Enhancing Farmer Learning and Adoption of Digital Extension: A Case Study Report of Sorghum and Millet Farmers in Western Kenya

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Enhancing Farmer Learning and Adoption of Digital Extension: A Case Study Report of Sorghum and Millet Farmers in Western Kenya

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Executive Summary

Agricultural extension services remain critical for bridging the gap between agronomic research and on-farm adoption, yet systemic inefficiencies such as low farmer-to-agent ratios, fragmented knowledge dissemination, and limited accessibility of traditional methods of learning hinder progress. Digital tools offer transformative potential through scalability, real-time interaction, and tailored content delivery. However, their impact is often constrained by poor usability, lack of farmer-centric design, and uneven technological access.

In 2023, we piloted a case study in Western Kenya's Siaya and Busia counties, focusing on sorghum and millet cultivation. The initiative tested a hybrid extension model integrating GeoFarmer, a digital platform, with existing farmer networks. We explored the following research questions:

1. What insights can be drawn from the integration of peer-to-peer learning and two-way knowledge exchange in digital extension platforms? What specific mechanisms and interactions appear to facilitate or hinder knowledge sharing within the examined agricultural community?
2. How do farmers with varying technological backgrounds engage with a Human-Centred Design (HCD) digital platform? Which design elements ease adoption, and what challenges persist in the studied communities?
3. What emerging patterns suggest how digital extension networks can complement traditional in-person demonstration methods to support the wider adoption of improved agronomic practices?

The approach

The multi-phased case study in 2023 prioritised understanding local agricultural ecosystems, tailoring digital solutions to farmer needs, and iteratively refining interventions through stakeholder feedback. The core activities underpinning this approach were:

1. Field observation - Understanding the landscape
    - We conducted initial field visits to assess challenges and opportunities in sorghum and millet cultivation; two climate-resilient crops critical to regional food security.
    - We identified systemic barriers including scarce extension resources, farmer preferences for in-person learning, and low adoption of existing digital tools.

2. Testing digital agricultural information platforms
    - We evaluated three digital platforms (GeoFarmer, Kenya Agricultural and Livestock Research Organization (KALRO) GAPs App, and Plant Village Nuru with farmers and extension agents to assess usability and relevance.
    - This enabled understanding of farmers' and extension agents' preference to diverse content formats (SMS, IVR, video) and delivery channels, emphasising accessibility for varying digital literacy levels and device access (smartphones vs. feature phones).

3. Onboarding and monitoring
    - We conducted participatory inception workshops with 35 stakeholders—including farmers, extension agents, and local institutions—to introduce GeoFarmer, the platform chosen by stakeholders. These sessions highlighted its features, benefits, and community-driven objectives.
    - The inception meetings also highlighted mechanisms for peer-to-peer learning, content co-creation, and feedback, fostering trust, legitimacy, and inclusivity.
    - We onboarded 99 farmers and extension agents onto GeoFarmer, supported by localised agronomic content in both written and visual formats.

- Farmers and extension agents were provided with incentives (data bundles, loaned tablets) to encourage initial engagement.
- Real-time monitoring of platform interactions and knowledge-sharing patterns took place.

4. Evaluation Focus Group Discussions (FGDs)
   - We conducted post-intervention focus group discussions with farmers and extension officers to evaluate learning outcomes, digital engagement, and platform accessibility and usability.
   - Key disparities in engagement levels and learning outcomes emerged between the two counties. Farmers in Busia showed higher participation, driven by proactive extension agent involvement, whereas those in Siaya engaged less, highlighting the crucial role of dedicated extension agents in digital learning and information platforms.

Key lessons

- *Human-Centred Design (HCD) drives adoption*: The use case underscored the need for digital platforms to prioritise accessibility and customisation to diverse user needs. Testing the digital platform revealed that farmers with varying technological literacy (e.g., phone users vs no phone device users) required tailored content formats (SMS, IVR, visual guides), validating the necessity of HCD principles in reducing barriers to engagement.
- *Hybrid models maximise reach*: While digital tools present scalable options, traditional methods like in-person demonstrations remain critical for reinforcing trust and practical learning. For instance, farmers in Busia - where extension agents actively bridged digital engagement with in-person interactions - showed higher engagement, emphasising the need for blended approaches.
- *Dedicated extension agent is non-negotiable*: The stark disparity in outcomes between Busia (high engagement) and Siaya (low engagement) highlighted that platform success hinges on proactive involvement of extension officers. Their role in moderating discussions, answering queries, and contextualising content proved indispensable.
- *Farmer networks amplify impact*: Pre-existing farmer groups and peer networks served as vital conduits for knowledge dissemination, particularly for indirect participants without direct platform access. This "facilitator model" mitigated digital divides and fostered community-led learning.
- *Unresolved questions on cost-effectiveness*: While digital networks showed promise in reducing reliance on overburdened agents, their comparative efficacy against traditional methods - particularly in terms of costs, adoption rates, and long-term behaviour change - requires empirical validation.

Key recommendations

- *Develop rigorous, multi-county experiments*: Conduct experiments across diverse agroecological zones to measure hybrid-digital extension's impact on learning, adoption, and cost-efficiency.
- *Invest in dedicated digital extension agents*: Deploy dedicated digital extension agents to enhance responsiveness, moderate interactions, and support farmers in integrating digital tools.
- *Iterate platforms via stakeholder feedback*: Establish continuous feedback mechanisms (e.g., quarterly FGDs, in-app surveys) to improve localisation, voice-based content, and offline functionality.
- *Scale hybrid delivery systems*: Integrate digital platforms with in-person touchpoints (e.g., field days) for updates, troubleshooting, and context-specific support.
- *Foster public-private partnerships*: For example, collaborate with telecoms to reduce data costs, engage agribusinesses for market-aligned content, and integrate digital extension into National Agricultural Research Systems (NARS), for research dissemination.

