DETERMINANTS OF ADOPTION OF DIGITAL AGRICULTURAL EXTENSION SERVICES AMONG SMALLHOLDER FARMERS IN MURANG'A COUNTY, KENYA

Samwel Okello

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in Agricultural Extension of Murang'a University of Technology

August, 2026

DECLARATION

Student's Declaration

I hereby declare that this thesis is my original work and, to the best of my knowledge, has not been presented for a degree award in this or any other University. I understand what plagiarism is, and I am aware of the University's policy in this regard. I understand that any false claim in respect of this work shall result in disciplinary action in accordance with the University Anti-Plagiarism Policy.

_____ _____

Samwel Okello Date

Reg no: GR402/5181/2024

Supervisors' Approval

The undersigned certify that they have read and hereby recommend for acceptance by Murang'a University of Technology a thesis entitled **"Determinants of Adoption of Digital Agricultural Extension Services Among Smallholder Farmers in Murang'a County, Kenya".**

_____ _____

Dr. George Mose Nyarigoti, Date

Department of Agricultural Economics and Extension,

Murang'a University of Technology

_____ _____

Dr. Marther Ngigi, Date

Department of Agricultural Economics and Extension,

Murang'a University of Technology

DEDICATION

This thesis is dedicated to my dearly loved parents, Simeon Ogendi Opere and Caroline Omollo Ogendi, and my elder brother, Lukas Otieno Ogendi, whose indefatigable and incessant efforts have paved the way for the successful completion of this work. Thank you all.

ACKNOWLEDGEMENT

First of all, I want to thank the Heavenly Father for giving me the ability to pursue this course. My special gratitude goes to the Management and Vice-Chancellor of Murang'a University of Technology, Prof. Dickson Nyariki, for awarding me a scholarship to pursue the Master of Science in Agricultural Extension Degree. The institutional decision relieved my financial burden and enabled me to write this thesis for this course successfully.

I would also like to extend my personal gratitude to my supervisors, Dr. George M. Nyarigoti and Dr. Marther Ngigi, for their unwavering effort in guiding, supporting, and encouraging me throughout my thesis work. I also acknowledge research funding support through the project "Mechanisms to Engage Youth in Food Systems Transformation in East Africa", funded by the Scottish Funding Council International Science Partnership Fund ODA block grant allocation to the University of Edinburgh and Machakos University.

I sincerely acknowledge the support from the County Government of Murang'a, smallholder farmers, agricultural extension officers, digital service providers, youth agripreneurs, and all key informants who participated in this study and generously shared their knowledge, experience, reports, and publications. I am also indebted to my parents, Simeon Ogendi Opere and my mother, Caroline Omollo Okombo, for their incessant support and encouragement. Ultimately, I am grateful to all those with whom I interacted as I carried out this research.

ABSTRACT

Digital Extension Services (DES) bridge the gap created by declining access to conventional extension systems by leveraging ICT tools to deliver real-time updates, cost-effective solutions, and scientific information that enhance agricultural productivity. Despite these advantages, the current digital landscape remains poorly mapped, and adoption of digital tools and platforms is still limited among smallholder farmers. This research examined the determinants of DES adoption among smallholder farmers in Murang'a County, Kenya. The study documented the current landscape and emerging trends in digital agricultural extension services; assessed the level of awareness, access, and utilization of DES; and determined the key factors influencing the adoption of digital agricultural extension services among smallholder farmers in Murang'a County. The study was anchored in two theories: Diffusion of Innovation (DoI) Theory and the Technology Acceptance Model (TAM). A mixed-methods approach was used to gather quantitative and qualitative data from the four sub-counties of Kiharu, Maragua, Kandara, and Gatanga using instruments such as a structured questionnaire and key informant interviews. Data were collected from a sample of 352 participants using Yamane's formula through a multi-stage sampling comprising purposive, random, snowballing, and proportionate sampling techniques. The data were analyzed in Stata version 19 using descriptive and inferential statistics and presented in tables and figures. The findings revealed that mobile applications such as the *MyMurang'a App* remain dominant due to their bundled services, while *Mugambo wa Murimi* on Inooro TV is the most preferred broadcast program for agricultural information. Emerging trends include the integration of blockchain technology, Common Interest Groups (CIGs), Farmer Field and Business Schools (FFBS), WhatsApp-based extension systems, agripreneur-driven extension models, short agricultural videos, digital soil mapping, and data-driven advisory services leveraging artificial intelligence. Results indicate that 73.6% of farmers were aware of DES, and about 53.1% reported use, with high cost of internet bundles as the most significant deterrent to frequent use of digital platforms. Bivariate probit analysis showed that awareness significantly influenced utilization. Awareness was shaped by marital status, soil fertility, connectivity, education, and market search, while cooperative membership, credit access, education, and off-farm employment determined use. Negative binomial regression indicated that intensity of use was positively associated with household size, land size, education, cooperative membership, extension access, market search, and credit access, but negatively influenced by age and marital status. Barriers to DES adoption included high data costs, limited digital literacy, restricted smartphone ownership, poor mobile connectivity, and insufficient knowledge of existing services. Policy recommendations emphasize reducing internet costs through partnerships with telecommunications firms to provide subsidized or zero-rated data packages for agricultural platforms, strengthening rural digital infrastructure, enhancing digital literacy programs, and localizing agricultural content to improve relevance and accessibility. Furthermore, integrating digital technologies into existing conventional extension services can create hybrid models that combine trusted face-to-face advisory systems with ICT-enabled platforms, thereby improving farmer confidence, reach, and sustained adoption.

TABLE OF CONTENTS

DECLARATION ..... **ii**
DEDICATION ..... **iii**
ACKNOWLEDGEMENT ..... **iv**
ABSTRACT ..... **v**
LIST OF TABLES ..... **ix**
LIST OF FIGURES ..... **x**
DEFINITION OF THE OPERATIONAL TERMS ..... **xi**
ACRONYMS AND ABBREVIATIONS ..... **xii**
CHAPTER ONE: INTRODUCTION **1**
1.1 Background of the Study 1
1.2 Statement of the Problem 3
1.3 Objectives of the Study 4
1.3.1 General Objective 4
1.3.2 Specific Objectives 5
1.4 Research Questions 5
1.5 Significance of the Study 5
1.6 Scope of the Study 6
1.7 Assumptions of the Study 7
1.8 Contributions of the Thesis 7
1.9 Organization of the Thesis 7
CHAPTER TWO: LITERATURE REVIEW **9**
2.1 Introduction 9
2.2 Concepts of Digital Extension Service (DES) 9
2.3 Evolution of Extension Service in Kenya: From paper to pixels 9
2.4 Current Landscape and Trends in Digital Agricultural Extension Services 13
2.4.1 Typology of Digital Extension Tools and Platforms 13
2.4.2 Emerging Digital Technologies in Agricultural Extension 15
2.5 Awareness, access, and utilization of digital extension services 17
2.6 Factors Influencing Adoption of Digital Agricultural Extension Services 20
2.7 Theoretical Framework 24
2.7.1 Diffusion of Innovation Theory- Rogers (2003) 24
2.7.2 Technology Acceptance Model (TAM) 25
2.8 Conceptual Framework 26
2.9 Gaps identified in the Literature 28
2.10 Chapter Summary 30
CHAPTER THREE: RESEARCH METHODOLOGY **31**

3.1 Introduction 31
3.2 Research Design 31
3.3 Study Area 31
3.4 Target Population 33
3.5 Sampling Techniques and Sample Size 34
3.6 Data Collection Instruments 36
3.7 Validity of the Instruments 38
3.8 Reliability of the Instruments 39
3.9 Piloting of the Instruments 39
3.10 Data Collection Procedures. 40
3.11 Data Analysis and Presentation 40
3.12 Econometric Modeling Framework 41
3.12.1 Bivariate Probit Model 41
3.12.2 Multivariate probit (MVP) model 42
3.12.3 Intensity of DES Use 43
3.12.4 Robustness, Diagnostics, and Estimation Considerations 44
3.13 Ethical Considerations 44
3.14 Chapter Summary 45
CHAPTER FOUR: RESULTS AND DISCUSSION 46
4.1 Introduction 46
4.2 Response rate 46
4.3 Farm and Farmers' Characteristics of the Sampled Farmers 47
4.4 Economic Characteristics of the Smallholder Farmers in Murang'a 51
4.5 Respondents' Access to and Control of Agricultural Land 54
4.6 Institutional Characteristics of the Respondents 55
4.7 Current Landscape and Emerging Trends in Digital Agricultural Extension ..59
4.7.1 Digital infrastructure, Availability, and Access in Murang'a County 60
4.7.2 Digital Extension Utilization 61
4.7.3 DES Applications available in Murang'a 62
4.7.4 Emerging Trends in Provision of Digital Extension Services 69
4.8 Awareness of Digital Extension Services 71
4.9 Awareness levels of Digital Extension Services 72
4.10 Access and Utilization of Digital Extension Services 74
4.11 Utilization of Digital Extension Services 75
4.12 Duration of Digital Extension Service Use by the Smallholder Farmers 77
4.13 Agricultural information sought by Farmers 78
4.14 Organizations that have supported or promoted Digital Agricultural Tools ..80
4.15 Extent of DES Information on Farm Decision Making 82
4.16 Farmers' Perception of Digital Agricultural Extension Service 82

4.17 Challenges in Access and Utilization of Digital Extension Services.....84
4.18 Enablers of Digital Agricultural Extension Service.....85
4.19 Factors Influencing the Adoption of Digital Extension Service.....87
4.19.1 Bivariate Probit Estimates on Determinants of Awareness and Use of DES.....87
4.19.2 Determinants of Use of Multiple Digital Extension Service (DES) Platforms - Multivariate Probit Estimates.....95
4.19.3 Determinants of Total DES Use (Negative binomial regression).....101
4.20 Chapter Summary.....104
CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS.....105
5.1 Summary of the Findings.....105
5.1.1 Current Landscape and Emerging Trends in Digital Extension Service..105
5.1.2 Awareness, Access, and Utilization of Digital Extension Service.....105
5.1.3 Factors Influencing Adoption of DES.....106
5.2 Conclusion.....107
5.2.1 Current Landscape and Emerging Trends in Digital Extension Service..107
5.2.2 Awareness, Access, and Utilization of Digital Extension Service.....107
5.2.3 Factors Influencing Adoption of DES.....107
5.3 Recommendations.....108
5.3.1 Policy recommendations.....108
5.3.2 Practice Recommendations.....108
5.3.3 Recommendations for further research.....108
REFERENCES.....110
APPENDICES.....133

LIST OF TABLES

Table 2.1: Gaps identified in the Literature 28
Table 3.1: Determination of sample size of the four Sub-Counties 35
Table 3.2: Matrix of Key Informant Interview Participants 35
Table 3.3: Method of data collection and analysis for each objective 37
Table 3.4: Cronbach's Alpha 39
Table 4.1: Response Rate 46
Table 4.2: Socio-demographic characteristics of the respondents (n=352) 48
Table 4.3: Economic Characteristics of the smallholder farmers in Murang'a, County (n=352) 52
Table 4.4: Agricultural Land Access and Ownership (n=352) 54
Table 4.5: Institutional Characteristics of the Respondents (n=352) 56
Table 4.6 Types of Digital Extension Service 65
Table 4.7 Awareness levels of Digital Extension Services among Respondents 73
Table 4.8 Farmers Access the Internet 74
Table 4.9 Type of Digital Extension Services/Platforms Utilized by the Smallholder Farmers 76
Table 4.10: The Type of Agricultural Information Farmers Receive through DES 79
Table 4.11: Organizations that Promoted Digital Agricultural Tools Among Smallholder Farmers 81
Table 4.12: Extent of DES Information on Farm Decision Making 82
Table 4.13: Farmers' perception of Digital Agricultural Extension Service (n=262) 83
Table 4.14: Challenges in Access and Utilization of Digital Extension Services (n=352) 84
Table 4.15: Enablers of DES 87
Table 4.16: Bivariate Probit Estimates on Factors Influencing Awareness and DES Use 88
Table 4.17: Determinants of Use of Multiple Digital Extension Service Platforms: Multivariate Probit Estimates 96
Table 4.18: Determinants of Total DES Use (Negative binomial regression) 101

LIST OF FIGURES

Figure 2.1: Components of Diffusion of Innovation Theory 25
Figure 2.2: Technology Acceptance Model 26
Figure 2.3: Conceptual Framework 27
Figure 3.1: Administrative map of Sub-Counties in Murang'a 32
Figure 4.1: Sources of Information that have created Awareness 71
Figure 4.2: Users and Non-users of Digital Extension Services 75
Figure 4.3: Duration of Digital Extension Services Use 77

DEFINITION OF THE OPERATIONAL TERMS

Access: Ability to obtain and use digital agricultural extension service**s** that provide farmers with advisory services for making informed decisions.

Adoption: The study defined adoption as the mental process of voluntary decision-making and action by farmers to accept, integrate, and consistently use a novel practice, service, or technology in their farming activities (Wosene et al., 2025).

Awareness: Recognition/familiarity or acquisition of knowledge of existing agricultural extension service tools and platforms, their attributes and functionalities (Mukherjee et al., 2024; Mwale & Chiweshe, 2024).

Digital Extension Service: The utilization of ICT or digital technologies, such as mobile applications, websites, social media, and call centers, that facilitate the exchange, delivery, and management of advisory services and information between extension officers, research stations, and farmers (Cheboi & Darso, 2025).

Landscape: The entire environment or context within which digital extension services operate. It includes digital platforms, tools, and technologies used, extension methods, models and approaches, key actors, opportunities, challenges, and services provided to facilitate the transfer of information and provide rural advisory services

Smallholder Farmer: A smallholder farmer is defined as a producer who owns and operates a small piece of land ranging from 1 to less than 10 hectares, who depends mainly on family labour, and whose production is primarily for home consumption (Begum & Vijaya, 2024).

Utilization: This is the actual use or application of the digital agricultural extension services. It extends beyond awareness, availability, and access to incorporate active leverage of ICT devices in extension with a view to meeting felt and unfelt needs of the farmers.

ACRONYMS AND ABBREVIATIONS

DES	Digital Extension Service
DET	Digital Extension Tool
FAO	Food and Agriculture Organization
GIS	Geographical Information System
ICT	Information and Communication Technology
IoT	Internet of Things
IVR	Interactive Voice Response
KALRO	Kenya Agricultural and Livestock Research Organization
KAOP	Kenya Agricultural Observatory Platform
KASEP	Kenya Agricultural Sector Extension Policy
KIAMIS	Kenya Integrated Agricultural Marketing Information System
ML	Machine Learning
MoA	Ministry of Agriculture
NGO	Non-Governmental Organization

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Agriculture is regarded as the mainstay of national economies due to its instrumental role in income generation, employment creation, rural economic development, contribution to Gross Domestic Product (GDP), and poverty alleviation worldwide (Anami, 2026; Singh, 2026; Rao, 2026). The sector is not standalone; it is strongly supported by the agricultural extension service, which bridges the gap among scientists, policymakers, and farmers (Mugabo et al., 2026; Karki et al., 2026; Maulu et al., 2021). A report by the Kenya Agricultural Sector Extension Policy defined extension as a set of services and institutions that facilitate access to agricultural information, skills, and technologies to improve agricultural efficiency, food and nutrition security, and overall individual well-being (KASEP, 2023).

Agricultural extension integrates functions like the dissemination of information, advisory services, encouraging adoption of modern technologies and sustainable agricultural practices, facilitating access to resources, technology transfer, training and education, research and development, farmer-market linkages, and participatory decision-making (Karki et al., 2026; Mpundu & Musenge, 2026; Chaudhari et al., 2024). These functions are driven by extension agents who serve as agents of change, promoting effective transfer of knowledge within the farming community, thereby enhancing accessibility of knowledge even by farmers in remote areas who may be grappling with digital literacy challenges. Extension agents present modern technologies to farmers and assist them in navigating through the technologies in the entire process of adoption (Lee et al., 2026; Karki et al., 2026).

Within sub-Saharan Africa, research has shown that agricultural extension and advisory services have undergone a tremendous technological change over the past decades (Mukherjee et al., 2025; Norton & Alwang, 2020). This transition is viewed through the lens of a traditional extension system that was marked by top-down approaches, such as the training and visits model, which were linear in nature, to a multi-stakeholder partnership that provides space for joint delivery of extension advisories by both public and private sectors. Top-down approaches fail to incorporate bottom-up experiences because of their purely teaching-oriented nature; hence, the

shift to a pluralistic extension system that allows learning through collective information sharing among stakeholders (Schultze et al., 2026).

Joint knowledge sharing is driven by demand and participatory-oriented extension. Demand-driven extension services have been widely implemented due to the unique needs of farmers and the heterogeneous nature of farming systems. Demand-driven approaches have emerged to better align extension content with smallholder context. These changes have also resulted in a shift in the role of the extension agent to that of a facilitator and knowledge broker, bridging the gap between research institutions, extension services, and the farming community (Schultze et al., 2026; Hainzer et al., 2024; Thapa et al., 2025).

In response to this shift, there has been a need to adopt new farming methods, techniques, and tools to increase agricultural efficiency, ushering in digitalization, in which decision-making is supported by digital technologies in a data-driven economy (Abati & Opoku, 2026; FAO, 2021). Farmers, who are the main recipients of extension services, require timely agricultural information to make informed farming decisions (Thapa et al., 2025). However, conventional extension, characterized by physical interaction, has failed to disseminate up-to-date information due to the use of antiquated methodologies, resource-intensive processes, a shortage of extension agents and funding, and an inability to meet the diverse needs of farmers for modern agricultural practices; hence limited in audience coverage. In addition, it didn't equally favour men and women, especially in participation in agricultural training and access to resources (Priya et al., 2025; Khatri et al., 2024; Sen et al., 2024).

Digitizing agriculture is regarded as a panacea for the challenges associated with the traditional extension system. Digital extension service complements traditional extension, thus aiding in solving the food insecurity problems (Bharti et al., 2026; Naika et al., 2021; Deji et al., 2024). Digital extension services integrate ICT tools with a view to enhancing accessibility, inclusivity, and efficiency in the dissemination of agricultural information. Digital extension leverages tools like mobile-based applications, websites, social media, call centers, internet platforms, mobile phones, drones, Geographical Information Systems (GIS), and emerging technologies such as blockchain and Artificial Intelligence (Byamukama et al., 2025; Khatri et al., 2024; Cheboi & Darso, 2025). These tools support agricultural production by providing

localized, context-specific advisory services, enhancing traceability, and improving network connectivity in agriculture (Porciello et al., 2022). Information obtained from these digital tools helps in better decision-making, hence increasing agricultural productivity (Priya et al., 2025; Sen et al., 2024).

Kenya has recorded rapid digital growth. A report by the Communication Authority of Kenya showed a high proliferation of mobile phone subscribers, usage, and connectivity, with a notable increase in overall mobile phone penetration, standing at 143%, with smartphones and feature phones standing at 80.8% and 62.2%, respectively, earning Kenya the nickname "Silicon Savannah." Despite high growth, utilization of these digital platforms remains low due to distrust, high device costs, limited capacity building, and limited access to information (Vutukuru & Njagi, 2023; Njuguna et al., 2025; Communications Authority of Kenya, 2025). The adoption of digital extension solutions is influenced by various factors, grouped as who, why, and where. The 'who' context encompasses farmers' structural and sociodemographic characteristics; the 'where' context encompasses institutional and spatial characteristics; and the 'why' dimension focuses on the motivation for innovation adoption (Miine et al., 2023).

In Murang'a County, the shift has been towards digitizing county services to ensure efficient delivery. It has witnessed a rapid proliferation of mobile phone ownership and the need for climate-smart agricultural technologies (Bitok et al., 2023). However, empirical evidence on determinants of the adoption of digital extension services remains limited. Therefore, this study sought to examine the determinants of the adoption of digital agricultural extension services in Murang'a County in Kenya.

1.2 Statement of the Problem

Kenya's economy and food security are heavily reliant on agriculture, which is the second-largest contributor to the country's gross domestic product, after the services sector, accounting for about 33% of total GDP. Agriculture is also a major source of income, as approximately 75% of the population depends on the sector. However, the sector's contribution has continued to fluctuate, disrupting agricultural productivity (Lokuruka, 2020). Smallholder farmers, who play a vital role in production, still face significant contextualized challenges, including unpredictable weather, soil degradation, financial resource challenges, limited market access, and unaffordable

inputs, further constraining agricultural productivity and resilience (Gumbi et al., 2023; Nyasimi et al., 2022). This is due to the conventional extension system's inability to meet farmers' specific needs (Kansiime et al., 2021).

Traditional extension is characterized by a shortage of extension personnel, outdated methods, limited resources, and an inability to provide localized and timely information (Byamukama et al., 2025; Tambo et al., 2020). Integration of digital extension services has been identified as a promising solution to surmount the contextualized challenges attributed to traditional extension services (Gumbi et al., 2023; Sen et al., 2025). Digital agricultural extension services leverage ICT tools such as mobile phones, Artificial Intelligence, Blockchain technology, drones, internet-based platforms, and Geographical Information Systems, providing real-time, cost-effective agricultural solutions and localized information (Byamukama et al., 2025). Furthermore, Kenya has advanced in mobile phone network coverage, with 99% of the population covered, but only 33.5% use the internet, creating a wide usage gap (Communication Authority of Kenya, 2024).

Despite the benefits of digital agricultural extension services, such as real-time updates, cost-effective solutions, and extensive mobile coverage, adoption remains relatively low and slow among smallholder farmers (Cui & Wang, 2023). Furthermore, there is limited empirical documentation of the digital extension landscape and emerging trends in Kenya, particularly in Murang'a County. While mobile applications, broadcast programmes, and social media platforms are proliferating, systematic evidence on their typologies, access, utilization, and inclusivity remains limited. Therefore, this study sought to examine the determinants of the adoption of digital agricultural extension services among smallholder farmers in Murang'a County.

1.3 Objectives of the Study

1.3.1 General Objective

The broad objective of this study was to examine the determinants of smallholder farmers' adoption of digital extension services in Murang'a County, Kenya.

1.3.2 Specific Objectives

To achieve the broad objective, the study was guided by the following specific objectives:

i. To document the current landscape and emerging trends in the provision of digital agricultural extension services (DES) in Murang'a County.
ii. To assess the level of awareness, access, and utilization of the digital extension services among smallholder farmers in Murang'a County.
iii. To determine the factors influencing the adoption of digital agricultural extension services among smallholder farmers in Murang'a County.

1.4 Research Questions

The researcher used the following research questions during the research:

i. What is the current landscape and emerging trends of digital agricultural extension services available to smallholder farmers in Murang'a County?
ii. What is the level of awareness, access, and utilization of digital extension services among smallholder farmers in Murang'a County?
iii. What are the factors influencing the adoption of digital agricultural extension services among smallholder farmers?

1.5 Significance of the Study

The determinants of adoption of digital extension services in Murang'a are a topic that has not been exhaustively investigated. However, with the digital age, it was significant to investigate the determinants of the adoption of digital extension services.

The study was significant in identifying gaps in the existing literature on digital technology, contributing to academic knowledge by extending the theories of Diffusion of Innovation and Technology Acceptance Model within the context of digital agricultural extension services. In addition, limited research on the current landscape and emerging trends in digital extension was a critical gap filled. The study was also beneficial for future comparative studies and analyses, since the same methodology can be applied to different contexts, thereby expanding beyond the geographical scope of Murang'a County.

The findings of this study would benefit multi-stakeholders. Relevant study insights can be leveraged by the government, policymakers, and agricultural practices both at the county and national levels. This assists in formulating targeted interventions that support digital agricultural extension, promoting agricultural development strategies. Extension agents would benefit from study insights by developing a nuanced understanding of the challenges of adopting digital services, enabling tailoring of extension approaches based on the needs of the farmer. In addition, farmers will derive direct benefits from this study by obtaining more tailored, accessible, and effective digital extension solutions for productivity and income improvement, which in turn leads to food and nutritional security, aligning with the Bottom-Up Economic Transformation Agenda (BETA). Moreover, the study will inform the implementation of the Kenya Agricultural Sector Transformation and Growth Strategy (ASTGS) 2019-2029, especially the flagship on digitization and agricultural data systems, and the Kenya Agricultural Extension Policy (KASEP) 2023, which emphasizes the utilization of ICTs in agricultural extension service delivery.

This study on digital extension has the potential to contribute to achieving the UN Sustainable Development Goals (SDGs). For instance, SDG 1 (no poverty) is supported by digital extension, which provides various agricultural information services related to weather, markets, pests, and diseases, among others, thereby raising income levels and farm productivity. SDG 2 (zero hunger) is achieved through the use of digital tools to offer precision advice, thereby contributing to increased yields; SDG 5 (gender equality) is promoted by ensuring inclusivity and empowering women to access financial services and resources digitally. In addition, SDG 10 (reduced inequalities) is achieved by bridging the information gap and ensuring equal access; SDG 13 (climate action) by providing information on climate-smart practices to mitigate climate change; and SDG 17 (partnership) through multi-stakeholder collaboration in extension, thereby strengthening agricultural partnerships.

1.6 Scope of the Study

Geographically, the study was confined to the County of Murang'a, with a key focus on the sub-counties of Gatanga, Maragua, Kandara, and Kiharu. The methodological approach employed a mixed-methods research design, integrating qualitative and quantitative data within a single study. Structured questionnaires, key informant

interviews, publications, and reports were used as sources to gather both primary and secondary data. The study subject scope was limited to smallholder farmers of Murang'a County who engaged in crop and livestock husbandry. The study gathered data on the digital landscape and trends on socio-economic, institutional, and technological factors of the smallholder farmers. Additionally, extension agents and digital extension service providers were also involved. The content scope concentrated on the current digital landscape and emerging trends, awareness, access, utilization, and factors influencing the adoption of digital agricultural extension solutions.

1.7 Assumptions of the Study

The study assumed that the respondents were potential users of digital extension platforms and services. The responses were anticipated as honest, accurate, and consistent with the data collection instruments administered. It was assumed that the data gathered were fairly representative of the study area.

1.8 Contributions of the Thesis

This study contributes empirical evidence on the adoption of digital agricultural extension services among smallholder farmers in Murang'a County. It documents the current digital extension landscape, emerging technologies, farmers' awareness, access, and utilization of digital extension services. The study also contributes evidence on socioeconomic, institutional, and technological factors influencing adoption and intensity of digital extension use. By focusing on Murang'a County, it adds location-specific evidence to the existing body of research, particularly on smallholder farmers engaged in crop and livestock production. Methodologically, the study contributes through its mixed-methods approach, combining quantitative and qualitative evidence. The findings also provide useful information for policymakers, extension practitioners, and digital service providers.

1.9 Organization of the Thesis

The study is organized into five chapters. Chapter one outlines the introduction, which encompasses the research study background, problem statement, broad and specific objectives, research questions, study justification, the study scope and limitations, and the operational definition of terms used in the study. Chapter two presents a review of related literature and studies. It highlights the reviews of the existing literature and relevant studies that have been carried out to assist in establishing the theoretical

foundation and scientific voids that the proposed study aims to fill. Chapter three presents the research methodology broken down into the study's research design, population, and sample sizes, data collection tool, procedures, and analysis techniques. Chapter four outlines results and discussions in terms of study findings for each objective and respective discussion; the methods used for data analysis and the form used to present the findings are also outlined, and Chapter five provides a summary, conclusions, and recommendations.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

Chapter two presents an empirical and theoretical review of digital extension services in agriculture. It shows related literature on concepts of DES, evolution of DES from paper to pixel, typology of digital extension services, and research theories underpinning the research. It places a special emphasis on establishing a theoretical and empirical ground by exploring key concepts of digital agricultural extension services, trends, the modern landscape, and scientific lacunae in the existing body of knowledge.

2.2 Concepts of Digital Extension Service (DES)

Digital extension services are defined as electronic services that farmers receive through digital platforms; they encompass weather information, agronomic and financial advice, and market access, inter alia (Byamukama et al., 2025). According to Awad (2021), digital agriculture extension integrates digital content and platforms, communication and advisory services, data and analytics, digital literacy and capacity building, and partnerships and collaborations (Awad, 2021).

Within the Kenyan context, digital solutions in agriculture leverage machine learning, mobile applications, satellite imagery, e-contracts, and decentralized technology, automated meteorological posts, artificial intelligence, and Macro Data utilizing Internet of Things (IoT) and cloud technologies, such as cameras, drones, sensors, inter alia (Duguma & Bai, 2024; Kiaka, 2024). Digitalization of agricultural extension blends ICT with existing conventional extension practices to deliver more timely, effective, targeted, and specific transfer of farmers' knowledge, information, and extension services (Awad, 2021).

2.3 Evolution of Extension Service in Kenya: From paper to pixels

Agricultural extension services have gradually shifted from traditional methods, which relied on pamphlets, face-to-face interactions, radio programs, and in-person visits (Priya et al., 2025). Despite conventional extension services having merits such as fostering trust through in-person interactions, accessibility to remote areas, local networking, and immediate feedback, they, however, posed serious hurdles such as higher costs in terms of travel, venue, and materials, limited reach, and time-

consuming organizing and coordinating in-person events (Purwadi et al., 2023). Before 1914, extension services in Africa, to a large extent, were provided by missionaries who set up farms as demonstration plots alongside their missionary work of spreading the gospel (Maratha et al., 2025). In Kenya, the agricultural extension service has its roots in the early 1900s. This service is not static but has undergone various transformations since the establishment of the colonial government (KASEP, 2023).

According to Mukembo & Edwards (2016), during the colonial period, Kenya adopted a bifurcated system of extension, which included a whole farm approach focused on food production and a commodity-based approach. The commodity-specialized approach was employed, supported by private companies, such as parastatals and corporations dealing with the production of commercial crops (Mukembo & Edwards, 2016). Commodity-based approaches were well packaged and encompassed advisory services alongside input subsidies and credit. They were mainly for the white settlers who were actively involved in the agricultural commercial farming system. However, the indigenous Africans cultivated for subsistence use and practiced pastoralism. Their extension approaches involved the use of force and threat because their settlements were marginalized (KASEP, 2023)

The year 1954 was marked by the introduction of the Swynnerton Plan, which aimed to shape agricultural policy by addressing the problems encountered by Africans (Samoei et al., 2025). The plan was divided into three phases, namely, land adjudication to discontinue the customary tenure system; consolidating land into blocks per household to eliminate fragmented parcels of land, to permit greater specialization in the production of cash crops, and finally, land registration to grant tenure security (Swynnerton, 1954).

The government believed that individual ownership of land would permit African farmers to adopt modern farming practices (Amatsimbi, 2024). It resulted in enhanced governmental engagement in the planning process through consolidating and enclosing the land holdings, land reforms leading to personal land ownership systems, the offering of banking and financial services, increased breeding of livestock, and supporting the continual farming of profitable crops (Amatsimbi, 2024).

Local African farmers were granted the rights to engage in cash crop husbandry and dairy farming, had access to marketing facilities, and were also granted an increase in technical assistance (KASEP, 2023). The plan also aimed to enhance the uptake of novel practices and technologies among African farmers to promote agricultural productivity. As a result, efforts were made and goals set for farm incomes to provide technical aid in all farming aspects (Amatsimbi, 2024). Following the implementation of the plan, the Agriculture Department provided advisory services to African farmers. Extension officers urged farmers to cultivate new varieties of crops, utilizing fertilizers to improve the yield of crops. The department set up research stations to educate farmers and promote the growth of novel agricultural technologies and various crop varieties suited to different agro-ecological zones (Amatsimbi, 2024).

However, Kenya's agricultural sector still experienced several limitations such as difficulty in accessing rural advisory services, low budgetary allocation for development of agriculture, limited adoption of farming techniques, land fragmentation, inappropriate regulatory frameworks, lack of credit facilities for farmers, absence of cohesive land policy, high input cost, soil degradation from outdated agricultural methods, inadequate infrastructure for transportation, and adulteration of agricultural products (Amatsimbi, 2024). In the 1960s and early 1970s, successes in extension were witnessed in hybrid maize technology dissemination, artificial insemination, and cooperative movement supported by established training centers for pastoralists and farmers (KASEP, 2023).

