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Influence of Project Environment on Adoption of Digital Tools among Rwandan Banana Farmers: Case Study of ICT4BXW project, Rwanda

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Abstract: *The purpose of this study was to assess the influence of project environment on adoption of digital tools among banana farmers in Rwanda under ICT4BXW project, Rwanda. This study assessed the influences of digital literacy on adoption of digital tools. System Theory, Lean Theory and Theory of Change grounded the research by employing a descriptive and correlational research design that uses quantitative and qualitative methods. A stratified random sample of 126 respondents was selected from 183 project stakeholders. Percentage of response rate was 79.36% from the sample size. Primary data were collected using structured questionnaires and semi-structured interviews, while secondary data were obtained from project reports, academic publications and analyzed using SPSS version 32, where descriptive statistics, Pearson correlation and multiple regression analysis were analyzed. Pearson correlation showed a strong positive and statistically significant relationship between digital literacy and adoption of digital tools among Rwandan banana farmers under ICT4BXW project with ($r = 0.589$, $p = 0.000$). Regression analysis demonstrated that digital literacy with $\beta = 0.516$, $t = 5.38$ and $p < 0.001$ had significant positive influences on the adoption of digital tools The regression model produced an R-value of 0.666 and an adjusted R^2 value of 0.421, indicating that approximately 42.1% of the variation in the adoption of digital tools was explained by digital literacy. The study concludes that encouraging the long-term adoption of digital tools among banana farmers requires moderate to high-level digital literacy among banana farmers. To improve the adoption of agricultural digital tools in Rwanda, the study suggests that policymakers, extension service providers and development partners invest in training on digital devices and application; improve institutional and extension support systems and expand access to reasonable priced digital services to banana farmers in Rwanda.*

Keywords: *Digital Literacy; Digital tool adoption; Banana Farmers; Banana Xanthomonas Wilt; ICT4BXW project; Rwanda*

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1. Introduction

Digital tools are used in agriculture for increasing efficiency and increasing crop production through disease control and prevention. Digital tools have significant potential to transform agriculture and improve livelihoods of smallholder farmers in developing countries. In addition, Digital Agriculture (DA) has significant advantages and acts as a pioneering frontier in enhancing sustainable food production by providing accurate and real time insights on factors influencing productivity such as plant health, soil quality, weather variability and pest and disease outbreak (Rambod, 2023).

Worldwide, traditional farming extension services fail to meet rural farmers' needs who are isolated from the sources of information. ICT has therefore become critical in linking farmers to a wide range of agricultural information systems. The adoption rate increased from 79% to 90.18% in Dauna in Eastern Nepal. It indicates a significant dependency on traditional ICT such as mobile phones, radios and televisions. ICT tools such as mobile applications, radios, televisions, internet, and wireless networks facilitate agricultural information access. New technologies, such as internet services and smartphone applications show lower adoption rates. It means slow integration into farming practices and slow integration into farming practices. Interestingly, there is a decrease in ICT usage that was more closely associated with higher academic status. That show the complexity of technology adoption in rural areas contexts (Dhungana, 2024). Furthermore, the adoption of digital identities is increasingly recognized as a critical step in enhancing citizen inclusion in the global economy (Nesri, 2025). Above the last decade, the adoption of Information, Communication and Technology (ICT) in agriculture has increased significantly in developing countries particularly through projects for providing market information and connecting farmers with both inputs and output markets (Julius, 2020).

In Sub Saharan Africa however, the full potential of digital agriculture remains limited by different global challenges that include unequal access to connectivity, limited digital literacy, poor infrastructures and devices affordability issues. Therefore, digital tools remain under used or their usage decline over time. According to Lutz (2021), for example in Sub Saharan Africa where hundreds of digital agriculture solutions exist, only small fraction achieve scale and maintain active users. These challenges highlight the need to understand the factors that drive sustainable use of digital agriculture tools beyond their initial adoption. According to Lutz (2021), the ICT-based tools ranging from smartphone applications to Unstructured Supplementary Service Data (USSD) and Short Message Service (SMS) services are increasingly enabling farmers to access agronomic advisories, pest and disease alerts, weather updates and market linkages in a timely manner. Emerging digital platforms such as Facebook, WhatsApp and mobile applications help farmers to access agronomic information, machinery services and digital training. Despite this advancement in digital agriculture, the adoption remains constrained by digital divides, costs, and infrastructural limitations (Ajibola, 2025).

Therefore, these insights emphasize the change potential of digital agriculture taking into consideration the persistent barriers that must be addressed to ensure widespread and sustainable adoption. Understanding these barriers (factors/dynamics) is essential for designing effective interventions that can enhance crop productivity to smallholder farmers, income and crop resilience particularly in control and prevention of crop diseases through digital innovations. Most low- and middle-income countries (LMICs), especially in SSA, still rely on agriculture for livelihoods, as nearly 54% of the labor force in SSA relies on the agricultural sector (Dennis, 2024). In addition, agriculture remains a vital sector for socio-economic development at the continental level, with an estimated 70% of the population dependent on the sector for their livelihoods (World Economic Forum, cited in Claudia (2022), yet productivity levels remain low and food insecurity remains high, spurring interest in ICT solutions to enhance productivity. The most popular ICTs are text- and voice-based mobile services, which are widely accessible and used by rural farmers, while radio continues to be an important medium to share agricultural information in rural settings, and computer-based technologies are largely employed by researchers and institutional actors (Claudia, 2022). Yet, as with the short-term use of digital agricultural tools, challenges to the long-term use of these tools remain, including weak network infrastructure, unreliable electricity supply, low smartphone penetration, high costs of devices and data, and low digital literacy among rural populations, which is compounded by gender gaps and broader socio-economic inequalities that constrain access and benefits for women and other small-scale farmers (Claudia, 2022).