Conclusion

This case study highlights the potential of digital extension to enhance service delivery, improve farmer learning, and drive technology adoption through inclusive, user-driven approaches. The use case in Western Kenya demonstrated that integrating digital tools like GeoFarmer with social networks and traditional extension methods can strengthen engagement and trust. Key insights emphasise the importance of hybrid delivery models, proactive extension agents, and farmer groups in scaling adoption. However, further validation through rigorous experiments is needed. Scaling digital extension requires multi-county trials, institutionalised digital roles, and public-private partnerships to bridge connectivity gaps and enhance farmer learning for improving agricultural livelihoods.

I. Introduction

The delivery of agronomic solutions to farmers faces significant challenges arising from a lack of coordination and inclusivity in existing approaches. Recommendations fail to acknowledge the unique production conditions of smallholder farmers making solutions un-customised to the needs of farmers (Ndege et al., 2024). The inefficiency and high costs associated with public extension services, especially when relying on traditional methods[2] alone, exacerbate the problem. In certain environments, the ratio of farmers to extension agents is disproportionately low, hindering effective interaction (Anderson & Feder, 2007). This is compounded by limited social proximity between extension workers and the farmers they aim to assist (Birner et al., 2006), particularly with marginalised farmers, further restricting their access to extension services necessary for adopting Good Agronomic Practices (GAPs) and fostering learning and experimentation.

Private extension services, on the other hand, often prioritise specific products that are aimed at those with a willingness to pay and capacity to use such products. A profit-centric motive can lead to non-inclusive solutions that are overly general and fail to consider the subjective capacities and circumstances of individual farmers. A critical issue lies in the dissemination of agronomic research, with much of it failing to reach end users – the farmers (Beaman et al., 2021; Pamuk et al., 2014). There is a pressing need to develop widely applicable and locally relevant solutions that address this disconnect, as well as enable farmers as active participants in adopting and improving agronomic practices for their specific contexts.

Persuasion emerges as a central concern – questions about who is doing the persuading, the source of information, the reliability of the persuader, and the inclusivity of information access channels become paramount. Digital farming applications (apps) often remain unused due to their lack of farmer-centric design, perceived illegitimacy among farmers, and failure to consider the limitations of farming communities, such as limited smartphone ownership and usage, or inadequate technical endowment (Steinke et al., 2022).

Though growing and beneficial in knowledge dissemination, the use of WhatsApp-like platforms for co-learning and sharing agronomic content faces several challenges. First, there are issues of coordinating the vast amount of information shared, as well as ensuring moderation and consistency in how content is presented. This can lead to confusion and dilution of key messages for farmers. Additionally, these digital platforms often provide limited opportunities for farmers to meaningfully contribute to the solutions and information being provided. Equally important, they can lack sufficient spaces for farmers to share knowledge that is relevant to the local farming contexts and experiences. This inhibits the ability to truly bridge the gap between researchers and farmers, as the platforms tend to be more one-way in their knowledge flow.

Unless these limitations are addressed, the full potential of digital tools to enable collaborative, two-way exchanges of agronomic knowledge may remain unrealised. Addressing these multifaceted challenges requires a re-evaluation of existing approaches and the development of more nuanced solutions that are deeply attuned to the diverse needs and circumstances of the farming communities they aim to serve.

Various efforts are continually made to introduce digital agricultural solutions aimed at accelerating access to and the sharing of updated farming information. However, according to Sida et al., (2023), many of these solutions have struggled to scale effectively to meet their intended goals. Challenges include technical limitations such as the lack of high-quality, site-specific data, the complexity of the tools, difficulties in scaling agronomic models across different zones, and poor integration with existing systems. Additionally, challenges arise concerning the customisation of information to specific contexts

[2] Traditional methods include Direct farm visits, field days, farmer meetings and demonstrations, and phone calls (undirected).

and inclusivity (Olagunju et al., 2021, Samadder et al., 2023), particularly in rural settings of the global south where farmers may not possess the technological infrastructure prevalent in urban areas (Aker & Ksoll 2016).

Sida et al. (2023) also emphasise the disconnect between developers and end-users, highlighting the need for a more human-centered design (HCD) approach. This is supported by policy issues like inadequate investment in digital infrastructure, unclear data governance, and a lack of sustainable funding models. A study by the Boston Consulting Group (BCG) revealed that in sub-Saharan Africa, few digital service providers have registered more than one million users, with only 15% to 30% of them being active (Baskaran-Makanju et al., 2021). Sida et al. (2023) similarly estimate that between 20% and 30% of farmers use Site-Specific Nutrient Management Decision Support Tools (SSNM-DST), raising concerns about the gap between sign-ups and active usage. Furthermore, there is limited evidence of the long-term impact and effectiveness of these digital tools, prompting questions about their real value (Deichmann et al., 2016).

Besides digital platforms that enhance information access, empirical literature highlights the pivotal role of networks in enhancing the diffusion and adoption of new agricultural technologies and practices, as well as fostering learning (Chuang & Schechter, 2015). Available research emphasises the effectiveness of concentrating efforts on specific key agents to maximise the diffusion of innovations (BenYishay & Mobarak, 2019) and underscores the significant role of catalysing networks in promoting social learning (Bandiera & Rasul, 2006).

A more innovative approach is to synergise the benefits of digital access to agronomic information with the power of social networks. On this premise, we initiated a use case wherein we explored the potential of extending farmer networks through a digital platform to create digital networks, aiming to enhance the learning and adoption of up-to-date agronomic practices for sorghum and millet. This approach serves two purposes: it assists extension agents in reaching many farming communities simultaneously; whilst facilitating farmer collaboration to co-create knowledge and learn together. It also connects farmers with each other and with extension agents to get their questions answered. By leveraging technology, we seek to alleviate the challenges posed by the high ratio of extension agents to farmers, thereby making agricultural extension more efficient and accessible.

