrastructure (Khan *et al*., 2021). Consequently, scholars advocate for integrating indigenous knowledge with modern scientific innovations to develop context-specific and sustainable storage systems that improve efficiency while preserving local cultural practices and environmental sustainability (Latulippe & Klenk, 2020).

Case Studies from Other African Regions

East Africa

Maasai Grazing Practices and Their Sustainability

The Maasai people of East Africa, mainly residing in Kenya and Tanzania, have developed advanced grazing techniques that illustrate sustainable livestock management. Traditionally, they practice transhumance and seasonal migration of livestock in search of water and pasture. This movement prevents overgrazing and allows vegetation in grazed areas to regenerate. The Maasai possess deep ecological knowledge of rangelands, including the identification of valuable forage plants and an understanding of the carrying capacity of diverse ecosystems. Their herding methods, such as rotational grazing and maintaining mixed herds of cattle, goats, and sheep, enhance the resilience of their pastoral systems amid fluctuating climatic conditions (Marty *et al*., 2022).

West Africa (excluding Nigeria)

Traditional Shea Butter Processing in Ghana

In Ghana, traditional shea butter processing is a crucial indigenous practice, especially among women in the Northern regions (Tulashie *et al*., 2020). The process involves several stages: gathering shea nuts, drying, roasting, grinding, and ultimately kneading to extract the butter. This traditional method, handed down over generations, guarantees the production of premium shea butter while minimizing environmental impact. The use of these age-old techniques also promotes community unity and offers substantial economic advantages, particularly benefiting women who often oversee these processes. Shea butter is a vital commodity in both local and global markets, prized for its applications in food, cosmetics, and pharmaceuticals.

Southern Africa

Zulu Irrigation Methods and Their Adaptation to Modern Agriculture

The Zulu people of South Africa have a long history of using traditional irrigation methods, especially in the fertile valleys of KwaZulu-Natal. They employ techniques such as furrow irrigation, where channels are created to direct water from streams to their fields. This method is highly efficient in water usage and is well-suited to the local topography and climate. Recently, there has been an effort to merge these traditional practices with modern agricultural technologies. This includes incorporating low-cost drip irrigation systems alongside the furrow method, which improves water efficiency and crop yields. The combination of indigenous knowledge with contemporary practices showcases the potential for sustainable agricultural development that honors and utilizes local expertise.

Conservation of Biodiversity and Traditional Knowledge

Importance of Preserving Local Biodiversity through Traditional Agricultural Practices

Traditional agricultural practices play a vital role in conserving biodiversity by promoting crop diversity, agroforestry, and the sustainable use of natural resources. Indigenous farming systems such as intercropping, polyculture, and the cultivation of indigenous crop varieties enhance genetic diversity and increase resilience to pests, diseases, and climate variability (Eriksson, 2021). Agroforestry further improves biodiversity, soil fertility, and water regulation by integrating trees with crops and livestock (Sharma *et al*., 2020). In addition, traditional management of wild plant species and community forests supports habitat conservation and ecological balance (Guadilla-Sáez *et al*., 2019). Indigenous post-harvest seed selection and storage practices also preserve local crop varieties, ensuring the conservation of genetic resources essential for long-term food security and climate adaptation (Sharma *et al*., 2020; Eriksson, 2021).

Challenges and Opportunities in Integrating IKS with Modern Agricultural Techniques

The integration of Indigenous Knowledge Systems (IKS) with modern agriculture presents both challenges and opportunities. Major constraints include the erosion of traditional knowledge due to modernization, inadequate documentation, weak policy support, and limited access to improved technologies and extension services (Negi *et al*., 2021; Phiri *et al*., 2022; Diko, 2023). Despite these challenges, integrating indigenous and scientific knowledge can promote sustainable agriculture, strengthen climate resilience, conserve biodiversity, and improve post-harvest management. Combining traditional storage practices with innovations such as hermetic storage and solar drying can significantly reduce post-harvest losses while maintaining cultural relevance and environmental sustainability (Didarali & Gambiza, 2019; Tahat *et al*., 2020; Khan *et al*., 2021).

