Smart Agriculture App for Enhancing Information Access: Case Study of North Division, Fort Portal City, Uganda

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Abstract

This study aimed to address critical challenges faced by smallholder farmers in North Division, Fort Portal City, Uganda, who struggle with limited access to timely and right agricultural information. These challenges include inadequate weather forecasts, fluctuating market prices, pest and disease outbreaks, and poor crop management practices, all of which hinder productivity and food security. A Smart Agriculture App was developed to bridge these gaps by providing real-time access to weather forecasts, market price trends, pest and disease alerts, and farming tips. The application was built using Flutter, React JS and Firebase, and its development followed a user-centered and participatory design approach involving local farmers. Evaluation results revealed improved planning, efficiency, and productivity among the farmers. The app shows the potential of digital technologies in enhancing agricultural practices and decision-making for rural communities.

Keywords: Smart Agriculture, Mobile App, Rural Farmers, Uganda, Information Access

1. Introduction

Agriculture plays a vital part in Uganda's economy, providing employment and livelihood to most of the rural population (Karamagi, 2023). In North Division, Fort Portal City, smallholder farmers continue to face significant challenges in accessing timely and right agricultural information. These challenges include inadequate weather forecasting, Market price fluctuations, pests, and diseases outbreaks, and poor crop management practices. Such issues have greatly reduced agricultural productivity, profitability, and food security in the area (Muhanguzi, 2022). The rapid growth of technologies for information and communication presents an opportunity to address these challenges (Subramanian, 2022}). Mobile applications have emerged as effective platforms for disseminating information, offering farmers improved access to knowledge and resources necessary for better farming decisions (Byamukama, 2022).

The design and development of a smart agriculture app was the focus of this study to close the knowledge gap that farmers in the research area faced. The app offers real-time, localized information

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such as market prices, crop management ideas, disease and pest management assistance, and weather forecasts. To guarantee that the software satisfies the demands of the intended users and helps to boost productivity and enhance livelihoods, the project uses a user-centered and collaborative design approach.

2. Literature Review

Mobile applications for agriculture have been widely used to increase farming practices productivity and information access. Globally, platforms such as Plantix (Plantix Team, 2024) and PlantVillage (PlantVillage, 2024) provide AI-driven crop disease diagnosis and pest management, but they often lack adaptability to localized agricultural conditions. In Africa, solutions like M-Farm in Kenya and Jaguza Livestock in Uganda address needs such as market prices and livestock health, yet they do not provide comprehensive crop management tailored to specific regions like Fort Portal City.

In East Africa, iKnowFarm delivers localized pest management and crop health advice, but its coverage is limited to certain crops and regions (iKnowFarm, 2024). Farmers in North Division, Fort Portal City, still rely mostly on traditional extension services, which are slow and irregular, depriving them of timely guidance. This situation highlights the need for a real-time, location-specific platform such as the proposed Smart Agriculture App.

It has been demonstrated that user-centered design increases farmer engagement and guarantees that programs satisfy user requirements. While global platforms like Plantix effectively use image recognition for plant disease diagnosis, they overlook the importance of region-specific recommendations. Localized solutions like iKnowFarm and community-based models like AgriShare in Uganda demonstrate the value of integrating local data and participatory features to enhance relevance and adoption (AgriShare, 2024).

The successful implementation of agricultural applications requires attention to both technological infrastructure and the unique challenges faced by farmers. Partnerships with local agencies, as demonstrated by PlantVillage, help ensure relevance. AI and IoT technologies, as used in Jaguza Livestock (Jaguza Livestock, 2024), can be adapted to crop farming to provide real-time alerts on pest outbreaks and weather changes (Karamagi, 2023). Involving local farmers and agricultural experts in the development process can further improve adoption and ensure continuous improvement of the Smart Agriculture App.

3. Methodology

3.1. Design Approach

A convergent mixed-method design was used in this study, in which both quantitative and qualitative data were gathered concurrently and combined for interpretation. To gather information on farmers' demographics, smartphone ownership, and access to agricultural data, the quantitative strand used a cross-sectional descriptive survey using structured questionnaires. Key informant interviews were used in the qualitative strand to investigate farmers' opinions, experiences, and difficulties with digital

agricultural solutions. This improved the validity of the results and gave a thorough comprehensive understanding of the
of the study issues.