We identified two counties in Western Kenya to test the use case on utilisation of digital agricultural information platforms. This selection enabled us to delve into the specific challenges faced by farmers and extension workers in the region. By engaging directly with these stakeholders, we aimed to gain insights into their preferences for digital tools and develop a broad understanding of their current network structures. This, in turn, would contribute to the development of a more user-friendly design, rooted in HCD principles. Several key activities were undertaken to address these objectives. The subsequent parts of this report outline the theory of change, and discuss the approach employed during the case study.

II. Theory of Change

The theory of change underpinning this initiative is rooted in the belief that integrating digital tools with existing farmer networks and traditional extension methods can address systemic inefficiencies in agricultural knowledge dissemination and adoption. By leveraging HCD principles, fostering peer-to-peer learning, and ensuring accessibility for diverse user groups, this approach seeks to empower smallholder farmers, improve agronomic practices, and enhance food security in climate-resilient crops like sorghum and millet.

Central to this theory is the recognition that meaningful stakeholder engagement and a consultative design process are essential for co-creating solutions that resonate with local contexts and needs. Prior to

implementation, extensive consultations with farmers, extension agents, and local institutions ensured that the chosen digital platform and content were tailored to reflect local contexts, preferences, and technological constraints. During implementation, iterative feedback mechanisms and collaborative refinement of the platform was aimed at fostering trust, ownership, and inclusivity among users. Figure 1 below summarises the conceptual representation of the use case.

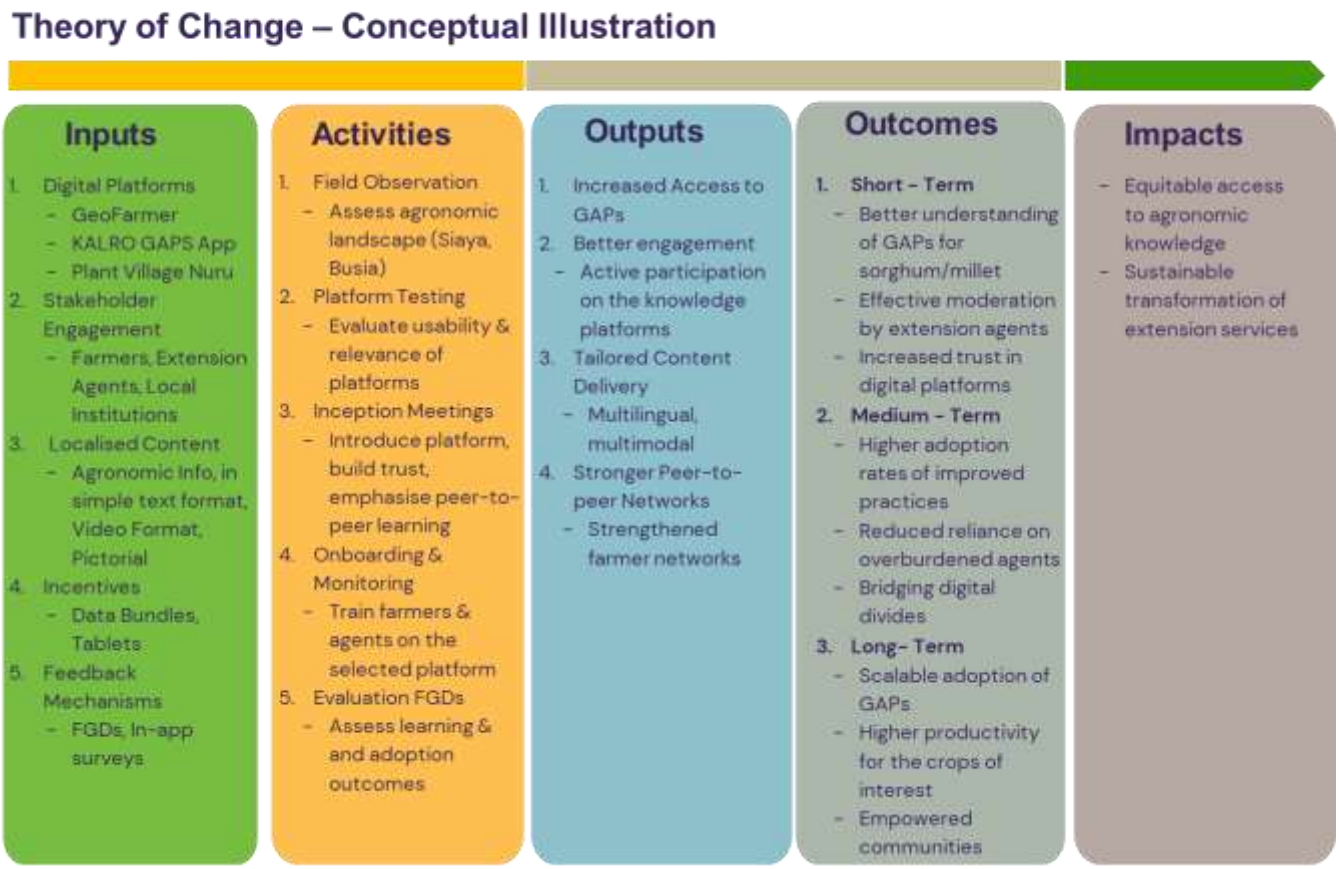

Figure 1: Conceptual Illustration of the Theory of Change

The goal of the initiative was to create resilient, farmer-centred extension approaches, where advancement in digital innovations and participatory methods synergise to improve the uptake of GAPs. By addressing systemic inefficiencies in extension services, the hybrid model can ensure equitable access to agronomic knowledge and the sustainable transformation of farming practices for sorghum and millet.

