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Indigenous Knowledge and Artificial Intelligence Nexus: A Review of Climate Change Adaptation Among Agrarian Households in the Upper West Region, Ghana.

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Abstract

The dependence of farming households in Ghana's Upper West Region on rainfed agriculture makes their livelihood climate vulnerable. Farmers in the area have relied on indigenous knowledge systems (IKS) for generations to adjust to changing climate. This includes observing animal behaviour, plant cycles, and performance of community rituals to guide farming decisions. Though these practices remain valuable, their reliability is reducing due largely to today's unpredictable climate parameters. Artificial Intelligence (AI) tools and technologies provide forecasting, pest detection, and digital advisory services. Despite these promising prospects, the integration of AI with IKS is still limited. There is clear evidence that using hybrid technologies and approaches such as AI-driven forecasting, community participation, and using local language interfaces can improve resilience while respecting local culture. There are, however, challenges to integration, which include data and infrastructure gaps, digital literacy, and ethical concerns around data ownership and bias. Many opportunities lie in inclusive policies and community-driven frameworks, as well as farmer-centered designs. This review concludes that blending AI with IKS provides a practical and culturally grounded pathway for climate-smart agriculture. Success in this regard, however, depends on trust among stakeholders, equity, and strong institutional support.

Keywords: Indigenous Knowledge, Artificial Intelligence, Integration, Adaptation, climate change

INTRODUCTION

Globally, artificial intelligence (AI) has become an important tool in dealing with challenges posed by climate change in the field of agriculture. AI is used as an instrument for pest detection, a technique for prediction, and resource optimisation, especially in developing countries (Ahmad et al., 2024). AI technologies help address global food security challenges by increasing productivity and fostering sustainable agriculture. This helps smallholder farmers in poor countries to withstand challenges (World Bank, 2024). When AI is combined with Indigenous Knowledge Systems (IKS), it has the potential to significantly transform and boost the world's food production.

Farmers across Africa have long depended on traditional practices. Rotating their crops, growing crops together, conserving water, and using organic manure to keep their soils fertile are common traditional practices (Siakwah et al., 2025; Gyampoh et al., 2009). These methods have supported communities across generations. However, new challenges such as climate change and other environmental stressors as well as the growing dependence on chemical fertilisers and generational gaps limit the effectiveness of traditional practices (Dorji et al., 2024; Apraku et al., 2021). In response to these limitations, new technologies are emerging. AI applications such as mobile-based advisory services and machine learning models are being piloted in East and Southern Africa (Mollel et al., 2025). The challenge lies in integrating modern digital tools with Indigenous Knowledge systems to promote inclusive adaptation.

It has been widely accepted in academia and policy circles that agriculture is the primary source of livelihood for rural Ghanaians (Amadou et al., 2015). This is particularly so in the Upper West Region, where the livelihoods of the people are principally dependent on rain-fed farming. Climate change has compounded the vulnerabilities that exist in this area, and it continues to remain a critical threat manifesting in the form of erratic rainfall, protracted droughts, devastating floods, and pests and diseases outbreaks (Chemura et al., 2020). These challenges continue to threaten food security and household income and weaken community resilience to environmental stressors.

Agricultural households in the Upper West Region have relied on Indigenous Knowledge Systems (IKS) to adapt to environmental variability, including climate change, for centuries by using traditional indicators such as animal behaviour, plant phenology, wind direction, and celestial observations to predict rainfall and guide planting decisions (Peprah & N-yelkabong, 2017). They also manage soil fertility through practices such as crop rotation, organic manure, mulching, and communal labour, while pests and diseases are controlled by indigenous plant-based remedies. It is widely accepted that the indigenous adaptation practices of farmers in the area

are an integral part of their culture and social practices, which makes them easily accepted by the people and adaptable to their environment.

Fortunately, AI has emerged as an important tool that can transform adaptation to climate change in agriculture. Examples of such applications include machine learning and image recognition for pest detection. These apps are precise in their prediction and can grow with farmers' needs (Appiah-Badu et al., 2021). Current initiatives in Ghana, such as the AI-powered agriculture hub, launched in 2025, mark an institutional commitment to digital transformation (Sesi Technologies, 2025).

If farmers in the area combine AI with IKS, they will be able to adapt effectively to climate change. Leveraging the ability of artificial intelligence to predict the weather using computer software and mobile and remote devices, together with the local knowledge of farmers, which has a relationship with their culture and social context, will provide a useful avenue to deal with the effects of climate change in the Upper West Region. Using the two systems together promotes cultural acceptance of technological initiatives while preserving traditional technologies. Such a balance makes adaptation much more sustainable.