The study was carried out in Fort Portal City, Uganda's North Division, which is home to many smallholder farmers. There were 1,847 farmers in the division, according to records from Mountains of the Moon University's Faculty of Agriculture. Purposive sampling was initially employed to identify farmers who owned or had access to cellphones and were willing to participate, as the study was centered on mobile-based solutions. The Yamane (1967) formula for finite populations was used to get the minimal sample size:

The required sample size was calculated using formula for finite populations:

$$n = \frac{N}{1 + N(e^2)}$$

where e is the margin of error (0.09, or 91% confidence level), n is the sample size, and N is the population size (1,847). This produced the suggested minimum of 120 participants, which is thought to be sufficient for both descriptive and inferential analysis.

After then, respondents were selected from the sampling frame using systematic random sampling with an interval of $k = 1{,}847 \div 120 \approx 15$. Every fifteenth farmer was added until the goal of 120 was accomplished, following a random start between 1 and 15. Ten of these engaged in two focus group discussions (FGDs), 20 conducted semi-structured interviews, and 90 completed structured questionnaires. Both breadth and depth of data collection were guaranteed by this mixed-methods strategy. Data collection tools included a structured questionnaire (covering demographics, farming practices, and mobile usage) as shown in (Figure 9), an interview guide (for in-depth exploration of experiences with agricultural information access), and an FGD guide (to capture collective perspectives and shared challenges).

3.2. Data Analysis

The quantitative data from the questionnaires were first checked, cleaned, and analysed. Simple descriptive statistics such as frequencies, percentages, averages, and standard deviations were used to summarise the farmers' characteristics, sources of agricultural information, and smartphone use. To examine whether there was a relationship between smartphone ownership and the frequency of receiving agricultural information, a Chi-square test (χ^2) was applied at a 5% level of significance. For the qualitative part, responses from interviews were systematically reviewed and then entered the questionnaire format to ensure consistency and allow comparison with survey data. This approach helped integrate both sets of information within the mixed-method framework. The interview responses were then coded and grouped into themes based on common ideas. These themes were compared with the quantitative findings to confirm and enrich the results, thereby strengthening the reliability of the study's conclusions. The results are as shown in (Table 1).

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Sources of Agricultural Information:

Table 9 information sources

Source	Count	%
Radio	45	38%
Fellow farmers	37	31%
Mobile app	25	21%
Extension workers	4	3%
Other	9	7%

3.3. Testing and System Development

The dual interface architecture of the Smart Agriculture App was created to accommodate the requirements of both farmers and administrators. React JS was used to create the admin panel, which offered a scalable and adaptable web-based interface for uploading agricultural material, controlling system statistics, adjusting market pricing, and keeping an eye on user activities. The farmer interface, on the other hand, was developed using Flutter, guaranteeing a cross-platform mobile application that offers a dependable and simple user experience on iOS and Android smartphones. Both components used Firebase as their back end, which allowed for smooth information synchronization, real-time database access, and effective administrator-farmer communication. This design ensured that administrators could easily manage and disseminate agricultural information, while farmers could conveniently access timely, accurate, and localized updates directly through their mobile devices.

3.4. Ethical Considerations

Approval for this study was granted by the Faculty of Science, Innovation, and Technology, Mountains of the Moon University Research Ethics Committee. Written informed consent was obtained from all participants prior to data collection. Participants were assured that their involvement was voluntary and that they could withdraw at any stage without penalty. To ensure confidentiality, no personal identifiers were collected, and all responses were anonymized during data analysis and reporting.

4. Results and Discussion

The Smart Agriculture App addressed the major challenges faced by farmers in North Division, Fort Portal City by integrating localized weather forecasts, market price updates, pest and disease management tips, and contacts of agricultural dealers. As shown in Figure 2, the weather forecast interface enabled farmers to plan their planting and harvesting activities more effectively. Similarly, (Figure 6) illustrates the market information interface, which farmers reported using to track commodity prices. The farmers' forum interface (Figure 3) facilitated peer-to-peer knowledge sharing, while the crop management interface (Figure 4) gave prompt advice on farming practices. The pest and disease alert system (Figure 5) was particularly valued, with 72% of farmers confirming that it helped them

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respond to outbreaks more quickly. The agricultural dealer contacts interface (Figure 6) also supported farmers in accessing farm inputs directly from trusted suppliers.