In Eastern Africa, it has been the leading region for digital agricultural technologies, with 217 digital solutions identified by a recent survey commissioned by Fairtrade Africa and carried out by the African Centre for Technology Studies across 34 producer organizations in nine African countries, 217 of which are in East Africa, compared to 135 in West Africa and 85 in Central and Southern Africa. Kenya had the largest number of deployed solutions, followed by Uganda, mainly because of good mobile connectivity, high mobile phone penetration, and established mobile money services (ACTS, 2024).

In Rwanda, the ICT4BXW Project was developed as part of this initiative to provide a digital solution for the management of BXW and includes the Android-based BXW App to standardize the diagnosis of the disease, crowdsourced reporting of incidence, and visualization of disease hotspots for near-real-time decision making for targeted interventions (Julius, 2021). It means that the project Multiplatform delivery of co-developed tools for national control and prevention of Banana Xanthomonas Wilt (BXW) in Rwanda: Scaling innovation for enhanced banana production and food security was launched by the International Institute of Tropical Agriculture (IITA) and Rwanda Agriculture and Animal Resources Board (RAB)

for the surveillance, control and prevention of BXW disease. The project also included complementary tools such as USSD/SMS/IVR-based advisory services, chatbots, and printed non-digital materials such as booklets and posters to reach farmers across different connectivity and device contexts (IITA, 2021). Therefore, The BXW App allows farmers and farmer promoters to recognize symptoms of the disease through step-by-step guides and images, access agronomic advice, and implement recommended control measures like the Single Diseased-Stem Removal (SDSR) technique interventions that they could not do without close extension support (PRESS, 2021). Under the ICT4BXW Project, over 325,000 farmers were reached, 1,200 farmer promoters were trained, and over 4,500 smallholder farms were surveyed for BXW at the national level, indicating significant reach and potential impact (RAB, 2023).

However, similar to trends seen throughout sub-Saharan Africa, challenges with low digital literacy, weak or inconsistent internet connections, lack of smartphones or the sharing of smartphones, and insufficient post-project institutional follow-up as emphasized by Dennis, (2024) have meant that long-term adoption and consistent use of the BXW App has been difficult to maintain. Therefore, the purpose of this study was to assess the influence of digital literacy on the adoption of digital tools with banana farmers in Rwanda.

1.1 Statement of the Problem

Agriculture remains a cornerstone of Rwanda's economy employing approximately 64.5% of the population and contributing about 25% to the national Gross Domestic Product (GDP) (BRD, 2025). According to MINICT (2025), by recognizing its importance, the Government of Rwanda has prioritized agricultural digitalization through initiatives such as the Smart Rwanda Master Plan. Within this policy framework, the ICT4BXW Project introduced the BXW App as a co-developed digital tool to empower farmer promoters and smallholder banana farmers by facilitating BXW data collection and providing access to reliable disease prevention and control information (Leeuwis, 2025).

During the project implementation phases, farmer promoters actively used the BXW App to deliver advisory services, conduct field inspections and report disease data. However, following the completion of the project, adoption of digital tools declined significantly. This decline might be attributed to limited digital literacy by banana farmers using android devices, digital agricultural tools such as BXW app, 845 services, Unstructured Supplementary Service Data (USSD), Interactive Voice Response (IVR) and WhatsApp Chatbot used in ICT4BXW project for BXW surveillance. These challenges underscore the need for a systematic assessment of the influence of digital literacy on adoption of digital tools in Rwanda, case study of ICT4BXW project. Understanding these factors is essential not only for improving banana disease management but also for informing broader national strategies on digital agriculture, extension system strengthening and resilient smallholder livelihoods.

This research study is guided by the following research objective:

i. To assess the influence of digital literacy on adoption of digital tools among Rwandan banana farmers, case study of ICT4BXW project.

2. Literature Review

This section presents a review of existing literature related to digital literacy as one of project environmental factor that influence the adoption of digital tools, with a particular focus on ICT4BXW project in Rwanda. The section discussed the concept of digital and explored its influence on adoption of digital tools such as BXW App, 845 services, Interactive Voice Response (IVR) and WhatsApp chatbot used under ICT4BXW project. It analyzed empirical studies conducted in different regions to highlight practical outcomes, challenges and lessons learned. Therefore, it identified the research gap that justifies the need to assess influence of digital literacy on adoption of digital tools among Rwandan Banana farmers, case of ICT4BXW project, Rwanda.