Adaptation and Integration into Contemporary Agriculture

Policy and Institutional Support

Governments have a central role in promoting Indigenous Knowledge Systems through supportive legislation, funding, agricultural education, extension services, and incentives that encourage sustainable practices such as agroforestry and organic farming (Latulippe & Klenk, 2020; Fernández-Llamazares *et al*., 2021). Investment in rural post-harvest infrastructure and farmer training can further strengthen the integration of indigenous and modern storage systems (Wheeler & Root-Bernstein, 2020).Non-governmental organizations (NGOs) complement these efforts by raising awareness, building farmers' capacities, documenting indigenous knowledge, and implementing community-based projects that combine traditional practices with modern innovations (Hartmann et al., 2019; Hoque et al., 2020; Abiddin *et al*., 2022). They also facilitate the adoption of culturally appropriate technologies such as hermetic storage, solar drying, and digital advisory tools to improve post-harvest management and sustainable agricultural development (Khan *et al*., 2021; Sharma *et al*., 2021).

Technological Innovations

Modern technologies can effectively complement Indigenous Knowledge Systems by improving agricultural efficiency without replacing traditional practices. Precision agriculture, mobile applications, renewable energy technologies, biotechnology, and small-scale mechanization enhance crop management, climate adaptation, water use efficiency, and post-harvest preservation while building on indigenous farming knowledge (Khan *et al*., 2021; Sharma *et al*., 2021). Integrating these innovations with Indigenous Knowledge Systems provides a practical pathway toward sustainable, climate-smart, and resilient agricultural systems in Africa.

Contribution of Indigenous Knowledge Systems to Sustainable Agriculture and Climate-Smart Agriculture

Indigenous Knowledge Systems (IKS) comprise locally developed knowledge, skills, and farming practices that have evolved through generations of interaction with the environment. In Africa, these practices, including crop rotation, intercropping, mulching, agroforestry, mixed farming, terracing, contour ploughing, indigenous seed preservation, and traditional weather forecasting, are increasingly recognized as key components of Climate-Smart Agriculture (CSA) because they enhance productivity, strengthen resilience, and promote environmental sustainability (Amare & Gacheno, 2021; Chavula, 2021). These practices remain the primary adaptation strategy for many smallholder farmers across sub-Saharan Africa, where agriculture is largely rain-fed (Amare & Gacheno, 2021). A major contribution of indigenous knowledge is the conservation of biodiversity and improvement of soil fertility. Practices such as crop rotation, intercropping, composting, manure application, fallowing, and mulching enhance soil organic matter, improve moisture retention, reduce pest and disease incidence, and lower dependence on synthetic fertilizers (Amare & Gacheno, 2021; El-Beltagi *et al*., 2022). Indigenous soil and water conservation measures—including terracing, contour ploughing,

and ridging—also reduce erosion, improve water infiltration, and increase resilience to erratic rainfall, while traditional weather forecasting supports timely farming decisions based on local environmental indicators Belachew *et al*., 2020; Amare & Gacheno, 2021).Agroforestry and mixed farming further demonstrate the relevance of indigenous knowledge to sustainable agriculture by improving soil quality, increasing biodiversity, enhancing carbon sequestration, and promoting efficient resource use through crop–livestock integration (Rosati *et al*., 2021; Chavula, 2022; Chavula & Turyasingura, 2022). Evidence from countries such as Ethiopia, Kenya, Tanzania, Zimbabwe, Malawi, Ghana, and Nigeria show that indigenous practices continue to improve climate adaptation, reduce land degradation, and contribute to greenhouse gas mitigation (Belachew *et al*., 2020; Amare & Gacheno, 2021; Rosati et al., 2021). Overall, the literature underscores that integrating indigenous knowledge with scientific innovations offers a practical pathway for achieving sustainable agriculture, food security, and long-term climate resilience in Africa (Amare & Gacheno, 2021; Chavula, 2021).

Relevance of Indigenous Knowledge Systems in Enhancing Climate Resilience in Contemporary Africa