By providing timely and reliable agricultural information that guides farm management, the Smart Agriculture App enhances farmer decision-making. While tutorials and best practice guidelines promote evidence-based decisions in crop management and resource usage, localized weather forecasts assist farmers in making more strategic planting and harvesting plans, lowering climate-related risks. By facilitating peer-to-peer knowledge sharing, the farmers' discussion forum improves decision-making even more. The software lowers uncertainty, encourages proactive management, and gives farmers the ability to make well-informed decisions that improve productivity, efficiency, and livelihoods because Firebase's real-time database guarantees up-to-date and accurate information.

A purposive sample of smallholder farmers in Fort Portal City's North Division took part in semi-structured interviews to evaluate the Smart Agriculture App's usefulness. Farmers were interviewed using open-ended questions that examined the app's usability, interface clarity, and perceived utility after interacting with its key features, which included weather forecasts, market price updates, pest and disease alerts, and agricultural tutorials. Even among those with low levels of computer literacy, 81% of farmers characterized the interface as "clear" or "very clear," according to their recorded, transcribed, and thematically analyzed comments. The app's simplicity and relevance made it a useful tool for supporting decision-making in areas like crop management, planting schedules, and market participation, according to participants, who also highlighted the importance of real-time updates made possible by Firebase integration, which guaranteed constant access to the most recent agricultural information.

The study's findings show that smallholder farmers' adoption and continued use of digital technologies are increased by a participative, user-centered design approach. This result supports earlier studies on ICT solutions for agriculture, including programs that prioritize user interaction, such PlantVillage, M-Farm, and iKnowFarm. However, by combining localized weather forecasts, current market prices, pest and disease management warnings, and a forum for farmers to communicate socially, the Smart Agriculture App provides a comprehensive and integrated solution in contrast to existing platforms. In addition to satisfying a variety of agricultural demands, this all-encompassing strategy promotes increased user engagement, usability, and relevance to the intended audience.

The Smart Agriculture App represents a context-specific digital solution for smallholder farmers, addressing practical challenges in North Division, Fort Portal City. While many global agricultural applications provide generalized information, they often lack content tailored to the needs of Ugandan farmers. By integrating farmer feedback throughout the development process, the app bridges this gap, offering actionable insights on weather, market prices, pest and disease management, and facilitating peer-to-peer interaction through the farmer forum. This community-driven approach not only enhances relevance and usability but also shows the potential of participatory innovation in improving agricultural productivity and decision-making.

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The study delivers convincing proof that using the Smart Agriculture App improves smallholder farmers' decision-making. Weather forecasts, market prices, and pest and disease alerts are examples of timely and localized information that can help farmers make better decisions regarding crop management, planting dates, and market participation. These improvements in decision-making align with previous studies demonstrate the beneficial effects of having access to reliable and practical agricultural information on smallholder farmers' productivity and resource management.

The Smart Agriculture App represents a relevant and context-specific digital solution for smallholder farmers. By addressing the practical challenges faced by farmers in North Division, Fort Portal City, the app provides critical support in areas such as weather forecasting, market price monitoring, pest and disease management, and peer-to-peer interaction through the farmer forum. Its design is tailored to the local agricultural context, ensuring that the information provided is both actionable and accessible. This relevance is further reinforced by user feedback, which indicates that farmers consider the app an essential tool for improving agricultural productivity and decision-making.

Although the Smart Agriculture App shows great promise for enhancing farmer decision-making, structural obstacles pertaining to smartphone ownership and internet availability severely limit its uptake. A significant percentage of smallholder farmers in many rural areas either do not possess cellphones or share devices among their households, which restricts their ability to utilize the app consistently and independently. Low storage space, low battery life, and expensive device costs are real barriers to long-term use, even for smartphone owners. Furthermore, access to real-time features like weather forecasts, market updates, and pest alerts is less reliable when there is irregular internet connectivity, which is frequently characterized by poor network coverage or expensive data rates. These obstacles are consistent with findings from more general research on digital agriculture, which indicate a persistent "digital divide" that disproportionately impacts underserved farming communities. Future versions of the app should put an emphasis on developing offline capabilities so that farmers may access saved data without a continuous internet connection. They should also incorporate lightweight design to minimize data usage to address these issues. Additionally, to increase farmers' confidence in using smartphone-based applications, focused digital literacy training is crucial. Adding capabilities like AI-driven crop health monitoring and livestock management to the app's scope could potentially boost its perceived value and encourage farming households to spend more money on smartphone adoption.

