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Towards Hybrid Agricultural Advisory in Africa: The FarmConnectAfrica Framework for Integrating AI, Peer Knowledge, and Extension Expertise.

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ABSTRACT

Information remains an important component of agriculture in Africa. Smallholder and family farmers play a central role in African food systems and rural livelihoods, with family farmers producing about 80% of the food consumed in Africa (FAO, 2020). This makes access to timely agricultural knowledge an important development concern, particularly as farmers face difficulties acquiring timely, relevant, localized, and actionable agricultural information. Existing approaches rely on governmental interventions, technology, farmer-to-farmer networks, and agricultural extension services. While each has areas of effectiveness, they present limitations in the distribution of valuable information. Conventional agricultural extension services, powered by agricultural extension agents (AEAs), face a significant workload, with agent-to-farmer ratios reaching 1:4,000 in Kenya (Singh et al., 2024). Recent evidence from digital farmer-to-farmer interventions also indicates that sustaining participation can be challenging; in the ShambaChat trial, participation declined over the study period. Digital and AI-based agricultural information systems improve the accessibility and scalability of agricultural advisory services but remain constrained by contextual limitations, language barriers, knowledge gaps, and difficulties in interpreting farmer-generated queries, potentially reducing the relevance and reliability of recommendations (Singh et al., 2024). This study aims to evaluate, identify, and demonstrate the value of existing approaches while proposing a possible solution to their limitations. Their complementary capabilities, however, remain insufficiently integrated into a unified farmer-centered information architecture. FarmConnectAfrica is proposed as an AI-powered agricultural social information platform that combines farmer-to-farmer information networks, agricultural expertise, AI advisory systems, localized information discovery, and feedback mechanisms. The paper aims to contribute a proposed architecture and conceptual framework for investigating whether integrating AI with peer and extension knowledge can provide more contextually useful and agriculturally reliable information to support farmer decision-making.

Keywords: Artificial Intelligence in Agriculture; Agricultural Advisory Systems; Farmer-to-Farmer Knowledge Sharing; Hybrid AI Systems; Agricultural Extension.

1. INTRODUCTION

The effects of climate change, technological changes in agriculture, and emerging crop and livestock diseases could make it increasingly difficult for farmers to respond quickly and effectively to changing agricultural conditions. Smallholder farmers often lack access to relevant and timely information, and delays in accessing such information can limit its usefulness for agricultural decision-making (Omulo & Kumeh, 2020).

Farmer networks are small clusters of farmers in a local setting that provide collaborative effort and information to facilitate collective growth and curb challenges affecting crops and livestock. They may include experienced and younger farmers, as well as other local agricultural actors. They function through word-of-mouth communication, meetings, and other forms of farmer-to-farmer (F2F) knowledge exchange, which digital platforms have increasingly extended beyond physical proximity (Omulo & Kumeh, 2020).

Agricultural extension agents (AEAs) are people with access to agricultural resources and knowledge, often developed through training and experience. They are sometimes affiliated with established organizations that train and equip them to inform and train other farmers. However, the gap between available AEAs and farmers remains a significant challenge. Across Africa, extension officer-to-farmer ratios average approximately 1:1,000, compared with the FAO-recommended 1:400 ratio, limiting the capacity of conventional extension systems to reach farmers effectively (Tata & McNamara, 2018).

Digital systems have also been tested in African communities to address agricultural information gaps. ShambaChat and Farmer.Chat demonstrated the potential of digital and generative-AI agricultural advisory while revealing limitations involving participation, language, localization, contextual information, and farmer-generated queries (Lasdun et al., 2025; Singh et al., 2024). While F2F networks can provide contextual and experiential knowledge that AI may not independently possess, AI can potentially serve large numbers of farmers with limited human intervention. These complementary strengths suggest an opportunity for both approaches to work together rather than independently.

While existing studies demonstrate the potential of digital F2F networks and generative-AI agricultural advisory systems independently, there remains limited research on architectures that deliberately integrate peer-generated knowledge, AI advisory, agricultural extension expertise, localization, verification, and feedback within a unified farmer-centered system.

FarmConnectAfrica (FCA) proposes that each layer of agricultural support, both human and technological, should complement rather than replace the others. Accordingly, this paper proposes a hybrid agricultural advisory architecture that integrates generative AI, farmer-to-farmer knowledge, agricultural extension expertise, localization, and feedback mechanisms to support context-aware farmer decision-making.