The 1980s and 1990s were marked by the introduction of structured extension approaches that encompassed training and visits (T&V) and farming systems (KASEP, 2023). Training and Visits was devised by Benor and Harrison in 1977 and prioritized extension service at the local level by having extension staff trained, who would later disseminate the information to the farmers (Benor, 1984). It was conducted in three phases: i) Workshops conducted on monthly basis where extension officers and researchers interacted to discuss technical agricultural subjects, and later formulation of practical technical recommendations, ii) training sessions conducted fortnightly where the technical and practical recommendations formulated during the workshops disseminated to frontline extension agents, and iii) the frontline extension agents after

getting the formulated recommendations were required to train the chosen farmers (Benor, 1984).

During the early 1990s, the introduction of Structural Adjustment Programs (SAPs) resulted in the government reducing funding of extension services, freezing the employment of extension personnel, and retrenching extension staff, which led to a decrease in advisory service delivery (Selim, 2026). In the year 2010, decentralization of governance was put in place by Chapter 11 of the 2010 Kenyan Constitution, which resulted in a devolved government system, thereby setting up 47 county governments with great autonomy. Devolution aimed to promote participation of the locals and dissemination of advisory services (Wekesa et al., 2025; Irene et al., 2017). This further led to structural adjustment in the Ministry of Agriculture, therefore transferring coordination to the County Departments of Agriculture to promote context-specific information and feedback in extension communication. However, effective delivery of advisory services at the county level was still constrained by poor coordination, insufficient funding, and limited capacity to support extension services (Hangula et al., 2026).

According to Bergström et al. (2024), the 2000s ushered in a significant shift in technology, with evidence of internet connectivity and mobile phone devices. The advent of ICT in the provision of agricultural extension services emerged in phases, namely the traditional and mass communication phase, the mobile and computer penetration phase, and the third phase marked by interactive and smart digital tools that provide two-way communication (Priya et al., 2025). These devices provide various applications, for instance, M-kilimo, which has significantly transformed the delivery of extension services expertly since they relay information on various key farming aspects such as weather, agronomy, and market, inter alia (Yashabh et al., 2025).

Modern agricultural technology now leverages Artificial Intelligence, drones, and remote sensors in supporting crop and livestock husbandry (Bhat, 2021). Despite these advances, the digital age still faces challenges related to infrastructure, data privacy, and digital literacy. Furthermore, technologies and practices to combat shocks of climate change have been adopted (Yu et al., 2024). Group and gender-based extension is being implemented to promote inclusivity in extension for social equality

and poverty alleviation (Priya et al., 2026). Multiple stakeholder partnerships are being promoted by the established Agricultural Technology and Innovation Centers (ATICs) because the centers provide a platform for knowledge brokering (Maryono et al., 2023).

2.4 Current Landscape and Trends in Digital Agricultural Extension Services.

In the last decade, digital agricultural extension services have rapidly progressed from the traditional officer-led approach to advisory services to a multifaceted knowledge delivery system using technology (Aker et al., 2021). The drivers of this transformation are the growing pressure on extension systems, which are affected by climate variability, the rising demands of the population, the reduction of the extension worker-farmer ratio, and the need for cost-effective scalability in agricultural advisory services (Ferdousi et al., 2024). Digital extension now stands as a key component of agricultural transformation policies and strategies in developing contexts, providing a means for real-time information exchange and supporting better decision-making and farmer responsiveness (Ongachi et al., 2026).

2.4.1 Typology of Digital Extension Tools and Platforms

Digital extension tools are the specific technologies that make up the digitalization of delivering agricultural information and advisory services directly to the farmers (Coggins et al., 2021). They are of varying complexity, accessibility, and interactiveness, depending on the digital maturity of agricultural systems (Aker et al., 2016). SMS-based advisory messaging is one of the most popular systems that sends brief agricultural information on weather forecasts, pest infestations, and input recommendations (Gitau et al., 2025). SMS is still very relevant because it is compatible with basic mobile phones and poses low literacy requirements, especially for smallholder farmers in rural areas (Midamba et al., 2026). Nevertheless, SMS tools have been mainly unidirectional, allowing limited interaction and feedback between farmers and extension providers, limiting their potential for long-term impact in supporting complex decision-making (Ifigeneia, 2015).

Interactive Voice Response (IVR) systems enable farmers to listen to pre-recorded agricultural information via voice commands in their native tongue (Mutisya & Kumar, 2025). IVR systems are particularly useful for farmers who may not be well-versed in reading and enhance access to digital agriculture (Mutisya & Kumar, 2025).

While IVR systems have the benefit of being accessible, they can be constrained by limitations such as outdated content, limited personalization capabilities, and reliance on mobile networks for functionality (Aker et al., 2021). Mobile applications (Apps) are a more sophisticated form of tool that delivers interactive agricultural advisory services that are multimedia in nature (Njuguna et al., 2025). Common features in these applications are pest diagnosis, weather forecasts, tracking market prices, and input recommendations (Njuguna et al., 2025).

Empirical evidence suggests that mobile apps enhance farmer decision-making by offering real-time, context-specific information (Njuguna et al., 2026). Other important ones are social media tools such as WhatsApp, Facebook, WeChat, TikTok, YouTube, and Telegram groups (Idrees et al., 2025). These platforms will help in farmer-to-farmer communication that will allow quicker dissemination of agricultural information, peer learning, and problem-solving (Ramavhale et al., 2024). Alongside this, WhatsApp groups have become a notable extension medium in rural Kenya, where they are significantly effective (Ojwang, 2024).

With the advent of new tools and chatbots powered by artificial intelligence, digital extension services are entering a new frontier (Sarfo et al., 2025). These are designed to leverage machine learning and natural language processing to deliver tailored agricultural advice to farmers in response to their inquiries and context (Sarfo et al., 2025). AI solutions for accessibility are being adopted in messaging services like WhatsApp and USSD. They are not widely adopted in smallholder settings, however, because of data limitations, lack of trust, and lack of infrastructure (Sarfo et al., 2025). Finally, the Internet of Things (IoT) is a tool for the emergence of precision agriculture systems (Boruah et al., 2024). The technologies capture real-time information on soil moisture, crop health, and climatic conditions, which enables highly localized and data-driven advisory services (Dey et al., 2025).

According to Priya et al. 2025, digital agricultural extension services leverage digital extension tools (DET). These tools aid in wider audience coverage and reach by facilitating agricultural information access and transfer. In addition, the use of these digital tools enhances farmers' knowledge and promotes farm productivity (Owusu et al., 2025). Digital tools act as knowledge brokers, and they include smartphone calls and applications such as WhatsApp (Coggins et al., 2021). Smartphone services and

information have a transformative ability, especially for farmers who possess smartphone devices. This, in turn, has enhanced the usage of m-services (Marwa et al., 2020).

The literature shows that Communication tools for delivering extension services can be one-way, two-way, or multidirectional (Apriani, 2023). First, one-way digital communication platforms do not enable direct interaction between the sender and the recipient and are characterized by a static, unidirectional flow of information. Radio is the most prevalent and the most economical, followed by platforms like short message services and videos (Silvestri et al., 2020). Interactive platforms facilitate the exchange of relevant experiences, information, and ideas, thereby enhancing multi-stakeholder collaboration and leading to improved agricultural output and returns (Sen et al., 2025).

Kenya is one of the technology hubs for digital agricultural tools in Africa, thus giving it the name "Silicon Savannah," resulting in 4.5 million smallholder farmers owning mobile phones. The study results showed applications that provide farmers with information, such as iShamba and Digi Farm, which link farmers with financial services such as credit, and the AgroCares Scanners, which provide personalized advice regarding soil health. Furthermore, ACRE Africa provides insurance against agricultural uncertainties (Njuguna et al., 2025). Digital tools that keep farmers in the loop and provide access to markets include DigiFarm, Apollo Agriculture, and Farms Drought Coins, while farm advisory services related to farm management are obtained from Farm Cloud and FarmShield, Twiga Foods, and Kenya Agricultural Observatory Platform (KAOP) (Kiaka, 2024).

2.4.2 Emerging Digital Technologies in Agricultural Extension

The integration of emerging technologies in agricultural extension is triggering the fourth revolution, termed agriculture 4.0. These digital technologies show potential to promote optimal use of farm inputs, minimize environmental degradation, and enhance agricultural productivity (Cui & Wang, 2023). The digital agricultural extension sector is in a state of flux, with the emergence of new technologies, convergence of platforms, and a shift toward blended service offering models (Akande, 2025). The advent of artificial intelligence (AI) and machine learning in agricultural advisory systems is one of the most visible trends emerging in agriculture

(Mishra & Mishra, 2023). Big data analytics and predictive modelling powered by AI are applied to understand crop performance, pest infestations, and climate change adaptation options (Thayalan et al., 2026). In recent years, these systems have been integrated into mobile interfaces to improve the usability and scalability of the application in rural areas (Özoğul, 2025).

Precision agriculture, aided by IoT and satellite-based remote sensing technologies, is another trend being observed (Agarwalla et al., 2026; Hussain et al., 2024). These systems can be used to gather data on farm conditions and make informed decisions about interventions that can enhance resource efficiency and productivity, while also providing a more targeted approach to addressing specific issues (Raji & Njoku, 2024). Research shows that precision agriculture is well-suited to meet the demands of climate-sensitive areas where uncertainty in rainfall and pest risks requires timely, site-specific responses (Asnakew et al., 2026; Njuguna et al., 2026). Yet, adoption is still hampered by smallholder farmers' infrastructural and financial constraints (Choruma et al., 2024).

Another notable trend is the creation of hybrid extension systems, where digital platforms are integrated with the human extension service (Hashim et al., 2024). To improve the efficiency of extension officers, digital tools are now being applied that use automated alerts, farmer databases, and decision-support systems. Combined with the speed and scalability of digital systems, this hybrid model enhances farmers' trust and adoption (Ongachi et al., 2026). Participatory and network-based extension ecosystems are also on the rise (*Next-Gen Agricultural Extension*, 2025). Farmers are no longer mere recipients of information in agriculture but active participants in digital communities like WhatsApp groups and online forums (Thirumal et al., 2026; Musafiri et al., 2022). They can facilitate the dissemination and sharing of knowledge and accelerate the diffusion of Innovation (Musafiri et al., 2022).

Furthermore, there is a transition towards data-driven and integrated agricultural platforms taking place, which combine multiple services, such as input supply and credit access through a single platform, as well as weather and market information. These platforms aim to provide all-inclusive agricultural support and reduce the extension silos in agricultural services delivery (Runck et al., 2021; Byamukama et

al., 2025c). Digital inequality and affordability pose important constraints to equitable access, however (Fabregas et al., 2022).

2.5 Awareness, access, and utilization of digital extension services

Although digital agriculture is rapidly gaining traction, the extent of the diffusion of the new technology among smallholders remains uneven, with awareness, access, and utilization determining whether smallholder farmers can or will adopt the new technology, particularly in sub-Saharan Africa (Ongachi et al., 2026; Njuguna et al., 2026). Although the implementation of ICTs in rural farming systems has been increasing, empirical studies over the past few years have revealed moderate to low awareness of the use of agricultural extension services using digital means (Ongachi et al., 2026).

While digital extension platforms have multiplied in the developing world, many farmers are still not aware of them, as disseminating information through digital platforms is challenging, and extension outreach is lacking, as emphasized by Ongachi et al. (2026). This gap is also seen in high coverage of mobile phones, which indicates that there is no direct link between access to ICTs and awareness of agricultural digital services, even in contexts with high mobile phone coverage (Ongachi et al., 2026; Mutisya & Kumar, 2025). Increased mobile phone penetration in rural Africa has led to enhanced access to agricultural extension services in digital format, with disparities in infrastructure and costs remaining (Njuguna et al., 2025; Parlasca et al., 2021).

Njuguna et al. (2026) contend that although smart sensor technology and mobile-based advisory systems have been rapidly expanding in recent years, farmers in Kenya's rural areas have not received the same access as their urban counterparts, as the cost of Internet data and the lack of mobile Internet connectivity in rural areas have been issues. Likewise, Kwikiriza et al. (2026) report that extension systems in East Africa are still disjointed, hampering farmers' consistent access to reliable and timely agricultural information.

While mobile phone usage is common, access to more advanced digital tools, including mobile phones with SIM cards, is limited because of infrastructure constraints, particularly in remote rural areas (Kwikiriza et al. 2026; Midamba et al. 2026). There is evidence that suggests that while the population has access to digital

agricultural extension services, the frequency and intensity of their use are low. Farmers in Western Kenya are also often users of ICT-based platforms, mainly WhatsApp groups, SMS alerts, and mobile-based market information systems, but use these services infrequently and are mostly brief and focused during specific agricultural events, such as planting, pest infestation, and market changes (Midamba et al., 2026).

Digital extension services are used as an auxiliary aid and support, but not as a farming systems decision-making support system (Midamba et al., 2026; Njuguna et al., 2026). Incorporating feedback systems in the digital advisory system is more likely to make the use of digital advisory systems consistent when the information is perceived as credible. However, when users lack trust in the information provided by the algorithm or sources outside it, their engagement with digital platforms is reduced in the long term (Njuguna et al., 2026; Ongachi et al., 2026). This corroborates the more general findings that usability and relevance are crucial factors for the uptake of agricultural technologies (Mutisya & Kumar, 2025).

Demographic factors such as gender, age, and education have particular effects on the patterns of awareness, access, and use. As highlighted by the authors of Majiwa et al. (2026), income differences, digital literacy, and access to digital devices are major challenges for women farmers in using sophisticated digital tools in agriculture, including AI-led advisory services. In the same way, Mutisya and Kumar (2025) determine that younger farmers are more inclined to use digital platforms than older farmers, primarily because younger farmers are more familiar with and open to innovation with digital platforms.

The use of digital agricultural information, which is further enhanced by education, helps the interpretation and application of digital information effectively by literate farmers (Majiwa et al., 2026; Mutisya & Kumar, 2025). The smallholder uptake of emerging technologies such as artificial intelligence (AI), Internet of Things (IoT), remote sensing, and machine learning is low in Africa, and these are now being integrated into agricultural extension (Asnakew et al., 2026; Njuguna et al., 2026). The technologies have the potential to advance precision agriculture and real-time advice services, but their uptake is hampered by their low awareness, low infrastructure, and affordability issues (Asnakew et al., 2026). Consequently, there is

a tremendous disparity in the technology development and application by farmers at the level of the user (Asnakew et al., 2026; Ongachi et al., 2026).

In Sub-Saharan Africa, there is relatively high awareness of digital extension services, such as basic mobile-based services. However, disparities exist between smallholder farmers in local areas and cities, as well as between male and female counterparts. By 2022, 23 percent of those who dwell in suburban areas used the internet in comparison to 64 percent of those living in urban areas (ITU, 2022). According to the Tegemeo Institute (2023), low use of digital tools is associated with distrust and unaffordable costs.

Farmers in distant places with poor internet access prefer radio to access information. Mobile phones with a good internet connection also facilitate easy access to information (Awasthi et al., 2025). However, women are more affected in accessing mobile phone services (Kansiime et al., 2021). On a global scale, approximately 37% of the total population does not have internet access (Priya et al., 2025). Poor access is caused by digital illiteracy, lack of ownership and control, and high charges for digital devices

Smallholder farmers access extension services through various channels, including traditional and digital, or a combination of both. However, traditional extension methods remain dominant (Purwadi et al., 2023). However, traditional methods still prevail. The findings of Purwadi et al. (2023) show that, of the conventional sources, radio is the most commonly used communication channel. Conventionally, extension services were delivered through various farmer groups, extension officers, exchange by local communities, and knowledge sharing among friends and families, and digitally through social media channels like YouTube, WhatsApp, and Short Message Service (Purwadi et al., 2023).

Radio is still dominant as the source used to provide agricultural information, followed by television and mobile phones. However, according to FAO (2021), digital illiteracy, a shortage of human capital, and limited infrastructural investments are major barriers to effectively leveraging these digital devices. This is attributed to low possession, control challenges, a shortage of time to listen to the programs, and engagement in other agricultural activities (Kansiime et al., 2021).

Ifeanyi-Obi &Corbon (2023) studied in Akwa Ibom State, Nigeria, about the delivery of extension digital services, showing a high utilization of extension tools among advisory agents in the exchange and dissemination of Agri-related information. According to Owolabi and Yekini (2022), awareness among agricultural extension agents, which in turn influences their utilization of digital tools in the delivery of extension services, is especially important when connecting farmers to the market. Furthermore, Digital extension services (DES) help farmers get the information required to enhance productivity and efficiency in the usage of resources (Sen et al., 2024).

Furthermore, Ifeanyi-Obi & Corbon (2023) reported that based on the utilization level of digital tools for the delivery of extension service the most common used digital tool is mobile phone calls followed by WhatsApp, video player, radio, television, SMS, Facebook, audio visual aids, computers and laptops, YouTube, tablets, Instagram, Geographical Information System (GIS), remote sensing equipment, blogs and finally LinkedIn. According to Alhassan et al. (2023) WhatsApp is the main digital platform leveraged by users for the dissemination of agricultural information. The most accessed and used digital platforms are TV, radio, and mobile phones, amounting to over 70%, with only 27.7 % of the users having internet access. WhatsApp and Facebook are moderately accessed, while Twitter and computers are the least used. Farmers who leverage these platforms mainly look for knowledge on agricultural production, crop protection strategies, and the market.

2.6 Factors Influencing Adoption of Digital Agricultural Extension Services

Research shows that technology adoption is shaped by socioeconomic factors that involve a user's or farmer's personal background. These factors include gender, age, marital status, farmer group membership, income, educational level, and years of experience in farming (Cui & Wang, 2023). For instance, young people are more open and willing to experiment with technology compared to the elderly because the youth are more tech-savvy. The old people show a negative perception towards digital extension services due to unwillingness to embrace change; they tend to be conservative and skeptical because of their long experience with indigenous technical knowledge (Bontsa et al., 2023).

Education level is also an important determinant of adoption behavior. With an educated farmer, they can better understand digital agricultural information and make better decisions, and they are more likely to be able to use mobile platforms (Amoussouhoui et al., 2024). The evidence presented in Kenya suggests that education is a key determinant of the adoption of agricultural services leveraging ICT tools, as it increases the perceived usefulness and ease of use, as outlined in the Technology Acceptance Model (Mutisya & Kumar, 2025; Waaswa et al., 2024). In addition, the attainment of formal education and years of farming experience positively correlates with technology adoption among the users (Cui & Wang, 2023).

Gender differences also exist in the adoption, and women farmers are also marginalized in terms of access to smartphones, income status, and access to training programmes (Majiwa et al., 2026). These inequalities lead to less exposure to the digital extension systems and limit the ability for women to use these systems over a prolonged period of time. Female farmers primarily assist with farming and may lack the resources to adopt digital technologies (Cui & Wang, 2023). The size of the household and farming experience also affect the decisions about adopting. Farm household size can also provide greater farm resources for using digital tools in management. But more experienced farmers may be resistant to new technologies as they heavily depend on the indigenous knowledge systems and farming experience (Waaswa et al., 2024).

Technological factors are technology-related attributes such as complexity of technology, technology cost, implementation, and triability that influence digital uptake. Affordable equipment is a motivating factor for technology adoption (Cui & Wang, 2023). A farmer who adopts digital extension services can make informed decisions, hence improving farming operations. However, poor internet connectivity and high costs of digital tools limit digital adoption (Gizachew et al., 2024). Technology characteristics influence adoption decisions to a high degree: perceived usefulness and ease of use are key to the Technology Acceptance Model (TAM). Digital extension services are more likely to be embraced by the farmers if they believe such services will boost productivity, reduce uncertainty, and enhance the efficiency of farm management (Njuguna et al., 2026). Compatibility also has an impact on adoption, as it relates to the viability of existing farming practices. Farmers are more

likely to accept technologies that fit in with their farming practices and local contexts and are less likely to sustain their use of complex technologies (Abdullahi et al., 2026).

Agroecologically related factors influencing technology adoption include natural resources found on the farm and land acreage that support the farmer. Farmers with large tracts of land are more inclined to adopt digital technologies. Large parcels of land offer farmers the best investment, cost, risk, and shock absorption mechanism. Soil quality, crop yields, availability of water for irrigation, and past weather shocks influence technology adoption; farmers tend to integrate technologies adaptable to the natural conditions (Cui & Wang, 2023).

Institutional factors include the collective role of government, private, and non-governmental agencies, and their effect on technology adoption. Government subsidies, financial support, access to extension services, and contract farming are institutional factors that can facilitate technology adoption among the smallholder farmers (Cui & Wang, 2023). A study conducted by Guay et al. (2025) on factors influencing the adoption of digital extension services in Kibanggay, Lantapan, Bukidnon, Philippines, revealed that institutional factors play a pivotal role in the adoption of digital extension services and that government policies, extension services, and support obtained from the institutions were positively correlated with farmers' utilization of digital extension services. Technical service mechanisms, such as training on the network.

Gao et al. (2024) examined three policy approaches acting as policy incentives promoting the adoption of digital extension services, such as financial support from the government, technical service support, and legal service rendered by the government. In terms of government financial support, enhancing transparency in fund allocation builds users' trust and understanding of the digital policy, making users enthusiastic to adopt. The government legal service is attained by publishing laws on digital extension services, which promote awareness of these regulations. Consistent legal support by the government enhances farmers' eagerness towards the adoption of digital extension services. Technical service measures assist in better understanding agricultural technologies. This understanding promotes digital application in the agricultural value chain, encouraging adoption of these technologies.

Extension agents are often the links between farmers and mobile agricultural advisory services, and they can help farmers understand how to use the services and the benefits they can provide (Ongachi et al., 2026). Training programmes and capacity development are also important. Digital literacy training has boosted the confidence of farmers in utilizing mobile-based agricultural services and also facilitated the inclusion of these services in their everyday farming decision-making (Mutisya & Kumar, 2025). Farmer groups and farmer cooperatives have also proven to be useful tools for improving adoption by providing farmers with access to agricultural information systems, peer learning, and shared experiences.

Gizachew et al. (2024) examined determinants of digital tool adoption among farmers who produce ginger in Southern and Central Ethiopia. The study used a mixed-method research design. The results indicated that the adoption of digital agricultural tools promotes agricultural productivity and an increase in income level. According to the study findings, barriers to digital adoption can be surmounted by policy interventions that focus on cost reduction and enhancing network coverage of the digital agricultural tools. In addition, investment in supporting digital infrastructure, designing user-friendly initiatives, frequent farmer training sessions, and incentivizing agriculture through the provision of subsidies and loans at low interest rates.

Psychological and behavioral factors encompass users' beliefs and attitudes towards technology (Cui & Wang, 2023). Farmers' motivation, confidence in using digital tools, and openness to technology affect decisions toward technology adoption (Guay et al., 2025). Attitude towards technology, perceived usefulness, and perceived ease of use form the basis of behavioral intention as described by the Technology Acceptance Model (Njuguna et al., 2026). Behavioral factors that can influence adoption include trust; if farmers trust that the advice provided is credible and reliable, they will be more inclined to adopt it. With little faith in the automated or external recommendations, the adoption rate is considerably reduced (Midamba et al., 2026).

Risk perception also affects behavior. Even if farmers have access to digital tools, they are less likely to adopt them if they see the tools as being risky, complex, and/or unreliable. On the other hand, positive experiences and trialability enhance confidence and persistence (Musafiri et al., 2021). The sustained adoption is due to habit formation. After farmers repeatedly use digital platforms and experience value from

them, usage becomes a habit and is integrated in the long run into farmers' decision-making processes (Mutisya & Kumar, 2025).

2.7 Theoretical Framework

A theoretical framework provides an overall guideline for the data analysis. It serves to test and challenge existing theories, clearly establish the connections between observations and facts, predict and control situations, and develop hypotheses (Van Der Waldt, 2024). The study was anchored on the following theories:

2.7.1 Diffusion of Innovation Theory- Rogers (2003)

The study was underpinned by the Diffusion of Innovation theory by Everett M. Rogers to explain how, why, and at what rate new ideas and technologies spread (Rogers, 2003). According to Hornor (2022), diffusion is the process by which an innovation is communicated through specific channels over time among smallholder farmers or members of a social system. An innovation is an idea, practice, or object perceived as new by an individual or other unit of adoption (Kouame & Ikporukpo, 2020). Diffusion of innovation comprises four main elements, namely the innovation, communication channels, time, and social system. Innovation is an idea or object that is perceived as new by an individual or other unit of adoption. Communication channels are the means by which messages are transmitted from one individual to another, whereas mass media channels are methods of transmitting messages, such as television, radio, and newspapers. Interpersonal channels involve face-to-face exchanges between two or more individuals. A social system is a set of interconnected units engaged in joint problem-solving to achieve a common goal. The members or units of a social system may be individuals, informal groups, organizations, and/or subsystems (Hornor, 2022).

According to Guo & Huang (2024), adoption is a five-stage decision process, namely, knowledge, persuasion, decision, implementation, and confirmation. However, there exist five adopter categories of an innovation, namely, the innovators, early adopters, early majority, late majority, and laggards. In the adoption process, the adoption units evaluate innovation within the purview of five characteristics, namely, relative advantage, compatibility, observability, trialability, and complexity (Christiansen et al., 2021; Zondo & Ndoro, 2023). In the context of this study, farmers, as members of the social system, tend to use digital extension services if their benefits are easy to see

(observability). In addition, the digital platform needs to be better than the one it seeks to replace in terms of benefits (relative advantage), align with their farming methods and practices (compatibility), be tested on a limited scale before full uptake (trialability), and be easy to understand and use (simplicity). This theory was important to the study in various ways. First, it provided a framework for assessing the adoption of digital extension services. Secondly, it helps in identifying factors affecting the process of adoption.

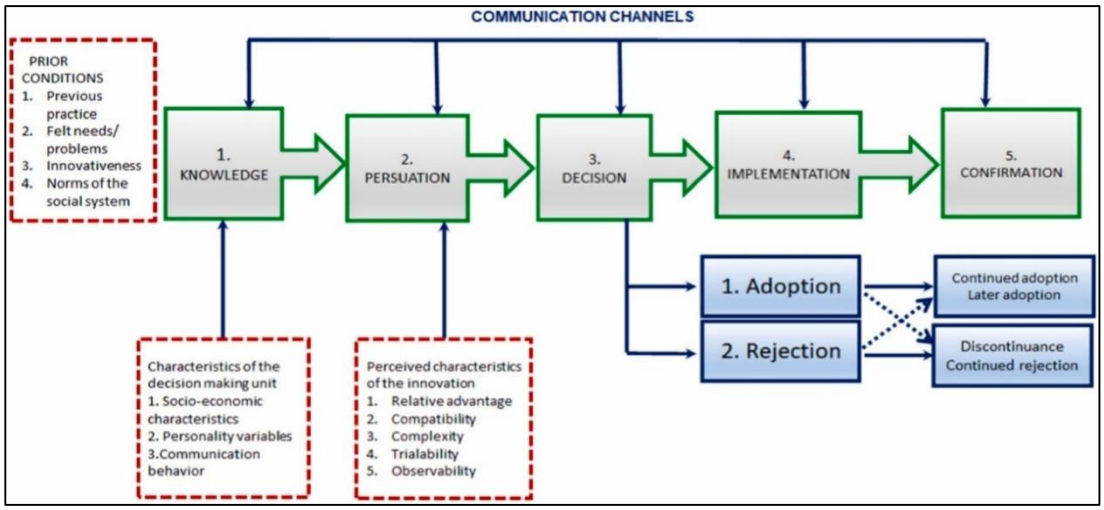


Figure 2.1: Components of Diffusion of Innovation Theory

Source: Savari et al. (2025)

2.7.2 Technology Acceptance Model (TAM)

The study was anchored on the Technology Acceptance Model (TAM), which was introduced by Fred Davis and Richard Bagozzi (1986) and used to illustrate how users come to accept and use a technology. TAM presents acceptance of technology as a three-stage process, by which the external variables initiate cognitive responses (perceived use of use and perceived usefulness) leading to affective response (attitudes and intention), which finally influences users' behavior (Marikyan & Papagiannidis, 2026; Ghanem & Elgamel, 2026). According to the theory, an individual's behaviour in using a novel technology is influenced by two primary factors, namely perceived usefulness (PU) and perceived ease of use (PEOU). Perceived usefulness is the extent to which a person believes that using a particular technology will enhance his or her job performance, while perceived ease of use is the extent to which a person believes that using a novel technology is effortless (Marikyan & Papagiannidi, 2026; Bazine, 2025; Mutisya & Kumar, 2025).

In the context of this study, TAM was employed to understand the perception and response of the smallholder farmers towards digital extension services and the association between farmer beliefs and external factors such as socio-economic, institutional, and technological factors that influenced the behavioural intention to use digital extension services. Furthermore, enabling understanding that there is a high likelihood of adoption if smallholder farmers perceive digital tools and platforms as useful (PU) in enhancing farm income, decision-making, and overall farm productivity, and if they perceive them as easy to navigate (PEOU) (Nyagango et al., 2023).

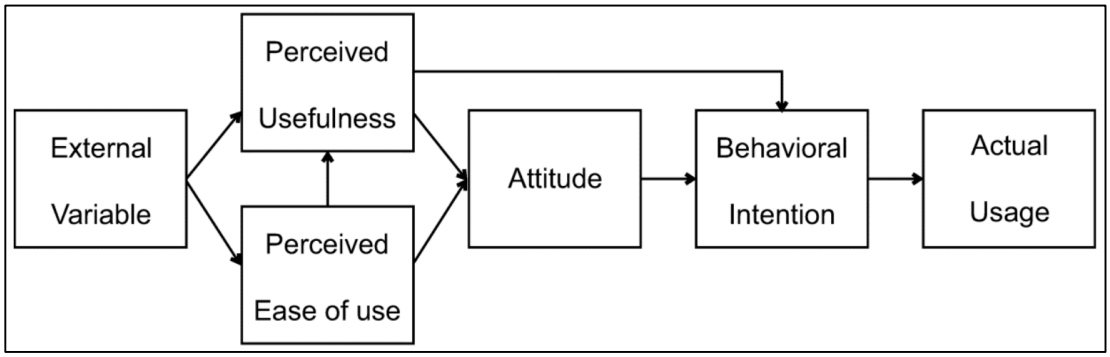


Figure 2.2: Technology Acceptance Model

Source: Du et al. (2024)

2.8 Conceptual Framework

A conceptual framework (CF) depicts the research study variables and points out their association with each other (Kiarie, 2020; Masanja et al., 2023). A conceptual framework, as a tool, helps build a connection between reviewed literature, research methodology, and research study design (Kulesa et al., 2024).

The conceptual framework in Figure 2.3 illustrates the causal relationship between adoption and socio-economic, institutional, and technological factors influencing the adoption of digital extension services. As such, the dependent variable is the adoption of digital extension services and the independent variables, were: (i) socio-economic factors such as gender, marital status, age, education level, and farming experience, (ii) institutional factors such as credit access, farmer group membership, credit, market, and extension service access and (iii) technological factors such as the cost of the devices, and internet connectivity. The framework integrated awareness and

access as the intervening variables. Adoption of digital extension services was measured in terms of intensity of use. The anticipated output of this study was improved productivity, food security, documentation of digital extension tools, platforms, and emerging trends, and poverty alleviation among smallholder farmers.