III. Grounded Research

Field Observation - Understanding the Landscape

To establish the foundation for the hybrid-digital extension model, an initial field visit was conducted in Siaya and Busia counties, Western Kenya, between July and August 2023. Sorghum and millet were selected as focal crops due to their comparative advantage in dryland farming, requiring fewer inputs and less water than maize (Frere 1984; Chaturvedi et al., 2022). These crops are increasingly recognised for their role in complementing staple crops like maize to enhance food security. The designation of 2023 as the International Year of Millets further underscores their growing global significance. Additionally, their resilience to drought makes them well suited for climate-adaptive cultivation. Despite their potential,

extension workers highlighted that sorghum and millet receive limited agronomic attention compared to maize, resulting in knowledge gaps on best practices. This initiative sought to address these gaps by evaluating the effectiveness of network-enabled digital learning as a complement to conventional extension methods.

The field visit aimed to gather insights and assess the feasibility of establishing a use case under the Excellence in Agronomy (EiA) Project. The key objectives were:

- To familiarise with local conditions, context, and environment.
- To understand farmers' cultivation challenges from their perspective.
- To observe farmer communities, engage with village elders, and identify existing formal groups or associations.
- To assess community dynamics and social structures.
- To explore the role of local institutions in agriculture, including facilitation of market engagement.
- To engage with local administrators at county, sub-county, and ward levels to understand extension services, learning approaches, and agricultural challenges.

By employing a grounded research approach, we gathered first-hand insights from local stakeholders, enabling a more precise assessment of the challenges shaping agronomic decisions on sorghum and millet cultivation. This facilitated the development of contextually relevant, economically viable solutions tailored to local conditions.

Key insights from stakeholder interactions

Interactions with farmers, agricultural administrators, extension agents, and KALRO (Kenya Agricultural Livestock and Research Organisation) revealed both challenges and opportunities inherent in the region:

Limited extension resources: Limited funding and insufficient staffing hindered the effectiveness of extension services, particularly in reaching remote or marginalised farmers. For example, each ward (hosting thousand of farmers) was typically allocated to only one extension officer.

Preference for in-person learning: Farmers showed a strong preference for face-to-face interactions, with limited use of existing digital tools. Low digital literacy and inadequate internet access further hindered the adoption of digital platforms, posing challenges to the effective dissemination of agronomic knowledge.

Crop-specific barriers: In Siaya, sorghum was the dominant crop, while millet struggled with adoption due to perceptions of labour intensity and limited consumption use. Additionally, affordable imports from neighbouring Uganda reduced incentives for local millet production. In Busia, both crops were common, though sorghum dominated, particularly in the lowlands. Farmers in both counties faced challenges such as bird and monkey interference, striga weed infestations, and reliance on outdated agronomic practices. These crop specific barriers furthered the capacity to adopt GAPs for these crops.

Seed system dynamics: Farmers largely relied on recycled seeds or sourced planting materials from neighbours, with limited uptake of improved varieties from agro-dealers. Concerns about increased bird attacks on improved varieties influenced farmers' seed choices.

Market constraints: While the presence of assured buyers like Kenya Breweries Limited (KBL) motivated sorghum cultivation, farmers expressed concerns about low prices (approximately KES 46/kg – leading to slim profit margins).

Knowledge gaps: A disconnect between research and extension services limited farmers' access to up-to-date agronomic information. Those adopting GAPs often received training through initiatives like Kenya Climate Smart Agriculture Project (KCSAP) by KALRO or development partners, highlighting the need for institutional reforms and structural adjustments to improve the dissemination of up-to-date agronomic research within the public extension system.

Potential for digital platforms: Despite scepticism towards existing tools, there was clear potential to improve accessibility and adoption through tailored digital solutions. Notably, some farmers with smartphones were already engaging with agricultural advisory services via text messages, WhatsApp groups or agriculture specific learning apps.

Peer-to-peer learning: Extension agents highlighted peer-to-peer learning as an effective strategy, especially when incentivising and mobilising lead farmers. Examples like the SIMA self-help group in Ugenya subcounty, illustrated how social networks can facilitate the adoption of GAPs among members.

Capacity building needs: Enhancing extension agents' expertise and bridging other stakeholders' knowledge gaps were noted as key to improving agronomic practices and market prospects of sorghum and millet.

Platform Testing – Evaluating Usability and Relevance

To assess the feasibility of digital agricultural platforms in delivering agronomic knowledge to smallholder farmers, three pre-existing platforms were tested in Siaya and Busia counties:

1. GeoFarmer (participatory research and feedback platform by the Alliance Bioversity-CIAT),
2. KALRO GAPs App (managed by KALRO),
3. Plant Village Nuru (research and extension platform from Penn State University).

The platform testing phase involved 24 farmers and 13 extension agents, providing a diverse sample of users with varying levels of technological literacy and preferences within these counties. The overarching goal was to evaluate the usability, relevance, and adaptability of these platforms in addressing the specific needs of sorghum and millet farmers in Western Kenya.

Key insights from platform testing

The platform testing exercise highlighted both strengths and limitations, offering key insights for designing human-centred digital solutions:

Content Accessibility: Platforms with clear, step-by-step agronomic guidance - combining written instructions and pictorial content - resonated well with visual learners.

Offline Functionality: The ability to access information offline was a major advantage, particularly for farmers in areas with poor internet connectivity.

Interactive Features: Platforms that enabled farmers to ask questions, share experiences, and engage with extension agents fostered a sense of community, akin to social media interactions.