Artificial intelligence leverages the latest technologies to support and enhance farmers' adaptive capacities in rural Ghana. However, the current software and devices in use largely rely on global databases that ignore local realities. Farmers risk being excluded from digital transformation efforts worldwide if AI tools are not aligned with local culture. On the flip side, IKS has, for generations, proven useful in addressing climate change in the Upper West Region. But as a standalone, it cannot deal effectively with the increasingly unpredictable climatic conditions (Mollel et al., 2025). The need, therefore, is to integrate AI and IKS so that farmers can benefit from the collective advantages of the two systems. This grey area has not been exploited.

This systematic review has been necessitated by the gap between AI and IKS. It seeks to bring together evidence and tools from both sides and come out with practical strategies for integration. Without such synthesis, climate change adaptation efforts will remain scattered, weakening agricultural households' resilience across communities in the region.

The first is the urgent need for the people of the Upper West Region to adapt to climate change. The region faces severe climate risks because of the dependence on rain-fed agriculture, which requires immediate and context-specific interventions. The second consideration is the potential AI offers in promoting effective adaptation to climate change. AI offers predictive and analytical capabilities that can complement indigenous knowledge systems and practices. The last and most important one is that existing literature lacks a comprehensive synthesis of how AI can be integrated into IKS for agricultural adaptation in Ghana, especially in the Upper West Region, leaving a gap in adaptation knowledge that must be filled.

This paper aims to achieve three important objectives, drawn from the main areas of contention: Indigenous Knowledge Systems (IKS), Artificial Intelligence (AI), and their integration. The paper examines local practices rooted in traditional knowledge that farming households in Ghana's Upper West Region use to adapt to climate change. It also analyses current applications of artificial intelligence tools and technologies in agriculture and climate resilience within Ghana and elsewhere in the world. Again, the paper explores practical, feasible pathways for integrating AI with IKS to strengthen household adaptation to climate change.

The study offers culturally relevant and AI-enhanced tools and techniques for building resilience. In addition, the paper aligns with global and regional development priorities such as SGD 2 (Zero Hunger) and SGD 13 (Climate Action) by promoting climate-resilient and sustainable agriculture. Also, it aligns with Goal 5 (Modern Agriculture for Increased Productivity and Production) of the African Union's Agenda 2063. It contributes to Ghana's National Climate Change Policy and the Climate-Smart Agriculture Strategy by focusing on integrating technology with local practices. It supports the Upper West Regional Coordinating Council's focus on food security and sustainable livelihoods. Lastly, the paper contributes to essential scholarship on the use of new technologies to advance and enhance adaptation to climate change among rural communities in the Upper West region. It does this by establishing the nexus between AI and IKS in agriculture, which is scarce in adaptation literature in the area.

This paper is organised into five sections. The introductory part covers the background of the issue. The next section outlines the methodology, which is followed by an examination of Indigenous Knowledge Systems that are practised in climate adaptation. Section four synthesises AI applications in agriculture, with a final section exploring feasible pathways for integrating AI with IKS. The conclusions are drawn, followed by policy implications.

METHODOLOGY

This study adopts the systematic review design guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework. It has been documented that systematic reviews are well suited to synthesising evidence across diverse sources, which ensures that findings are comprehensive and replicable while eliminating biases (Mother et al., 2009). Also, given that climate change adaptation is interdisciplinary in character, the sensitive nature of IKS, and the technological dynamics of AI, this design allows for the integration of literature from multiple areas such as agriculture, computer science, anthropology, environmental policy, and the social sciences.

A multi-database search was conducted between November 2025 and January 2026 for literature across many fields of practice and the academic world. Peer-reviewed journal articles were retrieved from Scopus and Web of Science. For broader academic coverage, more journal articles were obtained from Google Scholar. Institutional repositories such as FAO, World Bank, UNDP, and Ghanaian universities, including KNUST and the University for Development Studies, were searched. Grey literature, including NGO reports, policy briefs, and conference proceedings, was explored. Search terms were developed iteratively to capture the intersection of AI, IKS, and climate adaptation. Keywords used to search included the following: *Artificial Intelligence, Indigenous Knowledge, Agriculture in Ghana, Machine Learning, Climate Adaptation in Upper West Region, Digital Advisory Services, Indigenous farming in West Africa, and AI crop disease detection in Ghana.* Boolean operators (AND, OR) and truncations were applied to refined results.

To ensure relevance and assure quality, the basis for inclusion was clearly defined.

The review included studies published between 2008 and 2026, peer-reviewed articles, institutional reports, and credible grey literature. The paper reviewed literature in AI applications in agriculture and climate adaptation or resilience. It also explored studies documenting Indigenous Knowledge Systems in Ghana and comparable West African contexts. Studies that explore the use of modern technologies in indigenous adaptation strategies were included.

The literature excluded was limited to articles available in English, studies focusing solely on AI in non-agricultural sectors, publications lacking empirical or conceptual relevance to climate adaptation, and opinion pieces without methodological rigour.