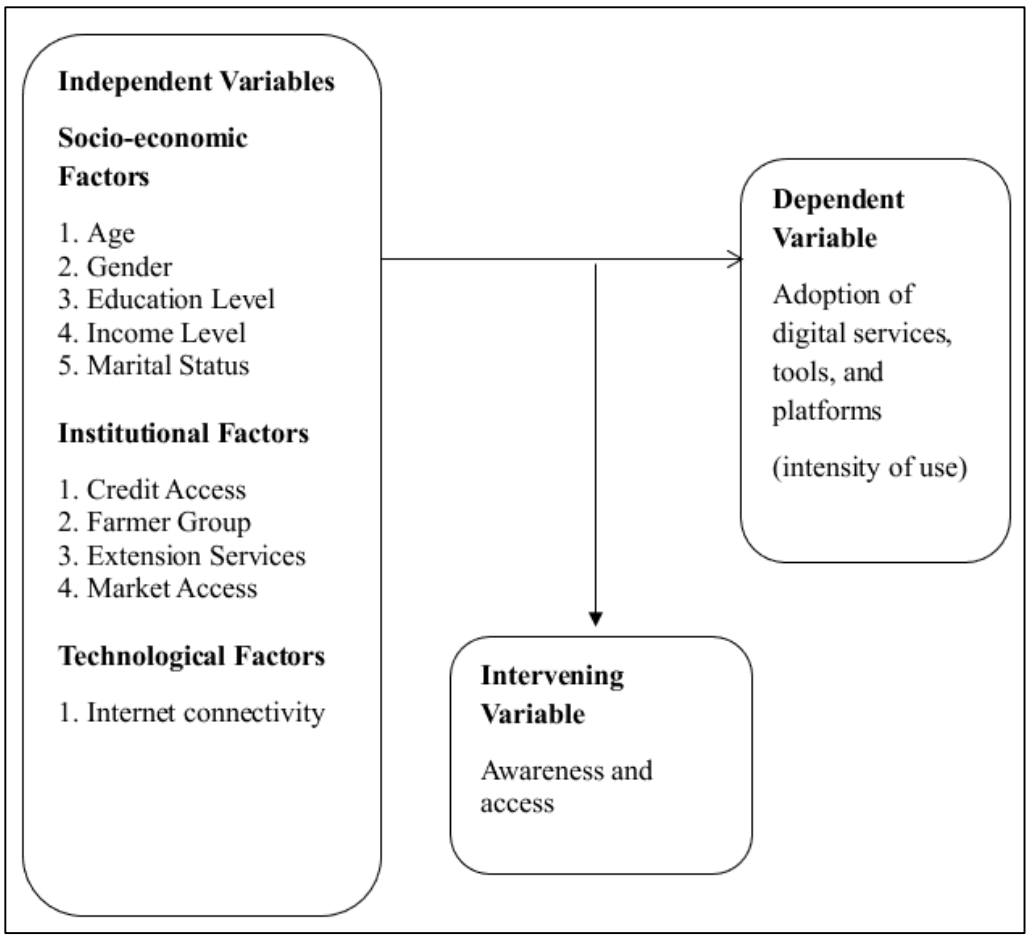


Figure 2.3: Conceptual Framework

2.9 Gaps identified in the Literature

The study intended to fill contextual, knowledge, and methodological gaps. The topic is studied, but not in the context of Murang'a County, particularly in the Kiharu, Gatanga, Maragua, and Kandara Sub-counties. In addition, digital extension is underexplored, and it is also evident that most of the past studies adopted quantitative methods and may have neglected the qualitative approach to enable the obtaining of rich data. The current study intends to fill the research gap by employing a mixed-methods approach to explore the determinants of adoption of digital extension services in Murang'a County in Kenya. The gaps are shown in Table 3.1 below.

Table 2.1: Gaps identified in the Literature

Author	**Title**	**Research findings**	**Gap in the study**	**Focus of the current study**
Kiarie (2020)	Determinants of digital technologies adoption among small-scale farmers in Kenya - a case of Embu and Kirinyaga Counties	Findings indicate that access to extension services, resources, and managerial capability had a significant effect on technology adoption.	The study was limited to the Counties of Embu and Kirinyaga. Solely focused on the descriptive research design.	The study intended to fill the geographical gap by focusing on Murang'a County. The current study integrated a mixed-method research design.
Okello et al. (2021)	Determinants of utilization of agricultural technologies	Farmer group membership and closeness to agricultural	The study was limited to dairy farmers only.	The study was extended to cover smallholder

	among smallholder dairy farmers in Kenya.	extension offices enhanced technology adoption.		farmers engaged in both crop and livestock production.
Amoussohoui et al. (2023)	Analysis of the factors influencing the adoption of digital extension services: evidence from the RiceAdvice application in Nigeria.	Indicates that perceived usefulness (PU) and perceived ease of use (PEOU) drive the use of digital applications.	The study solely concentrated on a digital application (RiceAdvice) and one crop (Rice)	The study delved into the broader landscape and emerging trends in digital extension.
Phanith et al. (2023)	Digital agricultural extension services for development of smallholder farmers in Southeast Asia.	The study indicates poor internet connectivity and infrastructure as the main challenges affecting extension in remote areas.	The study was limited to smallholder farmers in Southeast Asian countries of the Philippines, Cambodia, and Vietnam.	The current study focused on smallholder farmers in Murang'a County in Kenya.

2.10 Chapter Summary

Chapter two provides a review of the literature on digital agricultural extension services. It contains the empirical literature, theoretical framework, conceptual framework, and research gaps. The theories that guided the study included the Diffusion of Innovation (DOI) Theory and the Technology Acceptance Model (TAM).

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the methods used in the study to assess digital agricultural extension services among smallholder farmers and extension service providers. It provides the study design, study site, the targeted population, sampling techniques and size, data collection tools, data analysis, validity, reliability, pre-test, and ethical considerations.

3.2 Research Design

A research design is a systematic blueprint employed to study a scientific problem by answering research questions through data collection, measurement, and analysis, and for control of variance (Kiarie, 2020; Indu & Vidhukumar, 2020). A mixed-methods research design, combining quantitative and qualitative approaches in a single study, was employed (McLaughlin et al., 2025). A quantitative method was used to gather data on awareness, access, and utilization, as well as factors affecting the digital agricultural extension service. In contrast, a qualitative method was used to gain deeper insights into the landscape and current trends. A mixed-methods approach helps answer research questions by integrating the strengths of both approaches while minimizing the weaknesses of a single approach. In addition, it also permits deeper inquiry, answers a variety of research questions, provides more evidence, and solves problems with both words and numbers (Dawadi et al., 2021; Oranga et al., 2025).

3.3 Study Area

The study was carried out in the County of Murang'a, located in the central part of Kenya, with a total population of 1,056,640, at latitudes $0^0$34'S and $1^0$7'S and longitudes 36^0 E and $37^0$27' E (Kenya National Bureau of Statistics, 2019; Mwangi, 2021). The County lies at an altitude of 914m above sea level eastwards and at 3353 m above sea level westwards. Murang'a County was selected because it is the leading county in digital automation of job creation and e-government service ranked at 98.3%, with the rapid proliferation of digital tools and services, ranked at 62.3% after Nairobi (67.7%), Kirinyaga (65%), and Nyandarua (63.9%) for those who own a mobile phone (Communication Authority of Kenya, 2025; Otieno, 2026). The County has also shown integration of digital systems in the distribution of farm inputs, for

instance, maize, to farmers registered under the Inua Mkulima programme, marking a significant shift towards digitalization of county services (Kilimo News, 2026).

The County is located approximately 50 kilometers from the capital city of Kenya, Nairobi (Mwangi, 2021). It is bordered to the East by Kirinyaga, Embu, and Machakos counties, to the West by Nyandarua, to the North by Nyeri, and to the South by Kiambu. It covers an area of approximately 2558.8km^2, comprising seven sub-counties, namely Mathioya, Kangema, Kiharu, Kandara, Gatanga, Maragua, and Kigumo (Murang'a County Government, 2025). The sub-counties are divided into 35 wards, 32 divisions,118 locations, 294 sub-locations, and 4278 villages (Murang'a County Government, 2023). Geographically, the study focused on four sub-counties, namely Kiharu, Gatanga, Kandara, and Maragua, because they served as a good representation of all agro-ecological zones in Murang'a. Gatanga and Kandara cover the upper midland, depicting a high-potential area, and Kiharu and Maragua represent the lower midland, covering the semi-arid agroecological zones (Murang'a County Government, 2023).

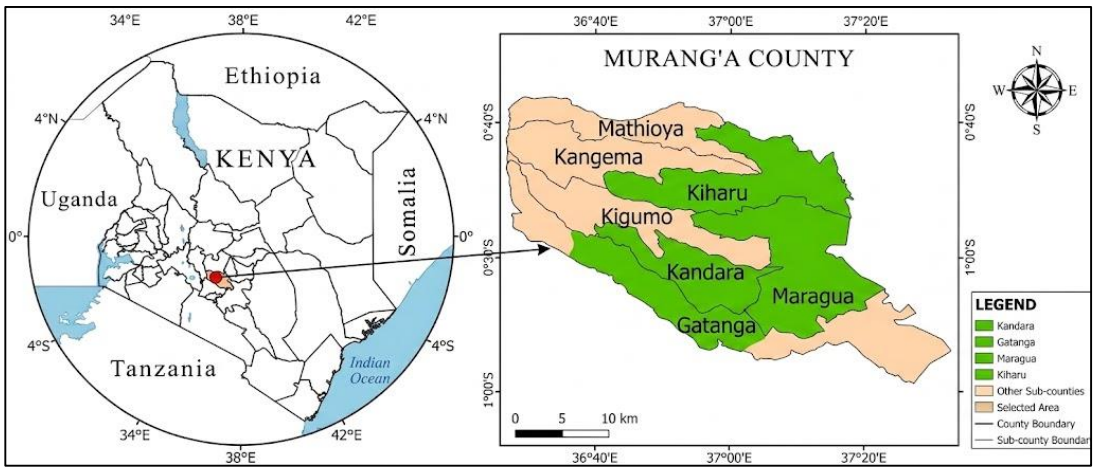


Figure 3.1: Administrative map of Sub-Counties in Murang'a

Source: Murang'a County CIDP, 2023-2027

Agricultural activities in Murang'a County contribute to about 70% of local employment opportunities and 60% of income sources (Murang'a County Government, 2023). The County has six agro-ecological zones and three main climatic

regions: western, central, and eastern. Zone 1, covering the western region, depicts the highest potential (upper highland humid) areas characterized by economic activities such as tea farming, tourism industry, and forestry, and extends to the sub-counties of Gatanga, Kandara, Mathioya, Kangema, and the higher parts of Kigumo.

Lower highland humid (LHH), upper midland subhumid and humid, located in the central region dominated by zones 2 and 3, east of the Aberdare ranges, are suitable for tea, maize, banana, dairy, and coffee farming. It covers Gatanga, Kigumo, Kahuro, and some parts of Kiharu, Mathioya, and Kangema. The fourth, fifth, and sixth agro-ecological zones are dominantly arid and semi-arid and are located in the lower parts of Maragua Sub-County in the flat region of Makuyu Division, Kiharu, Ithanga, and Kandara. These regions favor the cultivation of pineapple and coffee under irrigation (Murang'a County Government, 2023).

In terms of rainfall, the County receives rainfall ranging from 750-1700 mm per annum in two distinct seasons. Long rains are received from the month of March to May, with April being the peak in rainfall amount, recording approximately 213mm on average. The short rains are received in October, November, and December, recording 135mm on average. February is the driest month with an average rainfall of 21mm (Mwangi, 2021). In addition, the county has volcanic rocks, which enhance soil fertility, promoting agricultural activities (Murang'a County Government, 2023). This, therefore, provided a strong framework, making Murang'a County an ideal site for exploring the determinants of the digital extension service.

3.4 Target Population

According to Hossan et al. (2023), a population is defined as an entire group of individuals, objects, or events with similar observable characteristics. The target population is a specific subset of the larger study population that is the primary focus of inquiry (Willie, 2023). The study targeted 352 smallholder farmers who practice crop and/ or livestock husbandry and are potential users of digital extension services. Therefore, the unit of analysis was smallholder farmers. Participants were recruited through farmer groups, local farmer networks, and the county extension officer of Murang'a County. In addition, the qualitative component targeted 16 key informants, including the County Agricultural Director, extension agents in Murang'a, youth

agripreneurs under the digital extension model, the Principal of KATC Mariira Farm, and digital extension service providers.

3.5 Sampling Techniques and Sample Size

In research, sampling refers to the selection of settings, individuals, and/or units to participate in the study (Hossan et al., 2023). A multistage sampling procedure was used to select 352 smallholder farmers for the study. First, four sub-counties (Kiharu, Kandara, Gatanga, and Maragua) were purposively selected to represent the diverse agro-ecological zones and varying levels of uptake of digital agricultural extension services in Murang'a County. This purposive approach helped align the sample with the study objectives (Campbell et al., 2020). Second, three wards were randomly selected from each sub-county, yielding a total of twelve study wards.

Third, villages within each ward were randomly selected using village lists obtained from local sub-county agricultural extension offices. The sample was proportionally allocated across the four sub-counties based on the estimated number of farming households. Eligible smallholder farmers were then selected through simple random sampling from farmer registers maintained by ward agricultural offices and farmer groups. Where farmer registers were incomplete, snowball sampling was used to identify additional eligible respondents, thereby minimizing under-coverage in the selected villages.

Snowball sampling, also known as chain-referral or network sampling, is a non-probability sampling method used when participants are hard to identify or access. It involves starting with a small group of known individuals and relying on them to recruit or refer new individuals who meet the study criteria. This process continues until the desired sample size or a saturation point is reached (Nikolopoulou, 2023).

Yamane's formula (1967), suitable for an infinite population, a survey, and a simple random sampling approach, was used to obtain the study sample size.

$n=N/(1+N(e)^2$

Where n = the required sample size

N=the total population size; e = the margin of error (0.0532)

n=71,278/ {1+71,278(0.0532)^2} =352

Thus, the final sample size was 352 smallholder farmers.

The sample was distributed proportionately across sub-counties using: $n_i = \frac{N_i}{N} \times n$

Table 3.1: Determination of sample size of the four Sub-Counties

Sub-County	**Number of farmer households**	**Sample size**
Kiharu	24,915	123
Kandara	8,098	40
Gatanga	18,018	89
Maragua	20,247	100
Total	**71,278**	**352**

Source: Sub-County agricultural extension offices, 2026

A total of sixteen key informants were interviewed, including the County Agricultural Director, extension agents in Murang'a, youth agripreneurs under the digital extension model, the Principal of KATC Mariira Farm, and digital extension service providers. Interviews followed a structured KII protocol designed to elicit insights on typologies of DES, access, utilization, and constraints of digital extension services. Data collection continued until saturation was reached, ensuring that no new themes emerged (Guest et al., 2020).

Table 3.2: Matrix of Key Informant Interview Participants

Category	**No. of Participants**
Extension agents	4
Youth agripreneurs	4
DES providers	4
Agricultural directors	4
Total	**16**

3.6 Data Collection Instruments

Data collection involved a combination of primary and secondary sources. Primary data collection, conducted through surveys, was obtained by use of 352 structured questionnaires and key informant interviews conducted using the interview guides. A systematic desktop review of secondary data was conducted, drawing on diverse sources, including national government policy documents, county government periodic reports, NGO and donor reports, private-sector and AgriTech firm publications, academic and research outputs, and institutional and cooperative records. This triangulation of sources ensured a broad and reliable evidence base (Bowen, 2009).

Questionnaires were administered and recorded at the household level using Kobo Collect software by research assistants under the close supervision of the principal investigator. Five research assistants were trained to assist with data collection. These assistants used password-protected mobile devices and encrypted the collected data on Kobo servers to ensure only the researcher and academic supervisors had access. The questionnaires were written in English; however, translations into Kikuyu and Kiswahili were provided for respondents who did not understand English. Also, for in-depth exploration, sixteen key informant interviews (KII) were conducted to gather qualitative data from county agricultural extension officers and digital service providers to collect data on the landscape of digital extension.

Table 3.3: Method of data collection and analysis for each objective

Objective	Type of data	Approaches	Respondents	Data analysis and presentation
1. To document the current landscape and emerging trends in the provision of digital agricultural extension services (DES).	Primary and Secondary data (Qualitative)	Qualitative approach through document review and analysis. Key informant interviews.	Publications, journals, policy documents Experts, extension officers, digital extension service providers.	Thematic analysis to identify themes across documents.
2. To assess the level of awareness, access, and utilization of digital extension services among smallholder farmers.	Primary data (Quantitative and qualitative)	Mixed methods approach through a survey Questionnaire	Smallholder farmers	Descriptive statistics (frequencies, percentages, graphs, means). Thematic analysis

3. To determine the factors influencing the adoption of digital agricultural extension services.	Primary (quantitative data)	Structured questionnaire	Smallholder farmers.	Descriptive statistics (frequencies, percentages, means) Regression (bivariate probit, zero-truncated/negative binomial regression)

3.7 Validity of the Instruments

Validity refers to the extent to which a study instrument accurately measures what it intends to measure and how well the data collection tool performs its functions (Andersson et al., 2024; Sürücü & Maslakçi, 2020). The study instruments were subjected to content and face validity. Content validity refers to how representative the questions are and how well it covers the complete range of the construct being investigated. It helps inspect the data collection tools to see that it has all the necessary components (Ireri, 2022). This was made possible by carefully aligning the questions in the research instruments with the study's specific objectives. A judgment approach was also used, whereby expert and professional judgment was obtained by having my two knowledgeable supervisors read, judge, and make recommendations where necessary.

Face validity checks whether the data collection instrument looks right by examining how it appears in terms of readability, formatting, feasibility, and language consistency and style used (Ireri, 2022). Ireri (2022) further posits that face validity can be achieved by the researcher's subjective evaluation to check for relevance and presentation of the instrument. This was made possible by having the questionnaire scrutinized by my supervisors, who agreed that it met the face validity requirements. The responses gathered from the experts and the pilot test aided in understanding

whether the questions captured in the data collection tools accurately led to the anticipated response. Questions found unclear were revised to minimize the chances of misinterpretation by the respondents.

3.8 Reliability of the Instruments

Reliability refers to the consistency and stability of measurement across time, instruments, and different observers (Andersson et al., 2024; Sürücü & Maslakçi, 2020). The internal consistency, which checks for items' homogeneity, was tested using Cronbach's alpha, which tests the reliability of a scale. Cronbach's alpha values ranging from 0.7 to 1.0 are reliable (Yun et al., 2023). Cronbach's alpha was computed in Stata to assess the reliability of the items. The study items on the benefits of digital extension services have relatively high internal consistency, as the alpha coefficient for the 6 items is 0.8830.

Table 3.4: Cronbach's Alpha

Variable/Instrument Component	No. of items	Cronbach's Alpha
Type of information farmers seek/access through DES	13	0.7858
Enablers of Digital Extension Service	6	0.8830
Organizations that have supported DES	8	0.6834

3.9 Piloting of the Instruments

A pilot test, also known as a feasibility study, is a small-scale version of the methods and procedures carried out before large -scale quantitative research to evaluate the feasibility of the intended, full-scale project (Ireri, 2022). It was conducted in Kirinyaga County outside the study area to avoid contaminating the main sample. According to Bujang et al. (2024), 30 is the minimum acceptable sample size for a pilot study for assessing questionnaire reliability. Therefore, the data collection instruments were tested with 30 participants, who were given the same questionnaire to respond to. A pilot test was conducted to assess research feasibility and suitability and to examine the sufficiency of the instruments used in the research (Bujang et al., 2024). The pilot testing identified unanticipated challenges that may arise while using the research instrument to improve the research instrument. It aided in ensuring that

the research instruments are accurate and consistent before the initiation of the data collection exercise. The pre-test examined the clarity of the questions, the time taken to complete and respond to questions, and variability of responses (Fraser et al., 2018).

3.10 Data Collection Procedures.

Before the commencement of the data collection exercise, ethical clearance was sought from the Murang'a University of Technology Institutional Scientific and Ethics Review Committee (MUT-ISERC) under license number (P027/1/2026). Ethical approval was also granted by the National Commission for Science, Technology, and Innovation (NACOSTI/P/26/4185271) and by the County Agricultural Office of Murang'a County. Once in the study area, the researcher and the research assistants clearly introduced themselves to the respondents and explained the study purpose, both during the pre-testing stage and fieldwork. For the respondents who consented, survey questionnaires were then administered using Kobo Collect Toolbox (v2025.3.3), which enabled the capture of the GPS coordinates of the respondents' locations.

3.11 Data Analysis and Presentation

Data analysis is the organization and reduction of data to provide findings that need interpretation (Kiarie, 2020). Analysis of the data employed both descriptive and inferential statistics. Before analysis, all questionnaires were scrutinized for accuracy and completeness, which entailed editing, coding, exporting to Stata Software, and cleaning to correct possible errors before analysis. Descriptive statistics were conducted for quantitative data collected through a structured questionnaire and were analyzed using Stata version 19 software in the form of percentages, frequencies, means, and standard deviation to depict patterns. The results were then presented as tables, charts, and graphs. Inferential analysis was used to examine the relationship between dependent and independent variables using econometric models such as bivariate probit, multivariate probit, and zero-truncated/negative binomial regression. The interpretation of model estimates was based on standard errors, p-values, and coefficients. Qualitative data findings from open-ended questionnaires, key informant interviews, and data collected from secondary sources were thematically grouped and presented in narrative summaries supported by direct quotations where appropriate, accompanied by tables for clarity and comparison.

3.12 Econometric Modeling Framework

To address objectives (ii) and (iii), namely assessing awareness, access, and utilization of DES and identifying factors influencing adoption, the study employs a multi-stage econometric framework. This framework recognizes that awareness, adoption, and intensity of use are interrelated but distinct decisions.

3.12.1 Bivariate Probit Model

To correct for the potential endogeneity of awareness of DES and to evaluate its causal effect on service utilization, the study applies a bivariate probit model. This approach allows simultaneous estimation of awareness and adoption decisions while accounting for correlated unobserved factors (Greene, 2018). Previous studies have demonstrated the suitability of this framework. For example, Katengeza et al. (2011) examined awareness and use of electronic-based market information services in Malawi, showing that socio-economic characteristics and access to ICT devices significantly influenced adoption. Similarly, Mugari et al. (2025), in a South African context, analyzed the endogenous relationship between extension access and the implementation of sustainable land management practices (SLMP). These studies highlight the robustness of the bivariate probit model in capturing interdependencies between awareness, access, and adoption of ICT-based agricultural innovations.

The analysis jointly examines farmers' awareness and use of DES. These two decisions are likely influenced by similar observed and unobserved factors such as age, membership in farmer groups, ownership of ICT devices, and access to extension services (Katengeza et al., 2011). Since awareness is a necessary precursor to DES use, it becomes an endogenous explanatory variable. Estimating the two decisions separately may lead to biased results due to correlated error terms. Therefore, a bivariate probit model is employed.

The regression model for DES utilization is specified as:

$$DES_i = \propto_1 + \gamma aware_i + X'_i\delta_1 + P'_i\delta_2 + \mu_1 \quad (1)$$

Where, for each farmer, i, DES is the binary variable equal to 1 if the farmer utilized DES, and 0 otherwise. γ measures the effect of awareness on DES use; X_i is a set of exogenous variables influencing DES utilization; P_i represents awareness-related and

other exogenous variables not captured by X, while δ_1 and δ_2 are vectors of coefficients to be determined by the model, and μ_1 is the error term.
The variable *aware* in equation (1) can be modeled as:

$$aware_i = \propto_2 + X'_i\beta_1 + \mathrm{P}'_2\beta_2 + \mu_2 \quad (2)$$

Where for each farmer, i, $aware$ is the binary variable equal to 1 if the farmer is aware of DES and 0 otherwise. X_i is a vector of explanatory variables; and β_1 and β_2 are coefficient vectors, and μ_2 is the error term. Since $aware_i$ in Eq. (1) may be endogenous, the parameter γ would be inconsistent if estimated separately due to omitted variable bias. To address this, Eqs. (1) and (2) are estimated jointly using maximum likelihood, which yields consistent parameter estimates (Greene, 2018).
The error terms are assumed to follow a bivariate normal distribution:

$$\binom{\mu_1}{\mu_2} \sim N\left(\binom{0}{0}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right) \quad (3)$$

Where ρ Captures the correlation between awareness and use decisions. A significant ρ Justifies the use of a joint estimation approach.

3.12.2 Multivariate probit (MVP) model

Farmers often adopt multiple digital extension platforms simultaneously (e.g., SMS-based advisories, mobile applications, radio, social media, or WhatsApp groups). These adoption decisions are likely interdependent due to complementarities or substitution effects. To account for this, the study employs a multivariate probit (MVP) model, which allows joint estimation of correlated binary adoption decisions (Greene, 2018; Wooldridge, 2010). The MVP model has been applied to agricultural ICT adoption contexts and the use of DES. For example, Ntsoane et. al. (2025) examined smallholder farmers' choice of ICT tools in South Africa, while Asnakew et al. (2026) analyzed the adoption of multiple digital platforms in Ethiopia. Both studies highlight complementarities across ICT tools and justify the MVP framework for analyzing interdependent adoption decisions.

The latent adoption equation for each DES platform j is specified as:

$$DP^*_{ij} = X_i\beta_j + \varepsilon_{ij}, \qquad j = 1, \ldots, 8 \quad (4)$$

The observed outcome is:

$$DP_{ij} = \begin{cases} 1 & if\ DP^*_{ij} > 0 \\ 0 & otherwise \end{cases} \quad (5)$$

Where DP^*_{ij} is the latent propensity of the farmer i to adopt DES platform j; DP_{ij} is the observed binary adoption decision, X_i is a vector of explanatory variables; β_j is a platform-specific parameter vector, and ε_{ij} are error terms. The error terms follow a multivariate normal distribution such that

$$\varepsilon_i = (\varepsilon_{i1}, \varepsilon_{i2}, \ldots, \varepsilon_{iJ}) \sim MVN(0, \Sigma) \quad (6)$$

Where Σ is the variance–covariance matrix with non-zero off-diagonal elements. The off-diagonal elements ρ_{jk}capture correlations between adoption decisions across platforms.

3.12.3 Intensity of DES Use

Conditional on adoption, the second stage models the intensity of DES utilization, measured as the count of digital extension interactions or platforms used within a specified reference period. Because this outcome is discrete and non-negative, a count data model is appropriate (Cameron & Trivedi, 2013).

The baseline specification employs a Poisson regression model. However, since Poisson models restrict the mean equals the variance, the study formally tests for overdispersion. If overdispersion is detected, the model is re-estimated using a Negative Binomial regression (NBREG), which allows more flexible variance assumptions (Greene, 2018). To maintain conceptual consistency with the adoption decision, the intensity model is estimated only among adopters, using zero-truncated

Poisson or Negative Binomial estimators as appropriate (Wooldridge, 2010). Results are reported in terms of incidence rate ratios (IRR) and marginal effects.

The Negative Binomial regression is specified as:

$$DI_i \sim NB(\mu_i, \alpha) \qquad (7)$$

$$\ln(\mu_i) = X_i\beta \qquad (8)$$

Where DI_i is the intensity of DES use (count of digital platforms adopted by the farmer i); $\mu_i$is the expected number of platforms adopted, X_i is a vector of explanatory variables; β is a vector of parameters; and α is the dispersion parameter capturing overdispersion.

The variance is given by:

$$\text{Var}(DI_i) = \mu_i + \alpha\mu_i^2 \qquad (9)$$

This specification accounts for overdispersion in the count data, providing robust estimates of the factors driving deeper engagement with DES.

3.12.4 Robustness, Diagnostics, and Estimation Considerations

All models employed robust standard errors, with clustering at the ward or sub-county level where applicable to account for intra-location correlation. Multicollinearity was assessed using variance inflation factors (VIF). Sensitivity checks included alternative specifications of key explanatory variables (e.g., alternative measures of digital access and institutional support). Given the possibility that access to digital infrastructure may be correlated with unobserved household characteristics, the analysis controls for a comprehensive set of socio-economic and locational variables. The findings were therefore interpreted as associational, with robustness checks strengthening confidence in inference.

3.13 Ethical Considerations

Pursuant to ethical research principles regarding the use of human subjects, it was imperative to guarantee the protection of all participants. For this study, a permit letter was sought from the Murang'a University of Technology Institutional Scientific and Ethics Review Committee (MUT-ISERC) under license number (P027/1/2026) before

carrying out the research. The researcher also obtained approval from the National Commission for Science, Technology, and Innovation (NACOSTI/P/26/4185271) and from the County Agricultural Office of Murang'a County. The research purpose was introduced and elaborated, and enough information was provided concerning the objectives.

Informed consent was obtained from all participants, ensuring voluntary participation; participants' anonymity; confidentiality of responses; and the freedom to withdraw at any time without consequences. The research also ensured safe storage and adherence to the Data Protection Act (2019). Data will be stored securely for five years, after which any electronic data will be permanently deleted, and all hard copies used for data collection will be shredded. Research findings were disseminated in the form of a full thesis submitted to Murang'a University of Technology and published in academic journals, seminars, and conference presentations. Farmer feedback was shared through meetings and with county extension officers, excluding respondents' details. Only coded data was used for publication

3.14 Chapter Summary

In summary, this chapter provides a detailed methodological scope for examining digitized extension in the County of Murang'a. It employed a mixed-method research design to collect quantitative and qualitative data using structured questionnaires and KIIs on the digital extension service from Kiharu, Mbiri, and Gaturi Sub-Counties in Murang'a. It outlines the survey method and procedure for data collection. It also underscores the importance of ensuring the validity and reliability of test instruments and compliance with ethical issues regarding research

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

This chapter outlines the research findings and discussions on the determinants of adoption of digital extension services in Murang'a County, Kenya, under each specific objective. Data analysis was conducted using descriptive and inferential statistics. Descriptive analysis used mean, percentage, and standard deviation to present data on respondents' socio-economic and institutional characteristics. A descriptive analysis of the awareness, access, and utilization of digital agricultural extension services among smallholder farmers is also presented. The chapter also presents a bivariate probit that allows simultaneous estimation of awareness and adoption decisions while accounting for correlated unobserved factors and a Poisson regression that models the intensity of DES utilization, measured as the count of digital extension interactions or platforms used within a specified reference period. Qualitative data were obtained by key informant interviews and from secondary sources such as literature searches, reports, and publications.

4.2 Response Rate

Table 4.1 below represents the questionnaire response rate from the respondents.

Table 4.1: Response Rate

Item	**Frequency**	**Percentage (%)**
Respondent	352	100.0
Non-respondents	0	0.00
Total	**352**	**100.00**

The researcher administered 352 structured questionnaires, and all 352 responded, yielding a response rate of 100%. This was attributed to the researcher seeking participants' verbal consent before data collection, where only participants who consented were interviewed. Additionally, face-to-face data collection could also have led to a higher response rate. Since all questionnaires were complete and met the study's inclusion criteria, no cases were excluded from the final analysis. According

to Musiimenta et al. (2024), a response rate of 70% or higher is considered a good representation of the study target population. This rate is robust, comprehensive, and a good reflection of inclusive data collection. In addition, the response rate reflects a high level of participation, mitigating the risk of non-response bias and thereby enhancing the validity, reliability, and credibility of the study findings. A response rate of 100% surpassed the expected rate and was therefore considered adequate for data analysis.

4.3 Farm and Farmers' Characteristics of the Sampled Farmers

In this section, results on smallholder demographic characteristics that influence farmers' decisions to use digital extension services are presented. The socio-demographic characteristics analyzed include the respondent's gender, age, marital status, household size, farmer's age, and education level.