5. Application Design

A comprehensive user-centered and cooperative design strategy was used in the development of the Smart Agriculture App, guaranteeing that its features were customized to the needs, capacities, and environments of farmers in North Division, Fort Portal City. The app functions as the primary operational platform, and conceptually, the design shows a structured link between the independent, mediating, and dependent variables (Figure 8). Farmers' demographics, including age, education, and farm size, as well as their smartphone ownership and usage habits, are independent variables that affect how well farmers use digital solutions. Through mediating variables, such as the level of interaction

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with the app's features, such as usability, navigation, and content relevancy, and access to agricultural information, such as market pricing, insect-control advice, and weather updates, these independent variables interact with the app. Farmers are able to get timely, accurate, and useful information from this engagement, which helps them make better decisions and manage their farms more effectively. The adoption and use of digital agricultural solutions, which include increased agricultural productivity, increased income, improved market engagement, decreased crop losses, and improved knowledge sharing among farmers, is the dependent variable, which stands for the process's result. The design shows how demographic and technological factors, mediated by the app's functionalities, contribute to the effective adoption of digital agricultural solutions by explicitly linking these variables through the Smart Agriculture App. This helps to close information gaps, empower smallholder farmers, and support sustainable agricultural development in the study area.

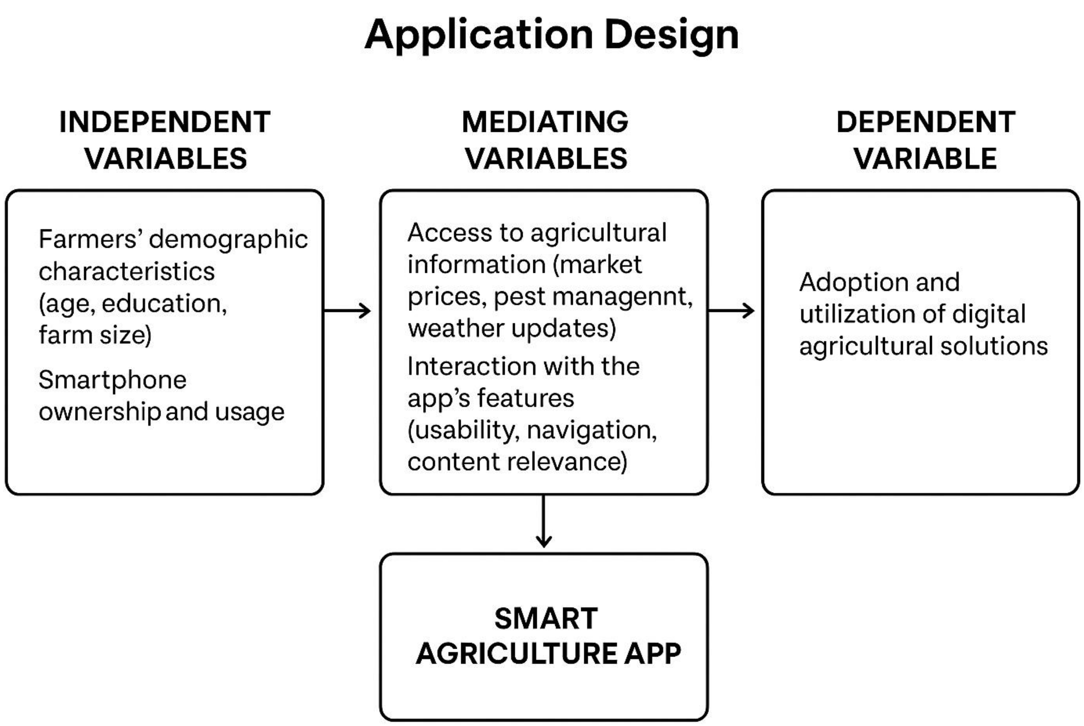

Figure 9 Application Design

6. Conclusion and Recommendations

This study set out to design and develop a Smart Agriculture App to address the persistent information gaps faced by smallholder farmers in North Division, Fort Portal City, Uganda. Agriculture remains the backbone of Uganda's economy, yet many rural farmers continue to face barriers in accessing timely and reliable agricultural information. The findings of this research confirm that digital innovations, when built around the real needs of end-users, can provide meaningful solutions to these long-standing challenges. By integrating localized weather forecasts, real-time market price updates, pest and disease management tips, crop tutorials, and a directory of agricultural dealers, the Smart Agriculture App offered a comprehensive and practical platform to improve agricultural decision-making and farm productivity. Importantly, the user-centered and participatory design approach ensured that farmers were

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not only beneficiaries but also active contributors throughout the development process, resulting in an application that was both relevant and acceptable to its intended users.