2.1 Digital Literacy

According to Mariette (2021), **digital** literacy (i.e. second-level digital divide) is a known limiting or enabling factor for participation. In the development and use of digital agriculture technologies this is often addressed with training. In the case of ICT4BXW, capacity building activities were indeed coupled with the design workshops, e.g. training participants (i.e. FPs) to operate a smartphone and BXW-App. Although user training was planned for in the project proposal, the real need for capacity building had been underestimated. Research using the User Readiness (UR) framework indicates that a significant "design-reality gap" exists among Rwandan farmers (Mariette, 2022), For example, 75% of our respondent's reported possession of a mobile phone, but only 3% own a smartphone. This not only indicates sub-optimal physical opportunities for users but also that sheer penetration of mobile phones may not simply be construed as a sign of readiness for adoption of all phone-based extension services among farmers (Mariette, 2021).

This lack of exposure translates into low levels of "e-literacy," where most FPs had never used a smartphone or any type of computing device before and procedures like typing or taking a picture were alien to them (Mariette, 2021). Kabirigi found a strong correlation between formal education and the perceived usefulness of mobile tools. It means approximately 83% of surveyed farmers had not progressed beyond primary education, which severely limits their ability to interact with text-heavy or complex digital interfaces. He found that Cooking Banana Farmers (CBF) typology are characterized by higher education and income and showed the highest propensity for smartphone adoption while Beer Banana Farmers (BBF) are the least educated, remained excluded due to literacy barriers (Michel, 2023).

In the context of this study, institutional support act as a strategic partnership between the International Institute of Tropical Agriculture (IITA) and the Rwanda Agriculture and Animal Resources Development Board (RAB), which co-led the project to ensure the tool's sustainability as a public good, underpin the adoption of digital tools in Rwanda. According to Baumüller, 2020 and Tsan et al., 2019 as cited by (Mariette, 2021) emphasized that the ICT4Rag strategy was one of the most progressive policies on the continent. Rwanda has the most ambitious objectives for use of ICT in rural and agricultural transformation in the African Great Lakes Region. The country profiles itself as the ICT hub in Africa and adopted several policies and strategies to enhance the use of ICT among which the 'National ICT for Rwandan Agriculture Strategy'. ICT4BXW project used the existing operational hierarchy of the national extension system and training for effectively reaching smallholders. It equipped village-level farmer promoters (Scaling Champions) with smartphones to provide support to peers who lack the hardware and digital literacy to use the BXW APP independently (Mariette, 2021). Those efforts support farmers to increase their digital literacy level thus contribute to digital tools adoption.

2.2 Adoption of Digital Tools among Banana Farmers

Adoption of digital tools is highly influenced by digital literacy level of banana farmers engaged in ICT4BXW project. Scaling up the use of apps across geographies depends on the proliferation of smart devices among smallholder farmers or last- mile extension delivery agents. (Jan Kreuze, 2022). Banana farmers in Rwanda are different in terms of socio-economic factors. It means that they are categorized in three distinct farm types. According to Michel, (2023), he indicated that a "one-size-fits-all" approach to digital extension is ineffective because farmers are highly heterogeneous. In the context of this study, they are three distinct farm types in Rwanda with varying technology profiles: Cooking Banana Farmers: This group uses a large amount of land for cooking bananas, and they believe that crop has a high economic value. They typically have higher levels of education and are the most likely to own and use smartphones. Extension agents frequently visit them, and they have active interactions with other farmers. They are highly to moderately use BXW App for BXW management (Michel, 2023).

In addition, Michel (2023) emphasized that Livestock based Farmers: These farmers combine raising livestock and growing bananas. They lag behind in the adoption of smartphones, but they are likely to own and use simple basic mobile phones. They are moderately using BXW App for BXW management. Beer Banana Farmers: This group is the least likely to own a mobile phone and they are characterized by lower income, low education level and low access to extension services. They rarely ignore the use of BXW App for BXW management (Michel, 2023). According to Mwizerwa (2020), to ensure that 60% of farmers using basic phones are not excluded; the ICT4BXW project integrates non-digital tools as well as low technological solutions**.** The 8-4-5 Service is a toll-free hotline which provides agronomic advice in Kinyarwanda via Interactive Voice Response (IVR) and USSD (845). This allows farmers with the simplest basic phones to access the same disease management information available on the BXW App regardless of internet connectivity**.** Therefore, according to the research made by Michel (2023) indicated that BXW App offers a sophisticated solution for real time disease management, its success depends on addressing infrastructure gaps and the socio-economic constraints of farmers.