This paper contributes a conceptual architecture for this integration, alongside an illustrative operational model and proposed framework for empirical evaluation, demonstrating how AI advisory, peer knowledge, and extension expertise can function as complementary components within a unified farmer-centered system.

2. RELATED WORK AND RESEARCH GAP

Existing agricultural information systems remain relevant in the African context, with artificial intelligence, extension services, F2F networks, and digital services providing different pathways for information and knowledge exchange. This paper explores these pathways and proposes a complementary architecture in which AI provides scalable information retrieval and personalization, while farmer networks provide contextual knowledge, experiential evidence, and human validation.

2.1 Traditional Agricultural Extension

Agricultural extension services (AESs) aim to provide support to smallholder farmers that they would otherwise be unable to afford by themselves. From access to opportunities beyond conventional F2F networks to farming techniques that improve yields and crop/livestock disease management, AESs work alongside local farmers to maximize their output. However, the requirements of the role mean that relatively few people are certified and capable of effectively performing such tasks, contributing to labor scarcity.

2.2 Farmer-to-Farmer and Digital Agricultural Networks

Peer-to-peer information exchange provides knowledge where extension services are unavailable. This involves the exchange of relevant information between farmers, often from experienced to inexperienced farmers or among farmers of similar knowledge levels. WeFarm, an SMS-based farmer-to-farmer knowledge-sharing platform in Kenya, demonstrated the potential of digital platforms to extend peer knowledge exchange beyond physical proximity (Omulo & Kumeh, 2020).

ShambaChat, however, was tested through a randomized controlled trial among smallholder maize farmers and recorded increased adoption of practices discussed on the platform. Intercropping adoption increased by 11–18 percentage points and organic fertilizer production by 15 percentage points, although participation in the chat groups declined over the study period (Lasdun et al., 2025).

2.3 AI Agricultural Advisory and Precision Agriculture

Artificial intelligence provides automated services to agricultural support mechanisms and beyond. From Microsoft's Farmer.Chat (Singh et al., 2024) to a ChatGPT study conducted in Nigeria (Ibrahim et al., 2024), AI-based agricultural advisory has demonstrated potential for reaching multiple farmers with fewer human resources. Farmer.Chat supported farmers in addressing common areas of difficulty, while the Nigerian study found that ChatGPT responses were rated highly by local agricultural experts, although its performance varied for context-specific agronomic questions. This highlights the potential of AI for scalable advisory while retaining a role for agricultural expertise in evaluating and contextualizing its responses. Although GPT provided valuable responses, limitations emerged in context-specific and environmental factors, highlighting the need for experienced agricultural professionals to assess and contextualize AI-generated advice (Ibrahim et al., 2024).

2.4 Comparison and Research Gap

The image below reveals the current capacity of agricultural mechanisms employed over the course of the study and the proposed capacity of FCA:

Table X. Comparative Analysis of Existing Agricultural Information Systems and the Proposed FarmConnectAfrica Architecture.

Approach/System	AI Advisory	Peer Knowledge	Expert/Extension Knowledge	Localization	Scalability	Information Verification	Feedback Mechanism	Primary Strength	Key Limitation
Traditional Agricultural Extension	—	—	✓	✓	△	✓	△	Human agricultural expertise and trusted guidance	Limited reach and resource-intensive delivery
Farmer-to-Farmer (F2F) Networks	—	✓	△	✓	△	△	✓	Contextual and experiential knowledge from real farmers	Variable information quality and scope of reach
Wefarm	—	✓	—	✓	✓	△	✓	Digital peer-to-peer information exchange at scale	Limited evidence of downstream impact on productivity
ShambaChat	—	✓	△	✓	✓	△	✓	Structured digital peer learning that influences practice adoption	Sustaining long-term engagement and active participation
Farmer.Chat	✓	△	△	✓	✓	△	△	Scalable AI advisory with multi-modal access (voice, text, image)	Contextual accuracy, localization depth, and real-time validation remain challenging
FarmConnectAfrica (Proposed)	✓	✓	✓	✓	✓	✓	✓	Integrated architecture uniting AI advisory, peer knowledge, extension expertise, localization, verification, and feedback	Proposed architecture; requires empirical validation and field evaluation

Note. ✓ indicates a core capability; △ indicates a partial, indirect, or limited capability; — indicates that the capability is not a core component. Characterizations should be verified against the cited literature. FarmConnectAfrica represents the proposed architecture and has not yet undergone empirical field validation.