Table 4.2: Socio-demographic characteristics of the respondents (n=352)

Categorical Variables	**Frequency**	**Percentage**
Gender of the Farmer		
Male	176	50.00
Female	176	50.00
Marital status		
Single	95	27.14
Married	239	68.29
Divorced/separated	8	2.29
Widowed	8	2.29
Level of education		
No formal	7	1.99
Primary	85	24.15
Secondary	196	55.68
Tertiary (college/certificate)	48	13.64
University (degree/higher)	16	4.55
Farming	350	99.43
Scale of farming operation		
Subsistence (mainly for home consumption)	87	24.86
Small-scale commercial (small surplus for sale)	222	63.43
Medium-scale commercial (regular sales, moderate income)	40	11.43
Large-scale commercial (significant production for markets/business)	1	0.29
Continuous variables	**Mean**	**Std. Dev.**
Household size	3.70	1.80
Age (Years)	33.5	10.64
Farming experience (years)	8.44	8.98

Regarding gender, 352 respondents took part in the survey; male respondents constituted 176 (50%), and female respondents constituted 176 (50%). The equal representation of male and female respondents indicates that digital extension services are relevant to both genders within the study area. This could suggest that gender differences in access to agricultural information have diminished due to digital technologies. Findings by Ajesh (2024) indicate that digital extension services reduce gender inequalities, aligning with SDG 5. Digital platforms promote gender inclusivity by empowering women farmers to access tailored agricultural information, financial services, and resources, often via a mobile application, hence bridging the information gap between the genders.

With respect to marital status, singles accounted for 27.14% of the respondents, the widowed for 2.29%, the divorced for 2.29%, and the married for 68.29%. This suggests that most respondents were from the family household, which may have implications for agricultural support and labour availability. According to Chepkemoi (2025), married farmers aid one another in decision-making, spreading risks, and providing additional labour to promote agricultural profitability. This finding is compatible with those of Joel et al. (2025), who conducted a study on the effectiveness of ICTs in extension service delivery among smallholder farmers in Nigeria and found that 66.7% of the respondents, who constituted the majority, were married.

The study results on education level reveal that the majority of respondents had attained a secondary level of education (55.68%), followed by primary education (24.15%), tertiary education (13.64%), university education (4.55%), and finally, those with no formal education at 1.99%. This suggests that the respondents had attained at least a basic level of education. Higher education levels produce individuals ready to integrate digital tools by equipping them with problem-solving skills, analytical capabilities, and exposure to technological platforms and tools. Furthermore, postgraduate education increases one's cognitive ability to understand and apply technological innovations (Makinde et al., 2025). However, effective traditional and digital extension approaches should be integrated to reach predominantly farmers with low levels of education and, consequently, low digital literacy. This finding is consistent with Joel et al. (2025), who reported that the majority of respondents (60%) who had attained at least secondary education had basic

numeracy and literacy skills, which promoted greater understanding and led to technology adoption.

With respect to farming, the majority of respondents (99.43%) engaged in farming. Results on the scale of farming operations show that 24.86% of respondents produced for subsistence, mainly for home consumption. Additionally, 63.43% of farmers engaged in small-scale commercial farming with small surpluses for sale, and 11.43% engaged in medium-scale commercial farming with regular sales and moderate income. Only 0.29% of farmers engaged in large-scale commercial production with significant market and business activity. These findings suggest that the majority of respondents engaged in a self-sustaining farming system, where farmers cultivate mainly to meet family needs as the priority, with market considerations for surplus produce in second place. Findings by Shedeed (2020) showed that not all subsistence farmers have access to land. Additionally, socioeconomic factors limit the expansion of agricultural plots and any increase in the level of production.

With respect to household size, the average household size of the respondents was 3.7 members. This indicates that most farmers in Murang'a County live in medium-sized households; such households with youth may help support the elderly in using digital tools since members can benefit from knowledge exchange, digital skills, and labour when needed. Findings of Alela et al. (2024) showed that a unit increase in household size results in low technology adoption because large households spend more money on food in order to maintain their family, instead of adopting technology. Findings by Majiwa et al. (2026) indicate that larger households provide additional income and labor resources, which can support the adoption of new technologies.

In terms of age, respondents' age averaged 33.5 years. The results suggest that a high number of respondents are in the youthful category, delineating individuals in their productive years who are economically active. This further implies the existence of a conducive ecosystem to experiment with digital solutions. According to Makinde et al. (2025), the younger generation is usually more receptive towards innovations and advances in technology, which might influence their willingness and ability to experiment with digital innovations, thus enhancing digital adoption. This finding aligns with Aja et al. (2024), who reported that youths show high adaptability, risk tolerance, and enthusiasm for technological change.

According to the farming experience, the sampled respondents averaged 8.44 years, suggesting that the majority of the small-scale farmers had moderate to extensive years of experience in farming. Farmers with extensive farming experience are likely to have more practical knowledge and skills in agricultural technologies that suit their farms by serving as the chief repository of indigenous knowledge, hence can evaluate new farming technologies and their accompanying benefits. These findings are in agreement with the findings by Joel et al. (2025), who conducted a study on the effectiveness of ICTs in extension service delivery among smallholder farmers in Nigeria. The researchers found that farmers who had farming experience of 6-10 years constituted the majority at 80.8%.

4.4 Economic Characteristics of the Smallholder Farmers in Murang'a

The section reports on the economic characteristics of the respondents, such as employment status, sources of livelihood, monthly income, and expenditure.

Table 4.3: Economic Characteristics of the smallholder farmers in Murang'a, County (n=352)

Categorical Variables	**Frequency (n)**	**Percentage (%)**
Employment status		
Unemployed	124	35.23
Fulltime	3	0.85
Part-time	13	3.69
Formally employed (with a contract)	20	5.68
Self-employment	192	54.55
Sources of livelihood		
Farming/livestock (own, family, or leased	345	98.01
Agricultural wage labour	98	27.84
Off-farm formal employment (salaried)	31	8.81
Off-farm informal employment(casual)	112	31.82
Entrepreneurship	61	17.33
Unemployed	1	0.28
Student	1	0.28
Household monthly income (KES)		
Less than 10,000	64	18.18
10,001-20,000	118	33.52
20,001-30,000	29	8.24
30,001-40,000	14	3.98
40,001-50,000	2	0.57
50,001-75,000	2	0.57
Prefer not to say	123	34.94

According to employment status, the results indicate that the majority of the respondents (54.55%) were self-employed. Furthermore, 35.23%, 0.85%, 3.69%, and 5.68% of the respondents were unemployed, employed full-time, employed part-time and formally employed with a contract, respectively. According to Alela et al. (2024), higher adoption intensity is witnessed among employed farmers than among unemployed counterparts. Formal employment enables farmers to access agricultural loans needed for the purchase and adoption of technology. In addition, employed farmers can obtain finances for hiring farm laborers to assist in implementing labour-demanding technologies. In terms of income source, the majority of the respondents (98.01%) obtain their livelihood from crop and livestock farming, followed by off-farm informal employment such as casual labour, accounting for 31.82%. Those who get their livelihood from off-farm employment, such as salaried work, constituted 8.81%, while 17.33% of the respondents obtained their income from entrepreneurial activities. A smaller proportion of the respondents, 0.28%, and another 0.28% were unemployed and students, respectively. According to Ke et al. (2025), off-farm employment expands farmers' social networks, facilitating technology adoption by diversifying sources from which they obtain knowledge, which increases understanding and application of technology. Further evidence indicates that off-farm income sources enhance the financial resource base of the family, increasing adoption, especially for technologies that need advanced investment (Gedikoglu et al., 2011). Similar findings were reported by Alela et al. (2024); farmers with off-farm employment had higher intensity of adoption of technologies that are risky and capital -intensive.

According to the results, the majority of respondents, about 34.94%, preferred not to disclose their total monthly income. 18.18% of respondents had a monthly income of less than KES 10,000. In addition, respondents with a monthly income in the range of KES 10,001 and 20,000 constituted 33.52%. 8.24% of the respondents had a monthly income of KES 20,001 to KES 30,000, while 3.98% had a monthly income of KES 30,001 to KES 40,000. A minority of respondents (0.57%) fell within the range of KES 40,001 to KES 50,000, and respondents with household income between KES 50,001 and KES 75,000 constituted 0.57%. The level of income has an influence on the farmer's capacity to meet basic human needs and also determines savings and investments. Higher income levels increase technology adoption as more financial

resources enable farmers to easily afford the costs of implementing a technology (Ke et al., 2025).

4.5 Respondents' Access to and Control of Agricultural Land

The table below shows the results on the nature of agricultural land of the smallholder farmers in the study area.

Table 4.4: Agricultural Land Access and Ownership (n=352)

Categorical Variables	**Frequency (n)**	**Percent (%)**
Access to agricultural land	349	99.15
Type of land ownership		
Owned (with title deed)	54	15.47
Owned (without title deed)	64	18.34
Inherited	182	52.15
Leased	46	13.18
Others (Family land)	3	0.86
Soil fertile	264	75.64
Continuous variable	**Mean**	**Std dev**
Average farm size (acres)	1.11	1.06

With respect to agricultural land access, the majority of the farmers (99.15%) had access to agricultural land. This indicates that access to land was unlikely to be a hindrance factor for adoption of digital extension services. In terms of land tenure, the majority of the respondents (52.15%) operated on inherited land. Respondents who owned land with a title deed constituted 15.47%, while 18.34% owned land without a title deed. Respondents who cultivated on leased lands constituted 13.18%. A minority of the respondents (0.86%) had another personal tenure system. Land ownership without a title deed suggests a lack of land tenure security that may limit investment in long-term agricultural farm activities. Findings by Zeng et al. (2018) showed that the land tenure system is a crucial determinant of technology adoption. Land tenure incentivizes or promotes technology adoption, while a lack of land tenure limits it. Land ownership promotes access to agricultural resources like credit, while its absence

may make farmers resort to land rentals, which may hinder them from future benefits associated with technology due to fear of eviction.

In terms of soil fertility, 75.64% of the farmers had fertile lands, with only 24.36% of the farmers having infertile lands. This suggests that most of the land in the study area is productive and can support farming. Higher soil fertility can increase crop yields and farm income, giving farmers greater financial capacity to purchase technologies such as improved seed, fertilizers, irrigation equipment, mechanization, and digital agricultural services. In addition, farmers who obtain good returns from their land may be more willing to adopt technologies that further increase productivity.

Respondents' land sizes averaged 1.11 acres, categorizing them as smallholder farmers. This indicates that farmers cultivated relatively small parcels of land, perhaps because of land subdivision and fragmentation attributable to population pressure. According to Alhassan et al. (2025), small parcels of land limit the agricultural resources farmers invest in novel technologies, which may constrain the adoption of digital agricultural extension services. Furthermore, farmers with large landholdings are likely to adopt new technologies due to greater incentives and capacity to invest in technologies (Ke et al., 2025).

4.6 Institutional Characteristics of the Respondents

The institutional characteristics of the respondents included access to credit, extension services, agricultural training, distance and time to market, and farmer group membership. Institutional characteristics are external factors, such as services provided by public and commercial institutions for overall agricultural growth (Kithome, 2022).

Table 4.5: Institutional Characteristics of the Respondents (n=352)

Categorical Variables	**Frequency**	**Percent (%)**
Access to credit	57	16.19
Sources of credit		
Mobile-based sources (e.g., mobile money loans)	41	71.93
Non-governmental organization (NGO)	1	1.75
Formal lender (bank/financial institution)	4	7.02
Informal lender (e.g., money lenders like shylock)	7	12.28
Friends/relatives	13	22.81
Group-based microfinance (e.g., SACCOs)	2	3.51
Informal credit systems (e.g., merry-go-rounds)	16	28.07
Access to extension services	120	34.09
Access to agricultural training	137	38.92
Areas of training		
Livestock management	64	46.72
Crop production and agronomy	119	86.86
Post-harvest handling and value addition	47	34.31
Marketing and Market Survey	27	19.71
Use of digital tools and ICT for agriculture	7	5.11
Climate-smart agriculture and agroecology	51	37.23
Group management/cooperative governance	8	5.84
Financial literacy or record-keeping	7	5.11
Youth and women's empowerment	28	20.44
Group membership	30	8.52
Services offered by group membership		
Aggregation and marketing	10	33.33
Access to inputs (e.g., seeds, fertilizers, animal feeds)	7	23.33

Access to financial services – credit/loans and savings products	15	50.00
Training & Capacity building - extension, knowledge transfer	21	70.00
Support for certification, grading, or quality assurance	1	3.33
Processing/value addition	5	16.67
Storage, transportation, and logistics services	3	10.00
Advocacy and engagement in agricultural policies	7	23.33
Climate Resilience and Environmental Services	1	3.33
Social and institutional strengthening – group formation, youth involvement	3	10.00
Continuous variables	**Mean**	**Std. Dev.**
Distance to the market (km)	4.27	3.77
Time taken to the markets (minutes)	19.78	18.19

Regarding access to credit, the majority of respondents (83.81%) did not have access. This suggests that most smallholder farmers in the study area lacked access to credit services from existing financial institutions and may face financial challenges that hinder their ability to invest in digital technologies. As a result, there is a need to enhance smallholder farmers' access to agricultural loans from financial institutions. Credit access enhances farmers' purchasing power, enabling the purchase of costly technologies for on-farm adoption (Alela et al., 2024).

Respondents who accessed credit (16.19%) obtained services from numerous sources. For example, the majority of respondents (71.93%) obtained credit from mobile-based sources like mobile money loans, 1.75% from non-governmental organizations, and 7.02% from formal lenders such as banks and other financial institutions. Furthermore, 12.28% of farmers obtained credit from informal lenders such as moneylenders like Shylock, while farmers who obtained credit from friends and relatives constituted 22.81%. Further analysis indicates that 3.51% of farmers obtained credit from group-

based microfinance, such as SACCOs, while only 28.07% of farmers obtained credit from informal credit systems like merry-go-rounds. According to Midamba et al. (2022), credit services prompt farmers to join various groups, where they receive information on agricultural extension services.

Regarding access to extension services, 34.09% of respondents had access in the last 12 months, while 65.91% did not. This suggests a significant disconnect between farmers and the traditional agricultural extension service providers, and thus smallholder farmers' inability to profit from agricultural extension support services. Agricultural extension is a way of disseminating agricultural technologies in the current world. Farmers with access to extension services are better placed to acquire information regarding improved or novel technologies, hence promoting adoption. Furthermore, Alela et al. (2024) noted that frequent visits by extension agents positively influence technology adoption. These findings are consistent with those of Mugari et al. (2025) and Midamba et al. (2022).

In terms of agricultural training, the majority of the farmers (61.08%) did not have access to agricultural training. Those who had access to agricultural training (38.92%) received the training on various agricultural topics. The majority of the farmers (86.86%) were trained on crop production and agronomy, 46.72% of the farmers were trained on livestock production, 34.31% on post-harvest handling and value-addition, and 19.71% on marketing and market survey. Furthermore, 5.11% of the farmers received training on the use of digital tools and ICT in agriculture, 37.23% on climate-smart agriculture and agroecology, while 5.84 % of the farmers were trained on group management or cooperative governance. Further analysis indicates that 5.11% of the farmers were trained on financial literacy or record-keeping, and 20.44% of the farmers on youth and women's empowerment. Agricultural training assists in transferring necessary farming skills for modern technologies, which enables farmers in the decision-making process on whether to adopt based on the practical experience acquired.

With respect to farmer group membership, the majority of the farmers (91.48%) did not belong to any farmer group. 8.52% of the respondents who were affiliated with farmer-based groups received numerous services. For example, the majority of the farmers (70.0%) benefited from training and capacity building, such as extension and

knowledge transfer services, followed by farmers who benefited from access to financial services like credit/loans and savings products. Furthermore, 33.33% of the respondents had access to aggregation and marketing services, 23.33% had access to farm inputs like seeds, fertilizers, and animal feeds, while 3.33% of the farmers benefited from support for certification, grading, and quality assurance. Farmers who received processing or value addition services constituted 16.67%, 10.00% obtained storage, transportation, and logistics services, 23.33% of the respondents received advocacy, and 10.00% of the farmers benefited from social and institutional strengthening, like group formation and youth involvement. Finally, a minority of farmers (3.33%) received climate-resilience and environmental services. This finding by Makinde et al. (2025), showed that farmer organizations provide networking platforms where members can exchange knowledge and get exposed to digital solutions, thus facilitating quick and easy navigation of these digital tools.

In terms of distance to the nearest market, on average, farmers covered a distance of 4.27 km within 19.78 minutes to reach the nearest market. Findings by Majiwa et al. (2026) indicate that farmers located closer to markets typically have greater access to digital service providers, mobile networks, infrastructure, and extension services, which promotes digital adoption. In contrast, those in more remote rural areas often battle with problems of limited connectivity, insufficient digital infrastructure, and limited opportunities to acquire knowledge of digital technologies. Shorter distance to input or output markets facilitates easy farmer access to agricultural technologies (Alela et al., 2024). Findings by Kiprotich et al. (2023) report that the difficulty in accessing the market limits the use of modern technologies because the excess yields go to waste after extensive technology investment.

4.7 Current Landscape and Emerging Trends in Digital Agricultural Extension

The study aimed to document the current landscape and emerging trends in the provision of digital extension services in Murang'a County through a literature review. Secondary data were sourced from National Government & Policy Documents, county government periodic reports, NGO & Donor Reports, Private Sector & AgriTech Firms, Academic & Research Publications, and Institutional & Cooperative Records and interviews. The study applied an analytical framework that combines ICT typologies with an access–use–constraint approach. Digital extension services were

first categorized by technology type (e.g., mobile, web, social media, and mass media). Each category was then analyzed in terms of (1) access (availability and affordability), (2) use (actual utilization patterns), and (3) constraints (technical, economic, and institutional barriers). This approach enables a structured assessment of both the diversity of digital tools and the factors shaping their effective use.

4.7.1 Digital infrastructure, Availability, and Access in Murang'a County

Qualitative findings indicate that Murang'a County possesses a relatively well-developed digital infrastructure that supports the delivery of digital agricultural extension services. Mobile network coverage is generally reliable across major trading centres and densely populated agricultural areas, facilitating access to digital advisory platforms. One county agricultural extension officer observed:

"Mobile network coverage in Murang'a County is generally *good, especially in trading centers and highly populated agricultural areas such as Kandara, Maragua, Kigumo, Kiharu, and parts of Gatanga. Safaricom is extensively used due to its 3G and 4G network coverage and its ability to combine both extension services and financial transactions (M-Pesa). Airtel is also used, but it is unreliable." KII#03*

Reliable network connectivity enables most farmers to access WhatsApp groups, SMS alerts, YouTube videos, and other online advisory platforms. However, connectivity remains uneven across the county. Farmers residing in hilly and forested areas frequently experience weak network signals and unstable internet connections, particularly during the rainy season. Consequently, many rely on low-bandwidth communication channels such as SMS, WhatsApp voice notes, phone calls, and radio programmes, which remain more dependable under constrained network conditions.

Electricity infrastructure has also improved through the Rural Electrification Programme and the Last Mile Connectivity Project. Increased household electrification in areas such as Kigumo, Maragua, and Kandara has enhanced smartphone ownership, regular device charging, and participation in digital agribusiness activities. Nevertheless, frequent power outages in remote villages continue to disrupt access to digital services. Some households have adopted solar charging systems, while older farmers often prioritize electricity for domestic needs, limiting the use of digital communication technologies for agricultural purposes.

Despite improvements in network and electricity infrastructure, the affordability of internet services remains the principal constraint to digital extension utilization. Respondents consistently identified the high cost of mobile data bundles as the greatest barrier to accessing data-intensive platforms such as YouTube, webinars, and web-based learning portals. As a result, farmers preferentially use low-cost platforms, particularly WhatsApp, which offers affordable and user-friendly communication. Older farmers and low-income households are further constrained by limited digital literacy, unfamiliarity with smartphone applications, and concerns over online fraud. These findings suggest that while digital infrastructure in Murang'a County has expanded considerably, equitable access to digital extension services continues to be constrained by affordability, digital capabilities, and infrastructural disparities, reinforcing the continued importance of SMS and radio as inclusive extension channels

4.7.2 Digital Extension Utilization

A greater percentage of farmers in Murang'a County use digital agricultural extension services, primarily through digital TV and radio, mobile phone services, internet searches, and social media.

During interviews, an extension officer explained:

"Digital agricultural extension services in Murang'a County are not equally accessible to all categories of farmers. Youth farmers are generally more active users of WhatsApp, Facebook, and YouTube, while older farmers prefer radio programs, SMS services, and direct phone communication. Many older farmers depend on children, neighbors, or extension officers to access information shared online."

Youth farmers typically demonstrate stronger internet skills, greater confidence in digital systems, and better smartphone navigation ability. In contrast, older farmers often struggle with downloading applications, using websites, navigating online forms, and identifying genuine information sources. Extension officers, therefore, provide basic digital literacy support during field visits. One agent noted:

“Murang’a County currently has 75 extension officers, but this number will be reduced by 30% by 2027. Limited mobile data, emerging pest and disease issues, inadequate transport facilitation, and restricted funding are some of the major challenges we face.”

Gender and socio-economic differences significantly shape inclusion. Women farmers actively participate in dairy and kitchen gardening through WhatsApp groups, but many face barriers such as limited smartphone ownership, reduced control over internet expenditure, and time constraints due to household responsibilities. Men, on the other hand, tend to dominate commercial digital agribusiness platforms.

An extension agent highlighted:

“Smartphone users access videos, mobile applications, webinars, and social media platforms, while farmers with basic phones mainly depend on SMS, USSD systems, and radio programs. This creates a digital divide between the two groups.”

Commercial farmers are more likely to use farm management applications, attend online trainings, and access digital markets, whereas smallholder farmers rely on WhatsApp groups, radio, and SMS advisories. Affordability limitations and uneven digital literacy levels across the county further reinforce these disparities.

4.7.3 DES Applications available in Murang’a

The findings reveal that digital agricultural extension in Murang'a County comprises a diverse ecosystem of complementary digital platforms that facilitate one-way, two-way, and interactive communication between farmers, extension providers, researchers, and market actors (Table 4.6). These platforms perform distinct but interconnected functions, ranging from information dissemination and advisory delivery to market linkage, farmer registration, financial inclusion, and knowledge exchange.

Mobile-based advisory platforms; Mobile applications constitute the most comprehensive digital extension tools in the county because they integrate multiple agricultural services into a single platform. Key applications include the MyMurang'a App, Kilimo App, DigiFarm, M-Kilimo, iCow, M-Farm, and Kuza One, which

provide advisory services on crop and livestock production, weather information, pest and disease management, market prices, mechanization services, digital finance, and input supply. According to the County Director of Agriculture:

"One of the programmes integrated in MyMurang'a App is the Inua Mkulima Programme... anchored in the Milk and Mango Programme, the maize programme, and veterinary services."

The findings indicate that mobile applications are particularly popular among youth, commercial farmers, and organized farmer groups because they provide real-time advisory services while simultaneously linking farmers to markets, financial services, and government support programmes. The integration of USSD services (e.g., DigiFarm *944#) further enhances accessibility for farmers with basic mobile phones.

Web-based knowledge platforms: Web-based platforms primarily support agricultural knowledge management and institutional service delivery. Frequently cited platforms include the Murang'a County Agriculture Portal, the Kenya Integrated Agriculture Management Information System (KIAMIS), KALRO's Big Data System (BDS), the Kenya Agricultural Observatory Platform (KAOP), the Cooperative Management Information System (CMIS), and the Livestock Management Information System (LMIS). These platforms provide access to policy documents, extension manuals, climate-smart agriculture resources, farmer registration services, and downloadable technical publications. Although widely used by extension officers, researchers, agribusiness professionals, and digitally literate farmers, their utilization among smallholders remains constrained by internet costs and limited digital skills.

Social media and video-based learning*;* Social media has emerged as one of the fastest-growing extension channels because it enables real-time communication and peer-to-peer knowledge exchange. WhatsApp, Facebook, TikTok, and Telegram were identified as the dominant platforms, with WhatsApp being the most preferred due to its affordability, ease of use, and ability to support group-based learning.

Similarly, YouTube has become an important repository of visual extension content. Farmers frequently access channels such as Shamba Shape Up, KALRO Mkulima, FarmKenya, Digital Green, and Mkulima Young, which provide practical demonstrations on dairy production, greenhouse farming, pest management, and climate-smart agriculture. Respondents noted that short videos shared through WhatsApp are increasingly preferred over longer YouTube content because they consume less data while enhancing visual learning and technology adoption. Nevertheless, concerns regarding misinformation and the credibility of online content remain significant challenges.

SMS, voice services, and broadcast media; Despite rapid digitalization, SMS, voice calls, radio, and television continue to play a critical role in ensuring inclusive extension service delivery. SMS platforms, including DigiFarm, WeFarm, M-Farm, Arifu, UjuziKilimo, county bulk messaging systems, and KALRO advisory services, primarily disseminate weather forecasts, pest and disease alerts, fertilizer recommendations, market information, and livestock vaccination reminders. These services remain particularly important for older farmers, low-literacy users, and households using feature phones.

Similarly, radio and television continue to provide trusted and accessible extension services. Vernacular stations such as Inooro FM, Kameme FM, and Inooro TV's Mugambo wa Murimi, together with national programmes such as Shamba Shape Up, were consistently identified as major sources of agricultural information. Their extensive reach, local language programming, and visual demonstrations make them especially valuable for awareness creation and technology dissemination, although opportunities for farmer feedback and interaction remain limited.

Hybrid digital extension systems; The findings further indicate an increasing shift towards hybrid extension models that integrate digital technologies with conventional face-to-face extension. ICT centres, ward agricultural offices, Huduma Centres, farmer training centres, demonstrations, and field days increasingly complement digital platforms by providing internet access, digital farmer registration, online training, and virtual learning opportunities. These centres utilize platforms such as

Zoom, Google Meet, Microsoft Teams, WhatsApp, Telegram, Digital Green, and FarmStack to facilitate farmer training and interaction with extension specialists. However, inadequate ICT infrastructure, limited staffing, and inconsistent internet connectivity continue to constrain their effectiveness

Table 4.6 Types of Digital Extension Service

Digital Extension Channel	Examples/Platforms in Murang'a	Key Services Provided	Main Users/Reach	Opportunities	Key Constraints
Mobile applications	MyMurang'a App, Kilimo App, M-Kilimo, KALRO Mkulima, PlantVillage Nuru, iCow, DigiFarm, AgriApp, M-Farm, Kuza One	Crop/livestock advisory, pest and disease control, market prices, input access, and financial services	Smartphone users, youth, commercial farmers, dairy/avocado/coffee farmers	Real-time advisory, personalized support, market linkage, mobile-money integration	Low smartphone ownership, low digital literacy, and high data costs
Web-based platforms	KALRO Mkulima, e-Extension Kenya Portal, Ministry of Agriculture website, Kenya, FarmBiz Africa	Training manuals, videos, policy updates, expert consultations, downloadable materials	Farmers with internet access, extension officers, and farmer groups	Centralized knowledge access, continuous learning, and access to technical information	Poor rural connectivity, limited internet skills, and device limitations
YouTube/video channels	KALRO Mkulima Channel, Shamba Shape Up, Farmers Trend, Dairy	Demonstrations, farmer success	Visual learners, youth, farmers with smartphones/internet	Enhances practical learning, peer learning,	High data cost, poor connectivity,

	Farming Kenya, Digital Green Videos, AgriTV Kenya	stories, pest control, dairy, and crop		and technology diffusion	and limited regular access
Social media	Facebook groups/pages: Murang'a Farmers Forum, Kenyan Farmers Group, Avocado Farmers Kenya, Dairy Farming Kenya, Mkulima Young	Market prices, weather alerts, pest warnings, farming tips, peer-to-peer advice	Youth, digitally active farmers, and farmer groups	Fast information sharing, networking, peer learning, farmer–expert interaction	Misinformation, unverified advice, unequal access
SMS and phone calls	DigiFarm SMS, iCow SMS, WeFarm, M-Farm alerts, Arifu, UjuziKilimo, county SMS systems, call centres	Weather alerts, pest alerts, market prices, input updates, and direct advisory support	Basic-phone users, rural farmers, low-literacy users	Most inclusive, low-cost, works without smartphones/internet	Limited message depth, language barriers, and need for follow-up clarification
Radio and television	Shamba Shape Up, Seeds of Gold TV, KTN Farmers TV, Inooro FM, Kameme FM, Mugambo wa Murimi	Agricultural programmes, modern farming practices,	Broad farmer audience, older farmers, vernacular-language users	Wide reach, trusted local language communication, useful for awareness creation	Limited interactivity, weak feedback mechanisms

		crop/livestock demonstrations			
ICT centres	KALRO platform access, e-extension portals, Zoom, Google Meet, Microsoft Teams, YouTube, WhatsApp Telegram, Digital Green, FarmStack	Video training, online conferencing, manuals, group learning, expert interaction	Farmer groups, extension officers, and organized community users	Builds digital literacy, supports collective learning, access to experts	Low awareness, distance to centres, and underutilization

Overall, the findings demonstrate that no single digital platform adequately meets the diverse information needs of smallholder farmers. Rather, digital agricultural extension in Murang'a County is characterized by a complementary ecosystem in which mobile applications, web-based systems, social media, broadcast media, SMS services, and hybrid learning platforms collectively enhance access to agricultural knowledge, advisory services, market information, and institutional support.

4.7.4 Emerging Trends in Provision of Digital Extension Services

The findings indicate that digital agricultural extension in Murang'a County is transitioning from conventional advisory approaches towards more integrated, data-driven, and participatory digital systems. The emerging innovations vary considerably in their level of maturity, ranging from established practices to pilot initiatives and technologies under development.

Among the established digital practices, the WhatsApp-based extension has become one of the most widely adopted communication channels among extension officers and farmer groups. Key informants reported that WhatsApp groups are increasingly complementing, and in some cases replacing, conventional farmer meetings because they facilitate rapid dissemination of advisory messages, short training videos, weather alerts, and peer-to-peer learning. Similarly, Common Interest Groups (CIGs), producer organizations, and Farmer Field and Business Schools (FFBS) remain integral institutional platforms through which farmers organized around avocado, coffee, mango, and dairy value chains receive technical training and market information. These approaches represent the county's mainstream digital extension model by integrating face-to-face learning with digital communication.

Several innovations are currently in the pilot or early implementation stage. For example, blockchain technology is being piloted within selected horticultural value chains, particularly avocado, to improve product traceability, transparency, and market credibility. Similarly, Murang'a County has trained seven youth agripreneurs who serve as digital extension intermediaries under the National Agricultural Value Chain Development Project (NAVCDP). Equipped with tablets and smartphones, this

agripreneurs support farmer profiling, digital registration, advisory delivery, and linkage of farmers to markets and service providers.

One youth agripreneur explained:

"In Murang'a County, the agripreneur-based extension model utilizes digital tools such as tablets, mobile phones, and online advisory platforms. Trained youths assist in farmer profiling, delivering extension services, linking farmers to value chains, and enhancing market access through initiatives such as NAVCDP. The model utilizes platforms such as KIAMIS and Know Your Farmer (KYF)." (KII #5)

The Know Your Farmer (KYF) platform, integrated with digital agricultural extension services verification tools, enables secure farmer registration, identity verification, and mobilization of farmers for advisory, financial, and input support services. The platform supports extension officers in maintaining farmer databases while complying with data verification requirements. Likewise, KAMIS is being used to collect market information to improve price transparency, while the Agricultural Digital Transformation (ADT) application is under development to integrate advisory services, agro-dealers, input suppliers, and market actors into a single platform. However, implementation challenges remain, including approximately 10% of registered farmers not receiving digital messages because of network and system limitations, while many elderly farmers continue to experience difficulties interpreting digital content.

The study further identified several emerging opportunities that are still at an early stage of adoption. These include artificial intelligence-driven advisory services, digital soil fertility mapping by KALRO, precision fertilizer recommendations, and the growing use of short-form agricultural videos distributed through YouTube, TikTok, and WhatsApp. Although these innovations are not yet widely adopted among smallholder farmers, key informants noted increasing interest, particularly among youth farmers and commercial producers, owing to their potential to deliver

personalized recommendations, improve input-use efficiency, and strengthen climate-smart decision-making.