Farmers in Rwanda are moving to modern agriculture where they need agronomic information, weather forecasting, pest and disease control measures and market information for their harvest. According to Michel (2024) bananas are a vital staple and cash crops grown by approximately 90% of households. However, banana plants are affected by several diseases including Banana Xanthomonas Wilt (BXW). Anne Rietvel (2020) defined BXW as a highly destructive bacterial disease that poses a severe threat to food security and rural incomes across East and Central Africa, including Rwanda. To manage this disease ICT4BXW developed digital tools, especially BXW App that support banana farmers for surveillance, control and prevention. BXW App needs internet connection to updates setting and upload diagnosed data on BXW server. Farmers faced challenges of lacking digital devices capable of installing BXW App and connecting to internet. In addition, the transition to digital agriculture is heavily influenced by the state of technological infrastructure and the socio-economic heterogeneity of the farming population (Michel, 2023). Thus, strengthening

rural ICT infrastructure, lowering device costs, and utilizing mentorship-based extension models are essential strategies for ensuring that digital innovations benefit all segments of the farming community (Gabriel, 2023). Therefore, to support banana farmers for adopting digital tools, there is a need to provide affordable smartphones, and increase internet connection to rural areas with affordable prices in order to increase their digital literacy level

2.3. Theoretical Review

This section examined System Theory as theoretical foundations that influenced the need to conduct this research study. This supported to explain the relationship of digital literacy and adoption of digital tools among Rwandan Banana Farmers under ICT4BXW project. System theory, widely known as General System Theory (GST), was developed by Austrian biologist Ludwig von Bertalanffy, with its foundational principles gaining significant traction in the 1950s and 1960s. Bui and Baruch (2010) as cited by Amagoh (2022), emphasize that GST was first introduced by Ludwig von Bertalanffy in 1940 but only gained prominence in the 1960s. General Systems Theory (GST) is an interdisciplinary framework that seeks to understand the fundamental principles governing the origin, function, and maintenance of both natural and social systems. Defined as a collection of interconnected elements that form a complex whole, GST emphasizes a holistic approach, focusing on systems as entities rather than merely analyzing their individual components. Pioneered by Austrian biologist Ludwig von Bertalanffy in the 20th century, GST has influenced various fields, including psychology, sociology, ecology, and cybernetics, and has contributed to the development of complexity and chaos theories (Issitt, 2024). Systems theory directly supports the adoption of digital tools by conceptualizing organizations as networks of information flow where data is recorded, processed, and stored to facilitate effective management. The system theory emphasizes feedback mechanisms, allowing organizations to learn from operational performance and continuously improve processes (WURISHE, 2021).

In the context of this study, System Theory provides a conceptual foundation for assessing the influence of digital literacy on the adoption of digital tools in at Bugesera, Burera, Gakenke, Gatsibo, Gicumbi, Gisagara, Huye, Kamonyi, Karongi, Kayonza, Kirehe, Muhanga, Musanze, Nyabihu, Nyagatare, Nyamagabe, Nyamasheke, Nyaruguru, Rubavu, Ruhango, Rulindo, Rusizi, Rutsiro and Rwamagana districts. ICT4BXW project has many interconnected elements such as researchers, help desk, field technicians, supplies, public and private stakeholders and operation procedures from IITA and RAB. It means that when there is a change in one area can influence the overall performance and adoption of digital tools. By applying Systems Theory, project teams can monitor these interdependencies, implement iterative adjustments, and respond proactively to emerging challenges. This approach enhances operational efficiency, ensures continuity of essential services to support banana farmers in project intervention areas, and improves farmers' digital literacy and adoption of digital tools developed under ICT4BXW project: BXW App, 845 services, IVR and WhatsApp chatbot.

2.4 Empirical Review

This section examined previous studies and research findings related to digital literacy factors and their influence on adoption of digital tools global, in Africa and in Rwandan contexts. By analyzing empirical studies from different contexts, the review identified influences digital literacy on the adoption of digital tools in Rwanda, case study of ICT4BXW project.

2.4.1 Digital Literacy and Adoption of digital tools

Globally, digital literacy is the primary filter for the successful adoption of digital tools. While digital extension services are essential, they can more easily reach small-scale, scattered landholders. Given the constraints of weak digital infrastructure and low levels of educational attainment among farmers in some mountainous regions, efforts should be made to develop context-specific, user-oriented, and technology-adapted digital application scenarios (Li Zhu, 2022). Understanding digital agriculture, therefore, requires moving beyond the question of adoption toward exploring how digital technologies are experienced within everyday farming life (Musaka, 2026). The fourth agricultural revolution (or Agriculture 4.0) promises to lead the way to an agricultural sector that is smarter, more efficient, and more environmentally and socially responsible. Digital and data generating tools are seen as critical enablers for this transformation and are expected to make farming more planned, predictive, productive, and efficient (Julius, 2021).

Evidence from Sub Sahara Africa demonstrated that digitalization in agriculture transforms farming practices, by offering particular promises for smallholder farmers in Sub Saharan Africa (SSA). Digital agriculture is progressively recognized as a strategic solution to innovate and improve agricultural production, enhance food security and support sustainable farm management especially in developing countries (Dennis, 2024). It provides real time insight into factors such as soil quality, weather variability, plant health, and pest and or disease outbreaks. Digital

tools enable farmers to make decisions that improve both productivity and crop resilience. Nowadays in emerging markets, digital technologies have the potential to transform the entire agri food systems by excellent operations across the value chain, including input suppliers and retailers. Government can benefit by using digital tools for critical functions such as subsidies distribution to farmers and managing stock in case of disasters. Therefore, when digital tools are integrated into national agriculture transformation programs, they can increase incomes for smallholder farmers, boost crop output and strengthen food security (Lutz, 2021).