Language Barriers: Farmers preferred content in local languages such as Swahili, Luo, and Teso. Stakeholders recommended a language drop-down menu for user selection.

Navigation Challenges: Many farmers, especially those with limited digital literacy, struggled with platform navigation. Simplified interfaces and guided tutorials were suggested as potential solutions.

Varied Digital Engagement: Farmers had diverse preferences—some favoured SMS updates, others preferred interactive audio content, and a smaller group was comfortable using smartphone apps. This diversity underscored the need for multi-format content delivery, including SMS, Interactive Voice Response (IVR), and visual guides.

Localised Content: Stakeholders emphasised the need to incorporate local knowledge into the platforms. For instance, integrating traditional pest management techniques alongside modern agronomic practices.

No platform fully addressed these specific needs of sorghum and millet farmers. The exercise also identified different farmer personas, encompassing smartphone and feature phone users with preferences for different content formats (Table 1). This lends support for a digital framework which accommodates various learning styles and technological constraints. This framework integrates SMS updates, IVR content, smartphone applications, and in-person interactions to deliver agronomic information effectively. Thus, the range of agents highlighted in table 1 need to be accounted for in a comprehensively robust digital platform.

Table 1: Summary of Farmer Personas - Digital Learning Preferences and Constraints.

Farmer persona	Phone holder		Digital learning preferences			
	Smartphone	Feature phone	Applications	SMS	USSD	Audio (e.g. calls, IVR)
Balanced Tech User	X		Comfortable with using	Prefers for quick updates		Open to IVR
Smartphone Savvy User	X		Prefers and actively uses to watch video tutorials	Only if complements apps	Only if complements apps	
Advanced Interactive smartphone user	X		•Highly proficient •Enjoys video tutorials and webinars •Actively participates in online forums and discussions •Open to sharing experiences and knowledge with other farmers through digital platforms.			
Data conscious smartphone user	X		Limited data usage for app interactions so prefers offline functionalities.	Prefer SMS updates		Open to exploring IVR for more in-depth learning.
Text focused smartphone user	X			•Prefers SMS updates •Finds short messages easy to grasp •Interested in receiving quick tips and reminders		Open to audio content but primarily interacts through SMS.
Feature phone listener		X		May occasionally use for brief and important updates.		•Prefers IVR/Audio Content •Would find IVR calls convenient for learning about new practices •Values voice instructions and interactive content.
Simple Feature phone user		X		•Prefers for updates •Finds SMS concise and easy to use •Primarily interested in essential agronomic tips.		Less likely to engage with
Less technologically proficient user guided by Proficient User	X	X	•Struggles with digital interface •Appreciates video content with guidance from a more proficient user.	Rely on assistance from family or community members to use.		Uses largely for basic communication
Visual Learner with Limited Tech Skills	X		•Limited tech proficiency •Prefers visual learning •Values image-based content, infographics, and diagrams •Open to short video clips and image-based content •Prefers simple, step-by-step visual instructions for agronomic practices.			

IV. Digital Platform Onboarding

Selection of GeoFarmer for Onboarding

GeoFarmer emerged as the most suitable platform for further implementation based on farmer and extension agent feedback. Its combination of accessible content, offline functionality, and interactive features positioned it as a strong candidate for enhancing farmer learning and peer-to-peer collaboration. Agronomic content on sorghum and millet cultivation was integrated into the platform in simplified, digestible formats to ensure clarity and practical applicability.

Key functionalities of GeoFarmer included (Figure 2):

- A digital library with localised agronomic content tailored to sorghum and millet.
- A Q&A section facilitating real-time interaction between farmers and extension agents.
- Offline access, ensuring usability in areas with limited internet connectivity.
- Multilingual support, accommodating local languages such as Luo and Teso.

These features collectively enhance knowledge dissemination and engagement, making GeoFarmer an effective tool for scaling digital agricultural advisory services.