Overall, the findings suggest that Murang'a County's digital extension ecosystem is characterized by a combination of mature communication platforms (WhatsApp, CIGs, FFBS), pilot digital innovations (blockchain, youth agripreneurs, KYF, KAMIS), and emerging technologies (artificial intelligence, digital soil mapping, and precision agriculture). While these innovations demonstrate considerable potential to improve extension effectiveness, their wider adoption will depend on strengthening digital infrastructure, improving digital literacy, and scaling pilot initiatives to reach a larger proportion of smallholder farmers.

4.8 Awareness of Digital Extension Services

Figure 4.1 below shows sources that created awareness of digital extension services.

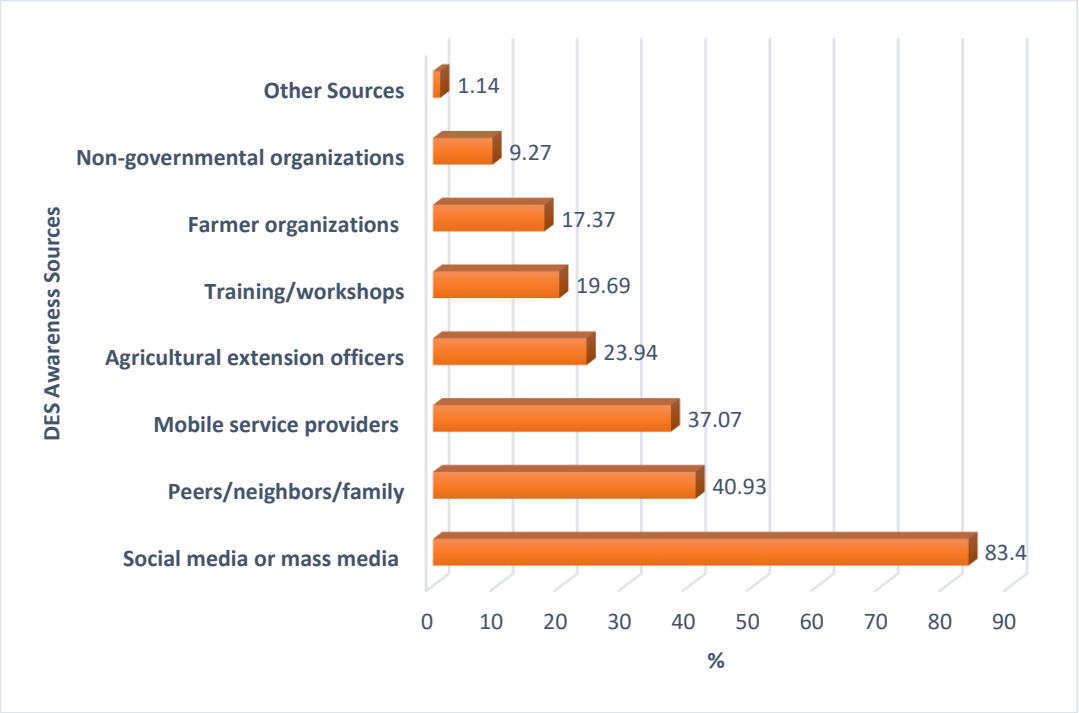


Figure 4.1: Sources of Information that have created Awareness

Among respondents who were aware of digital extension services, the main sources of information were social media (radio, television, newspapers, Twitter, Facebook, and LinkedIn), which accounted for 83.40%, followed by peers/neighbors/family, which constituted 40.93%, and mobile phone service providers like Short Messaging Service alerts and mobile applications, which constituted 37.07%. Agricultural

extension officers as a source of information accounted for 23.94%, followed by training, workshops, and agricultural expositions at 19.69%. Farmer organizations like groups, associations, and cooperatives accounted for 17.37%, while the least was the NGO or development project at 17.37%. Other sources specified by respondents were Biovision, Inua Mkulima Card, and Yara App.

These findings suggest that social media dominates as an information source on digital agricultural extension services, with the least sources being NGOs, agricultural extension, and farmer organizations. The findings, therefore, highlight the importance of strengthening partnerships and collaboration between agricultural extension officers, digital platforms, and smallholders through capacity building for the key stakeholders to enhance effectiveness in the delivery of extension services. According to Chowdary et al. (2024), farmers' use of social media platforms such as WhatsApp is most predominant due to its simplicity, ease of use, low internet data requirements, and its ability to relay information in multiple forms like audio, text, visuals, and web-based links.

Kansiime et al. (2021) also noted that social media sources are time-savers, very easy to access and understand, and the information provided by these sources was more relevant to the farming context. According to Umunakwe et al. (2025), diverse sources of information on digital agricultural extension services enhance users' breadth of knowledge and better understanding, which can promote technology adoption. Additionally, peer groups enable farmers to get guidance, support, and the urge to experiment with the digital extension service.

4.9 Awareness levels of Digital Extension Services

The study examined smallholder farmers' awareness of digital extension platforms and services. The findings indicate that farmers were more aware of accessible digital extension channels, particularly digital TV/radio (92.33%), government platforms (88.35%), social media (85.80%), and mobile phone services (84.66%). This aligns with studies showing that farmers commonly rely on familiar technologies such as mobile phones, WhatsApp, Facebook, radio, and television for agricultural information (Coggins et al., 2021; Mutuma et al., 2023). However, awareness of specialized platforms, including KIAMIS, E-soko/M-Farm, KOBO Toolkit, weather applications, and agricultural mobile apps, was relatively low. Previous studies

similarly identify limited digital literacy, poor awareness, inadequate infrastructure, data costs, and low discoverability as barriers (Coggins et al., 2022; Mutuma et al., 2023). By contrast, some Kenyan and other African contexts show higher levels of awareness and use of mobile applications (Miine et al., 2023).

Table 4.6 Awareness levels of Digital Extension Services among Respondents

	Awareness		**Awareness level**			
Digital Extension Services/platforms	**Aware (Freq.)**	**Percent (%)**	**Slightly aware**	**Neutral**	**Aware**	**Very much aware**
Mobile phone services	298	84.66	1	46	173	78
Mobile apps	71	20.17	1	21	36	13
Social media platforms	302	85.80	2	53	132	115
Government platforms	311	88.35	-	20	20	1
Digital TV or radio	325	92.33	-	27	120	178
Marketing platforms (E-soko, M-farm)	40	11.36	1	19	16	4
Weather Information platforms	54	15.34	2	14	30	7
Internet Searches	234	66.48	2	37	105	90
AI-supported platforms	94	26.70	-	19	38	37
Online portals/websites	66	18.75	2	16	42	6
KIAMIS	24	6.82	-	13	6	5
KOBO toolkit - registration	32	9.09	1	17	5	9

4.10 Access and Utilization of Digital Extension Services

Table 4.8 below shows how smallholder farmers access the internet when seeking digital extension services. Reliable internet access plays a key role in the adoption of digital agricultural extension services. A stable internet connection promotes users' confidence and interaction with the digital extension platforms (Mutisya & Kumar, 2025).

Table 4.7 Farmers Access to the Internet

Variable	Frequency	Percentage (%)
Mobile purchased data bundles	319	90.63
Wi-Fi	23	6.53
Cyber café	9	2.56
Shared hotspot from another device	1	0.28

According to the results, the majority of the respondents (90.63%) accessed the internet through mobile phones purchased data bundles. Respondents who accessed the internet through Wi-Fi constituted 6.53%. Those who accessed the internet through a cybercafé constituted 2.56%. A minority of respondents (0.28%) accessed the internet through a shared hotspot on another device. These results indicate that mobile-purchased data bundles remain the dominant method of internet access by smallholder farmers of Murang'a County and that the connectivity of Wi-Fi and hotspot services is limited. The high dependence of smallholder farmers on mobile phone data bundles to access extension services may lead to high internet costs, and access challenges can also be attributed to limited infrastructural facilities. Supporting studies (Mutisya & Kumar, 2025) similarly underscore that enhancing digital infrastructure is essential to bridging widening adoption gaps.

The results suggest the need for policy intervention to support the installation of stable, affordable Wi-Fi infrastructure to help farmers access digital extension devices without incurring high internet costs, which might otherwise lead to resistance to adopting digital extension solutions. These findings are in concordance with those of Abdulai et al. (2023), who conducted a study on digitization among smallholder

farmers in Africa and reported that 13.02% of respondents had cellular internet access and 2.7% had Wi-Fi access. Farmers who owned smartphones but lacked access were unable to afford data bundles, while Wi-Fi inaccessibility was attributed to poor network connectivity, especially in remote areas.

4.11 Utilization of Digital Extension Services

Figure 4.2 below shows the results of a survey in which respondents were asked whether they use digital extension services. According to the results, the majority of respondents (53.13%) used the digital agricultural extension service. This shows that slightly more than half of the respondents had used the digital extension service. The finding implies that utilization of digital agricultural extension services among the smallholder farmers was moderate

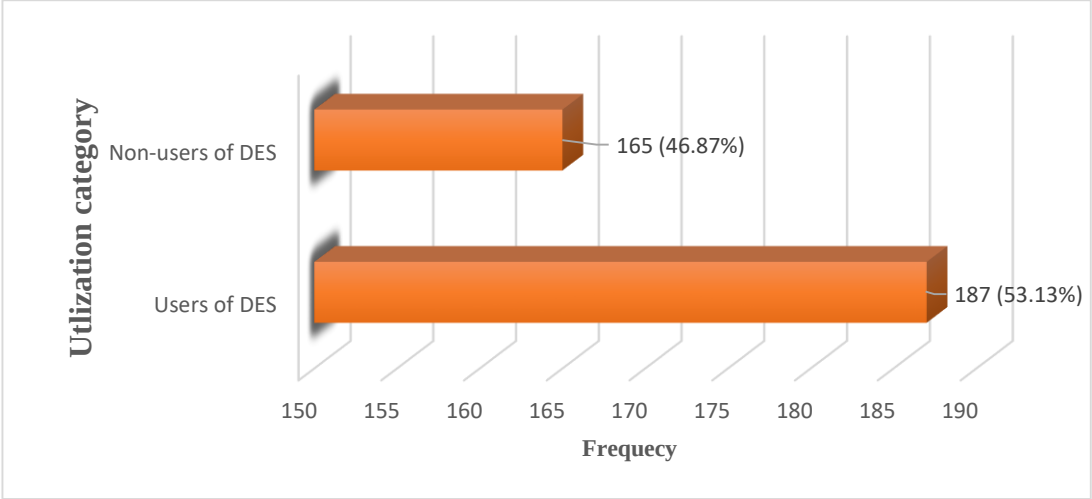


Figure 4.2: Users and Non-users of Digital Extension Services

Table 4.8 Type of Digital Extension Services/Platforms Utilized by the Smallholder Farmers

Type of DES/platforms	Frequency	Percent (%)
Digital TV or radio	276	84.92
Mobile phone services	240	80.54
Internet Searches	174	74.36
Social media platforms	197	65.23
AI-supported platforms	60	63.83
Weather Information platforms	34	62.96
Online portals/websites	41	62.12
Mobile apps	34	47.89
KOBO toolkit	14	43.75
Kenya Agricultural Market Information System	10	41.67
Government platforms	13	31.71
Marketing platforms	7	22.50
Digital video programmes	7	22.50

The research sought to examine whether smallholder farmers were using the digital extension tools and platforms listed in Table 4.12. Among those who were aware of digital extension services or platforms and proceeded to use them, the majority of farmers (84.92%) used digital TV or radio for farmers, such as Shamba Shape-Up and Mugambo wa Murimi (the 'Farmer's Voice '), followed by users of mobile phone services, such as calls, SMS alerts, and bulk messaging, who constituted 80.54%. The plausible reason for high utilization of "*Mugambo wa Murimi*" is due to the provision of localized agricultural content, which boosts listenership attributed to regional relevance. Farmers who used Internet searches, such as Google, accounted for 74.36%; 65.23% used social media platforms such as TikTok, WhatsApp, Facebook, X, Telegram, among others. Abdurrauf et al. (2025) found that farmers prioritize utilizing platforms such as WhatsApp due to their simplicity, user-friendliness and ability to provide quick and actionable insights for farm productivity improvement. 63.83% of the farmers used AI-supported platforms such as ChatGPT, Farm Chat, inter alia.

Further analysis indicates that 62.96% of the farmers used weather information platforms such as the KARLO Weather App, 62.12% used online portals/websites such as ministry or NGO websites, and 47.89% used mobile apps such as iShamba, KALRO App, among others. Furthermore, 43.75% of the respondents used the KOBO toolkit, 41.67% used the Kenya Agricultural Market Information System, and 31.71% of the farmers used government platforms such as E-kilimo. Furthermore, 22.50% used marketing platforms such as E-Soko and M-Farm. Abdurrauf et al. (2025) found that more than 1.5 million farmers in Africa have benefited from E-Soko's services, which have helped them negotiate higher prices for their produce and adjust to the changing climate. The least used digital extension service was the digital video program, used by 22.50% of the farmers.

4.12 Duration of Digital Extension Service Use by the Smallholder Farmers

Figure 4.3 reveals how long the smallholder farmers have used the digital extension services.

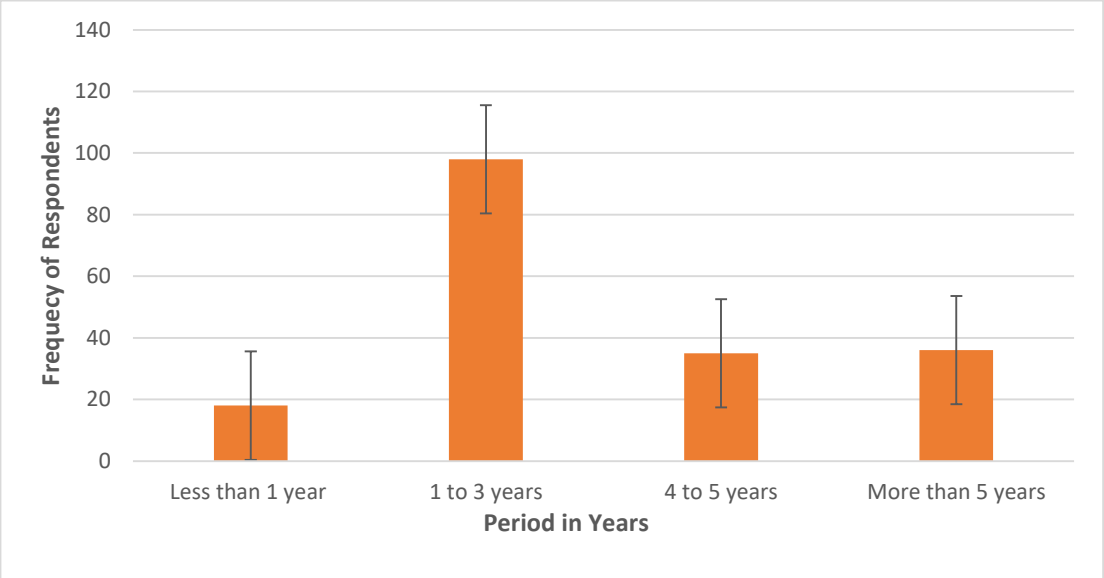


Figure 4.3: Duration of Digital Extension Services Use

Of the 53.13% of users of digital extension services, the majority of respondents (52.41%) have used them for 1 to 3 years. Respondents who had used digital extension services for less than 1 year constituted 9.63%. Respondents with 4 to 5 years of usage constituted 18.72%. Only 19.25% of the respondents had used the digital extension

services for more than 5 years. This suggests that farmers have used digital extension services for a relatively short period of time. Priya et al. (2025) reported that digital extension is a facet of innovation that has emerged to enhance dissemination of agricultural knowledge.

4.13 Agricultural information sought by Farmers

Table 4.10 below shows the type of information sought by farmers through digital extension platforms

Table 4.9: The Type of Agricultural Information Farmers Receive through DES

Type of information farmers seek	**The proportion of farmers who seek the information (n=187)**	
	Frequency	**Percentage (%)**
Crop-specific advice (e.g., pest and disease control, planting calendar)	149	79.68
Improved farming technologies/ practices (e.g., IPM, agroecology)	135	72.19
Information on access to farm inputs (e.g., seeds, fertilizers)	130	69.52
Market information (e.g., prices, quality requirements, demand trends)	117	62.57
Weather forecasts and climate updates	104	55.61
Government subsidies, agricultural policies, or program updates	85	45.45
Training opportunities	77	41.18
Financial advice (e.g., credit access, savings, and insurance)	74	39.57
Post-harvest handling and storage	73	39.04
Updates on farmer-producer organizations/ cooperatives	50	26.74
Value addition or processing techniques	50	26.74
Digital marketing platforms or e-commerce tools	40	21.39
Other information	6	3.21

The study aimed to establish the type of information sought by smallholder farmers from digital extension services. According to the results, out of the 187 (53.13%) who used the digital extension services to seek agricultural information, the majority of the farmers (79.68%) sought crop-specific advice, such as pest and disease control and planting calendars. The plausible reason was that farming emerged as the principal source of livelihood; hence, crop-specific advice directly addresses challenges they

encountered in farming, which determines yields and income. Further analysis indicates that 72.19% of the farmers sought information on improved technologies and practices such as agroecology and integrated pest management, and 39.57% sought financial advice such as credit access, savings, and insurance. Respondents who sought weather forecasts and climate change updates constituted 55.61%, while 62.57% of the farmers sought market information such as prices, quality requirements, and demand trends.

Further analysis indicates that 69.52% of the farmers sought information on access to inputs such as seeds and fertilizers, 26.74% sought value addition or processing information, 39.04 sought post-harvest handling and storage information, and 45.45% sought information on government subsidies, agricultural policies, or program updates. Furthermore, 41.18% of the farmers sought information on training opportunities, 21.39% of the respondents sought information on digital marketing platforms or e-commerce tools, and 26.74% sought updates on farm-producer organizations or cooperatives. Only 3.21% of the respondents sought other agricultural information, like livestock production and management, poultry management, and the perfect breed of pigs.

4.14 Organizations that have supported or promoted Digital Agricultural Tools

Table 4.14 indicates the results of organizations that had supported or promoted digital agricultural tools among the smallholder farmers in the study area.

Table 4.10: Organizations that Promoted Digital Agricultural Tools Among Smallholder Farmers

Organization type	Frequency	Percent (%)
Government agencies (e.g., county extension, MoA, e-voucher programs).	181	51.42
Non-Governmental Organizations (NGOs).	112	31.82
Mobile service providers / Telecom companies	107	30.40
Farmer cooperatives or producer organizations.	104	29.55
Research institutions/ Universities	86	24.43
Private extension services/ consultants	78	22.16
Financial institutions (e.g., banks, MFIs, SACCOs)	66	18.75
Private AgriTech Companies (e.g., market platforms).	49	13.92
Other organizations	2	0.57

According to the results, government agencies such as the county extension, the Ministry of Agriculture, and e-voucher programs have supported the majority of respondents (51.42%), followed by non-governmental organizations (31.82%). Moreover, private and AgriTech companies supported 13.92% of the farmers, while 29.55% of the respondents received support from farmer cooperatives or producer organizations. Another critical organization, such as private extension services or consultants, supported 22.16% of the farmers. Research institutions and universities supported 24.43% of the respondents; financial institutions like banks, SACCOs, and a microfinance institution supported 18.75%, and mobile service providers like telecommunication companies supported 30.40%. Other support came from other farmers, accounting for 0.57%. According to Abdulai et al. (2023), non-governmental organizations, in collaboration with providers of digital services, play a crucial role in agricultural digitization by integrating digital extension services into their projects as pro-poor initiatives. This provides farmers with experiences, making easy access to knowledge and information on agriculture.

4.15 Extent of DES Information on Farm Decision Making

Table 4.12 shows the extent to which information obtained from digital extension services influenced their decision-making in farming. According to the results, the majority of the respondents (40.82%) reported a moderate influence of the digital extension services (DES). Respondents who were very much influenced and extremely influenced by DES constituted 39.29% and 12.76%, respectively. Further analysis indicated that DES somewhat influenced 6.02% of the respondents. A minority of the respondents (1.02%) were not influenced at all by the digital agricultural extension services. This implies that digital extension services moderately influenced smallholder farmers' decision-making in the use of digital tools across various aspects of crop and livestock husbandry. According to Singh et al. (2023), as reported in a study on digital technologies in agricultural extension, farmers' access to relevant information and real-time data enhances risk management, improves productivity, and enables informed decision-making.

Key: 1=Not at all 2=Somewhat 3=Moderately 4=Very much 5=Extremely much

Table 4.11: Extent of DES Information on Farm Decision Making

Influence level	Frequency	Percentage
Not at all	2	1.02
Somewhat	12	6.02
Moderately	80	40.82
Very much	77	39.29
Extremely much	25	12.76

4.16 Farmers' Perception of Digital Agricultural Extension Service

Response scale:1=Strongly agree (SA), 2=Disagree (D), 3=Neutral (N), 4= Agree (A), 5= Strongly agree

Table 4.12: Farmers' perception of Digital Agricultural Extension Service (n=262)

Statement	Mean scale (1-5)	Strongly disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly agree (%)
DES can reduce overreliance on the traditional extension system.	3.97	_	3.44	19.8	52.67	24.05
DES provides personalized agricultural information.	3. 94	0.38	16.11	17.56	50.38	25.57
DES provides timely agricultural information.	4.11	_	4.20	15.65	45.42	34.73
DES has improved my farm income.	3.85	14.58	5.34	17.56	45.80	26.72
DES is reliable	3.99	2.29	6.87	14.50	42.37	33.97
DES is more cost-effective than conventional extension services.	3.87	1.53	8.40	16.79	48.47	24.81

The findings reveal that the smallholder farmers generally had a positive perception towards digital agricultural extension services, as all mean scores exceeded 3.8. Timely agricultural information reported mean score (4.11), indicating that farmers highly value the speed of digital information delivery. Reliability also scored highly (3.99), suggesting confidence in DES. Respondents further agreed that DES can reduce overreliance on traditional extension services (3.97) and provide personalized information (3.94). Cost-effectiveness (3.87) and improved farm income (3.85) received comparatively lower scores. Overall, the findings suggest that DES can complement conventional extension services, improve information access, and

potentially contribute to better agricultural decision-making and productivity. This finding buttresses the finding by Oke et al. (2020), who reported that radio, as a digital tool, improved the farmers' income level (97.5%).

4.17 Challenges in Access and Utilization of Digital Extension Services

Table 4.14 shows the results of challenges encountered by smallholder farmers in Murang'a County in accessing and utilizing digital agricultural extension services.

Table 4.13: Challenges in Access and Utilization of Digital Extension Services (n=352)

Challenge	Frequency (N)	Percentage
High internet cost	296	84.33
Limited digital literacy	122	34.76
Insufficient knowledge of existing services	115	32.76
Poor mobile connectivity	115	32.76
Limited access to a smartphone	114	32.48
Skepticism in digital tools	62	17.66
Lack of timely updates	58	16.52
Lack of electric power	57	16.24
Limited trust in digital information	46	13.11
Language barrier	30	8.55
Privacy concerns	18	5.13

The study highlighted several significant bottlenecks in accessing and utilizing digital extension services. According to the results, the majority of respondents (84.33%) experienced challenges of high internet costs, which may limit the uptake of these digital extension services. Similar findings were also reported by Kansiime et al. (2021), who found that high internet costs and low digital literacy were the major challenges in accessing digital extension services. Choruma et al. (2024) pointed out that high data costs can be mitigated by making extension services more affordable and cost-effective. About 17.66% were sceptical of digital tools and platforms, and 32.48% had limited access to smartphones. Further analysis indicated that 34.76%

reported limited digital literacy. This may be due to a lack of basic operational skills to efficiently leverage the digital platforms. According to Choruma et al. (2024), limited digital literacy skills hinder access to digital services. In addition, 16.52% of the respondents lacked timely agricultural updates on digital extension services. Furthermore, there were poor mobile connectivity challenges (32.76%), compounded by an epileptic power supply (16.24%). Language barriers hinder smallholder farmers' full appreciation of the DES, thereby limiting the benefits they can derive from digital platforms. 5.13% of the smallholder farmers reported issues of privacy concerns. Farmers express concern about data handling after the collection exercise concludes, which may prevent them from fully engaging with these digital tools and platforms. 32.76% of the respondents reported insufficient knowledge of the existing digital platforms. Respondents who had limited trust in digital information accounted for 13.11%. Bhattarai et al. (2026) found that farmers lose trust in digital tools due to ambiguous data handling practices.

This finding is consistent with that of Ifeanyi-Obi and Corbon (2023), who reported on challenges of using electronic tools in Imo state in Nigeria, including the high cost of purchasing the device (97.6%) and the high maintenance cost (75.3%), the need for novel skills (90.0%), and poor internet connectivity (98.4%) were major constraints hindering utilization of digital tools. Additionally, a study conducted by Vutukuru and Njagi (2023) revealed that low utilization of digital extension tools is attributed to distrust, high technology and transaction costs, inadequate training and capacity policy sessions, and lack of information access. Addressing these constraints requires a wide array of specific policy interventions. First, a reduction in the cost of digital tools to enable quick internet access. This will reduce the financial stress imposed by the use of these digital tools. To effectively tackle this, corrective measures such as tax relief, provision of subsidies, and grants to farmers need to be put in place. This will, in turn, aid in acquiring the resources. Secondly, the establishment of Digihubs for capacity building, where farmers can be trained on the use of digital agricultural extension tools and platforms.

4.18 Enablers of Digital Agricultural Extension Service

Enablers of DES highlight the critical role of affordability, infrastructure, training, and awareness in strengthening digital adoption. The findings that affordable data bundles

are the most critical enabler (27.0%) resonate strongly with broader studies on digital agriculture in sub-Saharan Africa. Research by Baumüller (2018) shows that high internet costs remain a major barrier to rural farmers' adoption of digital tools, often limiting them to low-data platforms such as SMS and WhatsApp. Similarly, the FAO (2021) emphasizes that reducing data costs and expanding rural broadband are essential for scaling digital extension services. Furthermore, 9.9% of respondents indicated a need for access to smartphones and other digital devices, and 24.1% indicated a need for training on the digital extension service. Additionally, 11.4% of respondents demonstrated a need for sensitization or awareness regarding the digital extension services, for example, alerts or notifications on the latest updates. 17.0% of respondents reported that improved connectivity and infrastructure could make them use the digital extension services more frequently, which encompassed network and electrical connectivity. 3.7% of respondents showed a need for financial assistance. Only 6.8% of respondents reported a need for notification of the latest updates.

Table 4.14: Enablers of DES

Enabler	Frequency	Percent
Affordable/cheap data bundles	95	27.0
Training on DES	85	24.1
Improved connectivity and infrastructure	60	17.0
Awareness creation	40	11.4
Availability and access to smartphones and other digital devices	35	9.9
Notification of the latest updates	24	6.8
Financial assistance/support	13	3.7

4.19 Factors Influencing the Adoption of Digital Extension Service

The analysis begins by examining farmers' awareness and use of digital extension services (DES) and the factors influencing these outcomes. Since awareness and use are often determined by similar factors, a bivariate probit model is employed to estimate these decisions jointly.

Second, farmers frequently use multiple DES platforms simultaneously, making adoption decisions interdependent. This justifies the use of a multivariate probit model rather than separate univariate probit or logit models for each platform. Finally, to assess the intensity of DES use, that is, the number of digital platforms adopted by each farmer, the study employs a negative binomial regression (nbreg). This approach accounts for overdispersion in the count data**,** providing robust estimates of factors driving deeper engagement with digital extension services.

4.19.1 Bivariate Probit Estimates on Determinants of Awareness and Use of DES

LR test of rho = 0: χ^2 (1) = 7.889, p = 0.005 indicates strong evidence of correlation between unobserved factors influencing awareness and use of DES; thus, joint estimation using a bivariate probit model is justified.

Table 4.15: Bivariate Probit Estimates on Factors Influencing Awareness and DES Use

	Awareness model			DES use		
Variable	**Coef.**	**Std. Err.**	**P>z**	**Coef.**	**Std. Err.**	**P>z**
Awareness of DES				3.033***	0.187	0.000
Age	-0.008	0.008	0.331	0.013	0.008	0.118
Gender (male)	-0.030	0.171	0.860	-0.020	0.164	0.902
Marital (married)	0.426**	0.177	0.016	0.073	0.180	0.685
Household size	0.028	0.057	0.623	-0.094	0.059	0.114
Soil fertility	0.459**	0.182	0.012	0.000	0.194	0.999
Cooperative membership	0.231	0.205	0.260	0.622***	0.194	0.001
Commercial farming	0.159	0.190	0.402	-0.003	0.185	0.986
Land size	0.172**	0.085	0.043	0.076	0.074	0.307
Credit access	-0.533	0.217	0.014	0.585**	0.265	0.027
Connectivity	0.462**	0.175	0.008	0.105	0.166	0.529
Smart phone	-0.019	0.186	0.918	0.217	0.180	0.227
Education (secondary and above)	0.533**	0.180	0.003	0.611***	0.190	0.001
Agricultural extension	-0.028	0.187	0.879	0.091	0.184	0.620
Training	0.257	0.190	0.176	-0.053	0.184	0.772
Market search	0.469*	0.196	0.017	-0.285*	0.177	0.107
Off-farm employment	-0.172	0.167	0.302	0.357**	0.165	0.031
Non-food expenditure	-0.001	0.024	0.981	0.037	0.024	0.118
Constant	-0.730*	0.455	0.109	-3.556***	0.503	0.000
N	348					
Prob > chi2	0.0000					
LR test of rho=0	7.889***					

* p < 0.1, ** p < 0.05, *** p < 0.01

Awareness of digital extension services had a positive and highly significant influence on farmers' use of digital extension services (Coeff = 3.033, $p < 0.01$). This implies that farmers who know about the services and advantages of digital extension services have a much greater probability of using them, compared with those with lower awareness. The first step in the technology adoption process is awareness, which means that a farmer cannot adopt a technology that he or she is not aware of. The finding aligns with that of Sen et al. (2025), who found that knowledge and motivation were among the most powerful factors influencing interactive digital extension adoption by smallholder farmers in developing countries. In the case of Ghana, Ayisi-Nyarko et al. (2024) found that level of awareness, as a result of extension campaigns and ICT initiatives, significantly affected farmers' willingness to utilize e-extension services.

The age factor was negatively associated with awareness ($\beta = -0.008$, $p = 0.331$) but positively associated with use of digital extension services ($\beta = 0.013$, $p = 0.118$), although not statistically significant. This means that there was no significant difference between age groups in awareness of or use of digital extension services. The results indicate that access to digital agricultural information is similar for both young and old farmers in the study area. This is similar to Amoussohoui et al. (2023), who reported that age had a significant effect on the preferences of some digital extension business models, but not always on the choice of the farmers to adopt digital extension once other socioeconomic factors were taken into account. Likewise, Sen et al. (2024) found that the age of farmers had different impacts in different countries, indicating that institutional support and perceived usefulness played a crucial role in the adoption rather than the age of farmers.

Gender had no significant influence on awareness ($\beta = -0.030$, $p = 0.860$) or on the use of digital extension services ($\beta = -0.020$, $p = 0.902$). The results suggest that male and female farmers experienced similar levels of access to information on digital extension services, and also to access digital platforms. This could suggest that gender differences in access to information in agriculture have diminished due to digital technologies. The results are contrary to those of Gao et al. (2024), who revealed that women farmers had a higher level of acceptance of digital agricultural extension

services when institutional support and policy incentives were provided. Likewise, Mutisya and Kumar (2025) found gender to be a significant influence on technology uptake among Kenyan youth farmers due to variations in technology ownership, financial resources, and digital literacy. In the present study, this minimal gender relationship can therefore be considered as a sign of reduction in gender gaps as there is better access to mobile technologies and inclusive extension programmes in the study area.