In Rwanda**,** the ICT4BXW project introduced the BXW App, an Android-based diagnostic and advisory tool designed to combat Banana Xanthomonas Wilt (BXW), a disease capable of causing 100% yield loss according to Ndungo, 2026, as cited by Julius (2025) and Mariette (2021). However, early understanding of user "U" needs, readiness "R", and relevant context is a prerequisite for successful adoption and sustainable use of digital extension services. Findings demonstrate limited capacity to access and use phone-based extension services, especially those requiring a smartphone, and a mismatch between expected UR and actual UR, current capabilities and opportunities (Mariette, 2021). The extension system relies on Farmer Promoters (FPs). According to Wennink & Mur, 2016 as cited by Mariette (2021), a farmer promoter is a village-level extension agent who is a farmer him-/herself. Every village in Rwanda has an FP and he/she is the last-mile actor in the country's extension system. To facilitate adoption, the project selected 140 FPs as "Scaling Champions," equipping them with smartphones and training (Mwizerwa, 2020). While the farmers are designated as end-users, the village-level extension agents (i.e., farmer promoters) were considered as the next users of our digital solutions because of their knowledge and influence within the community, combined with their government-assigned duty to support peer farmers within their respective villages (Julius, 2025). These farmer promoters serve as essential literacy facilitators (intermediaries), bridging the literacy gap for end-users (banana farmers) who lack the skills to operate the BXW App independently. Therefore, this research study is limited to assess influence of digital literacy on adoption of digital tools among Rwandan Banana farmers under ICT4BXW project.

3. Methodology

The methodological approach that directed the study on the evaluation of project environmental factor, especially digital literacy on the adoption of digital tools under the ICT4BXW project in the districts of at Bugesera, Burera, Gakenke, Gatsibo, Gicumbi, Gisagara, Huye, Kamonyi, Karongi, Kayonza, Kirehe, Muhanga, Musanze, Nyabihu, Nyagatare, Nyamagabe, Nyamasheke, Nyaruguru, Rubavu, Ruhango, Rulindo, Rusizi, Rutsiro and Rwamagana districts in Rwanda, is presented in this chapter. Descriptive and correlational research approach was selected because it will allow the researcher to find connections between project contextual elements and digital tools adoption as well as to depict real life scenarios as they naturally occur. This is appropriate for this study in order to seek how project environmental factors such as digital literacy influence the adoption of digital tools in the ICT4BXW project and produce evidence-based findings that represent the adoption of digital tools particularly the BXW App.

The targeted population of 183 respondents involved in ICT4BXW project implementation and user of digital tools that include project lead, project manager at RAB, field officers at RAB, monitoring and evaluation (M&E) officer at IITA, sector agronomist and farmer promoters were obtained. To guarantee that all important stakeholder groups involved in ICT4BXW project activities are proportionately represented in this study, a stratified random sample technique was employed. This enabled the researcher to gather relevant and comprehensive data on the adoption of digital tools in Rwanda. In this study, the sample size was determined using Yamane's formula (1967) at 0.05 or 5% margin of error, a sample of 126 respondents was determined from the population. These groups of respondents were selected because they were directly involved in project implementation and scaling activities

This research study collected both primary and secondary data. Primary data were collected using surveys and interviews. Researchers interviewed project lead, RAB project manager, RAB technicians, M&E officer, and sector agronomists while farmer promoters answered questions of structured questionnaire. It was digitalized to reduce time for data entry and cleaning processes. These techniques gave accurate information about how digital literacy influence digital tools adoption in Rwanda's ICT4BXW project intervention districts. Secondary came from ICT4BXW project newsletters and reports, CGIAR and IITA publications, ICT4BXW project management guidelines, and journals about digital tool use in Rwanda. This data supplemented the primary data that was gathered from respondents by offering background information on the implementation of the ICT4BXW project, performance trends, farmer challenges, and the influence digital literacy on the adoption of digital tools, particularly the BXW App.

The Statistical Package for Social Sciences (SPSS) Version 32 was used to analyse the gathered data. Descriptive statistics, such as frequencies, percentages, means, and standard deviations, were used to summarise quantitative data. The link and impact of digital literacy on Rwandan

banana producers' adoption of digital tools were investigated using inferential statistics. In particular, the strength and direction of the association between digital literacy and tool adoption were determined using Pearson correlation analysis, and the impact of digital literacy on tool adoption was ascertained using simple linear regression analysis. Interview-derived qualitative data was subjected to thematic analysis by grouping responses into significant themes pertaining to digital tool usage and digital literacy. Given that the research concentrated on a single independent variable. Interview-derived qualitative data was subjected to thematic analysis by grouping responses into significant themes pertaining to digital tool usage and digital literacy. The analytical model was stated as follows because the investigation only looked at one independent variable:

$$Y = \beta_0 + \beta_1 X_1 + \varepsilon$$

Where:

Y = Adoption of Digital Tools

β_0 = Constant

β_1 = Regression coefficient

X_1 = Digital Literacy

ε = Error term

To ascertain if shifts in digital literacy significantly predict shifts in Rwandan banana producers' adoption of digital technologies, a regression model was employed. Increases in digital literacy are linked to the adoption of digital tools for future use, according to a positive and statistically significant regression coefficient; conversely, a non-significant coefficient would suggest that digital literacy levels have no statistically significant impact on the adoption of digital tools. Therefore, by receiving consent from the University of Kigali and obtaining a formal introductory letter from the International Institute of Tropical Agriculture (IITA) to permit access to ICT4BXW project stakeholders, the study adhered to ethical issues throughout the research procedure. All participants gave their informed consent, confidentiality and anonymity were upheld, participation was voluntary, and participants were made aware of their choice to withdraw from the study at any time. Every piece of data was managed securely and used only for educational purposes. Throughout the research procedure, these ethical guidelines safeguarded the participants' rights, privacy, and dignity.