Several studies on existing agricultural approaches demonstrate that useful agricultural knowledge can be delivered through complementary pathways. Traditional extension provides human expertise, farmer-to-farmer networks offer contextual and experiential knowledge, and digital platforms expand the reach of peer communication. AI-based systems also provide scalable and personalized access to agricultural information for decision-making and knowledge dissemination.

However, these capabilities remain distributed across different approaches. Systems centered on extension provide expertise but face scalability constraints; peer-based systems provide contextual knowledge but may face challenges concerning information quality and sustained engagement; and AI advisory systems provide scalability but remain dependent on the quality, relevance, and contextualization of available information.

These capabilities, if paired together, could complement one another and provide services that each approach does not individually possess. A farmer facing a localized crop problem may benefit simultaneously from AI's ability to retrieve and explain information, the experience of nearby farmers facing similar conditions, and the judgment of an agricultural extension professional.

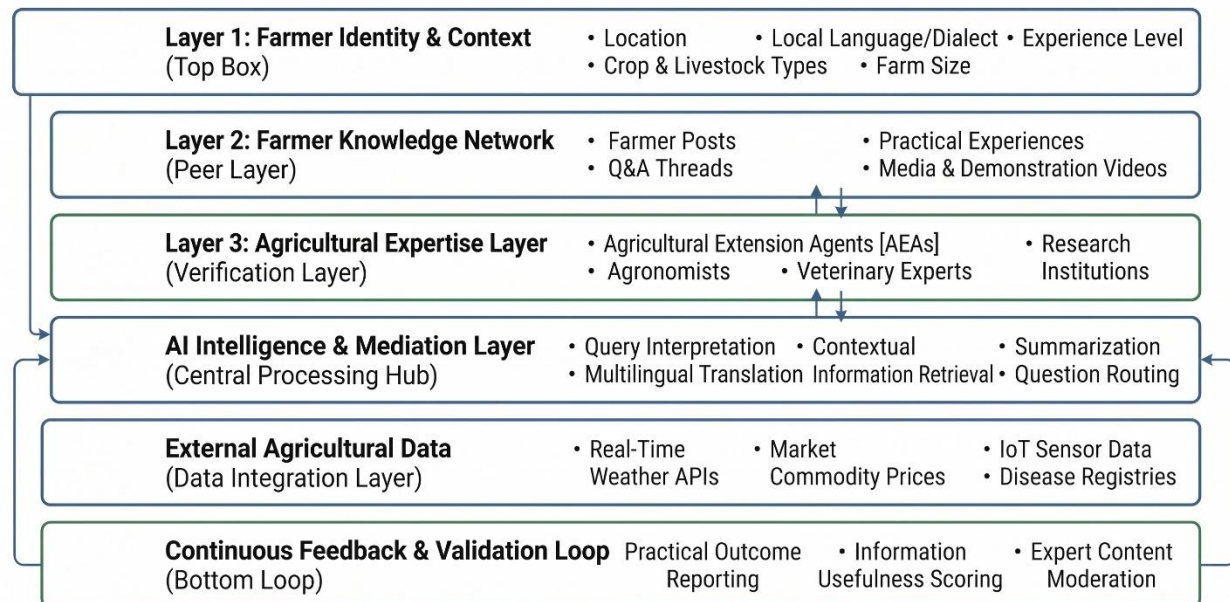
FarmConnectAfrica (FCA) is proposed to perform this complementary integration. It addresses the gap by proposing a unified farmer-centered architecture in which AI advisory, peer-generated knowledge, agricultural extension expertise, localization, verification, and feedback operate as complementary components rather than isolated information pathways.

3. FarmConnectAfrica – Proposed System Architecture

3.1 Core Concept and System Components

The following is the architectural structure of FarmConnectAfrica’s pipeline - a proposed AI-powered social platform designed for farmers, extension agents, and agricultural entities. Each phase is designed to either integrate the strengths of existing agricultural mechanisms or provide relevant information required for the dissemination of relevant information.

FarmConnectAfrica (FCA) System Architecture



3.2 Farmer Context and Knowledge Network

The first two layers focus on acquiring information from farmers to support content specialization and improve personalization on the platform.

This is important for AI query-response activities, where the model uses information provided by the farmer upon login to provide environmentally and geographically contextualized responses to their queries. It strengthens existing mechanisms in F2F networks, with posts, comments, discussions, content, and queries providing information relevant to the farmer while contributing to the system’s learning process.

Farmer feedback and extension agent validation are incorporated into the system to improve the quality and relevance of future advisory responses. This feedback can help identify useful, inaccurate, or contextually unsuitable information, allowing the platform to continuously improve its advisory and information-sharing mechanisms.