The initial search yielded 1500 records. After removing duplicates, 1,100 records remained. Titles and abstracts were screened for relevance, reducing the pool to 220 studies. Full-text reviews were conducted, and 55 studies met the inclusion criteria. Thirty-eight of these were peer-reviewed journal articles, 11 were institutional reports, and six (6) were grey literature sources.

A structured data extraction sheet was developed to capture key information from each study, including the author(s), year of publication, and country of study. It also captured the type of AI application, such as Machine Learning, image recognition, and predictive analytics; the Indigenous Knowledge practices documented, for example, rainfall prediction and soil fertility management among others; the agricultural context, such as the crop type, farming system and the region of practice; and the climate adaptation outcome, such as yield improvement, risk reduction, and resilience building. Lastly, it captured the identified challenges and limitations.

This study employed a thematic synthesis approach, which grouped the studies into thematic categories. The categories are: *Indigenous Knowledge Systems in climate*

adaptation, AI applications in agriculture and climate resilience, and Pathways for integrating AI into IKS.

The results were compared to identify trends within each category in the literature. This made it easier to uncover the pros and cons of each category in the adaptation discussions.

The Critical Appraisal Skills Programme (CASP) served as a guide for evaluating various studies to ensure their integrity and reliability. Institutional reports were examined for their appropriateness and suitability for this review. Peer-reviewed articles were appraised for their methodological strength.

RESULTS AND DISCUSSION

INDIGENOUS KNOWLEDGE SYSTEMS IN CLIMATE ADAPTATION

Rainfall Prediction and Weather Forecasting

Farmers in the Upper West Region have long relied on Indigenous Knowledge Systems (IKS) to anticipate rainfall and weather changes. Farmers observe the behaviour of animals, such as ant migration patterns, frog croaking, and bird nesting habits, as indicators of impending rainfall (Peprah & N-yelkabong, 2017; Jarawura, 2014). Similarly, they pick up signals of seasonal transitions from plant Phenology, such as the flowering of certain trees. The phases of the moon and the positions of the stars were observed to predict rainfall and guide farming decisions.

These practices are an integral part of the people's culture and are transmitted from generation to generation. Even though they remain valuable to the people, the variable nature of climate has reduced their reliability. There is a decreasing regularity in the alignment between traditional indicators and actual weather events, largely due to the erratic nature of rainfall (Chemura et al., 2020; Ayanlade et al., 2017). This brings about the urgent need to integrate AI into traditional weather forecasting for sustainable climate change adaptation.

Soil Fertility and crop management

Indigenous knowledge Systems (IKS) are key to African and Ghanaian farmers' management of soil fertility, cropping systems and planting regimes under climate change/variability. Farmers employ organic methods to manage soil fertility. Many farmers in Ghana continue to use manure to fertilise their soil, especially when livestock are integrated with crops. Siakwah et al. (2025) show that farmers in Ada and northern districts wisely prefer and use organic manure due to its availability and role in soil structure and erosion control. Similar practices are adopted by farmers in the Vea catchment area of the Upper East Region (Limantol et al., 2016)

Elsewhere in Southern Africa and India, farmers use farmyard manure, compost, crop residues and sometimes mixed botanical inputs such as cow dung and urine to

sustain soils under variable rainfall (Rana et al., 2019; Mapfumo et al., 2016; Baul & McDonald, 2014).

Ghanaian farmers practice mixed cropping and crop rotation to buffer against erratic rainfall, improve soil fertility and control weeds and pests (Siakwah et al., Sullo et al., 2020; Gyampoh et al., 2009). Intercropping maize with legumes such as Cowpea is common in both Ghana and across Africa (Chaudhary et al., 2021; Son et al., 2021). The planting of drought-resistant and "climate-resilient" crops is another strategy that farmers in Ghana use to survive the climate- induced crisis. Farmers in Ada have shifted towards the use of Kokoba (Sorghum leaves) and watermelon due to their drought resilience and market value (Siakwah et al.,2025). Farmers in the northern part of Ghana and in some parts of the Sahel-Sahara mostly use early-maturing varieties of millet and sorghum to adjust to the unreliable rainfall in the area (Siakwah et al., Derbile, 2013; Zougmore et al., 2023). Farmers also time and adjust their planting dates in line with the changing seasons in Ghana. Elsewhere in Africa, indigenous climate signals are used by farmers as a guide to align planting dates with seasonal rainfall variation (Siakwah et al., 2025; Landicho et al., 2016; Chaudhary et al., 2021). Examples from other parts of the world, such as Nepal and India, also show that farmers practice seasonal crop rotation to adapt to changing rainfall patterns. A case in point is that they move maize from the monsoon to the winter season and rice into former maize fields to accommodate variation in rainfall patterns (Chaudhary et al., 2021; Baul & McDonald, 2014; Ingty, 2017). In a nutshell, indigenous soil and crop management knowledge provides low-cost, flexible adaptation strategies, even though it is often under pressure from chemical inputs and market incentives.