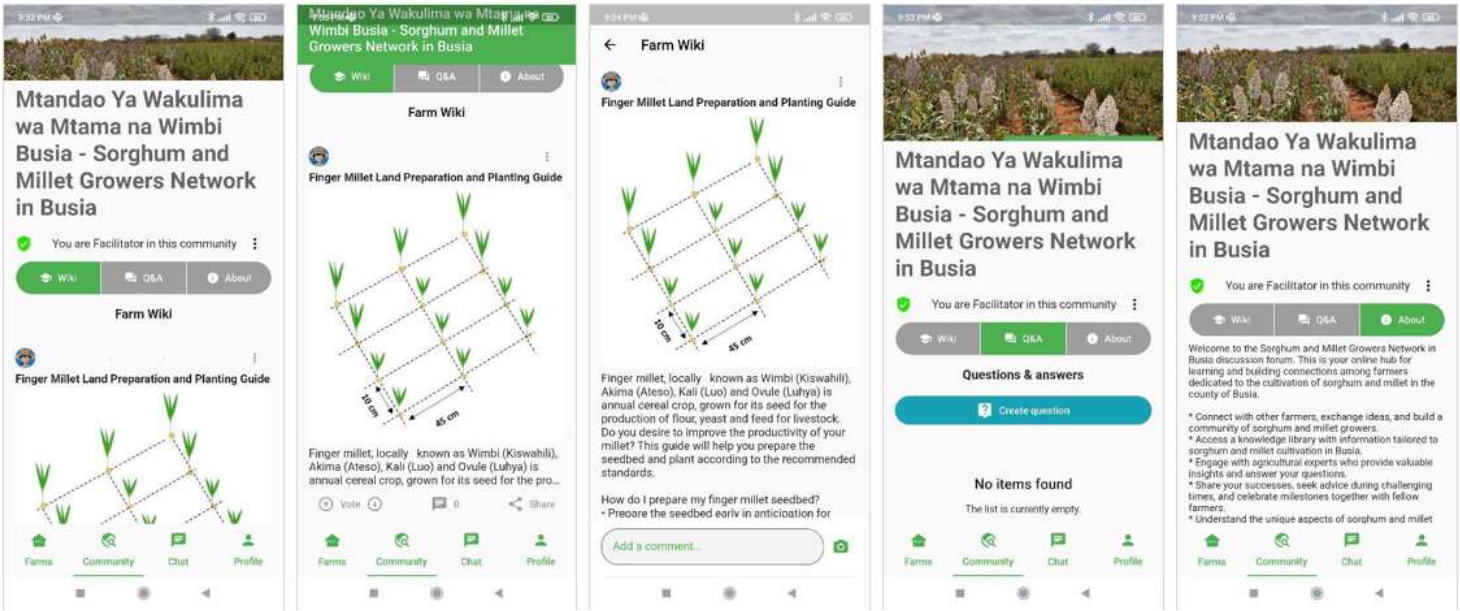

Figure 2: GeoFarmer channel for Busia Farmers

Inception Meeting and Stakeholder Engagement

As legitimacy was highlighted as an issue during initial interviews with farmers, before onboarding farmers and extension agents onto the platform, an inception meeting was held to introduce the GeoFarmer platform to farming communities in Busia and Siaya counties. The session brought together 35 stakeholders, including farmer group leaders, extension agents, KALRO representatives, and county agricultural officials. The meeting aimed to raise awareness, build trust, and foster user engagement,

addressing initial scepticism and ensuring sustained participation. Participants were introduced to the platform's purpose, key features, and benefits.

The meeting outlined the implementation strategy to stakeholders, providing clear usage guidelines:

Community engagement and Peer-to-peer learning: Farmers were encouraged to share experiences and best practices, fostering a collaborative environment.

Content co-creation: Extension agents were required to share extension content beyond the agronomic library, while farmer-led solutions were encouraged to enhance relevance, usability, and interactivity.

Feedback mechanisms: Stakeholders were assured that the platform would evolve based on user feedback to remain aligned with their needs. Thus, they were encouraged to provide feedback and suggest improvements.

Incentives: To overcome cost-related barriers to digital access, some participants received data bundles and loaned tablets. This support was particularly crucial for farmer group leaders, enabling them to engage with their networks, including farmers who lacked compatible smartphones or reliable internet connectivity.

Data privacy: Users were assured that their data would be securely managed and used solely to enhance the platform.

This structured, participatory approach ensured a smooth onboarding process while strengthening user ownership and engagement with the platform.

Onboarding Farmers and Extension Workers

Following the inception meeting, the onboarding process commenced in October 2023, involving extension workers and 99 farmers and across Busia and Siaya counties. Figure 3 illustrates the process by which farmers join the online community and connect with others on the platform. Agronomic refresher training sessions were also provided for agricultural officers in Busia and Siaya. It was also emphasised that platform engagement was designed to complement their existing responsibilities rather than add to their workload.

We focused on farmers from pre-existing groups like Ndenga CBP VSLA, Tumaini Catholic Farmers, and Amani SILC SHG. Additional spaces were available for independent farmers. However, coordination challenges indicated that onboarding entire farmer groups was more effective in ensuring inclusivity, particularly for those without smartphones.

The process was as follows:

1. *Facilitators*: Ward Agricultural Officers[3] (WAOs) acted as facilitators, guiding participants through the sign-up, login, and channel-joining processes. They also acted as digital extension agents providing agronomic insights to farmers on the platform.
2. *Channels*: Two separate channels were created—one for each county to ensure localised and context-specific interactions.
3. *Incentives*: Participants received data bundles and loaned tablets to overcome barriers related to device access and connectivity.

[3] By this we refer to Extension Agents.

4. *Localised content*: Agronomic content on sorghum and millet cultivation was simplified and presented in both written and visual formats to cater to varying literacy levels and learning preferences.