Climate resilience is the ability of agricultural systems and farming communities to anticipate, withstand, adapt to, and recover from climate-related shocks while sustaining agricultural productivity and livelihoods. In Africa, increasing droughts, floods, erratic rainfall, and land degradation have heightened the importance of Indigenous Knowledge Systems (IKS) as cost-effective and locally adapted strategies for strengthening the resilience of smallholder farmers (Amare & Gacheno, 2021; Chavula, 2021).Indigenous knowledge enhances climate resilience through practices such as traditional weather forecasting, crop diversification, intercropping, crop rotation, agroforestry, mixed farming, soil and water conservation, and the preservation of drought-tolerant indigenous crop varieties (Amare & Gacheno, 2021). Traditional weather forecasting, based on observations of environmental indicators including cloud formations, flowering patterns, birds, insects, and wind direction, continues to support farming decisions in many African countries, particularly where access to formal climate information is limited. Combining indigenous knowledge with scientific weather forecasts has been shown to improve farmers' adaptation to climate variability (Amare & Gacheno, 2021). Indigenous farming practices also strengthen ecosystem resilience by conserving soil and water resources, improving biodiversity, and enhancing carbon sequestration. Agroforestry, contour farming, terracing, and mulching reduce soil erosion, improve moisture retention, and sustain crop production under variable climatic conditions (Belachew *et al*., 2020; Rosati *et al*., 2021; El-Beltagi *et al*., 2022). Despite these benefits, Indigenous Knowledge Systems face challenges such as inadequate documentation, loss of traditional knowledge, urbanization, and limited integration into formal agricultural policies (Amare & Gacheno, 2021; Chavula, 2021). Consequently, integrating indigenous knowledge with scientific

innovations and climate-smart agricultural programmes is increasingly recommended to strengthen climate adaptation, food security, and sustainable agricultural development across Africa (Rosati *et al*., 2021; Chavula &Turyasingura, 2022).

Significance of Indigenous Knowledge Systems in Sustainable Agriculture and Climate-Smart Agriculture

Indigenous Knowledge Systems (IKS) play a vital role in promoting sustainable agriculture and Climate-Smart Agriculture (CSA). Developed through generations of interaction with local environments, these systems provide practical and environmentally sustainable solutions for improving agricultural productivity, conserving natural resources, and strengthening farmers' resilience to climate change. Indigenous practices promote biodiversity through crop diversification and agroforestry, enhance soil fertility and water conservation using techniques such as mulching, terracing, contour bunding, and organic composting, and support sustainable livestock management through traditional grazing systems (Amare & Gacheno, 2021; Chavula, 2021).IKS also contributes to climate resilience by supporting indigenous weather forecasting, mixed farming, conservation agriculture, and the cultivation of drought-tolerant indigenous crop varieties. These practices improve farmers' adaptive capacity, reduce dependence on external inputs, and support greenhouse gas mitigation through nature-based farming systems such as agroforestry and indigenous soil management (Rosati *et al*., 2021; Chavula & Turyasingura, 2022). Overall, Indigenous Knowledge Systems offer a holistic and low-cost approach to addressing climate change, land degradation, biodiversity loss, and food insecurity, making them an indispensable component of sustainable agricultural development in Africa (Amare & Gacheno, 2021; Rosati *et al*., 2021).

Future Directions for Research and Policy

Greater integration of Indigenous Knowledge Systems (IKS) into mainstream agriculture and Climate-Smart Agriculture (CSA) requires coordinated research and policy interventions. Future research should prioritize the documentation and preservation of indigenous agricultural knowledge through digital archives and case studies to prevent knowledge loss (Diko, 2023). Collaborative research involving indigenous communities, researchers, and policymakers is also needed to validate traditional practices and integrate them with scientific innovations for locally appropriate climate-smart solutions (Sangha et al., 2019). In addition, empirical studies should evaluate the impacts of combining IKS with modern agricultural technologies on productivity, climate resilience, environmental sustainability, and rural livelihoods to provide evidence for wider adoption (Latulippe & Klenk, 2020; Hambati, 2022). From a policy perspective, governments should develop inclusive frameworks that recognize and protect Indigenous Knowledge Systems while safeguarding indigenous intellectual property rights (Fernández-Llamazares *et al*., 2021). Policies should also strengthen extension services, climate information systems, financial support, and capacity-building programmes that facilitate the

integration of indigenous and scientific knowledge. Furthermore, incentive programmes and public awareness campaigns should encourage the adoption of sustainable indigenous practices such as agroforestry, indigenous seed conservation, and integrated soil and water management, while promoting intergenerational knowledge transfer to ensure the continued relevance of IKS in sustainable agricultural development (Sangha *et al*., 2019).

Conclusion

In conclusion, integrating Indigenous Knowledge Systems with modern agricultural science and Climate-Smart Agriculture provides a practical pathway towards more productive, resilient, and environmentally sustainable agricultural systems in Africa. Recognizing the value of indigenous knowledge while strengthening collaboration among farming communities, researchers, policymakers, and development partners will enhance climate resilience, improve food security, conserve biodiversity, and support sustainable agricultural transformation across the continent.

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