Pest and Disease Management

In the context of pest and disease management, indigenous knowledge is equally important. Farmers depend on local knowledge of their environment, including their understanding of plant medicine, to deal with crop pests and diseases. For example, Zambian and Indian farmers use a combination of neem tree extracts, Chilli, and mustard oil to deal with worms in livestock and crops (Sakapaji, 2021; Rana et al., 2019). Again, in the Hills of Nepal and the Himachal Himalayas, farmers use local plants for animal disease management, such as treating scabies and stomach ailments, and to protect stored seeds and grain from insects (Baul & McDonald, 2014; Rana et al., 2019). Cropping strategies are also used for pest management (Sedegah et al., 2023). Mixed cropping and crop rotation are deliberately used as biological control mechanisms. Intercropping cereals with legumes reduces pest incidence, while maintaining yield and spreading risk (Siakwah et al., 2025; Son et al., 2021). Traditional landraces often exhibit higher tolerance to local pests and diseases. Farmers prefer them for their robustness and storage qualities despite lower market appeal (Nyantakyi-Frimpong, 2013; Baul & McDonald, 2014; Amare, 2018).

The use of chemicals is also widespread among farmers. Ghanaian and African farmers are gradually becoming addicted to the use of chemicals such as fertilisers, weedkillers, and pesticides because of convenience and pressure to increase yields (Siakwah et al., 2025; Apraku et al., 2021). Younger, more formally educated farmers tend to adopt agrochemicals more quickly than older farmers who seek to blend indigenous methods with modern products (Siakwah et al., 2025; Apraku et al., 2021). Indigenous Knowledge provides ecologically sound pest management options, but these are often undercut by the short-term effectiveness of synthetic inputs.

Water management and irrigation

Rainfall variability is becoming more challenging, and climate change is making indigenous knowledge more critical in water management, even though the scale and infrastructure limitations are considerable. Rainwater harvesting and local water conservation techniques have been employed by local African farmers. Even though most housing designs limit rooftop water harvesting, agricultural households harvest rainwater from rooftops into barrels to cope with water shortages (Gyampoh et al., 2009). In savanna areas of Ghana and East Africa, farmers use strategies to reduce surface runoff and conserve soil moisture. Techniques including earthing-up, mulching, ridging, and Zai pits have been promoted to help save soil and water (Amare, 2018; Siakwah et al., 2025; Derbile, 2013). In Ghana, managing water also depends on wetlands and traditional ways of watering crops. More farms in the Ada and Builsa South areas are adopting small-scale irrigation systems, such as canals, wells, and district-run schemes. Some farmers plant in valley bottoms, while others adjust their planting schedules to cope with the late onset of rains and intra-seasonal droughts (Siakwa et al., 2025). Farmers in Africa and Asia use wetlands and valley bottoms to garden throughout the dry season. They combine old ways of managing water with new pumps and tiny reservoirs (Nunn et al., 2024). Fulani herdsmen in Kpongu, northern Ghana, notice that pools of water are getting smaller and that dry spells are getting longer. They respond by moving flocks further apart and picking water-harvesting spots based on their long-term micro-hydrology, even though they often have to use substandard water when the area is very dry (Napogbong et al., 2021). Small-scale irrigation is noted as a tool that can help poor farmers adapt to climate change if local knowledge of water is linked with technical support from organisations (Burney & Naylor, 2011; Nunn et al., 2024). This evidence suggests that Indigenous Knowledge in water management is rich at micro-scale but often lacks the infrastructure and external investment needed to buffer large regional droughts.

Social Institutions and collective action

Indigenous adaptation systems are not only about techniques; they are also deeply connected to local institutions and relations (Li & Han, 2022; Elum et al., 2017). These institutions and customary rules enhance adaptation mechanisms. Traditional