FCA doesn’t merely treat farmers as consumers of information. They also contribute knowledge to the system.

3.3 AI Advisory and Knowledge Integration

The AI layer's tasks are streamlined to specific responsibilities relevant to the farmer. Some of its tasks include:

Query Interpretation:

The AI layer provides information after grasping the full context of the farmer's question and the information required, asking relevant questions to reinforce its understanding.

Personalization: The information provided by the farmer upon login provides a foundation for the AI to respond based on the farmer's preferences.

Retrieval: AI is tasked with using relevant research tools and algorithms to find information pertinent to the farmer's query.

Summarization: Information is streamlined and compressed to provide concise responses.

Translation: Multilingual capacity provides options for local smallholder farmers.

Recommendation: The AI model provides human connections, content, and articles that complement its responses upon request.

Routing: The AI does not need to answer everything, especially when the possibility of an incorrect or potentially unhelpful response is high. Routing involves connecting the farmer to personnel with expertise in the related matter.

3.4 Expert, Verification and Feedback Mechanism

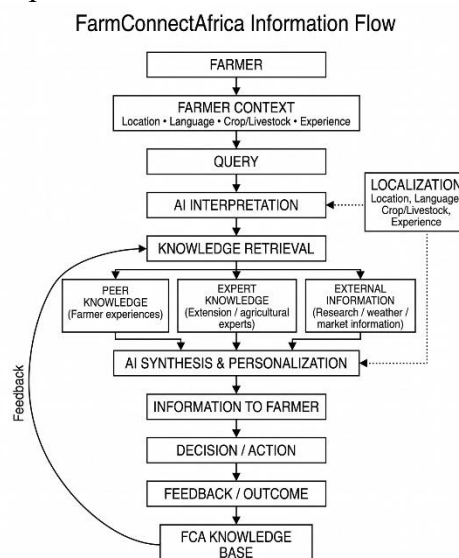
While the proposed platform has the potential to provide numerous benefits, the possibility of bad information infiltrating the platform reveals a possible flaw in its architecture. However, limits set in place could offset this limitation.

Reviews, verification, and reputation mechanisms propose a solution to this possible flaw. Agricultural experts—including AEAs, agronomists, researchers, veterinary professionals, and certified agricultural practitioners—can review information and promote valuable content or demote unreliable information. Multiple independent responses, farmer feedback, and community reporting can also flag and demote bad information. AI-assisted identification of questionable information and expert escalation provide additional means of dealing with unreliable information.

These proposed techniques might provide useful guardrails against misinformation.

3.5 FCA Information Flow and Localization

The image below reveals the proposed information flow from the farmer's perspective:



4. Illustrative Use Cases and Expected Operation

This section provides further insight into FCA's internal processes through illustrative use cases and a proposed model of operation.

4.1 Crop Disease

Use Case 1:

“My maize leaves are developing symptoms”

FCA:

Identifies context → interprets query → retrieves agricultural information → finds relevant farmer experiences → surfaces expert knowledge → synthesizes information → allows escalation → receives outcome feedback.

The above pipeline shows the processes FCA follows to provide contextual and applicable information to the farmer.

4.2 Livestock/Poultry

A question under this category follows a similar process as Use Case 1, leveraging existing queries and responses from other farmers or routing to experienced extension agents while providing personalized responses.

4.3 Product/Market Decision

Questions ranging from fertilizer strategy, planting timing, market gaps and opportunities, input choice, and legal considerations in specific geographical territories can receive verified, customized responses using the architectural pipeline proposed in previous sections.

5. Discussion, Limitations and Future Evaluation

The technical overview of FCA examines the human-AI partnership, its potential for effective information dissemination, and its possible limitations.

5.1 Human-AI Complementarity

Human involvement in the system enables two-way communication and multi-way verification of information provided by fellow humans and AI systems. The AI's basic role is to provide scalability in information dissemination, enabling farmers to gain access to specific and timely information while simultaneously reducing the workload on AEAs.

There are three proposed pipelines in this model:

Farmer ↔ AEA/peer ↔ Information

Farmer ↔ Artificial Intelligence ↔ Information

Farmer ↔ AI ↔ Peer Network ↔ Experts ↔ Information

Each of the pipelines represented above is designed to potentially resolve numerous forms of requests and queries farmers might present to the platform.

5.2 Potential Benefits and African Relevance

FCA could improve how information is shared among farmers while potentially addressing pressing challenges such as food shortages, agricultural supply-chain waste, and the financial and knowledge limitations faced by smallholder farmers.