4. Results and Discussion

This section presents data analysis, results, response rates, and discussion, organized in alignment with the research objectives and the applied methodology. Therefore, it presents the results and discussion of the study on the influence of digital literacy on adoption of digital tools among Rwandan banana farmers under ICT4BXW project, Rwanda.

4.1. Findings

The results of the questionnaires and interviews are presented in this study together with a discussion of how they relate to the goal of the research and the body of current empirical literature. This section covers the response rate, respondents' characteristics, descriptive findings, correlation and regression analysis and qualitative findings on digital literacy (X_1) and its influence on adoption of digital tools (Y) among Rwandan banana farmers.

4.1.1 Response Rate

The study included 126 potential participants. Five took part in interviews, and all 126 were given questionnaires. Of these, 100 questionnaires were returned, yielding a response rate of 79.4%. Altogether, 105 people participated, which is an overall response rate of 80.15%.

Table 1: Response Rate

Response Rate	Frequency	Percentage (%)
Questionnaires Returned	100	79.4
Questionnaires Not Returned	26	20.6
Total Questionnaires Distributed	126	100.0
Interview Respondents	5	100.0
Total Targeted Sample	**131**	**100.0**
Total Study Respondents	**105**	**80.15**

Source: Primary Data (2026)

Table 1 shows the response rates. Of the 126 questionnaires sent, 100 were returned (79.4%), and 26 were not (20.6%). Five people also took part in interviews. In total, 105 out of 131 targeted respondents participated, giving an overall

response rate of 80.15%. This rate was enough for data analysis and interpretation.

The research objective was to assess the influence of Digital Literacy on the Adoption of Digital Tools among banana farmers in Rwanda.

4.1.2 Descriptive statistics of Digital Literacy Factors

Table 2: Digital Literacy Factors

Digital literacy dimension	N	Strongly Agree + Agree	Disagree + Strongly Disagree	Interpretation
Basic device operation skills	100	92%	8%	Very high level of confidence
Navigation app usage skills	100	93%	7%	Very high level of confidence
Information access skills	100	97%	3%	Highest reported competency
Problem-solving skills	100	73%	27%	Moderate competency, with a notable skills gap

Source: Primary data, 2026

Table 2 results show that the respondents generally had good digital literacy, even though the level of competence differed according to the various aspects examined. As the findings indicate, 92% of the respondents either strongly agreed or agreed that they had the basic skills needed to operate devices, whereas just 8% disagreed or strongly disagreed. In a similar way, 93% of them said that they were confident about navigating and using applications, which shows that the majority of the respondents were at ease when interacting with digital applications. The greatest Levin competency was in conveying information, as 97% of respondents agreed or strongly agreed they had the necessary skills, while only 3% disagreed. This indicates that the respondents were particularly skilled at using digital devices and applications to access information.

However, the level of agreement on problem-solving skills was comparatively low, with 73% of respondents agreeing or strongly agreeing and 27% disagreeing. The lower level of agreement on problem-solving skills suggests that, although people may be at ease with routine digital tasks, they might have difficulty with technical problems, unfamiliar application features, or situations requiring independent troubleshooting. The relatively low score in this area indicates that further practical training, refresher courses, and user support should be provided to improve respondents' ability to independently address the kinds of problems they encounter when using digital agricultural tools.

Table 3: Digital Literacy and Implications for Adoption of Digital Tools

Digital literacy variable	N	Mean	SD
Basic Device Operation Skills	100	3.61	0.67
Navigation App Usage Skills	100	3.42	0.65
Information Access Skills	100	3.51	0.56
Problem-Solving Skills	100	2.99	0.73
Combined Mean		**3.38**	

Source: Primary data, 2026 where M=Mean, SD=Standard Deviation

The data presented in Table 3 provide descriptive evidence that respondents generally possessed the digital skills required to use digital tools. All dimensions, except for problem-solving, had mean scores above 3.0. Notably, high mean scores for basic device operation (3.61), information access (3.51), and navigation or application usage (3.42) suggest that respondents had a strong foundation for engaging with digital agricultural technologies.

Problem-solving skills (M = 2.99, SD = 0.73) represented the lowest level of competence among the assessed

dimensions. This finding is significant because successful adoption of digital tools depends not only on initial proficiency but also on the ability to address practical challenges independently or seek appropriate assistance when difficulties arise. The considerable variation in problem-solving skills suggests substantial differences among respondents in their capacity to manage unexpected technical issues. The descriptive findings suggest that digital literacy facilitates adoption where the combined mean of 3.38 indicates a favorable overall perception of digital literacy level among the respondents. However, targeted efforts to enhance troubleshooting and problem-solving abilities may be especially beneficial for promoting sustained and effective use of digital tools.