authorities, particularly chiefs and priests in rural Ghana, play an important role in managing the environment by performing rituals that influence rainfall and enforcing taboos on protected species of plants and animals (Gyampoh et al., 2009; Dakurah et al., 2024; Taremwa et al., 2021). Taboos such as forbidden days for accessing rivers, sacred groves, and "no-fishing days" serve as de facto conservation and risk-management mechanisms (Gyampoh et al., 2009; Wani & Ariana, 2018; Maliano et al., 2022). Collective Knowledge sharing and social learning play an important role in adaptation. Farmers in Africa learn from pioneer adopters of technologies through group activities and contact with trained officers. Such interactions shorten the time to adopt new technologies by 50% in Tanzania and Malawi (Manda et al., 2024; Hermans et al., 2020). Village Knowledge Centres (VKCs) and multi-actor platforms are created in Asia and East Africa. These serve as spaces for participation in the generation and sharing of knowledge from both local and scientific sources (Mwantimwa & Ndege, 2022; Karuppiah & Rajakumar, 2013). Rituals that call for rain and the closing of markets when it is about to rain are collective community actions taken in some Ghanaian societies to address climate change (Dakurah et al., 2024; Gyampoh et al., 2009). Herders moved their animals to and from pastures and water sources, depending on the season, through negotiation and dialogue with landowners, in line with local laws and regulations (Fernandez-Gimenez et al., 2021; Napogbong et al., 2021). Such a social institution can either promote or hinder adaptation depending on the nature of social regulations and norms in place.

Limitations of Indigenous Systems

The importance of Indigenous systems cannot be contested. It is an invaluable part of any successful adaptation programme in Ghana and elsewhere. However, the literature is clear about its limits in the face of rapid climate and socio-economic change. Some people have shown that Indigenous Knowledge is highly localised (Yaro, 2013), which makes it difficult to scale or replicate beyond specific ecological and cultural contexts (Nyantakyi-Frimpong, 2013; Mase et al., 2017; Makondo & Thomas, 2018; Dorji et al., 2024). Indicators tied to species such as butterflies, frogs, and specific stars become unreliable when ecosystems change, or species disappear (Nyadzi et al., 2021; Napogbong et al., 2021). There is also the erosion of these knowledge systems due to generational gaps. My search has revealed a worrying situation in which youth place higher priority on modern technologies over indigenous practices, which are gradually killing indigenous knowledge systems and practices (Siakwah et al., 2025; Dorji et al., 2024; Nunn et al., 2024). For example, the introduction of foreign religious doctrines has downplayed traditional ritual explanations of environmental phenomena and knowledge, creating divergent narratives about the causes of climate change (Dakurah et al., 2024; Scoville-Simonds, 2018). People argue that because IKS depends on historical experience, it is unable to explain extreme changes in the climate system (Tessema & Simane, 2021), which

weakens its ability to predict climate extremes (Makondo & Thomas, 2018; Dorji et al., 2024). Spiritual explanations may divert attention from the actual causes of climate change, such as deforestation and greenhouse gas emissions, and from practical measures to address it (Dakurah et al., 2024; Salite, 2019). Issues of power, gender, and equity have also been framed as challenges to indigenous knowledge. It has been argued that, because traditional knowledge often places women and other groups on the margins in favour of elders and male leaders, it is gender-biased and inequitable in its application (Nyantakyi-Frimpong & Bezner-Kerr, 2015; Dorji et al., 2024). Decisions rooted in authority or taboos can limit experimentation with new adaptation options. For example, tree planting in Ghana has been disincentivised by timber tenure laws (Gyampoh et al., 2009; Siakwah et al., 2025). The limitations of traditional knowledge make it insufficient to succeed on its own in current adaptation efforts and must be complemented by modern technologies such as AI applications.

AI APPLICATIONS IN AGRICULTURE AND CLIMATE ADAPTATION

Better Weather and Climate Prediction

One of the most critical applications of AI in agriculture is in weather forecasting and climate modelling. Rainfall variability in Ghana's Upper West Region makes traditional forecasting unreliable. The literature review points to the possible use of AI applications with proven success, such as Machine learning algorithms (e.g., Random Forest, Support Vector Machines (SVM), and Artificial Neural Networks (ANN). These have been effectively utilised in some regions of Ghana (Appiah-Badu et al., 2021).

Random Forest is a supervised machine learning method that uses many decision trees to improve prediction accuracy. It can model complex, non-linear relationships among variables such as temperature, humidity, and rainfall in climate modelling. It is a better way to predict the weather in places with ever-changing climatic conditions, such as Ghana's Upper West Region (Appiah-Badu et al., 2022). The main reason is that a single tree might overfit the data and memorise noise instead of learning the patterns underlying the system. The model becomes more robust, accurate and resistant to overfitting when the results of a "forest" of many uncorrelated trees are averaged.

Support Vector Machines (SVMs) are more efficient for tasks such as classification and regression. They find patterns in climate data, such as distinguishing between years of normal rainfall and years of drought. They are good at dealing with high-dimensional data, which makes them good for predicting climate outcomes where many variables are involved (Sharma, Verma, & Hardaha, 2023)

Artificial Neural Networks (ANNs) are computational models that work like the human brain using large sets of data. This network contains an input layer that

receives data. It also contains one or more hidden layers that process information and an output layer that produces predictions. They are especially helpful for predicting changes in temperature and rainfall because they can find patterns that are not obvious in climate data. Traditional methods of predicting weather systems are inferior to the ANN models (Jan, Mohapatra & Samal, 2025).