The potential relevance of this architecture to African agricultural communities lies in its ability to account for diverse geographical, linguistic, socio-economic, and agricultural conditions. By combining context-aware AI with local knowledge, farmer networks, and agricultural expertise, FCA could provide a more adaptable approach to agricultural information access while complementing existing mechanisms.

Its design also considers extension-agent constraints, variable connectivity, and the need for sustainable and responsible AI implementation. This alignment with Africa's diverse agricultural realities could make FCA a potentially valuable framework for context-aware AI in agriculture.

5.3 Limitations and Risks

While the proposed platform has the potential to support smallholder and established farmers and other agricultural entities, FCA remains a proposed architecture and has not yet undergone field deployment or empirical validation.

The weaknesses of individual agricultural mechanisms stated in previous sections still exist, and the aim is to offset those weaknesses through their integration. For example, AI hallucinations can be mitigated through human and AEA evaluation, as well as feedback and reviews from other farmers.

Another possible limitation is limited internet accessibility in rural areas. This constraint may lessen as connectivity infrastructure and digital technologies continue to develop. Time also plays a crucial role in the implementation of FCA.

5.4 Proposed Evaluation Framework

Studies in previous sections have evaluated AI-based agricultural advisory and farmer-to-farmer information systems in different settings. However, FCA has not yet been deployed or empirically evaluated. A future evaluation could compare three groups:

- AI-only
- F2F/peer-to-peer knowledge
- Hybrid: AI advisory + contextual peer knowledge

The evaluation would test three major outcomes:

- Overall information quality
- User response
- Agricultural outcomes

The central research question therefore is: “Does integrating AI advisory with contextual farmer knowledge produce more useful agricultural decision support than either pathway operating independently?”

Conclusion

Smallholder farmers face various challenges, ranging from crop and livestock diseases and market volatility to the effects of climate change. Valuable agricultural information remains difficult to access effectively due to constraints in resources, geography, connectivity, and available expertise.

However, existing agricultural information mechanisms provide different forms of support, each with unique strengths and limitations. For example, farmer-to-farmer (F2F) networks provide

locally relevant support and experiential knowledge but may face limitations in reach, information quality, and access to broader agricultural expertise. FCA proposes a hybrid architecture that complements these existing mechanisms by integrating AI advisory, peer knowledge, agricultural expertise, and localization. The architecture and framework presented in this paper remain a proposed model and require empirical deployment and evaluation to determine their effectiveness.

References

- Food and Agriculture Organization of the United Nations. (2020, July 29). *Family farmers are the backbone of food security and nutrition in Africa, let their voices be heard*. <https://www.fao.org/africa/news-stories/news-detail/Family-farmers-are-the-backbone-of-food-security-and-nutrition-in-Africa-let-their-voices-be-heard/en>
- Ibrahim, A., Senthilkumar, K., & Saito, K. (2024). Evaluating responses by ChatGPT to farmers' questions on irrigated lowland rice cultivation in Nigeria. *Scientific Reports*, 14, 3407. <https://doi.org/10.1038/s41598-024-53916-1>
- Lasdun, V., Harou, A. P., Magomba, C., & Guereña, D. (2025). Peer learning and technology adoption in a digital farmer-to-farmer network. *Journal of Development Economics*, 176, 103496. <https://doi.org/10.1016/j.jdevec.2025.103496>
- Omulo, G., & Kumeh, E. M. (2020). Farmer-to-farmer digital network as a strategy to strengthen agricultural performance in Kenya: A research note on 'Wefarm' platform. *Technological Forecasting and Social Change*, 158, 120120. <https://doi.org/10.1016/j.techfore.2020.120120>
- Singh, N., Wang'ombe, J., Okanga, N., Zelenska, T., Repishti, J., Jayasankar, G. K., Mishra, S., Manokaran, R., Singh, V., Rafiq, M. I., Gandhi, R., & Nambi, A. (2024). *Farmer.Chat: Scaling AI-powered agricultural services for smallholder farmers*. arXiv. <https://doi.org/10.48550/arXiv.2409.08916>
- Tata, J. S., & McNamara, P. E. (2018). Impact of ICT on agricultural extension services delivery: Evidence from the Catholic Relief Services SMART skills and Farmbook project in Kenya. *The Journal of Agricultural Education and Extension*, 24(1), 89–110. <https://doi.org/10.1080/1389224X.2017.1387160>