Marital status (married) had a positive and significant effect on awareness ($\beta = 0.426$, $p = 0.016$), meaning married farmers were more aware of digital extension services than unmarried farmers. Farmers who were married tended to have wider social networks through farmers' groups, community groups, and family members, and therefore were more exposed to agricultural information. But marital status was not significantly related to the use of digital extension services ($\beta = 0.073$, $p = 0.685$), indicating that awareness of digital extension services does not necessarily lead to adoption. The discovery reinforces recent research, highlighting social capital's role in spreading agricultural innovations. Rahman et al. (2024) revealed that community organizations, farmer groups, and family networks were found to be significant in enhancing farmers' awareness of agricultural innovations through farmer exchange of information and peer learning. This implies that social mobility that is linked to marriage may boost information flow without impacting uptake.

Perceived soil fertility positively and significantly influenced awareness of digital extension services ($\beta = 0.459$, $p = 0.012$) but had no significant effect on their use ($\beta = 0.000$, $p = 0.999$). Farmers with productive land are more likely to actively look for agricultural information to help sustain productivity and maximize returns. However, soil fertility is not the deciding factor when it comes to eventual adoption of digital advisory practices by farmers. Recent research in digital agriculture suggests that farmers' production environment is a strong driver of information-seeking behaviour, whereas the adoption process is more strongly linked to the perceived usefulness of the information, the institutional support environment, and digital accessibility than to biophysical farm characteristics. Similarly, in their study, Gao et al. (2024) found that the cognitive perception and the policy support of the farmers have a greater influence in the adoption of digital extension than farm production characteristics.

Cooperative membership was not a significant contributor to awareness (β = 0.231, p = 0.260), but positively and highly significantly contributed to the use of digital extension services (β = 0.622, p = 0.001). This suggests that although farmers may not always be connected to digital extension services through the cooperative, their use of these services will be more likely once they are aware of them. Cooperatives enable peer learning, simultaneous training, information exchange, and connection with extension workers and advisors, which helps to promote the use of digital technology. The finding agrees with Warucu and Lufuke (2024), who found that cooperative membership significantly increased the adoption of modern agricultural technologies among bee farmers in Kenya through improved access to training, markets, and information. Likewise, Gao et al. (2024) reported that membership in agricultural cooperatives significantly enhanced farmers' enthusiasm for adopting digital agricultural extension services by improving knowledge sharing and institutional support. These findings underscore the importance of strengthening farmer organizations as channels for promoting digital extension services among smallholder farmers.

The findings show that participation in commercial farming had a positive, although not statistically significant (β = 0.159, p = 0.402), effect on awareness of digital extension services and no significant effect on the use of digital extension services (β = -0.003, p = 0.986). It indicates that a farmer who was involved in commercial farming was not more likely to be aware of nor use digital extension services than a subsistence-oriented farmer. The discovery suggests that digital extension is not guaranteed by commercialization and is not necessarily adopted in all farming categories when digital infrastructure, education, and institutional support are comparable between the farming categories.

Size of land had a positive and statistically significant influence on the awareness of digital extension services (β = 0.172, p = 0.043) but a positive and insignificant influence on the use of digital extension services (β = 0.076, p = 0.307). This means that farmers holding larger landholdings were more likely to be seeking information and to be aware of digital extension services, as they have more of a stake in improving the productivity of their farms. Yet, the actual use of digital extension platforms was not significantly greater with larger farm ownership. One of the findings aligns with

that of Amoussohoui et al. (2024) which suggested that preference for digital extension business models is significantly influenced by farm size as larger farms need efficient management of information and decision support. Likewise, a study of Kenyan dairy farmers revealed that farm size had a positive impact on the adoption of agricultural mobile applications, but this did not always drive the uptake of digital technologies.

Access to credit was negatively and statistically significantly associated with awareness ($\beta = -0.533$; $p = 0.014$), while it was positively and statistically significantly associated with the use of digital extension services ($\beta = 0.585$; $p = 0.027$). The reverse relationship with awareness could suggest that farmers who use formal credit contracts are not aware of agricultural information from awareness campaigns, but rather from financial institutions. Once farmers learn about digital extension services, however, access to credit grows to become a powerful tool to use digital services, as farmers can buy a smartphone, a bundle of internet, farm inputs, and other complementary technologies. Recent research confirms the positive effect of credit on the adoption of technology. A research study by Ingutia and Sumelius (2024) in Kenya revealed that greater access to credit had a significant positive impact on farmers' investment in agricultural technologies and productivity, as it alleviated financial barriers.

Awareness of digital extension services was positively and significantly influenced by connectivity ($\beta = 0.462$, $p = 0.008$), whereas use was positively, though not significantly, influenced ($\beta = 0.105$, $p = 0.529$). This means that farmers' exposure to digital agriculture information and awareness campaigns greatly benefits from reliable internet and mobile network coverage. However, even with connectivity, the use of digital extension services is not assured, as digital literacy, cost of Internet services, and perceived usefulness also affect adoption rates. This result is in line with Simbu and Tambua (2024), who found that the availability of broadband service was the best predictor of digital extension adoption among farming households in Papua New Guinea. Agriculture households connected with high-quality 4G signals were almost four times as likely to use mobile advisory services as agriculture households connected with low-quality 4G signals.

Awareness ($\beta = -0.019$, $p = 0.918$) and digital extension service use ($\beta = 0.217$, $p = 0.227$) were not significantly affected by smartphone ownership. Results indicate that awareness and use of digital extension services do not necessarily follow from the

ownership of a smartphone. Agricultural use of the smartphone might not be a priority for farmers, but rather for communicating, entertaining, or conducting financial business. This is in contrast to recent research that has identified smartphones as an important enabler of access to digital agricultural information (Abdullahi et al., 2025). A study in Ghana by Eduafo et al. (2024), for instance, revealed that the adoption of smartphones positively contributed to farmers' access to agricultural information via social media and other digital communication platforms. Similarly, in Tanzania, Ndimbo et al. (2024) showed that mobile phones had a significant impact on improving farmers' access to agricultural extension information by improving communication with extension officers and farmer networks.

The awareness and use of digital extension services were positively and significantly influenced by education (secondary level and above) ($\beta = 0.533$, $p = 0.003$ and $\beta = 0.611$, $p = 0.01$, respectively). This suggests that higher education levels among farmers were associated with being informed about and using digital extension services. Education improves the competence of farmers to know and understand digital platforms, assess agricultural information, and make informed decisions on production. The results corroborate Amoussohoui et al. (2024), who noted that education was one of the factors that significantly influenced farmers' preference and uptake of the digital extension service business models in Nigeria, as it was believed that educated farmers could better grasp the advantages of digital technologies. Likewise, Sen et al. (2024) identified that the enhancements of farmers' education, digital literacy and training resulted in a significant improvement in the uptake of digital extension services in Cambodia, Vietnam and the Philippines. The results also align with evidence from Kenyan smallholder dairy farmers, where additional years of schooling significantly increased the probability of adopting mobile phone applications for agricultural information.

The findings suggest that awareness of digital extension services had a negative, though statistically not significant, effect on agricultural extension contact ($\beta = -0.028$, $p = 0.879$), while use of digital extension services had a positive association but not statistically significant ($\beta = 0.091$, $p = 0.620$). The results indicate that the use of traditional extension services with farmers was not significant enough to affect their awareness and utilization of digital extension services in the study area. This could

suggest that there is not an adequate digitalization of public extension services in advisory services or that it is not being used often enough to encourage farmers to use digital technology. The results are different from those of Marwa et al. (2020), who reported that the use of ICT-based extension services was found to have a significant positive effect on farmers' welfare, income, and milk production in Kenya using the iCow extension service platform.

Awareness ($\beta = 0.257$, $p = 0.176$) and use of digital extension services ($\beta = -0.053$, $p = 0.772$) were positively affected but not significantly by agricultural training. This means that there was no significant effect on awareness or use of digital extension services as a result of agricultural training programmes. This may be because the training programmes offered to farmers were primarily on production practices and not on digital technologies and extension through ICT. Recent research by Sen et al. (2024) highlights the importance of training and its ability to enhance technology use if it focuses on digital skills. For instance, training programs which address digital skills have been demonstrated to boost individuals' capacity to embrace new technology and boost productivity. The findings suggest the need to incorporate modules on the use of smartphone applications, digital advisory platforms, online marketing and digital financial services into agricultural training programmes to boost the use of digital extension.

The awareness of digital extension services was influenced positively and significantly by market search ($\beta = 0.469$, $p = 0.017$). Many digital applications are combined with market information and agronomic extension services, which explains why farmers actively searching for market information were more likely to be aware of digital extension services. The effect of market search on the use of digital extension services was negative and insignificant ($\beta = -0.285$, $p = 0.107$). This indicates that market-oriented farmers have access to digital information, but that doesn't mean that market information is directly translated into regular use of digital extension services. The discovery is partially supported by recent research in Kenya, which indicates that digital marketing platforms provide access to agricultural information to farmers and promote commercialization, particularly for farmers who have more access to credit and farmer organizations (Maina et al., 2024). The findings indicate that digital

extension platforms should combine agronomic information and a full set of marketing services to promote continued use.

Awareness was negatively affected by off-farm employment, but the effect did not reach statistical significance (β = -0.172, p = 0.302); off-farm employment had a positive and statistically significant impact on digital extension service use (β = 0.357, p = 0.031). It also suggests that the farmers who did not depend on agriculture were not necessarily more aware of digital extension services, but if they were aware, they were more likely to use them than those who only depended on agriculture. This could be because working off-farm can boost income for farmers, and they can use that extra money to buy a smartphone, internet bundle, and other digital resources needed to access digital advisory services. The extra funds also help remove financial constraints of adopting digital technologies. The results are consistent with recent research that has found a positive effect of non-farm employment on household income and welfare, which in turn has a positive effect on households' ability to invest in productive technologies.

Non-food expenditure was not statistically significantly influenced by awareness (β = -0.001, p = 0.981) or use of digital extension services (β = 0.037, p = 0.118). This implies that non-food spending in the domestic consumption level didn't play a significant role in farmers' awareness or use of digital rural extension services. Household spending is not an appropriate measure of the resources allocated to purchasing digital technologies, like the internet, mobile data, or smartphones.

4.19.2 Determinants of Use of Multiple Digital Extension Service (DES) Platforms - Multivariate Probit Estimates

Model diagnostic: The likelihood ratio test for the null hypothesis that the error terms across the adoption equations are uncorrelated ($\rho_1 = \rho_2 = \ldots = \rho_n = 0$) is highly significant (χ^2 (28) = 219.74, $p < 0.001$), indicating that farmers' decisions to use different digital extension service platforms are interdependent and justifying the use of a multivariate probit model.

Table 4.16: Determinants of Use of Multiple Digital Extension Service Platforms: Multivariate Probit Estimates

	Mobile phone services	Mobile apps	Social media platforms	Digital TV or radio	Internet Searches	AI-supported platforms	Online portals/ websites
Awareness of DES	0.141	0.962***	0.692***	-0.506**	0.867***	0.283	0.461
	(0.177)	(0.342)	(0.185)	(0.204)	(0.204)	(0.217)	(0.345)
Age	0.003	-0.013	-0.026**	-0.013	-0.012	-0.039***	-0.007
	(0.010)	(0.015)	(0.010)	(0.009)	(0.009)	(0.013)	(0.012)
Gender (male)	-0.104	0.335	0.072	0.049	-0.104	-0.167	0.031
	(0.171)	(0.261)	(0.178)	(0.186)	(0.183)	(0.206)	(0.207)
Marital (married)	0.114	0.286	-0.404**	-0.077	-0.465**	-0.097	0.307
	(0.192)	(0.276)	(0.199)	(0.196)	(0.198)	(0.246)	(0.271)
Household size	-0.003	0.128*	0.133**	-0.006	-0.011	-0.005	-0.083
	(0.060)	(0.071)	(0.066)	(0.052)	(0.056)	(0.074)	(0.072)
Soil fertility	0.301	-0.016	-0.004	-0.205	0.226	0.865**	1.065**
	(0.190)	(0.325)	(0.198)	(0.226)	(0.206)	(0.394)	(0.419)
Cooperative membership	-0.185	0.054	0.124	0.298	0.392**	0.479**	0.165
	(0.204)	(0.225)	(0.203)	(0.202)	(0.196)	(0.220)	(0.241)
Commerci	-0.055	0.172	-0.094	-0.018	-0.038	0.453*	-

al production							0.917***
	(0.182)	(0.253)	(0.181)	(0.198)	(0.205)	(0.268)	(0.252)
Land size	0.308***	0.140**	0.247***	0.112	0.087	0.374***	0.020
	(0.097)	(0.063)	(0.089)	(0.080)	(0.065)	(0.091)	(0.064)
Credit access	0.567**	-0.147	0.222	0.304	0.467**	0.203	0.260
	(0.241)	(0.321)	(0.225)	(0.209)	(0.224)	(0.264)	(0.296)
Connectivity	-0.025	0.669***	0.182	-0.301*	0.278	-0.294	0.040
	(0.173)	(0.208)	(0.167)	(0.178)	(0.182)	(0.223)	(0.221)
Smartphone	-0.005	-0.487*	-0.010	-0.172	-0.562***	-0.263	-0.297
	(0.182)	(0.283)	(0.189)	(0.194)	(0.205)	(0.242)	(0.247)
Education (secondary and above)	0.265	0.855**	0.413**	-0.012	1.055***	1.076***	0.232
	(0.192)	(0.364)	(0.184)	(0.194)	(0.205)	(0.331)	(0.300)
Agricultural extension	0.155	0.383	-0.056	0.349	0.143	0.190	1.057***
	(0.205)	(0.277)	(0.210)	(0.229)	(0.200)	(0.217)	(0.266)
Training	0.486**	0.212	-0.100	-0.317	-0.079	0.204	-0.295
	(0.190)	(0.247)	(0.197)	(0.202)	(0.188)	(0.225)	(0.267)
Market search	0.562***	0.267	0.877***	0.555***	0.933***	0.610***	0.555**
	(0.192)	(0.249)	(0.187)	(0.200)	(0.197)	(0.234)	(0.252)
Off-farm employment	0.018	-0.298	-0.259	-0.300*	-0.466***	0.153	0.240
	(0.168)	(0.236)	(0.166)	(0.177)	(0.175)	(0.189)	(0.226)

Nonfood expenditure	0.038	-0.009	-0.029	-0.002	-0.021	-0.059*	0.045
	(0.025)	(0.035)	(0.027)	(0.026)	(0.028)	(0.034)	(0.044)
Constant	-1.126**	-4.038***	-0.332	1.689***	-1.053**	-2.425***	-2.965***
	(0.501)	(0.771)	(0.423)	(0.453)	(0.462)	(0.599)	(0.661)
n	348	348	348	348	348	348	348
χ^2 (21)	137.46***						

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The multivariate probit estimates reveal both common and platform-specific determinants of digital extension service adoption among farmers. For example, awareness of digital extension services significantly increased the likelihood of using mobile applications (Coeff = 0.962, p < 0.01), social media platforms (Coef = 0.692, p < 0.01), and internet searches (Coef = 0.867, p < 0.01), but decreased the likelihood of using digital TV/radio (Coef = −0.506, p < 0.05). This indicates that farmers are more likely to be aware and move towards more interactive digital channels rather than conventional extension channels. The findings concur with Mutisya and Kumar (2025), who reported that awareness is crucial for the adoption of digital extension by the smallholder farmers in Kenya.

Marital status negatively affected the use of social media (Coef = −0.404, p < 0.05) and internet searches (Coef = −0.465, p < 0.05). For married farmers, there may be increased household demands which limit time spent on online information platforms. The same finding was shared by Mutisya and Kumar (2025), who noted that participation in digital agricultural platforms was affected by marital responsibilities.

Household size positively influenced the use of mobile applications (Coef = 0.128, p < 0.10) and social media (Coef = 0.133, p < 0.05). Households with larger size are

more likely to have younger and educated members that help to access digital technologies. This result aligns with Kithome (2022), who reported that larger households had higher acceptance of agridigital technologies as they have access to more labour and knowledge sharing. The use of Aided platforms ($\beta = 0.865$, $p < 0.05$, online portals ($\beta = 1.065$, $p < 0.05$) was positively influenced by perceived soil fertility. Landowners on productive land are more likely to look for new technologies that maximize farm productivity. This finding supports Wang and Dong (2023), who reported that farmers' expectations of improved productivity increase the adoption of advanced digital agricultural technologies.

The use of AI-supported platforms ($\beta = 0.479$, $p < 0.05$) and internet searches ($\beta = 0.392$, $p < 0.05$) was likewise significantly higher for those who were cooperative members. Farmer groups enable access to information, peer learning, and exposure to digital innovations. The same results were obtained by De Jesus Mendes et al. (2023), who concluded that farmer groups had a significant role in facilitating the adoption of digital technology using social learning. According to Miine et al. (2023), group membership has a positive effect on access to digital agricultural solutions.

Commercial production had a positive impact on the use of AI-supported platforms ($\beta = 0.453$, $p < 0.10$), whereas a negative effect on the use of online portals ($\beta = -0.917$, $p < 0.01$). Commercial farmers seem to favor technologies for specialized decision-support as opposed to Internet-based general information. This is in line with Aker (2011), who found that those farmers who are engaged in commercial farming activities tend to accept technologies that have direct impacts on production efficiency and profitability.

Land size positively influenced the use of mobile phone services ($\beta = 0.308$, $p < 0.01$), mobile applications ($\beta = 0.140$, $p < 0.05$), social media ($\beta = 0.247$, $p < 0.01$), and AI-supported platforms ($\beta = 0.374$, $p < 0.01$). Farmers' information needs and incentives to invest in digital advisory services are greater for larger farms. This result is consistent with Miine et al. (2023), who reported a positive relationship between the size of farms and the adoption of digital agricultural technologies in Ghana.

Access to credit had a significant positive effect on the use of mobile phone services ($\beta = 0.567$, $p < 0.05$) and internet searches ($\beta = 0.467$, $p < 0.05$). Having access to

financial resources helps farmers buy smartphones and internet plans as well as use digital extension services. This is confirmed by Abate et al. (2021), who found that credit access has a very positive impact on investment in agricultural technology.

The mobile apps were positively influenced by Internet connectivity ($\beta = 0.669$, $p < 0.01$), while the use of digital TV/radio was negatively impacted ($\beta = -0.301$, $p < 0.10$). Having a reliable internet connection promotes the adoption of interactive mobile technologies and minimizes reliance on traditional media by farmers. This result aligns with the results of Mwaseba et al. (2024), who noted that a better internet connection strongly enhanced the usage of digital agricultural applications by farmers in Tanzania.

Education significantly increased the use of mobile applications ($\beta = 0.855$, $p < 0.05$), social media ($\beta = 0.413$, $p < 0.05$), internet searches ($\beta = 1.055$, $p < 0.01$), AI-supported platforms ($\beta = 1.076$, $p < 0.01$), and online platforms (Coeff=0.232, $p < 0.1$). Farmers' educational level is linked to their ability to access, interpret, and apply digital agricultural information. This is in line with Guay et al. (2025), who reported that education has an overall positive impact on digital literacy and on the uptake of agricultural information technologies. Agricultural extension services contributed greatly to the use of online portals and websites ($\beta = 1.057$, $p < 0.01$). Extension officers have a significant role to play in helping farmers navigate towards trusted online sources of agricultural information. The same was found by Kithome (2022), who noted that farmers' access to digital agricultural technologies was significantly encouraged by extension contact.

Use of mobile phone services was affected by positive training ($\beta = 0.486$, $p < 0.05$). Training develops farmers' knowledge and confidence in how to effectively use mobile-based advisory services. This result is consistent with Miine et al. (2023), who revealed a positive relationship between agricultural training and farmers' uptake of digital technologies. Market search was a positive factor for mobile phone services, social media, digital TV/radio, internet search, AI-supported platforms, and online portals. That means farmers who actively look out for market information are more likely to use (more) than one platform of digital extension. A similar conclusion was reached by Fabregas et al. (2019), who observed that farmers who wanted information on the market were more likely to use digital advising services.

Off-farm activity had a negative impact on the use of digital TV/radio ($\beta = -0.300$, $p < 0.10$) and internet searches ($\beta = -0.466$, $p < 0.01$), indicating that farmers involved in off-farm work spend less time using digital agricultural information. The same finding agrees with the study by Kithome (2022), which found that off-farm employment decreases farmers' involvement in agricultural information seeking. The negative effect of non-food expenditure was relatively small ($\beta = -0.059$, $p < 0.10$) on the use of AI-supported platforms. This could suggest that families with higher spending on non-food items spend less on cutting-edge digital technologies. Ogutu et al. (2014) reported a similar finding, that expenditure patterns of households affect investments in agricultural innovations.

4.19.3 Determinants of Total DES Use (Negative binomial regression)

Table 4.17: Determinants of Total DES Use (Negative binomial regression)

Variable	Coef.	Std. Err.	P>z
Awareness of DES	0.456***	0.071	0.000
Age	-0.010**	0.003	0.002
Gender (male)	0.077	0.056	0.169
Marital (married)	-0.152**	0.062	0.013
Household size	0.049**	0.019	0.011
Soil fertility	-0.052	0.071	0.461
Cooperative membership	0.136**	0.056	0.015
Commercial farming	-0.095	0.066	0.149
Land size	0.042**	0.018	0.021
Credit access	0.170***	0.065	0.009
connectivity	0.057	0.060	0.343
Smart phone	-0.079	0.064	0.214
Education (secondary and above)	0.261***	0.073	0.000
Agricultural extension	0.286***	0.071	0.000
Training	0.008**	0.068	0.909
Off-farm employment	0.011	0.054	0.836
Market search	0.319***	0.059	0.000
Non-food expenditure	-0.012	0.010	0.250

Constant	0.529***	0.171	0.002
n	348		
Prob > chi2	0.0000		
lnalpha	-15.051***		

* p < 0.1, ** p < 0.05, *** p < 0.01

The results revealed that use of digital extension services was positively and significantly influenced by awareness of digital extension services (Coef = 0.456, and p-value < 0.01). This suggests that farmers who have information about the digital extension services available are more likely to use more digital platforms. Raising awareness helps farmers to know more about the technologies available and the perceived advantages, so that they are more likely to use them. This result aligns with the study carried out by Mutisya and Kumar (2025), which concluded that awareness is the key enabler of digital agriculture technology adoption by the smallholder farmers in Kenya.

The total use of DES was also found to be significantly negatively related to age (Coef = -0.010, p < 0.05), meaning that older farmers were less likely to use more than one digital extension platform than younger farmers. This could be due to a lack of digital literacy, resistance to technological change, and less familiarity with new digital tools among older farmers. The results of this study align with those of Miine et al. (2023), who reported that younger farmers were more likely to use a wider variety of digital agricultural technologies.

Marital status was found to be significantly negatively related to the level of DES adoption (Coef = -0.152, p < 0.05), indicating that married farmers are less likely to use digital platforms than unmarried farmers. This could be due to conflicting household tasks and financial constraints that prevent the investment of more than one type of digital technology. This result is consistent with Mutisya and Kumar (2025), who noted that family responsibilities can be a hindrance to farmers' involvement in digital extension services.

Household size had a positive and significant effect on the intensity of the use of DES (p < 0.05, Coef = 0.049). Families are likely to have more tech-savvy, younger, and educated members who can facilitate access to different digital platforms and promote

technology adoption in larger households. The finding is in line with Kithome (2022), who found that larger households are more likely to adopt agricultural technologies because they have more labour and can share information.

Cooperative membership had a significant impact on the number of digital extension platforms adopted (Coef = 0.136, $p< 0.05$). Farmer organization membership facilitates access to agricultural information, peer learning, and technology dissemination, which motivates farmers to make effective use of more than one digital extension service. The results are in line with De Jesus Mendes et al. (2023), who reported that social networks are significant promoters of the adoption of agricultural technology.

The size of the land had a positive and significant impact on the total use of DES (Coef = 0.042, $p<0.05$), which means that the larger the farmland, the greater the probability of using multiple digital extension platforms. Digital advisory services are more likely to be needed by larger farms, where there is a need for more information for effective management. This conclusion is supported by Martey et al. (2020), who noted that the size of the farms had a positive relationship with the adoption intensity of agricultural technologies.

An increase in the intensity of DES was found to be positively associated with credit access (Coef = 0.170, $p<0.01$), suggesting that farmers who have access to credit can invest in resources such as smartphones, internet services, and other resources that are needed for using multiple digital platforms. Regassa et al. (2023) reported the same; credit access is a strong determinant of technology adoption by smallholder farmers.

Education (secondary level and above) had a strong positive influence on the total use of DES (Coef = 0.261, $p < 0.01$). Educated farmers have a higher level of digital literacy and can better comprehend, analyze and apply various sources of digital information. This finding is consistent with that of Guay et al. (2025), who found that farmers' education has a significant impact on the adoption of digital technologies in agriculture.

Agricultural extension use was also a significant factor in the intensity of DES use (Coeff = 0.286, $p < 0.01$). Extension officers are responsible for introducing digital

technologies to farmers and assisting with the technical aspects of these, and for supporting the use of several digital advisory platforms. This is in line with the finding of Kithome (2022) that extension contact has a positive effect on the adoption intensity of digital agricultural technologies.

The total DES use was also found to be positively associated with market information seeking, with a highly significant effect (Coeff = 0.319, $p < 0.01$). The more farmers actively use market information, the more likely they are to use a variety of digital platforms to gain access to price information, buyers, market opportunities, and production information. This result aligns with the result of Fabregas et al. (2019), who indicated that farmers whose agricultural practice is market-oriented are more likely to use digital agricultural advisory services.

Other factors, such as gender, soil fertility, commercial farming, internet connectivity, smartphone ownership, training, off-farm work, or non-food expenditure, were not significant factors affecting the intensity of DES use. They are not statistically significant, indicating that they are not the sole determinants of how many digital platforms are adopted once farmers know of digital extension services.

4.20 Chapter Summary

Chapter Four presented the empirical findings and their interpretation in relation to the study objectives. The results demonstrated that Murang'a County has experienced considerable growth in digital agricultural extension, with farmers accessing agricultural information through a diverse range of digital and hybrid platforms. The findings showed that awareness of digital extension services was relatively high, but access and utilization were comparatively constrained. Farmers' utilization was affected by internet costs, network availability, digital literacy, smartphone ownership, and socioeconomic circumstances. Different groups of farmers also showed different patterns of digital technology use, with younger and commercially oriented farmers more likely to use advanced digital platforms, while older and resource-constrained farmers relied more heavily on SMS, radio, and voice-based services.

CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of the Findings

The study aimed to examine the determinants of the adoption of digital agricultural extension services by smallholder farmers in Murang'a County. In particular, the purpose of the study was to document the landscape and the emerging trends in digital extension services, assess the awareness level, access, and use, and determine the factors that can affect digital adoption.

5.1.1 Current Landscape and Emerging Trends in Digital Extension Service

The study established that Murang'a County has increasingly embraced digital agricultural extension services as a result of better mobile network coverage, rural electrification, and availability of various digital platforms. Farmers gain extension information from mobile applications, social media, web platforms, SMS, radio, TV, and hybrid extension. But utilization is still limited due to several factors, including high internet rates, unequal network coverage, low digital literacy, low smartphone ownership, and a socio-economic gap. The study also identified that advanced digital technologies are the leading technologies used by the youth and commercial farmers, whereas SMS, radio, and voice call are the most commonly used technologies among older farmers, women, and resource-poor farmers. Emerging innovations such as artificial intelligence, blockchain, youth agripreneurs, and digital farmer registration present significant opportunities to strengthen extension service delivery

5.1.2 Awareness, Access, and Utilization of Digital Extension Service

The researchers discovered that the level of awareness of smallholder farmers about digital extension services was high. The origins of such awareness were, however, more informal, with social and mass media being highest, then peers and family members. Conversely, the institutional channels, which include formal sources like agricultural extension officers, contributed to the dissemination of information to a lesser degree, implying that there is a low involvement of institutional channels in the dissemination of information.

Further disaggregation revealed that awareness was most prominent in the case of universally available platforms like digital TV and radio and mobile phone services

and was considerably lower in the case of more specialized platforms like marketing systems and AI tools. Access to digital extension services was limited due to infrastructural and financial barriers, although the level of awareness was relatively high. Most farmers depended on mobile data bundles to access the internet, with a small percentage using Wi-Fi access and cyber cafe access. Such extensive reliance on mobile data presupposes a pay-as-you-go model that creates recurrent expenses for farmers.

The affordability issue was also highlighted with the realization that the majority of the respondents cited high internet costs as a significant source of hindrance to the use of digital extension services. Regarding utilization, the research found that 53.13% of farmers were actively utilizing digital extension services, which showed the level of adoption was moderate. Among them, the largest segment had been using the services between one and three years, which indicates that adoption is not very old.

The most frequently used platforms were digital television and radio programs, use of mobile phone services, internet search, and use of social media sites. On the contrary, more dedicated platforms like marketing tools and government portals showed much lower usage rates, which means that the formal and advanced systems were not used extensively. The researcher also established that farmers mostly used the digital extension services to obtain crop-specific advice; next came better farming practices, access to inputs, and weather updates. Additionally, digital extension services were identified to moderately affect the decision-making process of the farmers. This shows the empirical applicability of digital extension services in increasing agricultural productivity and farm management.

5.1.3 Factors Influencing Adoption of DES

The econometric models' findings show that awareness of digital extension services is the strongest determinant of adoption and use among smallholder farmers in Murang'a County. The bivariate probit results indicate that awareness and use are jointly determined and significantly influenced by education, land size, internet connectivity, marital status, cooperative membership, credit access, and off-farm employment. The multivariate probit model further shows that awareness and education, farm size, market search, association with the cooperative society, access to credit, internet,

agricultural extension and training are the main factors influencing multiple digital extension platforms, while older age, marital responsibilities, and off-farm activities are associated with decreased odds of adopting more advanced digital technologies. The negative binomial regression show that awareness, education, agricultural extension services, information search for markets, access to credit facilities, membership in cooperatives, household size, and land size are the key determinants of the intensity of digital extension services use among Murang'a smallholder farmers, while the age and marital responsibilities are key factors that make it less likely for smallholder farmers to adopt multiple digital extension platforms. The findings highlight the need to build farmer awareness, conduct education and digitize literacy, strengthen extension services, and enable farmer organizations to boost the intensity of use of digital extension services by farmers.

5.2 Conclusion

5.2.1 Current Landscape and Emerging Trends in Digital Extension Service

Digital agricultural extension has improved access to agricultural information and agricultural advice services in Murang'a County. But it is hindered by infrastructure gaps, cost, low digital literacy, and unequal access to digital technologies. So, digital extension should support traditional extension methods and not supplant them to reach all types of farmers with extension.

5.2.2 Awareness, Access, and Utilization of Digital Extension Service

The research concludes that despite a relatively high level of awareness about digital extension services, access and usage are moderate because of financial and infrastructural limitations. High dependence on mobile data indicates the high expense of accessing digital services. Although the digital extension services have been shown to have a positive impact on decision-making and productivity, their potential is still not fully achieved because they are less accessible and expensive.

5.2.3 Factors Influencing Adoption of DES

The findings demonstrate that awareness is the foundation of digital extension service adoption, while education, access to extension services, cooperative membership, credit access, market orientation, and farm resources significantly enhance both the adoption and intensity of digital extension use. Although digital infrastructure is necessary, it is insufficient on its own to promote widespread adoption. Strengthening

farmer awareness, digital literacy, institutional support, and access to complementary services is therefore essential for increasing the uptake and sustained use of digital agricultural extension services among smallholder farmers in Murang'a County.

5.3 Recommendations

The following are recommendations made from the study, supported by the analyzed data and the present landscape of digital extension services.