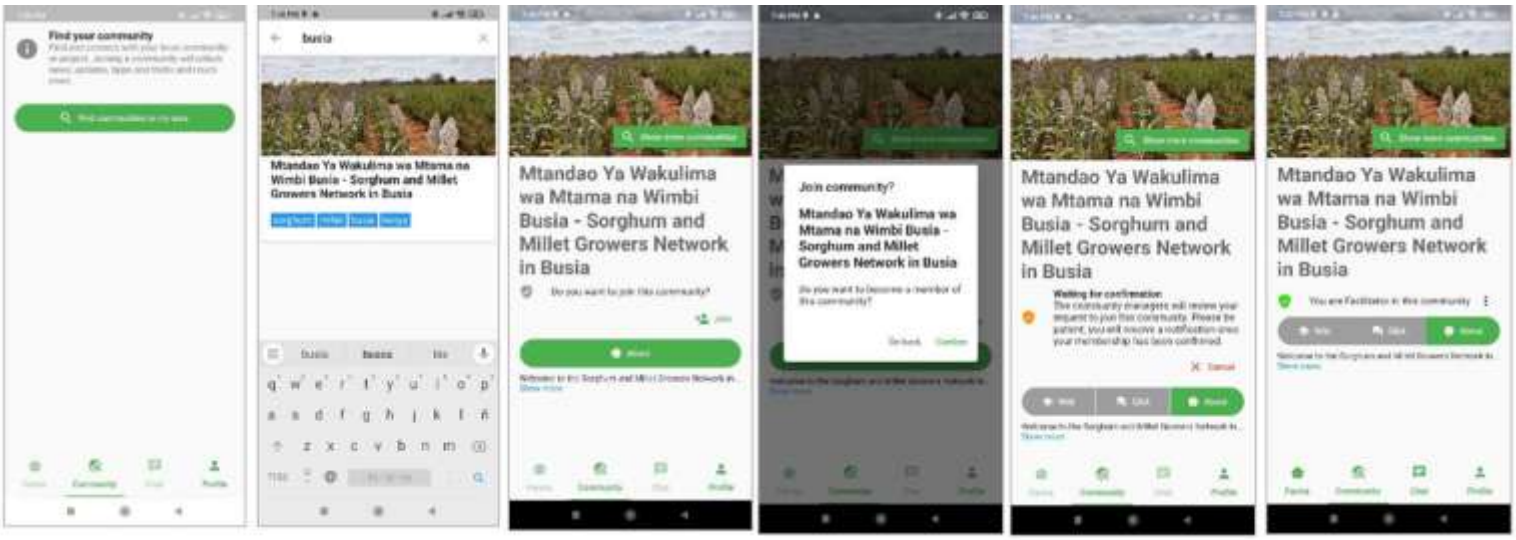

Figure 3: Joining a community on GeoFarmer

Recognising the low prevalence of smartphones among farmers, the onboarding process adopted a hybrid approach:

- *Group facilitation*: Each farmer group had facilitators equipped with tablets to interact with GeoFarmer content, share knowledge, and ask questions on behalf of group members who could not access the real-time content.
- *Multimodal delivery*: Content was delivered on the app, as well as through physical posters with visual guides, ensuring accessibility for users with different literacy (digital or otherwise) levels.

Post-onboarding, farmer and extension agent interactions were actively monitored. This included app engagement tracking and regular check-ins with farmers and WAOs. Field feedback on the agronomic library was collected to refine content. Additional activities included developing and disseminating new content, translating materials into local languages, and coordinating with KALRO Alupe for technical support.

Challenges

The implementation process revealed some challenges and lessons including:

Digital literacy barriers: Many farmers required additional training to navigate the platform confidently. Simplifying interfaces and providing guided walkthroughs emerged as critical solutions.

Moderation needs: Active moderation by extension agents was essential to maintain engagement and ensure timely responses to queries. However, varying levels of agent responsiveness highlighted the need for dedicated digital-specific roles.

Localised content gaps: While the platform addressed many agronomic challenges, some localised solutions such as strategies for managing striga weed and bird interference required further refinement.

V. Assessing Learning Outcomes and Platform Effectiveness

Focus Group Discussions (FGDs)

To evaluate the impact of the GeoFarmer platform as a tool for delivering agricultural extension services and fostering learning exchanges among farmers, post-intervention focus group discussions (FGDs) were conducted in Busia and Siaya counties. These sessions involved both farmers and extension agents. The general aim was to gather feedback on the platform's usability, relevance, and effectiveness in promoting the adoption of improved agronomic practices for sorghum and millet.
The objectives of the FGDs were to:

1. Assess whether participating farmers learned and adopted improved agronomic practices.
2. Evaluate how effectively the platform facilitated extension work and knowledge dissemination.
3. Identify challenges and opportunities for refining platform design and content delivery.

The FDGs included three key participant groups. Direct participants were farmers with smartphones or tablets who engaged with the GeoFarmer platform independently. Indirect participants lacked direct access to digital tools and relied on facilitators or intermediaries to interact with the platform. Extension officers who had served as moderators, addressing queries, contextualising content, and facilitating discussions. To capture diverse perspectives and experiences, separate discussions were conducted with farmers and extension officers in both counties.

Findings from the FGDs

Feedback from the FGDs highlighted key benefits and challenges from the use case. Key benefits highlighted include:

Platform utility: Direct participants found the platform highly useful for accessing agronomic information, particularly through the WIKI tab, which provided a library of GAPs tailored to different stages of sorghum and millet cultivation. The offline functionality was especially valued, given the region's limited internet infrastructure.

Community interaction: The platform fostered knowledge dissemination and peer-to-peer learning, with engagement resembling social media interactions. However, farmer participation varied between counties, heavily influenced by extension officer involvement. In Busia, where extension agents were more responsive and actively engaged, farmer participation was consistently high. In contrast, Siaya experienced lower engagement levels, with reduced farmer postings due to limited extension officer involvement. This highlighted the importance of active facilitation to sustain engagement and discussion.

Localised content: Content adapted to local dialects and simplified formats resonated well with users, particularly those with low literacy levels. Voice-based instructions in Luo and Teso were particularly appreciated. However, observations suggested that cultural practices influenced millet cultivation, underscoring the need for more contextualised agronomic guidance tailored to local farming traditions.

Key challenges identified include:

Translation issues: Some farmers faced difficulties with translated content, leading to confusion about specific agronomic practices. Participants again recommended introducing a language drop-down menu to allow users to select their preferred language.

Navigation difficulties: Farmers, particularly those with limited technological proficiency, found the platform challenging to navigate initially. Simplified interfaces and guided walkthroughs were suggested as potential solutions.

Delayed feedback: The platform's effectiveness relied on timely responses from extension officers, but engagement varied by county. In Siaya, limited extension support led to delays, discouraging farmer participation and weakening trust in the platform. Conversely, in Busia, proactive extension agents ensured timely responses, fostering higher engagement and a more interactive learning environment. The contrast underscores the critical role of dedicated digital extension agents in sustaining engagement and maximising the platform's impact.

Content gaps: While the platform covered key agronomic challenges, some issues—such as managing striga weed and bird interference—were either inadequately detailed or missing. This reflects broader research limitations, as comprehensive solutions for these challenges remain an ongoing area of study. Communicating this uncertainty to farmers, while also incorporating local solutions, is essential for a more adaptive and responsive platform.