The descriptive results indicate that respondents generally possessed adequate digital literacy skills, providing a favorable foundation for adopting digital tools. High average scores in basic device operations, application navigation and usage, and information access demonstrate practical competence in interacting with digital technologies. However, the lower average score for problem-solving skills highlights a potential gap in users' ability to independently address technical challenges.

4.1.3 Correlation Analysis

This section presents the Pearson correlation analysis examining the relationship between the adoption of Digital Tools and Digital Literacy. With values ranging from -1 to +1, correlation analysis is used to ascertain the direction and strength of correlations between variables. The strength of statistical evidence is indicated by significance levels ($p < 0.05$, $p < 0.01$, and $p < 0.001$), whereas a positive number denotes a positive association. The results of correlation are presented in Table 4 below:

Table 4: Correlation Analysis

		Adoption of Digital Tools	Digital Literacy
Adoption of Digital Tools	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	100	
Digital Literacy	Pearson Correlation	.589***	1
	Sig. (2-tailed)	0.001	
	N	100	100

***. Correlation is significant at the 0.001 level (2-tailed).

Source: Primary data, 2026

On the other hand, according to the results presented in Table 4 the above, Pearson correlation analysis identified a positive and statistically significant relationship between digital literacy and the adoption of digital tools among Rwandan banana farmers with ($r = 0.589$, $p < 0.001$, $N = 100$). The correlation coefficient of 0.589 demonstrates a moderate-to-strong positive association, indicating that farmers with higher digital literacy are more likely to adopt digital tools in banana farming. Competencies such as operating digital devices, navigating applications, accessing digital information and solving technology-related problems are associated with increased use and acceptance of digital tools in banana farming activities. The statistically significant p-value ($p < 0.001$) suggests that the observed relationship is unlikely to be due to chance within the study sample. Therefore, digital literacy is an important factor associated with the adoption of digital tools among Rwandan banana farmers under ICT4BXW project. However, as Pearson correlation measures association rather than causation, this result does not establish that digital literacy causes the adoption of digital tools.

4.1.4 Regression Analysis

In this study, a simple linear regression analysis was conducted to determine the influence of digital literacy on adoption of digital tools among Rwandan farmers under ICT4BXW project, Rwanda. Adoption of Digital tools (Y) was treated as the dependent variable, while Digital Literacy (X_1) was considered as the independent variable. The analysis was conducted to establish the extent to which digital literacy predicts adoption of digital tools and to determine whether the relationship between the two variables is statistically significant. The regression model summary, ANOVA results, and regression coefficients were used to assess the predictive power and significance of digital literacy in explaining variations in adoption of digital tools among Rwandan banana farmers.

Table 5: Modal Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.666a	0.444	0.421	0.56929

[a] Predictors: (Constant), Digital Literacy (X_1), Source: Primary data, 2026

The regression model presented in the above Table 5 yielded a correlation coefficient of R = 0.666, according to the model summary, suggesting a moderate to strong positive link between the adoption of digital tools and digital literacy. The R Square value of 0.444 indicates that digital literacy accounts for 44.4% of the variation in the use of digital technologies. This suggests that the model has moderate explanatory power, indicating that digital literacy significantly contributes to the explanation of respondents' usage and adoption of digital tools. The Adjusted R Square of 0.421 shows that digital literacy still accounts for approximately 42.1% of the variation in adoption. This demonstrates that even after modification, the model is still reasonably reliable. The average distance between observed values and the regression line is displayed as the Standard Error of the Estimate (0.56929). Although there is still some unexplained fluctuation, a reasonably moderate value indicates that the model has a respectable degree of prediction accuracy.

Table 6: Analysis of Variance (ANOVA[a])

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	24.594	4	6.149	18.972	<.001[b]
	Residual	30.789	95	0.324		
	Total	55.383	99			

"**a**" Dependent Variable: Adoption of Digital Tolls (Y); "**b**" Predictors: (Constant), Digital Literacy (X1)

The results in Table 6 of the Analysis of Variance (ANOVA) show that the regression model is statistically significant, as indicated by F (4, 95) = 18.972 and p < 0.001 that is below the 0.05 level of significance. This means digital literacy significantly predicts adoption of digital tools by banana farmers under ICT4BXW Project.

Table 7: Regression Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	0.521	0.229		2.275	0.025
	Digital Literacy	0.82	0.152	0.516	5.38	0

a. Dependent Variable: Adoption of digital tools

The regression results as presented in Table 7 show that the model baseline level of digital tool adoption when digital literacy is set to zero is statistically significant with standardized beta coefficient of 0.521 that indicates a strong contribution of digital literacy to the adoption of digital tools among Rwandan banana farmers with p value of 0.025. Digital literacy had the most favorable and statistically significant influence on the adoption of digital tools among banana farmers with B = 0.820; β = 0.516; t = 5.380 and p < 0.001. This suggests that adopting digital tools is much more likely when one is more digitally literate. It is the model's most significant predictor. The formula also shows that adoption of digital tools would rise by 0.820 units for every unit increase in digital literacy. Digital Literacy significantly influenced the adoption of digital tools among Rwandan banana farmers, under the ICT4BXW project.