5.3.1 Policy recommendations

Policy recommendations emphasize reducing internet costs through partnerships with telecommunications firms to provide subsidized or zero-rated data packages for agricultural platforms, strengthening rural digital infrastructure, such as setting up community Wi-Fi Hubs, enhancing digital literacy programs, and localizing agricultural content to improve relevance and accessibility. Furthermore, weaving digital technologies into existing conventional extension services can create hybrid models that combine trusted face-to-face advisory systems with ICT-enabled platforms, thereby improving farmer confidence, reach, and sustained adoption.

5.3.2 Practice Recommendations

Specifically, practitioners are advised to work on increasing the level of digital literacy among farmers by means of specific training programs, given the low percentage of farmers who are trained in ICT. The adoption of local languages should also be a priority so that the content can be localized to enhance usability. Additionally, it is possible to combine the use of digital tools with traditional extension strategies to make it inclusive and reach more people.

5.3.3 Recommendations for further research

The study was limited to the study objectives on the determinants of smallholder farmers' adoption of digital extension services in Murang’a County. The study therefore recommends that future scholars consider:

I. **Extension of Study Scope**

This study analyzed the determinants of digital extension service adoption in a single County in Kenya; therefore, future research could consider extending beyond the

geographical scope of Murang'a to other counties in Kenya and comparing these findings with the present study.

II. Long-term effects of DES

The long-term effects of digital extension services on agricultural productivity and livelihoods should also be studied. While short-term gains are often documented, longitudinal studies are needed to evaluate the sustained impact of these technologies over time.

REFERENCES

Abati, O. E., & Opoku, L. K. (2026). Bridging knowledge and resilience: communication and extension strategies driving agricultural innovation in the United States. epra International Journal of Agriculture and Rural Economic Research, 33. https://doi.org/10.36713/epra26097

Abdulai, A., Quarshie, P., Duncan, E., & Fraser, E. (2023). Is agricultural digitization a reality among smallholder farmers in Africa? Unpacking farmers lived realities of engagement with digital tools and services in rural Northern Ghana. Agriculture & Food Security, 12, 1-14. https://doi.org/10.1186/s40066-023-00416-6

Abdullahi, H. O., Mahmud, M., & Rahim, E. E. A. (2025). Mobile Technology in Agriculture: A Systematic Literature review of emerging trends and future research directions. *Ingénierie Des Systèmes D'Information*, *30*(2), 307–315. https://doi.org/10.18280/isi.300202

Abdullahi, H. O., Mahmud, M., & Rahim, E. E. A. (2026). Adoption of mobile technology in agricultural practices among small-scale farmers in Somalia using integrated theories. Cogent Food & Agriculture, 12(1). https://doi.org/10.1080/23311932.2026.2631187

Abdurrauf, I. A., Hussain, L. A., Adeyinka, M. S., Ibironke, E. A., Ajala, O. S., & Ayorinde, B. J. O. (2025). Assessment of adoption of digital extension services for sustainable agriculture by farmers in Lagos State, Nigeria. *Educational Advancement and Development Journal*, *1*(2), 124-132.

Agarwalla, A., H, B. G., Neog, P., Ajay, Saikia, B., Ahmed, R., Dash, S., & Phukon, B. (2026). Digital-agriculture integration of remote sensing, GIS and IoT for precision crop management: A review. *International Journal of Advanced Biochemistry Research*, *10*(3S), 616–623. https://doi.org/10.33545/26174693.2026.v10.i3sh.7957

Agwu, A. E., Suvedi, M., Chanza, C., Davis, K., Oywaya-Nkurumwa, A., Najjingo Mangheni, M., & Sasidhar, P. V. K. (2023). Agricultural extension and advisory services in Nigeria, Malawi, South Africa, Uganda, and Kenya. *Partnerships for Innovative Research in Africa (PIRA) Research Report. East Lansing, Michigan, USA: Alliance for African Partnership, Michigan State University*.

Agyekumhene, C., de Vries, J. R., van Paassen, A., & Macnaghten, P. (2022). The role of digital agricultural platforms in enabling sustainable farming practices in Africa. *NJAS: Impact in Agricultural and Life Sciences, 94*(1), 1-21

Aja, I., Hassan, A., Okeke, C. (2024). Adoption of agricultural innovations among extension personnel: A review. Journal of Agricultural Technology Studies, 22(3), 198-215

Ajesh, P. S. (2024). *Digital extension services and their role in achieving sustainable development goals (SDGs)* [Conference presentation]. Masters Seminar, Navsari Agricultural University, Navsari, India. https://doi.org/10.13140/RG.2.2.27401.61285

Akande, U. (2025). Digital Transformation in Agricultural Extension: Lessons from Global Case Studies. *Zenodo (CERN European Organization for Nuclear Research)*. https://doi.org/10.5281/zenodo.17192128

Aker, J. C. (2011). Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics, 42*(6), 631–647. https://doi.org/10.1111/j.1574-0862.2011.00545.x

Alela, B., Kule, E. K., Midamba, D. C., & Mugonola, B. (2024). Determinants of adoption of integrated soil fertility management practices among coffee producers in Mid-Northern Uganda. *Cogent Social Sciences, 10*(1). https://doi.org/10.1080/23311886.2024.2417807

Alhassan, Y. J., Mba, R., & Tsukutoda, I., I. (2025). Effectiveness of digital extension services in enhancing rural development for households in Kebbi State. *Zenodo (CERN European Organization for Nuclear Research)*

Alhassan, Y. J., Muhammad, A. M., & Chari, A. D. (2023). Social media usage and agricultural extension Service Delivery. Implications for effectiveness in Northwest Nigeria. *Transactions on Networks and Communications, 10*(5). https://doi.org/10.14738/dafs.105.13870

Amatsimbi, H. M. (2024). The Swynnerton Plan: Lessons from Kenya's colonial agricultural policy. *African Social Science and Humanities Journal, 5*(3), 241–249

Amoussohoui, R., Arouna, A., Bavorova, M., Verner, V., Yergo, W., & Banout, J. (2023). Analysis of the factors influencing the adoption of digital extension services: evidence from the RiceAdvice application in Nigeria. *The Journal of Agricultural Education and Extension, 30*(3), 387–416. https://doi.org/10.1080/1389224x.2023.2222109

Amoussouhoui, R., Arouna, A., Ruzzante, S., & Banout, J. (2024). Adoption of ICT4D and its determinants: A systematic review and meta-analysis. *Heliyon, 10*(9)

Anami, A. (2026). Agricultural productivity and economic transformation in Tanzania: A review of challenges and strategic interventions. *African Research Reports, 2*(2), 108–118. https://doi.org/10.65221/0174

Andersson, M., Boateng, K., & Abos, P. (2024). Validity and Reliability: The extent to which your research findings are accurate and consistent. *Civil Engineer and Researcher, 1*(1), 1-7

Apriani, R. (2023). Digital communication in agricultural extension in the era of the Industrial Revolution 4.0. *Quality Festival 2023*

Asnakew, F. T., Gebresenbet, G., & Kassie, K. E. (2026). Digital technologies in agricultural knowledge management and innovation systems at the rural household level in Northern Ethiopia. *Discover Food, 6*(1). https://doi.org/10.1007/s44187-026-00907-y

Awad, M. (2021). Digitization of agricultural extension. *International Journal of Modern Agriculture and Environment*, *1*(2), 99–112. https://doi.org/10.21608/ijmae.2023.214939.1007

Ayisi-Nyarko, D., Masambuka-Kanchewa, F., & Yakubu, B. N. (2024). Post-Covid-19 pandemic extension delivery: A systematic review of E-extension services prospects in Ghana. *Heliyon*, *10*(4), e26058. https://doi.org/10.1016/j.heliyon.2024.e26058

Ayuningtyas, E. A., Ilmi, B., Bisa, G. A., & Nabila, A. (2025). Spatial Database Mapping of Paddy Fields for Agricultural Extension Workers In Banjarmasin City, South Kalimantan. *transformasi: jurnal pengabdian pada masyarakat*, *5*(1), 77. https://doi.org/10.31764/transformasi.v5i1.29789

Baumüller (2018) - Baumüller, H. (2018). Realizing the potential of digital technologies for agricultural development in Africa: Towards affordable, usable and integrated ICT solutions. Center for Development Research (ZEF), Bonn. https://research4agrinnovation.org/publication/pari-policybrief11/

Bayingana, M. (2020). Digital Transformation Strategy for Africa (2020-2030) (PO).

Bazine, I. (2025). Exploring the development of the Technology Acceptance Model (TAM): A chronological overview. *International Journal of Research and Scientific Innovation*, *XII*(VI), 1643–1655. https://doi.org/10.51244/ijrsi.2025.120600138

Begum, N. N., & Vijaya, V. (2024). Challenges of Smallholder Farmers in Sub-Saharan Africa: A Perspective from Roger Thurow's, The Last Hunger Season. *International Academic Journal of Humanities*, *11*(2), 1–4. https://doi.org/10.9756/iajh/v11i2/iajh1108

Benor, D., Baxter, M. W. P., & Harrison, J. Q. (1984). *Agricultural extension: The training and visit system*. World Bank

Bergström, J., Von Butovitsch, P., Ekelund, B., Gustafsson, K., & Lundsjö, J. (2024). The history of mobile internet: the technology transformation that changed the lives of billions. *Ericsson Technology Review*, *2024*(2), 2-8

Bharti, P., Gakhar, S., Variar, M., Sharma, S., Bharamappanavara, S. C., & Patnaik, G. P. (2026). Evaluating the effects of in-person and virtual agro-advisories dissemination on farmer adoption rates—a case study of Rice Crop Manager, Odisha, India. *Frontiers in Sustainable Food Systems*, *10*. https://doi.org/10.3389/fsufs.2026.1701246

Bhat, S. A. (2021). Artificial intelligence in agriculture and animal production-innovations for sustainable food systems: a review. *American Journal of AI Cyber Computing Management*, *1*(1), 42-47.

Bhattacharyya, T., Wani, S. P., & Tiwary, P. (2021). Empowerment of stakeholders for scaling-up: digital technologies for agricultural extension. In *Scaling-up solutions for farmers: technology, partnerships and convergence* (pp. 121-147). Cham: Springer International Publishing

Bhattarai, R., Koch, J., Jentner, W., Habib, M., Wimberly, M. C., & Ebert, D. (2026). Scale, trust, and the digital divide: A systematic review of AI and ML for agricultural applications. *Frontiers in Artificial Intelligence*, *9*, 1798896. https://doi.org/10.3389/frai.2026.1798896

Bisson, A., Chamberlin, R., Cramer, L. K., Dhulipala, R., Kimoro, B., Kohler, G., ... & Wassie, S. E. (2025). Investment Roadmap: Digital Services for Livestock Methane in LMICs.

Bitok, E. K., Nyariki, D. M., & Amwata, D. A. (2023). *The nature and extent of adoption of climate-smart agriculture technologies in Murang'a County, Kenya: A case of Kiharu Constituency*. *Journal of Emerging Technologies and Innovative Research, 10*(9), c1–c15

Bontsa, N. V., Mushunje, A., & Ngarava, S. (2023). Factors Influencing the Perceptions of Smallholder Farmers towards Adoption of Digital Technologies in Eastern Cape Province, South Africa. *Agriculture*, *13*(8), 1471. https://doi.org/10.3390/agriculture13081471

Bontsa, N., Mushunje, A., Ngarava, S., & Zhou, L. (2024). Awareness and perception of digital technologies by smallholder farmers in the Eastern Cape Province, South Africa. *Suid-Afrikaanse Tydskrif Vir Landbouvoorligting/South African Journal of Agricultural Extension*, *52*(5), 73–93. https://doi.org/10.17159/2413-3221/2024/v52n5a16200

Boruah, S., Pathak, M., Sarmah, K., & Sahoo, B. K. (2024). Internet of Things (IoT) in precision agriculture. In S. Menon, A. K. Maurya, D. Patra, & P. Jayswal (Eds.), Futuristic trends in agriculture engineering & food sciences volume 3 book 6 (pp. 21–31). Iterative International Publishers. https://doi.org/10.58532/V3BCAG6P1CH3

Bowen (2009). Document Analysis as a Qualitative Research Method. Qualitative Research Journal, 9(2), 27–40. https://www.emerald.com/qrj/article-abstract/9/2/27/360733/Document-Analysis-as-a-Qualitative-Research-Method?redirectedFrom=PDF

Bujang, M. A., Omar, E. D., Foo, D. H. P., & Hon, Y. K. (2024). Sample size determination for conducting a pilot study to assess reliability of a questionnaire. *Restorative Dentistry & Endodontics*, *49*(1), e3. https://doi.org/10.5395/rde.2024.49.e3

Busungu, C., Gongwe, A., Naila, D. L., & Munema, L. (2019). Complementing extension officers in technology transfer and extension services: understanding the influence of media as change agents in modern agriculture. *international journal of research -granthaalayah*, *7*(6), 248–269. https://doi.org/10.29121/granthaalayah.v7.i6.2019.802

Byamukama, W., Ssemakula, E., Ssekandi, J., Shaman, A., Businge, P., Kalibwani, R., Atukunda, C., & Turyasingura, B. (2025). A Review of ICT Integration in Agricultural Extension Services. A Global Perspective. *East African Journal of Interdisciplinary Studies*. https://doi.org/10.37284/eajis.8.1.3023

Cameron, A. C., & Trivedi, P. K. (2013). Regression analysis of count data. In *Cambridge University Press eBooks*. https://doi.org/10.1017/cbo9781139013567

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., Bywaters, D., & Walker, K. (2020). Purposive sampling: Complex or simple? Research case examples. *Journal of Research in Nursing*. https://doi.org/10.1177/1744987120927206

Chaudhari, R. U., Patel, U. M., Parikh, N. L., & Raval, K. N. Extension services for agripreneurship. *Advances In Agriculture Extension*, 245.

Cheboi, A., & Darso, J. (2025). Leveraging digital extension services for job creation. Kenya Institute for Public Policy Research and Analysis (KIPPRA). https://kippra.or.ke

Chepkemoi, Y. F. (2025). Socioeconomic and farm Structure Characteristics of Potato Farmers in Kuresoi North Sub-County, Nakuru County, Kenya. *International Journal of Research and Innovation in Applied Science*, *10*(10), 1116-1128

Choruma, D. J., Dirwai, T. L., Mutenje, M. J., Mustafa, M., Chimonyo, V. G. P., Jacobs-Mata, I., & Mabhaudhi, T. (2024). Digitalisation in agriculture: A scoping review of technologies in practice, challenges, and opportunities for smallholder farmers in sub-Saharan Africa. *Journal of Agriculture and Food Research*, *18*, 101286. https://doi.org/10.1016/j.jafr.2024.101286

Chowdary, K., Kishore, M., Ramu, Y., Sarada, R., & Devi, J. (2024). Role of Social Media in Agricultural Extension Service Delivery: A Stakeholder Analysis. *Ecology, Environment, and Conservation*. https://doi.org/10.53550/eec.2024.v30i01s.021

Coggins, S., McCampbell, M., Sharma, A., Sharma, R., Haefele, S. M., Karki, E., Hetherington, J., Smith, J., & Brown, B. (2021). How have smallholder farmers used digital extension tools? Developer and user voices from Sub-

Saharan Africa, South Asia and Southeast Asia. *Global Food Security*, *32*, 100577. https://doi.org/10.1016/j.gfs.2021.100577

Communications Authority of Kenya & Kenya National Bureau of Statistics. (2024). *Fact sheet: Key indicators on uptake of ICTs based on 2023/24 Kenya Housing Survey*

Communications Authority of Kenya. (2025, June 30). *Mobile, data, and digital services on the rise, CA report shows*. Communications Authority of Kenya. https://www.ca.go.ke/index.php/mobile-data-and-digital-services-rise-ca-report-shows

Cui, L., & Wang, W. (2023). Factors Affecting the Adoption of Digital Technology by Farmers in China: A Systematic Literature Review. *Sustainability*, *15*(20). https://doi.org/10.3390/su152014824

Dawadi, S., Shrestha, S., & Giri, R. A. (2021b). Mixed-Methods Research: A Discussion on its Types, Challenges, and Criticisms. *Journal of Practical Studies in Education*, *2*(2), 25–36. https://doi.org/10.46809/jpse.v2i2.20

De Jesus Mendes, J., Carrer, M. J., De Mello Brandão Vinholis, M., & De Souza Filho, H. M. (2023). Adoption and impacts of messaging applications and participation in agricultural information-sharing groups: an empirical analysis with Brazilian farmers. Journal of Agribusiness in Developing and Emerging Economies, 14(4), 676–693. https://doi.org/10.1108/jadee-09-2022-0194

Deji, O. F., Famakinwa, M., Faniyi, E. O., Ojo, T. f., & Opayinka, a. o. (2024). Opportunities and challenges associated with AI-based digital technologies usage for agricultural extension services in Nigeria. *Scientific Papers Series Management, Economic Engineering in Agriculture & Rural Development*, *24*(1)

Dey, S., Widanagamage, N., Achar, S., Debangshi, U., Palla, S., Kim, J., & Jha, G. (2025). Precision Agriculture tools, techniques, and future directions for climate resilience. In *Sustainability Sciences in Asia and Africa* (pp. 89–115). https://doi.org/10.1007/978-981-96-7699-6_5

Dibbern, T., Romani, L., & Massruhá, S. (2024). Drivers and Barriers to Digital Agriculture Adoption: A Mixed-Methods Analysis of Challenges and Opportunities in Latin America. *Sustainability*, *17*(8), 3676. https://doi.org/10.3390/su17083676

Dong, H., Wang, H., & Han, J. (2022). Understanding Ecological Agricultural Technology Adoption in China Using an Integrated Technology Acceptance Model—Theory of Planned Behavior Model. *Frontiers in Environmental Science*, *10*, 927668. https://doi.org/10.3389/fenvs.2022.927668

Du, S., Hashim, N., & Kamarudin, S. (2024). Unveiling the Technology Acceptance Model: a systematic review of evolution, impact across industries and future

directions. *Pakistan Journal of Life and Social Sciences (PJLSS)*, *22*(1). https://doi.org/10.57239/pjlss-2024-22.1.0083

Duguma, A. L., & Bai, X. (2024). How the internet of things technology improves agricultural efficiency. *Artificial Intelligence Review*, *58*(2). https://doi.org/10.1007/s10462-024-11046-0

Eduafo, I., Osei, C. K., Bakang, J. A., & Tham-Agyekum, E. K. (2024). Could social media be a game-changer in improving agricultural extension delivery in Ghana? *Heliyon*, *10*(12), e33293. https://doi.org/10.1016/j.heliyon.2024.e33293

Fabregas, R., Kremer, M., & Schilbach, F. (2019). Realizing the potential of digital development: The case of agricultural advice. *Science*, *366*(6471). https://doi.org/10.1126/science.aay3038

Fan, C. (2023). English learning motivation with TAM: Undergraduates' behavioral intention to use Chinese indigenous social media platforms for English learning. *Cogent Social Sciences*, *9*(2). https://doi.org/10.1080/23311886.2023.226056

FAO, F. A. O. S. T. A. T. (2018). Food and Agriculture Organization of the United Nations. *Rome, URL: http://faostat. fao. org*, *403*.

Ferdousi, R., Islam, M. A., & Rashid, M. M. U. (2024). Role of Extension Service for climate Change Adaptation in agriculture: A Systematic Review for Developing countries. *Journal of the Bangladesh Agricultural University*, *22*(4), 490–496. https://doi.org/10.3329/jbau.v22i4.78863

Ferrari, A., Bacco, M., Gaber, K., Jedlitschka, A., Hess, S., Kaipainen, J., Koltsida, P., Toli, E., & Brunori, G. (2022). Drivers, barriers, and impacts of digitalisation in rural areas from the viewpoint of experts. *Information and Software Technology*, *145*, 106816. https://doi.org/10.1016/j.infsof.2021.106816

Food and Agriculture Organization of the United Nations. (2022). The State of Food and Agriculture 2022.

Food and Agriculture Organization of the United Nations. (2025). *Digital extension*. FAO.

Food and Agriculture Organization, International Center for Tropical Agriculture, & World Bank. (2021). *Digital agriculture profile: Kenya*. FAO. https://openknowledge.fao.org/items/fab01c51-9c1e-4497-8d4b-6f8477a177c2

Fountas, S., Espejo-Garcia, B., Kasimati, A., Mylonas, N., & Darra, N. (2020). The Future of Digital Agriculture: Technologies and Opportunities. *IT Professional*, *22*(1), 24–28. https://doi.org/10.1109/MITP.2019.2963412

Fraser, J., Fahlman, D., Arscott, J., & Guillot, I. (2018). Pilot testing for feasibility in a study of student retention and attrition in online undergraduate programs. *The International Review of Research in Open and Distributed Learning*, *19*(1). https://doi.org/10.19173/irrodl.v19i1.3326

Gao, T., Lu, Q., Zhang, Y., & Feng, H. (2024). Does Farmers' Cognition Enhance Their Enthusiasm for Adopting Sustainable Digital Agricultural Extension Services? Evidence from Rural China. *Sustainability*, *16*(10), 3972. https://doi.org/10.3390/su16103972

Gao, T., Lu, Q., Zhang, Y., & Feng, H. (2025). The influence of digital agricultural technology extension service cognition on farmers' pro-environmental behaviour: the moderating role of policy support. *International Journal of Agricultural Sustainability*, *23*(1). https://doi.org/10.1080/14735903.2025.2569186

Gedikoglu, H., McCann, L., & Artz, G. (2011). Off-Farm employment effects on adoption of nutrient management practices. *Agricultural and Resource Economics Review*, *40*(2), 293–306. https://doi.org/10.1017/s1068280500008078

Getahun, A. A. (2020). Challenges and opportunities of information and communication technologies for dissemination of agricultural information in Ethiopia. *International Journal of Agricultural Extension*, *8*(1), 57-65

Ghanem, M. S., & Elgamel, P. (2026). Applying Technology Acceptance Model (TAM) to Chatbots as a Customer Support Tool in Choosing Tourism and Hospitality Services in Egypt. *Journal of Association of Arab Universities for Tourism and Hospitality*, *30*(1), 248-275

Gichamba, A., Wagacha, P. W., & Ochieng, D. O. (2017). *An assessment of e-Extension platforms in Kenya*. International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET), 3(7), 36–40

Gitau, K., Gitumu, D. M., Chilambe, P. A., Koech, G. J., Gamoyo, M. J., Milimo, H., ... & Niza, B. (2025). Supporting smallholder farmer resilience with weather advisory information.

Gizachew, F., Kuma, B., Tafesse, A., & Lambamo, A. (2024). Digital tools and welfare: adoption determinants among ginger producers in Southern and Central Ethiopia. *Frontiers in Sustainable Food Systems*. https://doi.org/10.3389/fsufs.2024.1443775

Greene, W. H. (2018). *Econometric analysis* (8th ed.). Pearson

Guay, C. M. B., Esteban, J. C., Bacus, M. S., & Quijano-Pagutayao, A. S. (2025). Factors influencing farmers' adoption of digital extension services in Kibanggay, Lantapan, Bukidnon, Philippines. *International Journal of Research and Innovation in Social Science*, *IX*(V), 3677–3681. https://doi.org/10.47772/ijriss.2025.905000278

Guay, C. M. B., Esteban, J. C., Bacus, M. S., & Quijano-Pagutayao, A. S. (2025). Factors influencing farmers' adoption of digital extension services in Kibanggay, Lantapan, Bukidnon, Philippines. *International Journal of Research and Innovation in Social Science*, *IX*(V), 3677–3681. https://doi.org/10.47772/ijriss.2025.905000278

Guest, Greg, Emily Namey, and Mario Chen. "A simple method to assess and report thematic saturation in qualitative research." *PloS one* 15.5 (2020): e023207

Guest, Namey & Chen (2020). A simple method to assess and report thematic saturation in qualitative research. PLoS ONE, 15(5), e0232076 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0232076

Gumbi, N., Gumbi, L., & Twinomurinzi, H. (2023). Towards Sustainable Digital Agriculture for Smallholder Farmers: A Systematic Literature review. *Sustainability*, *15*(16), 12530. https://doi.org/10.3390/su151612530

Hainzer K, O'Mullan C, Brown PH (2024), "Agricultural extension in Papua New Guinea: the challenges facing demand-driven extension from the perspective of practitioners". *Journal of Agribusiness in Developing and Emerging Economies*, Vol. 14 No. 5 pp. 1161–1175, doi: https://doi.org/10.1108/JADEE-06-2022-0131

Hangula, M. M., Togarepi, C., Thomas, M., & Chuma, B. L. (2026). Assessment of extension agents' constraints to effective delivery of agricultural extension services in north central areas of Namibia. *Journal of Asian and African Studies*. https://doi.org/10.1177/00219096261437719

Hossan, D., Mansor, Z. D., & Jaharuddin, N. S. (2023). Research population and sampling in quantitative study. *International Journal of Business and Technopreneurship (IJBT)*, *13*(3), 209–222. https://doi.org/10.58915/ijbt.v13i3.263

Hussain, M. R., Meraj, J. T., & Sarker, O. A. (2024). Precision farming through the use of internet of things (IoT) innovations in agriculture. *Journal of Sustainable Agricultural Economics*, 18. https://doi.org/10.63471/sa24004

Idrees, U., Aslam, M. J., & Munawer, S. (2025). Social media platforms as tools of global cultural exchange. *Research Journal for Social Affairs*, *3*(5), 649–656. https://doi.org/10.71317/rjsa.003.05.0363

Ifeanyi-Obi, C. C., & Corbon, B. L. (2023). Utilization of digital tools in extension service delivery amongst extension agents in Akwa Ibom State, Nigeria. *Journal of Agricultural Extension*, *27*(4), 67–76. https://doi.org/10.4314/jae.v27i4.7

Ifigeneia, M. (2015). SMS: a new way of communication and promotion. *International Journal of Wireless Communications, Networking and Mobile Computing*, *2*(2), 19-26.

Indu, P. V., & Vidhukumar, K. (2020). *Research designs—An overview*. *Kerala Journal of Psychiatry, 32*(1), 64–67. https://doi.org/10.30834/KJP.32.1.2019.179,

Indu, P., & Vidhukumar, K. (2020). Research designs: an overview., 32. https://doi.org/10.30834/kjp.32.1.2019.179.

Ingutia, R., & Sumelius, J. (2024). Does cooperative membership facilitate access to credit for women farmers in rural Kenya? *Journal of Agriculture and Food Research*, *18*, 101425. https://doi.org/10.1016/j.jafr.2024.101425

Ireri, D. M. (2021). Role of ICT in the dissemination and access of agricultural information by smallholder farmers in South-Eastern Kenya. Acta Informatica Malaysia, 5(1), 31–41. https://doi.org/10.26480/aim.01.2021.31.41

Ireri, E. M. (2022). *Influence of digital distribution strategies on uptake of bank products and services in Kenya* (Doctoral dissertation)

Joel, A. F., Bamidele, J., Oyediji, B. I., Olaitan, M. A., Eleke, U. P., Joel, O. J., Tata, A. T., & Sennuga, S. O. (2025). Effectiveness of ICTs in Extension Service Delivery among Smallholder Farmers in Kwali Area Council, Abuja, Nigeria. *Global Academic Journal of Agriculture and Biosciences*, *7*(01), 8–17. https://doi.org/10.36348/gajab.2025.v07i01.002

Juliet Akoth Ojwang (2024). Kenyan farmers turn to WhatsApp & AI tools to combat crop diseases. Mongabay Conservation news. DOI: https://doi.org/10.66709/news-283717

Kansiime, M. K., Mugambi, I., Rware, H., Alokit, C., Aliamo, C., Zhang, F., Latzko, J., Yang, P., Karanja, D., & Romney, D. (2021). Challenges and capacity gaps in smallholder access to digital extension and advisory services in Kenya and Uganda. *Frontiers of Agricultural Science and Engineering*, *9*(4), 642. https://doi.org/10.15302/j-fase-2021423

Karki, P., Sharma, S., Sharma, S., Thakur, A., & Dhankar, A. (2026). Role of Agricultural Extension Services in Transfer and Adoption of Agricultural Technology in India: A Review. *Ecology, Environment and Conservation*. https://doi.org/10.53550/eec.2026.v32.i01s.04

Katothya, G., Kilelu, C., Sikumba, G., & Van Der Lee, J. (2020). Emerging private extension and advisory services models in the Kenyan agrifood sector: selected case studies. https://doi.org/10.18174/523776

Ke, J., Dan, H., Wang, Q., & Razzaq, A. (2025). The role of off-farm employment in promoting sustainable farm development through integrated pest management technology adoption. *Frontiers in Sustainable Food Systems*, *8*, 1503951

Kemibaro, M. (2025, April 12). *Rural reality check: Safaricom & Airtel mobile internet speed tests in Murang'a*. *Medium*.

https://moseskemibaro.medium.com/rural-reality-check-safaricom-airtel-mobile-internet-speed-tests-in-muranga-a1f6bae0512a

Kenya National Bureau of Statistics. (2019). *2019 Kenya Population and Housing Census Volume I: Population by County and Sub-County*. Nairobi, Kenya: Kenya National Bureau of Statistics. https://www.knbs.or.ke/wp-content/uploads/2023/09/2019-Kenya-population-and-Housing-Census-Volume-1-Population-By-County-And-Sub-County.pdf

Kenya News Agency. (2024, May 29). *State banks on youth agripreneurs to revitalise extension services*.
Awasthi, S., Tripathi, S., Pandey, A., & Pandey, A. (2023). *Bridging the gap: Enhancing farmers' access to extension services in rural areas*. Just Agriculture, 4(1), 488–496

Khalaf, A. G., & Al-Mashhadani, A. L. J. (2024). problems of using digital agricultural extension in providing agricultural extension services from the viewpoint of agricultural extension agents: problems of using digital agricultural extension in providing agricultural extension services from the viewpoint of agricultural extension agents. *Iraqi Journal of Market Research and Consumer Protection*, *16*(2), 86-100

Khatri, A., Lallawmkimi, M. C., Rana, P., Panigrahi, C. K., Minj, A., Koushal, S., & Ali, M. U. (2024). Integration of ICT in Agricultural Extension Services: A review. *Journal of Experimental Agriculture International*, *46*(12), 394–410. https://doi.org/10.9734/jeai/2024/v46i123146

Kiarie, H. (2020). *Determinants of digital technologies adoption among small scale farmers in Kenya - a case of Embu and Kirinyaga Counties*. http://hdl.handle.net/11071/10422

Kilimo News. (2026). *Murang'a shifts to digital system for maize seed and fertilizer distribution*. https://kilimonews.co.ke/science-and-technology/muranga-shifts-to-digital-system-for-maize-seed-and-fertilizer-distribution

Kiprono, K. (2024). Youth Participation in Agriculture and Its Effect on Welfare: The Case of Youth in Bomet County, Kenya (Doctoral dissertation, Kenyatta University).

Kiprotich, S., Mogaka, H., Ndirangu, S. N., & Onyari, C. N. (2023). Determinants of adoption and adoption intensity of integrated soil fertility management technologies among sorghum farmers in Upper Eastern Kenya. *Soil Use and Management*, *40*(1). https://doi.org/10.1111/sum.1295

Kithome, M. M. (2022). *Factors Affecting Adoption and Effect of Irrigation Technologies on Productivity and Profitability among Small-scale Farmers in Machakos County, Kenya* (Doctoral dissertation, Mary Muluki Kithome)

Klerkx, L., Jakku, E., & Labarthe, P. (2022). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS: Impact in Agricultural and Life Sciences, 94*(1), 1-17

Kouame, K. J. M. B., & Ikporukpo, C. O. (2020). Diffusion of agricultural innovation. *The International Journal of Humanities & Social Studies*, *8*(11). https://doi.org/10.24940/theijhss/2020/v8/i11/hs2011-048

Krell, N. T., Giroux, S. A., Guido, Z., Hannah, C., Lopus, S. E., Caylor, K. K., & Evans, T. P. (2020). Smallholder farmers' use of mobile phone services in central Kenya. *Climate and Development, 13*(3), 215–227. https://doi.org/10.1080/17565529.2020.1748847v

Kwikiriza, G., Muthoka, M., Luttamaguzi, A. N., Efitre, J., Kisakye, J. J., Magondu, E., Munguti, J., Aruho, C., & Tibihika, P. D. (2026). Aquaculture extension systems in East Africa: development, challenges, and future opportunities. *Aquaculture Science and Management.*, *3*(1). https://doi.org/10.1186/s44365-026-00034-w

Le Thi Hoa Sen, Tullo, E., Douangsavanh, L., Jayasinghe-Mudalige, U. K., & Paris, T. R. (2024). *Barriers and enablers of digital extension services' adoption among smallholder farmers: The case of Cambodia, the Philippines, and Vietnam*. Frontiers in Sustainable Food Systems.