The results provide straightforward evidence that digital tools have the potential to transform agriculture in Uganda by bridging information gaps, strengthening farmers' resilience against shocks such as unpredictable weather and pest outbreaks, and improving household incomes through informed market negotiations. However, despite these promising outcomes, the study also revealed critical barriers that limit widespread adoption. These include limited access to smartphones among rural farmers, inadequate digital literacy, low affordability of data bundles, and poor or unstable internet connectivity in remote communities. Unless these structural barriers are addressed, the scalability and impact of such digital innovations will remain constrained.

Based on these findings, several recommendations are proposed. First, future development of the Smart Agriculture App should incorporate offline functionality, ensuring that farmers without stable internet access can still benefit from essential features such as weather alerts and market updates. Second, digital literacy training programs should be introduced in collaboration with extension workers, local governments, and NGOs to build farmers' capacity and confidence in using mobile technologies. Third, partnerships with agricultural institutions, government agencies, telecom operators, and private sector actors will be crucial to ensure sustainability, affordability, and wider adoption. Such collaborations could, for example, support subsidized smartphone ownership or data packages tailored to rural farmers.

In addition, the app's scope can be expanded in future iterations to include livestock management tools, soil testing recommendations, and value chain integration that link farmers directly to buyers, cooperatives, and agro-input suppliers. Multilingual support should also be prioritized to cater for farmers with limited proficiency in English, thereby improving inclusivity and usability. By addressing these areas, the Smart Agriculture App can evolve from a local pilot project into a robust, scalable, and regionally adaptable platform.

At a broader level, this research contributes to the growing body of knowledge on ICT for agriculture by demonstrating that localized, participatory, and multi-feature mobile applications can address gaps left by existing platforms such as Plantix, M-Farm, and iKnowFarm, which tend to be narrow in scope or poorly adapted to specific local contexts. Unlike these solutions, the Smart Agriculture App integrates multiple services in one platform while being tailored to the realities of smallholder farmers in rural Uganda. The study therefore not only offers practical insights for app developers and policymakers but also provides a replicable model for other sub-Saharan African countries facing similar agricultural challenges.

In conclusion, the Smart Agriculture App demonstrates that technology, when co-designed with its users and adapted to local conditions, can become a powerful enabler of inclusive and sustainable agricultural development. Expanding this innovation and addressing adoption barriers has the potential to uplift farming communities, strengthen food security, and contribute significantly to national and regional development goals.

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Appendix

Appendix A: Smart Agriculture App Interface Screenshots

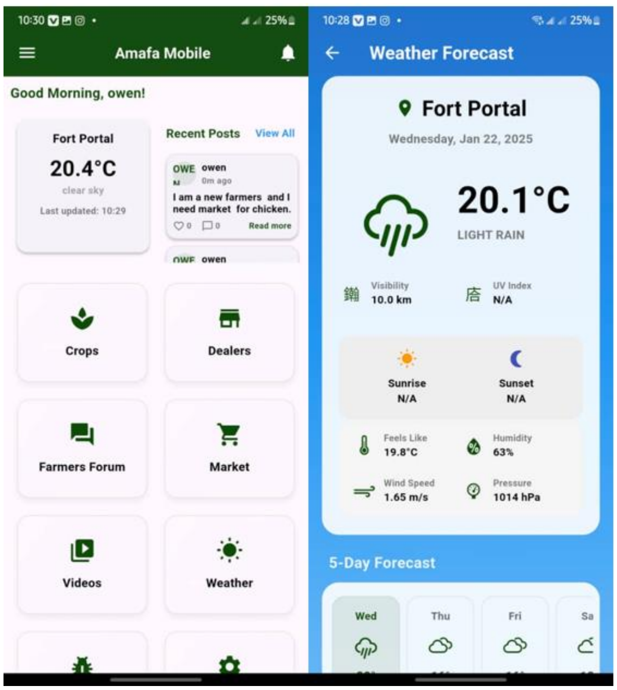

Figure 3: The weather forecast Interface and home interface.