4.2. Discussion of Findings

The purpose of this study was to assess the influence of the project environment on the adoption of digital tools among Rwandan banana farmers under the ICT4BXW project. Specifically, the study assessed the influence of digital literacy on the adoption of digital tools. The findings demonstrated that digital literacy was the most influential factor affecting adoption of digital tools among Rwandan banana farmers. The majority of respondents demonstrated competence in basic device operation, navigation of mobile applications and access to information through digital platforms. Regression results showed that digital literacy had the strongest positive effect on adoption of digital tools among Rwandan banana farmers with $\beta = 0.516$ and $p < 0.001$ respectively. This suggests that farmers who possess the necessary digital skills are more likely to adopt and effectively utilize digital tools for crop management.

Regression model's explanation of 44.4% of the variation in the adoption of digital tools ($R^2 = 0.444$) among Rwandan banana farmers under ICT4BXW project. However, the remaining 55.6% of unexplained variations that are not included in the studied model suggests that other factors such as farmers' attitudes, perceived usefulness of digital tools, social influence, innovation characteristics, institutional support and cultural factors among others may also influence the adoption of digital tools. This means that these variables are highly significant and need to be investigated to enhance the adoption of digital tools under ICT4BXW project. In addition, the level of adoption of digital tools would rise by 0.820 units for every unit increase in digital literacy. Overall, the findings demonstrate that the success of digital agricultural initiatives depends more on farmers' digital skills. Therefore, improving the long-term adoption and sustainability of digital tools among Rwandan banana growers requires bolstering digital literacy initiatives. By emphasizing the significance of human capability in encouraging the adoption of digital technology within Rwandan smallholder farming systems. The findings support the argument that digital literacy serves as the primary filter for the successful adoption of digital tools (Li Zhu, 2022).

Study results is well explained by finding of Dennis (2024) who emphasized that digital agriculture has increased rapidly in SSA in recent years, with scholars estimating that by 2023, tens of millions of smallholder farmers and pastoralists across the region are registered for digital agricultural services, such as weather alerts, market information, advisory support, and extension services, delivered mainly via mobile platforms. However, persistent barriers such as lack of flexible tools, high costs, low digital literacy, low participation of women and older farmers, and low income and education levels remain a constraint to widespread adoption. A more recent scoping review by CGIAR centers also reaffirms that digital and non-digital ICT tools (i.e., mobile applications, USSD/SMS/IVR services, and extension chatbots) are increasingly being used in African countries as complements or, in some instances, alternatives to traditional extension systems. Therefore, a significant increase in digital literacy level among Rwandan banana farmers can contribute to the adoption of digital tools under ICT4BXW project in Rwanda.

5. Conclusions and Recommendations

5.1 Conclusion

The study concluded that digital literacy has a significant and positive influence on the adoption and use of digital tools among Rwandan banana farmers in the ICT4BXW project. Farmers with higher levels of digital literacy are more likely to effectively use digital technologies for accessing agricultural information, reporting, monitoring, and supporting the prevention and control of Banana Xanthomonas Wilt (BXW) disease. The study therefore concludes that strengthening farmers' digital skills, together with access to affordable and user-friendly digital devices, reliable internet connectivity, and continuous technical support, is essential for promoting sustainable adoption of digital tools in banana farming. In addition, regular training, refresher programmes, and digital extension services should be integrated into agricultural extension systems to enhance farmers' capacity to use and maintain digital technologies effectively. Strengthening these complementary factors can contribute to the sustained use of digital tools and improve their effectiveness in supporting BXW prevention and control in Rwanda.

5.2 Recommendations

Based on the study findings on the influence of digital literacy on adoption of digital tools among Rwandan Banana farmers under ICT4BXW project in Rwanda, the following three main recommendations are provided:

1. Boost Programs for Digital Literacy and Capacity Building: It is necessary to expand and maintain focused training programs for farmers since digital literacy was found to be the most significant factor influencing the adoption of digital tools. These should emphasise advanced skills including problem-solving, troubleshooting, and efficient use of agricultural applications in addition to fundamental device operation and navigation. Constant practical instruction and farmer-centered learning

strategies will boost self-assurance and long-term use of digital instruments.

2. Enhance Institutional Support and Extension Services: Given the significant influence of institutional support on adoption of digital tools among Rwandan banana farmers under the ICT4BXW project, it should strengthen extension service delivery done by RAB, MINAGRI, district and sector agronomists. This includes increasing the frequency of field visits, improving access to advisory services and ensuring the timely dissemination of digital agricultural information to farmers. Strengthening collaboration between extension agents such as RAB technicians, ICT helpdesk at IITA and farmers will further improve engagement and adoption of digital tools.
3. Make Digital Infrastructure More Accessible and Affordable to banana farmers: Internet pricing is still a significant barrier even though infrastructure factors like network availability and electricity availability were comparatively robust. It is advised that stakeholders work with telecom companies like MTN and Airtel to lower the price of internet bundles for farmers by discounted packages while using Digital tools for crop management. Furthermore, increasing the availability of rural connections will guarantee fair access and promote the regular application of digital tools in agricultural operations.

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