These findings underscore the importance of extension agent responsiveness and the need for dedicated digital-specific roles to sustain engagement. These agents not only facilitate the platform's learning environment but also serve as a vital link in the feedback loop, relaying farmer concerns to enhance platform functionality and improve the overall knowledge-sharing experience.

Lessons Learned

This case study yielded key lessons that can inform future refinements in digital agricultural extension.

HCD for Better User Experience: Tailoring digital platforms to meet the diverse needs of farmers is crucial for reducing barriers to engagement. Key considerations include multilingual content, offline access, and multimodal formats such as voice-based instructions and visual guides. Many farmers, even those who own smartphones, rely on basic handsets that lack advanced capabilities, reinforcing the need for simple, accessible platforms with offline functionality. Farmer-centred digitisation requires direct user involvement in the design process and openness to continual improvement based on stakeholder feedback. This approach not only enhances usability but also ensures that farmer agency is proactively incorporated into digital adoption and the evolution of extension systems, allowing farmers to play an active role in shaping the tools designed for their benefit.

The Role of Extension Agents in Digital Platforms: The success of digital extension services hinges on the active participation of extension agents, who play a crucial role in moderating discussions and responding to farmer queries. There is a need for dedicated digital extension personnel or partnerships with National Agricultural Research Systems (NARs) to ensure prompt and reliable support for farmers.

Strengthening Feedback Mechanisms: Establishing continuous feedback mechanisms, such as quarterly FGDs and in-app surveys, will help refine platform design and ensure ongoing improvements. These mechanisms can inform localisation efforts, including expanding content in local dialects and addressing literacy barriers. While the platform provided valuable agronomic information, certain localised solutions required further refinement. Iterative feedback mechanisms are essential for identifying and addressing these gaps. Expanding localised content through voice-based materials, instructional videos, and farmer-driven knowledge-sharing can enhance a platform's relevance. Facilitator approaches that leverage farmer networks can also help bridge socio-economic constraints by enabling knowledge-sharing within social networks.

VI. Conclusion

This case study highlights the potential of digital extension approaches to enhance the efficiency of extension service delivery, improve farmer learning, and drive technology adoption by actively involving farmers and key stakeholders in the development and implementation of digital tools. The use case in Western Kenya demonstrates that when digital platforms are integrated with social networks and tailored through HCD, they can transform agricultural extension services. By combining GeoFarmer's digital platform with traditional methods such as in-person demonstrations, the initiative reinforced the critical role of proactive extension agents and peer networks in fostering engagement and trust. Key lessons - such as the necessity of hybrid delivery models and the amplification of impact through farmer groups - underscore the need for context-aware, inclusive solutions. However, these findings require validation through experimental approaches. Moving forward, expanding multi-county experiments, institutionalising digital extension roles, and fostering public-private partnerships will be essential in bridging connectivity gaps and strengthening digital advisory services. This approach charts a pathway towards resilient, farmer-centric systems where technology and traditional methods work together to empower smallholders and advance the adoption of GAPs for improved livelihoods.

Key Recommendations

Expand rigorous, multi-county experiments: Design an experiment e.g. randomized controlled trial (RCT) across diverse agroecological zones to quantify the impact of hybrid-digital extension on learning outcomes, adoption rates, and cost-efficiency relative to traditional methods.

Invest in dedicated digital extension agents: Train and deploy "digital extension champions" to bridge gaps in agent responsiveness. These roles could focus on moderating digital interactions, real-time farmer support, and facilitating the integration of digital tools with on-ground activities.

Iterate platforms via stakeholder feedback: Establish continuous feedback mechanisms (e.g., quarterly FGDs, in-app surveys) to refine platform design. Prioritise localisation - such as expanding voice-based content in local dialects and offline functionality - to address literacy and connectivity gaps.

Scale hybrid-digital delivery systems: Develop a national framework for blended extension services, combining GeoFarmer-like platforms with mandatory in-person touchpoints (e.g., monthly field days). Use digital tools for routine updates and troubleshooting, while reserving face-to-face sessions for complex, context-specific challenges.

Foster public-private partnerships: For example, collaboration with telecom companies to subsidise data costs for farmers and co-design low-bandwidth solutions. Engage agribusinesses to align platform content with market insights, enhancing relevance and uptake, or systemising digital extension in a consistent manner with NARS, to facilitate updated insights on research, reaching farmers and extension workers.

Future Directions

Empirical evidence is lacking on the extent to which this approach holds true in improving farmer learning, efficiency of extension delivery and adoption of GAPs, especially as compared to traditional extension models, or other farmer learning pathways, such as in-person social networks or self-directed study. As such, the comparative efficacy of this digital hybrid approach against traditional methods in terms of costs, learning outcomes, and long-term behaviour change is yet to be empirically tested.

To build a stronger evidence base, future research should explore the viability of dedicated digital extension services as a complement or alternative to conventional approaches. This could involve implementing controlled experiments across multiple counties to rigorously evaluate the impact of digital extension agents on farmer knowledge acquisition, adoption of GAPs, and the overall effectiveness of extension service delivery. Empirical assessments, such as a randomized controlled trial (RCT) or lab-in-field experiments aligned with the crop growing season, would provide robust, context-specific insights into the comparative advantages of digital platforms over traditional extension methods.

Simultaneously, iterative improvements to digital extension platforms should be informed by continuous feedback from both farmers and extension agents. A user-centric refinement process will help ensure that digital advisory tools are more responsive to farmers' needs, fostering greater engagement and adoption of recommended practices.

By integrating impact evaluation with ongoing platform development, this research can move beyond an exploratory case study to provide a more comprehensive, evidence-driven assessment of digital extension networks. These insights can inform the design of more effective and scalable agricultural advisory services, ultimately contributing to improved productivity, and economic outcomes for farmers.

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