Robust AI platforms integrate satellite data with local weather station data to produce more locally relevant and efficient forecasts. Integrating data from global and local sources can yield context-specific predictions. Farmers in the Upper West Region could benefit from being connected to these platforms, as they would receive timely information on temperature and rainfall (Penplusbytes, 2024; World Bank, 2024).

In East Africa, farmers receive weather information directly on their mobile phones via AI-powered chatbots. These systems turn complicated climate data into simple advice. A typical example is when chatbots tell farmers when it is going to rain, which then informs their planting and irrigation dates (Mollel et al., 2025).

An automatic weather station works on its own. Sensors are used by an automatic weather station (AWS) to collect raw data on temperature, rainfall, wind speed and humidity. It does not rely heavily on AI on its own. It is mostly a way to collect data. However, when AI algorithms are used with AWS data, the system becomes much stronger and smarter. AI can be used to analyse collected data and identify patterns, which are then used to build predictive models. This turns a simple monitoring station into a tool that helps people decide how to adapt to climate change (Responsible AI Lab, 2025).

These AI applications have been shown to be better than conventional statistical methods at capturing non-linear relationships among climatic variables. Again, to provide local weather forecasts, AI-controlled platforms combining satellite data with localised weather stations can be created in the Upper West Region. This can be done by learning from the East African model, where AI-enabled chatbots deliver weather information to farmers via mobile phones (Mollel et al., 2025).

Improving Crop Disease and Pests Detection

It has been documented that, elsewhere in Ghana, mobile applications such as KaraAgro AI allow farmers to upload images of diseased crops, which are then analysed using deep learning algorithms to identify pathogens, helping find solutions to crop diseases (Penplusbytes, 2024).

An agritech project in Ghana, KaraAgro AI, uses artificial intelligence to provide farmers with climate-smart solutions. The main goals of the platform are to increase crop yields, forecast weather and soil conditions, and provide advisory services specific to regional farming methods. This AI helps peasant farmers make decisions

about planting dates, when to water their crops, and pest control measures. This is done by integrating AI statistics with easy-to-use tools for farmers. This aligns with larger efforts in Ghana to use AI to build resilience to climate change and transform agriculture (World Bank, 2024; Penplusbytes, 2024).

The fall armyworm outbreak in Ghana underscores the urgent need to replicate such technologies nationwide. AI-based pest monitoring will provide early alerts, reducing crop losses. Technological tools like drones and sensors can be used with AI to identify the areas of farms most affected by pests and diseases.

Precision in Agriculture

In the past, AI technologies have been used in Ghana to predict maize output using Random Forest algorithms, which were more accurate than indigenous knowledge. In the Upper West Region, AI can be used to integrate data from soil sensors and satellite imagery, as well as drone imagery, to provide recommendations for sites. For example, AI can predict soil nutrient deficiencies and recommend fertiliser application rates. Again, Machine learning models can be used to optimise water use, reducing irrigation waste in the area. AI models can also be used to predict crop yields, helping farmers plan harvesting and marketing.

Digital Services.

One effective way farmers elsewhere are helped to adapt to climate change is the provision of Digital Climate Advisory Services (DCAS) in the farming communities. These services use mobile apps to send text or audio messages that include weather forecasts, soil data and crop models. In Ghana, projects like the AI-powered agricultural hub launched in 2025 aim to expand digital advisory services across the country (Sesi Technologies, 2025). Farmers get advice on when to plant, how to deal with pests and what the market prices are. AI chatbots also enable farmers to talk to each other and get answers to questions relevant to their needs.

Even though Ghana has demonstrated commitment through initiatives such as the $100M AI-Powered agriculture hub (Sesi Technologies, 2025) and World Bank programs promoting climate-smart agriculture technologies across Africa (World Bank, 2024), policy gaps remain in areas such as data governance, farmer training, and infrastructure development. These initiatives highlight the growing importance of AI's role in the agricultural value chain and must be worked on assiduously in the Upper West Region

FEASIBLE PATHWAYS AND FRAMEWORK FOR INTEGRATION

Uniting Artificial Intelligence (AI) with Indigenous Knowledge Systems (IKS) will help farmers in the Upper West Region adapt effectively to a changing climate. AI will accurately predict the weather for them, while traditional knowledge addresses

the cultural context of the issue. If the two are used together, the resulting systems will be trusted and useful.

Hybrid Forecasting Models

Indigenous rainfall prediction methods, such as observing animal behaviour, plant phenology, and celestial signs, remain important but are becoming unreliable due to climate variability and change (Nyantakyi-Frimpong & Bezner-Kerr, 2015). Intelligent software can be useful in that regard. Such software can compare weather signals from nature with data from the Ghana Meteorological Service. This will generate a hybrid system that is scientifically accurate and trusted by farmers in the Upper West Region (Appiah-Badu et al., 2021).