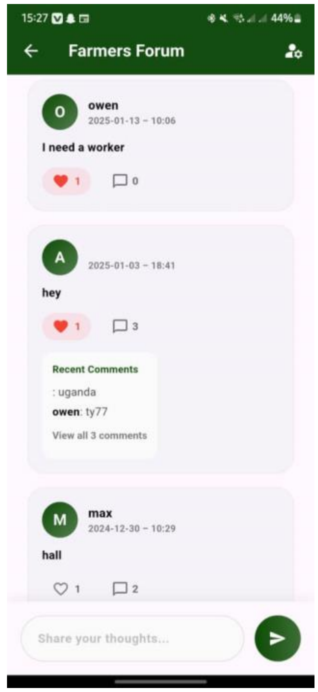

Figure 4: farmers forum interface.

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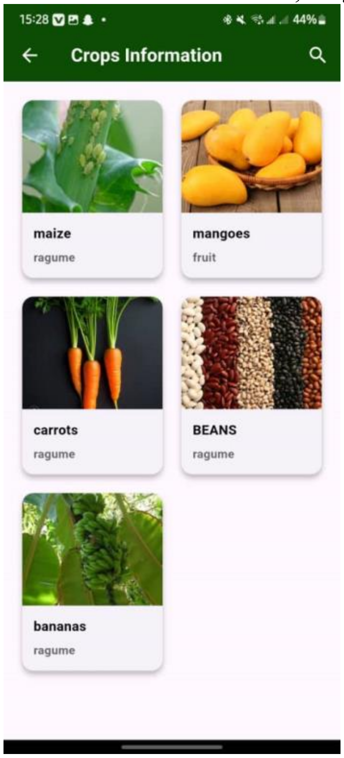

Figure 5: crop management interface.

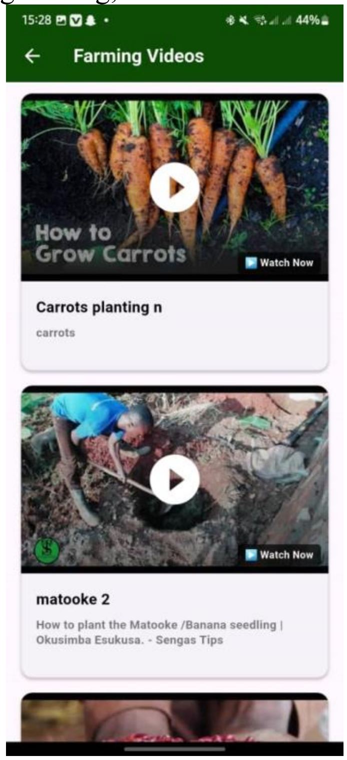

Figure 6:: farming tutorials.

References

AgriShare. (2024, October 8). Retrieved from AgriShare: https://www.agrishareapp.com

Byamukama, W. a. (2022, 12). Information Communication Technology Devices for Agricultural Information Dissemination among Smallholder Farmers in Uganda (Rubanda, Mayuge Districts, and Mbarara City). East African Journal of Agriculture and Biotechnology, pp. 238-243.

iKnowFarm. (2024, October 7). Retrieved from iKnowFarm: https://www.iknowfarm.org

Jaguza Livestock. (2024, October 8). Retrieved from Jaguza Livestock: https://www.jaguzalivestockapp.com

Karamagi, A. M. (2023). Agricultural Development in Uganda: Challenges and Opportunities. Journal of Agricultural Science, pp. 45-56.

M-Farm. (2024, October 7). Retrieved from M-Farm: https://www.mfarm.co.ke

Muhanguzi, D. a. (2022). Challenges smallholder farmers face in extracting value from agricultural information. The African Journal of Information Systems, 1.

Plantix Team. (2024, October 8). Retrieved from Plantix: https://plantix.net/en/

PlantVillage. (2024, October 7). Retrieved from PlantVillage : https://www.plantvillage.psu.edu

Subramanian, K. a. (2022}). The role of ICT adoption in promoting livelihoods in Eastern Africa: Evidence from Uganda.

IJBEST ISSN (2959-586X) and ISBN (978-9970-9943-4-2)