AI-Enhanced Soil Fertility and Crop Management

Farmers in the Upper West Region already use methods that help to manage the land. They use organic manure to maintain soil health, rotate their crops and practice intercropping (Boafo et al., 2016), which must be maintained. Software and sensors can be developed to analyse soil health in the area and provide recommendations, including crop choices that will do well in such soils and the type and amount of fertiliser to apply. Using both systems together protects the environment and increases farm output.

Pest and Disease Control

Apart from using plant extracts, such as those from the neem tree, ash, tobacco, and pepper, by farmers in the Upper West Region as natural solutions for controlling crop diseases and pests (FAO, 2019), cameras and sensors can also be used to identify pests and crop diseases early for action. Software can be developed to prescribe pesticides for spraying crops. Integrating both systems reduces crop losses and makes farming more profitable for farmers in the area. It also protects the environment. In other words, develop mobile apps that combine AI detection with indigenous treatment options.

Water Management and Irrigation

The sources of water for farmers in the Upper West Communities include personal and community wells, small earth dams, and rainwater harvesting. Computer-based software can improve this system by forecasting water demand and scheduling when to apply water to farms based on local weather signals. Mollel and colleagues (2025) argue that this blend of indigenous and new practices provides farmers with both confidence and assurance.

Participatory Design and co-creation

As with most development initiatives, AI tools and systems are accepted and appreciated when various stakeholders in communities, such as elders, local leaders, and farmers, are part of their design process from the beginning through to their application. In other words, integrating AI into IKS requires involving farmers in the development process, ensuring that tools reflect local realities.

Local Language Interfaces

Language can be a barrier to farmers' use of AI platforms. Much of their indigenous knowledge is shared orally in local languages such as Dagaare, Sissali, and Waali. AI systems need voice-based interfaces in these languages so that farmers can access and share knowledge without losing their cultural context. This makes the technologies more inclusive and much easier to use.

Community Data Hubs

Indigenous knowledge grows best in local communities. In this regard, AI should be integrated in ways that bring people together rather than isolate them. The creation of Community data hubs in the Upper West Region can serve as shared spaces where farmers pool their traditional insights, which AI then transforms into practical, localised guidance for everyone.

POLICY IMPLICATIONS

The integration of AI and IKS requires a strong policy push to make it work. Programmes like Ghana's AI agriculture hub are good examples and must be targeted at the vulnerable farmers in the Upper West Region. This aligns with the Ghana National Climate Change Policy (GNCCP, 2026), which calls for putting climate-smart agriculture at the heart of the mainstream development agenda. Digital infrastructure to support AI systems, such as mobile phones, laptops, and community radios, must be provided by the Government of Ghana in the area. Again, in line with the GNCCP's (2026) emphasis on strengthening institutions, MOFA must be retooled to provide digital advisory services to farmers in the Area.

To strengthen social institutions and collective action, Indigenous Knowledge can be documented and transmitted using AI. AI-assisted platforms such as voice-to-text, multilingual translation, and semantic search can help communities document stories, rituals, indicators, and rules in their own languages and make them accessible to youth and schools (Olatade & Mogaji, 2025). Social network analytics can be engineered by analysing communication patterns such as WhatsApp groups and local radio call-ins.

AI and Indigenous Knowledge must be complementary entities. They must not be seen as mutually exclusive. They both aim at improving livelihoods. The process must be transparent, fair and inclusive. Marginalised groups like women and

children must be equally involved. Communities in the region must also be given the chance to own their data. The GNCCP emphasises equity and inclusiveness.

A co-creation workshop involving various stakeholders, such as farmers, community leaders, researchers, and technology developers, must meet to develop solutions that address the challenges of climate change, informed by traditional knowledge and AI technologies. The process is shared rather than relying solely on expert decisions. This process involves merging two systems: farmers bring their indigenous solutions, while technology developers provide AI tools. Both developers and indigenous people test ideas together and ensure they are adjusted to local conditions. They also ensure that the solutions generated are workable and fair, while respecting the people's culture.

Policies should promote the development of hybrid data to build farmers' trust. There are not enough localised hybrid datasets. AI models need large, high-quality datasets for farmers to learn from and to verify their work. Most AI models used in Ghana rely on datasets from either the national headquarters or international sources. In most cases, such datasets do not reflect local conditions (Chemura et al., 2020). This sometimes makes predictions wrong or not relevant to farmers. If hybrid datasets which combine scientific and indigenous insights are not captured and used, it makes farmers less likely to trust the technology.

Training programmes should be organised to enable women and youth to use digital tools. The majority of farmers in the Upper West Region cannot read and write in English, which hinders their ability to acquire the skills needed to use mobile devices, interpret data generated by computer software, and participate in digital advisory services (Penplusbytes, 2024). The patriarchal nature of rural northern Ghana has affected women's ability to use mobile devices compared to their male counterparts. This disparity prevents women farmers from accessing mobile and other digital opportunities. Without tackling this challenge, AI technologies will remain underutilised, even if they are made available. This calls for the training of more women than men in the use of digital technologies in agriculture to promote inclusivity.

To effectively use AI technologies, communities must be connected to electricity and a reliable internet connection. But most communities in the area do not have reliable internet or broadband services, even though they are connected to the national grid. There are also frequent power outages (World Bank, 2024). This impedes the access and use of digital support services. Such gaps need to be addressed through investments in rural electrification expansion and the extension of broadband services to the farming community, so that even the few literate farmers can benefit from digital support services.

The AI policies should protect indigenous knowledge and ensure that tools reflect local context. The majority of AI systems and applications currently in use were designed on Western principles and models, making them unsuitable for the local context of rural communities in Ghana. As a result, there is a high probability of marginalising local practices despite their cultural and environmental appropriateness (Boafo et al., 2016). AI tools must reflect local conditions to prevent farmers from abandoning them as unfit and unknown commodities. This is why hybrid tools and applications are recommended to complement rather than replace local knowledge systems.

There is a need for strong AI governance and regulation. Collaboration among government agencies and NGOs in the area is key. Policy frameworks for AI in Agriculture remain inadequate, even though Ghana has launched initiatives such as the AI-powered agriculture hub (Sesi Technologies, 2025). Data governance bottlenecks persist due to a lack of policies on data ownership, privacy, and data sharing in farming. There are also limited guidelines on data access and use fairness. Issues of transparency and accountability in data management remain unresolved. Additionally, there exists weak collaboration among government agencies, NGOs and private actors. These gaps must be addressed; otherwise, AI adoption may be haphazard, inequitable and unsustainable. There also needs to be strong governance frameworks to ensure ethical and inclusive deployment of AI technologies.

Subsidies, credit support, and insurance guarantees should be extended to farmers in the area. The capital requirements of AI technologies such as drones, sensors, and advanced mobile applications are quite high, making it difficult for poor farmers to procure them on their own. The World Bank (2024) documented that smallholder farmers in the Upper West Region are impoverished and lack the resources to buy these tools on their own. They need help from government and groups. Credit facilities are limited, and insurance schemes for climate risks are not common. These barriers limit the adoption of AI in agriculture.

Community participation must be encouraged to build trust among farmers. AI technologies must reflect local environmental and social contexts for them to be trusted and accepted by rural communities. The experiences of farmers with similar technologies in the past may positively or negatively affect the adoption of new ones. Failed past predictions about AI may make AI seem irrelevant to farmers, leading them to abandon the technology. If farmers view AI technology as irrelevant, they will not accept it and vice versa (Nyantakyi-Frimpong & Bezner-Kerr, 2015).

CONCLUSION

This review paper shows that Indigenous Knowledge Systems (IKS) remain an important pillar for agricultural households in the Upper West Region to adapt to climate change. However, their usefulness is waning due to changes in weather

conditions and Socio-Economic pressure. Artificial Intelligence (AI) can help IKS by providing predictive, analytical and advisory skills. This can cause technically sound, culturally meaningful systems to be integrated. The literature provides evidence of effective practices, such as hybrid forecasting, participatory co-design, and local language interfaces, that can enhance resilience while preserving community trust.

Integrating AI and IKS requires reasoned institutional support. Priority should be given to policy frameworks that protect the autonomy of data and ensure fair and just access to digital technological tools. Policy should equally promote farmer-focused designs. Indigenous knowledge must be positioned as a foundation for AI innovations rather than downgraded during integration. Concerted efforts must target the provision of digital infrastructure in farming communities, the availability of extension services, and the development of skills that make them digital literates. If these policies are implemented, it will bridge the gap between indigenous knowledge and modern technology.

Future research should progress beyond merely describing the application of indigenous Knowledge and AI and rather focus on the co-creation of these systems in practice. This involves testing integrated models to assess the propriety of AI-driven tools developed in local languages and to address bias in data ownership. Conducting research across different countries in Africa and other developing countries would also provide depth in understanding how these approaches can be applied and expanded.

The integration of AI and IKS offers Ghana, particularly the Upper West Region, a significant opportunity to retool climate-smart agriculture for sustainable adaptation. Integrating modern technology with local knowledge ensures efficiency and inclusiveness while building resilience. Collaboration across disciplines, strong ethical safeguards, and firm policy support will help realise this vision. Bringing AI and IKS together empowers communities to address climate change in a cultural context rather than through a technical solution.

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