Lee, C., Orton, G., & Oliveira, L. (2026). Strengthening human infrastructure for smart farming through competency-based assessment of extension agents in precision agriculture. *Scientific Reports*, *16*(1). https://doi.org/10.1038/s41598-026-39596-z

Lokuruka, M. (2020). Food and Nutrition Security in East Africa (Kenya, Uganda and Tanzania): Status, Challenges and Prospects. *Food Security in Africa*. https://doi.org/10.5772/intechopen.95036

Lwoga, E. T., Sangeda, R. Z., & Mushi, V. G. (2021). The role of mobile phones in enhancing access to agricultural information in Tanzania. *Information Development, 37*(1), 108-122.

Mabika, B. (2019). *The use of mobile phones in disseminating agricultural information to farmers in Mashonaland west province of Zimbabwe*. University of South Africa (South Africa)

Maina, F., Mburu, J., & Nyang'anga, H. (2024). Drivers of extent of commercialization of potato farming through digital marketing platforms in Nakuru County, Kenya. *Frontiers in Sustainable Food Systems, 8*. https://doi.org/10.3389/fsufs.2024.1307978

Majiwa, E., Ndaka, A. K., Ratemo, H., & Agembo, E. (2026). Artificial intelligence (AI) adoption and its perceptions among smallholder women farmers in Kenya. *Discover Agriculture*, *4*(1). https://doi.org/10.1007/s44279-026-00626-z

Makinde, O., Abidemi, A., Ogunlade, I., Oladele, O., & Shuaib, A. (2025). Knowledge and Attitude of Extension Educators Towards Digitising Agricultural Extension Services in Kwara State, Nigeria. *Zeszyty Naukowe SGGW w Warszawie - Problemy Rolnictwa Światowego*. https://doi.org/10.22630/prs.2025.25.2.7

Manzoor, F., Wei, L., Siraj, M., Lu, X., & Qiyang, G. (2025). Digital agriculture technology adoption in low and middle-income countries—A review of contemporary literature. *Frontiers in Sustainable Food Systems*, *9*, 1621851. https://doi.org/10.3389/fsufs.2025.1621851

Mapiye, O., Makombe, G., Molotsi, A., Dzama, K., & Mapiye, C. (2023). Information and communication technologies (ICTs): The potential for enhancing the dissemination of agricultural information and services to smallholder farmers in sub-Saharan Africa. *Information Development*, *39*(3), 638-658.

Maratha, P., Soni, S., Singh, S., Panotra, N., Upadhyay, L., Azad, M. S., Kumar, S., & Kumar, A. (2025). The Evolution of Agricultural Extension: A Comprehensive review of historical developments and modern practices. *Archives of Current Research International*, *25*(12), 476–491. https://doi.org/10.9734/acri/2025/v25i121686

Marikyan, D.& Papagiannidis, S. (2026) Technology Acceptance Model: A review. In S. Papagiannidis (Ed), TheoryHub Book. Available at https://open.ncl.ac.uk / ISBN: 9781739604400

Martey, E., Etwire, P. M., & Kuwornu, J. K. (2020). Economic impacts of smallholder farmers' adoption of drought-tolerant maize varieties. *Land Use Policy*, *94*, 104524. https://doi.org/10.1016/j.landusepol.2020.104524

Marwa, M. E., Mburu, J., Oburu, R. E. J., Mwai, O., & Kahumbu, S. (2020). Impact of ICT based extension services on dairy production and household welfare: the case of ICOW service in Kenya. *Journal of Agricultural Science*, *12*(3), 141. https://doi.org/10.5539/jas.v12n3p141

Maryono, M., Killoes, A. M., Adhikari, R., & Aziz, A. A. (2023). Agriculture development through multi-stakeholder partnerships in developing countries: A systematic literature review. *Agricultural Systems*, *213*, 103792. https://doi.org/10.1016/j.agsy.2023.103792

Maulu, S., Hasimuna, O. J., Mutale, B., Mphande, J., & Siankwilimba, E. (2021). Enhancing the role of rural agricultural extension programs in poverty alleviation: A review. *Cogent Food & Agriculture*, *7*(1). https://doi.org/10.1080/23311932.2021.188666

Mburu, P. (2013). Factors influencing access to agricultural information by smallholder farmers through ICT channels in Deiya location, Kiambu County

McCampbell, M., Schumann, C., & Klerkx, L. (2022). Good intentions in complex systems: Exploring the socio-technical challenges of digital agricultural extension. *Agricultural Systems, 201*, 103474.

McLaughlin, J. E., Kane-Gill, S. L., & Snyder, M. E. (2025). Research and scholarly methods: Mixed methods studies. *Journal of the American College of Clinical Pharmacy*, *8*(10), 1071–1077. https://doi.org/10.1002/jac5.70068

Meena, S. (2024). Blockchain technology: An emerging mechanism in agriculture. *Agri Business: A Managerial Perspective*, 46-53.

Mengist, W., Soromessa, T., & Legese, G. (2019). Method for conducting systematic literature review and meta-analysis for environmental science research. *MethodsX*, 7. https://doi.org/10.1016/j.mex.2019.100777

Midamba, D. C., Agbolosoo, J. A., Kule, E. K., Ouko, K. O., & Kwesiga, M. (2026). Assessing the determinants and effects of ICT use on maize productivity among peasant farmers in Western Kenya. *Discover Sustainability*, *7*(1), 371

Midamba, D., Muteti, F., Mpofu, T., Ouko, K., Kwesiga, M., Ouya, F., & Chepkoech, B. (2022). Socio–economic Factors Influencing Access to Agricultural Extension Services among Smallholder Farmers in Western Uganda. *Asian Journal of Agricultural Extension, Economics & Sociology*. https://doi.org/10.9734/ajaees/2022/v40i1031172

Miine, L. K., Akorsu, A. D., Boampong, O., & Bukari, S. (2023). Drivers and intensity of adoption of digital agricultural services by smallholder farmers in Ghana. *Heliyon*, *9*(12), e23023. https://doi.org/10.1016/j.heliyon.2023.e23023

Mishra, H., & Mishra, D. (2023). Artificial intelligence and machine learning in agriculture: Transforming farming systems. In *Zenodo (CERN European Organization for Nuclear Research)*. https://doi.org/10.5281/zenodo.15157536

Moakofhi, M. K., Phiri, T. V., Leteane, O., & Bangomwa, E. (2019). Using technology acceptance model to predict lecturers' acceptance of Moodle: case of Botswana University of Agriculture and Natural Resources. *Literacy Information and Computer Education Journal*, *10*(1), 3103–3113. https://doi.org/10.20533/licej.2040.2589.2019.0407

Mpundu, C., & Musenge, D. (2026). The Role of Agriculture Extension in the Development of Agriculture in Luanshya District of Zambia. *International Journal of Advanced Multidisciplinary Research and Studies*. https://doi.org/10.62225/2583049x.2026.6.1.5862

Mugabo, A., Ogar, E., Wang, H., & Brady, C. (2026). Comparative analysis of agricultural extension models in the United States, Rwanda, and Nigeria: Innovations in capacity building, technology integration, and educator preparation. *Agricultural and Environmental Education, 5*(1), em013. https://doi.org/10.29333/agrenvedu/18356

Mugari, E., Mathebula, N., Mogale, T. E., Mamabolo, E., Mashala, M. J., Mabitsela, K., & Ayisi, K. K. (2025). Influence of public agricultural extension services on sustainable land management practice adoption among smallholder farmers in Fetakgomo Tubatse Local Municipality, South Africa. *Frontiers in Sustainable Food Systems*, *9*. https://doi.org/10.3389/fsufs.2025.161893

Mukembo, S., & Edwards, M. C. (2016). Agricultural extension in Sub-Saharan Africa during and after its colonial era: the case of Zimbabwe, Uganda, and Kenya. Journal of International Agricultural and Extension Education. https://doi.org/10.5191/jiaee.2015.22304

Mukherjee, S., Padaria, R. N., Burman, R. R., Velayudhan, P. K., Mahra, G. S., Aditya, K., Sahu, S., Saini, S., Mallick, S., Quader, S. W., Shravani, K., Ghosh, B., & Bhat, A. G. (2025). Global trends in ICT-based extension and advisory services in agriculture: A bibliometric analysis. *Frontiers in Sustainable Food Systems*, *9*, 1430336. https://doi.org/10.3389/fsufs.2025.1430336

Murang'a County Government. (2023). *Murang'a County Third County Integrated Development Plan (CIDP) 2023–2027*. https://muranga.go.ke/wp-content/uploads/2023/08/MURANGA-COUNTY-CIDP

Musafiri, C. M., Kiboi, M., Macharia, J., Ng'etich, O. K., Kosgei, D. K., Mulianga, B., ... & Ngetich, F. K. (2022). Adoption of climate-smart agricultural practices among smallholder farmers in Western Kenya: do socioeconomic, institutional, and biophysical factors matter? *Heliyon*, *8*(1)

Musau, E. (2024). Sustainable Agriculture leveraging artificial intelligence systems in Kenya's agri-food supply chain. Agricultural Science, 7(2), 153–171. https://doi.org/10.55173/agriscience.v7i2.128

Musiimenta, F., Balimutajjo, S., & Arinaitwe, J. (2024). Parenting styles and pupils' morals in Upper Primary Schools of Kabula County, Lyantonde District. *East African Journal of Education Studies*, *7*(2), 363–374. https://doi.org/10.37284/eajes.7.2.1979

Mutisya, S. M., & Kumar, A. (2025). Adoption of technology enabled agricultural extension services by Kenya's youthful farmers. *Journal of the Kenya National Commission for UNESCO*. https://doi.org/10.62049/jkncu.v5i1.418

Mwale, M., & Chiweshe, N. (2024). *Techvolutionaries: Navigating the technological frontier in Ndola: Zambia's entrepreneurial landscape during the Fourth Industrial Revolution (4IR)* (pp. 1–15). In *Fostering Innovation in Venture Capital and Startup Ecosystems*. IGI Global. https://doi.org/10.4018/979-8-3693-1326-8.ch001

Mwangi, B. M. (2021). Threats of land use changes on wetland and water areas of Murang'a County, Kenya. Applied Ecology and Environmental Sciences/Applied Ecology and Environmental Science, 9(6), 585–590. https://doi.org/10.12691/aees-9-6-2

Mwaseba, S., Dimoso, P., & Timothy, S. (2024). Drivers of Small-Scale farmers' adoption of mobile phone technology for rice production and marketing in Dodoma region. *Rural Planning Journal/Rural Planning Journal*, *26*(1), 1–12. https://doi.org/10.59557/rpj.26.1.2024.75

Naika, M. B., Kudari, M., Devi, M. S., Sadhu, D. S., & Sunagar, S. (2021). Digital extension service. In *Elsevier eBooks* (pp. 285–323). https://doi.org/10.1016/b978-0-12-821470-1.00006-9

Ndimbo, G. K., Gu, J., Haulle, E., & Yu, L. (2024). Why mobile phone matters: The role of ICT in promoting farmers' access to agricultural information and extension services in a tea outgrowing scheme in Tanzania. *Information Development*. https://doi.org/10.1177/02666669241284235

Next-Gen agricultural extension. (2025). https://doi.org/10.61887/glp.2025.140

Nikolopoulou, K. (2023). *What is snowball sampling? Definition & examples*. Scribbr. https://www.scribbr.com/methodology/snowball-sampling/

Njuguna, E., Birner, R., Daum, T., & Mburu, J. (2026). Smart sensors, fragile trust: Governance of digital soil-testing tools in smallholder agriculture in Kenya. *Agricultural Systems*, *236*, 104771. https://doi.org/10.1016/j.agsy.2026.104771

Njuguna, E., Mburu, J., Birner, R., & Daum, T. (2025, January 20). *Kenya's farmers have lots of digital tools to help boost productivity – how they can be made more effective*. The Conversation.

Norton, G. W., & Alwang, J. (2020). Changes in agricultural extension and implications for farmer adoption of new practices. *Applied Economic Perspectives and Policy*, *42*(1), 8–20. https://doi.org/10.1002/aepp.13008

Ntsoane, M. M., Ndoro, J. T., & Wayi-Mgwebi, N. (2025). Multivariate Probit model analysis of the factors influencing smallholder farmers' choice of ICT tools: a case study of Mpumalanga, South Africa. *Agriculture*, *15*(17), 1817. https://doi.org/10.3390/agriculture15171817

Nyagango, A. I., Sife, A. S., & Kazungu, I. (2023). Use of mobile phone technologies for accessing agricultural marketing information by grape smallholder farmers: a technological acceptance model (TAM) perspective. *Technological Sustainability*, *2*(3), 320–336. https://doi.org/10.1108/techs-01-2023-0002

Nyasimi, M., Olimba, L. A., & Kange'the, E. (2022). Climate-smart agriculture and food security in Kenya: A review of the literature. *Cogent Food & Agriculture*, *8*(1), 2061680

Nyoike, E. (2015). Radio and small-scale farming in Murang'a: a study of Mugambo wa murimi program in Inooro FM

Ogundipe, F., Bakare, O. I., Sampson, E., & Folorunso, A. (2023). Harnessing Digital Transformation for Africa's Growth: Opportunities and Challenges in the Technological Era

Ogutu, S. O., Okello, J. J., & Otieno, D. J. (2014). Impact of Information and Communication Technology-Based Market Information Services on smallholder farm input use and productivity: the case of Kenya. *World Development*, *64*, 311–321. https://doi.org/10.1016/j.worlddev.2014.06.011

Oke, O., Adeoye, A., Jatto, K., Adelusi, F., & Ojo-Fakuade, F. (2020). Assessment of information and communication technologies usage by maize farmers in Afijio Local Government area of Oyo State, Nigeria. *Information Impact Journal of Information and Knowledge Management*, *10*(2), 109–123. https://doi.org/10.4314/iijikm.v10i2.8

Okello, D., Owuor, G., Larochelle, C., Gathungu, E., & Mshenga, P. (2021). Determinants of utilization of agricultural technologies among smallholder dairy farmers in Kenya. *Journal of Agriculture and Food Research*, *6*, 100213. https://doi.org/10.1016/j.jafr.2021.100213

Olorunfemi, O. D., Mamiane, T. A., & Matiwane, M. B. (2024). Investigating access and use of digital tools for agriculture among rural farmers: A case study of Nkomazi Municipality, South Africa. *Open Agriculture*, *9*(1), 20220380. https://doi.org/10.1515/opag-2022-0380

Ongachi, W., Belinder, I., Bhat, B., Hussain, S., & Dub, R. (2026). Strengthening agricultural extension services to enhance farmers' capacity and resilience for sustainable development: a systematic review. *BMC Agriculture*, *2*(1). https://doi.org/10.1186/s44399-026-00039-9

Oranga, J., Matere, A., & Njurai, E. (2025). The Mixed Methods Research Approach: An Overview. *Postmodernism Problems*, *15*(1), 84–99. https://doi.org/10.46324/pmp2501084

Owolabi, A. O. & Yekinni, T. O. (2022). Utilization of Information and Communication Technologies for Agricultural Extension Service Delivery in Public and Non-public organizations in southwestern Nigeria, *Heliyon*,8 (9),10676. https://doi.org/10.1016/j.heliyon.2022.e10676.

Owusu, E. S., Arouna, A., Yergo, W. G., Narrod, C., & Bravo-Ureta, B. (2025). Digital Agricultural extension and Productivity Impacts in rice Farming: Lessons from Nigeria. *Agricultural Economics*, *57*(1). https://doi.org/10.1111/agec.70079

Özoğul, G. (2025). Applications of artificial intelligence technologies in agriculture: advantages, challenges, risks, prospects, and recommendations. *Cogent Food & Agriculture*, *11*(1). https://doi.org/10.1080/23311932.2025.2568199

Parlasca, M. C., Johnen, C., & Qaim, M. (2021). Use of mobile financial services among farmers in Africa: Insights from Kenya. *Global Food Security*, *32*, 100590. https://doi.org/10.1016/j.gfs.2021.100590

Phanith, C. H. O. U., Hoa, S. L. T., & Dacuyan, F. (2023). Digital agricultural extension services for development of smallholder farmers in South East Asia

Porciello, J., Coggins, S., Mabaya, E., & Otunba-Payne, G. (2022). Digital agriculture services in low- and middle-income countries: A systematic scoping review. *Global Food Security*, *34*, 100640. https://doi.org/10.1016/j.gfs.2022.100640

Porciello, J., Tui, S. H., & Baines, D. (2020). A review of the literature on digital agriculture and its potential for sustainable development in sub-Saharan Africa. *Global Food Security, 26*, 100431

Priya, N. K., Patel, K., Abrol, P., Babu, N. N., Kavyasree, K., Bijoy, D., Chand, K., & Kumar, A. (2026). A Review of Gender-Responsive Extension Approaches for Enhancing Women's Participation and Empowerment in Food Technology Systems. *Archives of Current Research International*, *26*(1), 261–280. https://doi.org/10.9734/acri/2026/v26i11720

Priya, N. K., Patil, S. S., Vishwakarma, S. K., Saikanth, D. R. K., Mishra, I., Tripathi, S., Pathak, A. K., & Shastri, S. (2025). Digital Innovations in Extension Education: A Review of Emerging Technologies and Their Impact on Agricultural Knowledge Dissemination. *Journal of Experimental Agriculture International*, *47*(5), 408–423. https://doi.org/10.9734/jeai/2025/v47i53430

Priya, N. K., Sivanarayana, G., & Babu, N. N. (2025). Evolution of Agricultural Extension: From Traditional to Digital Approaches.

Purwadi, P., Firmansyah, E., & Nurjanah, D. (2024). *Challenges and gap capacity of palm oil farmers in accessing digital extension and assistance services*. *Agrisocionomics: Jurnal Sosial Ekonomi Pertanian, 8*(2), 471–484. https://doi.org/10.14710/agrisocionomics.v8i2.18099

Ragetlie, R., Najjar, D., & Oueslati, D. (2022). "Dear Brother Farmer": Gender-Responsive Digital Extension in Tunisia during the COVID-19 Pandemic. Sustainability, 14(7), 4162. https://doi.org/10.3390/su14074162

Rahman, A., Morgan, A., Sharma, P., & Kim, D. (2024). The role of social networks and community organizations in disseminating agricultural innovations among smallholder farmers. *International Journal of Agriculture Extension and Social Development*, *7*(1), 210–213. https://doi.org/10.33545/26180723.2024.v7.i1c.3108

Raji, I., & Njoku, T. K. (2024). Data-Driven Decision Making in Agriculture: Enhancing Productivity and Sustainability through Predictive Analytics. *International Journal of Research Publication and Reviews*, *5*(9), 2708–2719. https://doi.org/10.55248/gengpi.5.0924.2656

Rajkhowa, P., & Qaim, M. (2021). Personalized digital extension services and agricultural performance: Evidence from smallholder farmers in India. *plos one*, *16*(10), e0259319. https://doi.org/10.1371/journal.pone.0259319

Ramavhale, P., Zwane, E., & Belete, A. (2024). The benefits of social media platforms used in agriculture for information dissemination. *Suid-Afrikaanse Tydskrif Vir Landbouvoorligting/South African Journal of Agricultural Extension, 52*(2), 77–90. https://doi.org/10.17159/2413-3221/2024/v52n2a15342

Ranjan, A., Gosh, B., Barman, B., Quader, S. W., PN, F. A., Tiwari, S., Saurav, S. K., & Bishnoi, S. K. (2024). Role of agricultural extension in addressing food security. *European Journal of Nutrition & Food Safety*, *16*(9), 67–85. https://doi.org/10.9734/ejnfs/2024/v16i91527

Rao, B. N. (2026). The essential connection: agriculture as the cornerstone of Viksit Bharat. *international journal of professional studies*, *21*(3), 217–222. https://doi.org/10.37648/ijps.v21i03.032

Regassa, M. D., Degnet, M. B., & Melesse, M. B. (2023). Access to credit and heterogeneous effects on agricultural technology adoption: Evidence from large rural surveys in Ethiopia. *Canadian Journal of Agricultural Economics/Revue Canadienne D Agroeconomie*, *71*(2), 231–253. https://doi.org/10.1111/cjag.12329

Republic of Kenya. (2019). *Data Protection Act, No. 24 of 2019*. National Council for Law Reporting (Kenya Law).

Rodriguez, E., Mwangi, J. O., Chen, L. W., & Al-Jabri, F. Digital Transformation of Agricultural Extension Services: Global Experiences and Best Practices

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Runck, B. C., Joglekar, A., Silverstein, K. A. T., Chan-Kang, C., Pardey, P. G., & Wilgenbusch, J. C. (2021). Digital agriculture platforms: Driving data-enabled agricultural innovation in a world fraught with privacy and security concerns. *Agronomy Journal*, *114*(5), 2635–2643. https://doi.org/10.1002/agj2.20873

Ryan, M., & Stahl, B. C. (2020). Artificial intelligence ethics guidelines for developers and users: Mapping their content to an EU governance framework. *AI and Ethics, 1*(2), 1-13

Samoei, B., Kurgat, P., & Opondo, P. (2025). How colonial policies stalled the agrarian revolution in independent Kenya: 1954 to 1992. African Journal of History and Geography, 4(1), 191–211. https://doi.org/10.37284/ajhg.4.1.3221

Samson P. Katengeza, Julius J. Okello and Edouard R. Mensah (2011). Factors Influencing Awareness and Use of Electronic–Based Market Information Services for Farming Business in Malawi. Int. J. Eco. Res., 2011 2(4), 43-58

Sarfo, J. B., Aremora, S., Adebote, M. O., Balogun, K. M., & Fashina, A. T. (2025). Generative AI: A new frontier for agric extension service in Africa - revolutionizing farmer information access. *Computer Science & IT Research Journal*, *6*(2), 94–103. https://doi.org/10.51594/csitrj.v6i2.1870

Savari, M., Amghani, M. S., & Malekian, A. (2025). Application of the diffusion of innovation theory to identify factors affecting the use of treated wastewater in crop irrigation: a study in Tehran province. *Cleaner Engineering and Technology*, *29*, 101094. https://doi.org/10.1016/j.clet.2025.101094

Schultze, M., Kankam, S., Sanfo, S., & Fürst, C. (2026). Improving the provisioning of agricultural extension services in West Africa to strengthen land management practices: case studies of Burkina Faso and Ghana. Land, 15(2), 277. https://doi.org/10.3390/land15020277

Selim, A. (2026). Did the Structural Adjustment Program Succeed in Kenya? *Research Square*. https://doi.org/10.21203/rs.3.rs-10244420/v1

Sen, L. T. H., Chou, P., Dacuyan, F. B., Nyberg, Y., & Wetterlind, J. (2024). Barriers and enablers of digital extension services' adoption among smallholder farmers: the case of Cambodia, the Philippines and Vietnam. *International Journal of Agricultural Sustainability*, *22*(1). https://doi.org/10.1080/14735903.2024.2368351

Sen, L. T. H., Phuong, L. T. H., Chou, P., Dacuyan, F. B., Nyberg, Y., & Wetterlind, J. (2025). The Opportunities and Barriers in Developing Interactive Digital Extension Services for smallholder Farmers as a Pathway to Sustainable agriculture: A Systematic review. *Sustainability*, *17*(7), 3007. https://doi.org/10.3390/su17073007

Shedeed, S. (2020). Subsistence farming towards sustainable economic agriculture of small farmers in the developing countries. *NASS Journal of Agricultural Sciences*.

Silvestri, S., Richard, M., Edward, B., Dharmesh, G., & Dannie, R. (2020). Going digital in agriculture: how radio and SMS can scale up smallholder participation in legume-based sustainable agricultural intensification practices and technologies in Tanzania. *International Journal of Agricultural Sustainability*, *19*(5–6), 583–594. https://doi.org/10.1080/14735903.2020.1750796

Simbu, B. K., & Tambua, K. M. (2024). Digital connectivity and rural broadband access as enabling conditions for technology-mediated extension delivery. *International Journal of Agriculture Extension and Social Development*, *7*(10), 45–48. https://doi.org/10.33545/26180723.2024.v7.i10a.3060

Singh, N. K., Sunitha, N. H., Tripathi, G., Saikanth, D. R. K., Sharma, A., Jose, A. E., & Mary, M. V. K. J. (2023). Impact of digital technologies in agricultural extension. *Asian Journal of Agricultural Extension Economics & Sociology*, *41*(9), 963–970. https://doi.org/10.9734/ajaees/2023/v41i92127

Singh, S. (2026). Agriculture in the Indian economy: growth, employment, and structural challenges. *Social Science Journal for Advanced Research*, *6*(1), 73–77. https://doi.org/10.54741/ssjar/6.1.2026.321

Spielman, D. J., Lecoutere, E., Makhija, S., & Van Campenhout, B. (2021). Information and communication technologies (ICTs) and agricultural extension in developing countries. *Annual Review of Resource Economics, 13*, 177-201

Steinke, J., Van Etten, J., Müller, A., Ortiz-Crespo, B., Van De Gevel, J., Silvestri, S., & Priebe, J. (2020). Tapping the full potential of the digital revolution for agricultural extension: an emerging innovation agenda. *International Journal of Agricultural Sustainability*, *19*(5–6), 549–565. https://doi.org/10.1080/14735903.2020.1738754

Sürücü, L., & Maşlakçı, A. (2020). validity and reliability in quantitative research. *Business & Management Studies: An International Journal*. https://doi.org/10.15295/bmij.v8i3.1540.

Swynnerton, R. J. (1955). A plan to intensify the development of African agriculture in Kenya.

Swynnerton, R. J. M. (1954). *A plan to intensify the development of African agriculture in Kenya*. Government Printer.

Tambo, J. A., Uzayisenga, B., & Mugambi, I. (2020). Toward inclusive digital extension services: Evidence from a field experiment in Rwanda. *World Development, 135*, 105043.

Tegemeo Institute. (2023). *Utilization of digital agricultural extension services in Kenya: Technical report*. Egerton University

Thapa, M., Signorini, G., & Specht, A. (2025). Understanding factors influencing the adoption of digital tools among extension agents of Nepal. *Journal of Agribusiness in Developing and Emerging Economies*. https://doi.org/10.1108/jadee-07-2024-0221

Thayalan, K. J., Govindasamy, M., Shanmugam, S., Karuppiah, P., & Eswaranpillai, U. (2026). Predictive Modeling in Pest Dynamics: Forecasting Infestations with AI. In *Advancements in Entomology: Bridging Forensic Science and Sustainable Agriculture* (pp. 441-460). Singapore: Springer Nature Singapore

Thi Hoa Sen, L., Chou, P., Dacuyan, F. B., Nyberg, Y., & Wetterlind, J. (2024). Barriers and enablers of digital extension services' adoption among smallholder farmers: the case of Cambodia, the Philippines, and Vietnam. *International Journal of Agricultural Sustainability*, *22*(1). https://doi.org/10.1080/14735903.2024.2368351

Thirumal, A., Babu, G. S., Deepika, R. B., & Harish, B. P. (2026). Digital extension in Agriculture: A review of WhatsApp groups for information dissemination in

India. *Asian Journal of Agricultural Extension Economics & Sociology*, *44*(4), 125–135. https://doi.org/10.9734/ajaees/2026/v44i42916

Umunakwe, P., Madukwe, M., Anaeto, F., Nwakwasi, R., & Aja, O. (2025). Proficiency in Digital Extension Service Delivery among Public Agricultural Extension Personnel in Imo State, Nigeria. *Journal of Agricultural Extension*. https://doi.org/10.4314/jae.v29i1.7

Van Campenhout, B., Spielman, D. J., & Lecoutere, E. (2023). Learning through social media: How farmers use YouTube to manage climate risk. *World Development, 161*, 106100

Van Der Waldt, G. (2024). Constructing theoretical frameworks in social science research. *The Journal for Transdisciplinary Research in Southern Africa, 20*(1). https://doi.org/10.4102/td.v20i1.1468

Vutukuru, S. V., & Njagi, T. (2023). The Development of Digital Services and Their Utilization in Agriculture in Kenya

Waaswa, A., Nkurumwa, A. O., Kibe, A. M., & Kipkemoi, J. N. (2024). Adapting agriculture to climate change: institutional determinants of adoption of climate-smart agriculture among smallholder farmers in Kenya. *Cogent Food & Agriculture*, *10*(1). https://doi.org/10.1080/23311932.2023.2294547

Wahome, A., Kiema, J., Mulaku, G., & Mukoko, I. (2024). Characterization of Small-Scale Farmers and Assessment of Their Access to Crop Production Information in Selected Counties of Kenya. *Agricultural Sciences*. https://doi.org/10.4236/as.2024.155032

Wang, B., & Dong, H. (2023). Research on the farmers' agricultural digital service use behavior under the rural revitalization strategy—Based on the extended technology acceptance model. Frontiers in Environmental Science, 11. https://doi.org/10.3389/fenvs.2023.1180072

Warucu, R. G., & Lufuke, M. (2024). The impact of cooperative membership on adoption of modern technology by bee farmers in Kenya. *International Journal of Research and Innovation in Social Science*, *8*(III), 270-284

Wekesa, M. K., Ogemah, V., & Ndiema, A. C. (2025). The effect of devolved agricultural extension services on food production in Kwanza sub-county, Kenya. *African Journal of Empirical Research*, *6*(4), 1093–1102. https://doi.org/10.51867/ajernet.6.4.97

Willie, M. M. (2023). Distinguishing between population and target population: A mini review. *Surgery Research Journal, 3*(2). https://doi.org/10.33425/2768-0428.1027

Wooldridge, J. M. (2010). *Econometric analysis of cross-section and panel data* (2nd ed.). MIT Press.

Wosene, G., Pang, Y., Cao, J., Aynalem, M., & Jadoon, A. U. (2025). Socioeconomic drivers of adoption and use intensity of improved Teff seed in northwest Ethiopia. *Food Science & Nutrition*, *13*(10), e71030. https://doi.org/10.1002/fsn3.71030

Wyche, S., Steinfield, C., & Grue, A. (2020). Why don't farmers use cell phones to access market prices? Re-examining technology affordances and barriers to market information services adoption in rural Kenya. *Information Technology for Development*, *26*(2), 295-312

Yashabh, Naman, Fayaz, A., & Kaundal, M. (2025). Leveraging mobile technology to enhance agricultural extension Services: A review. *Archives of Current Research International*, *25*(7), 804–817. https://doi.org/10.9734/acri/2025/v25i71380

Yu, J., Bekerian, D. A., & Osback, C. (2024). Navigating the digital landscape: challenges and barriers to effective information use on the internet. *Encyclopedia*, *4*(4), 1665–1680. https://doi.org/10.3390/encyclopedia4040109

Yun, V. W. S., Ulang, N. M., & Husain, S. H. (2023). Measuring the internal consistency and reliability of the hierarchy of controls in preventing infectious diseases on construction sites: the Kuder-Richardson (KR-20) and Cronbach's Alpha. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *33*(1), 392–405. https://doi.org/10.37934/araset.33.1.392405

Zeng, D., Alwang, J., Norton, G., Jaleta, M., Shiferaw, B., & Yirga, C. (2018). Land ownership and technology adoption revisited: Improved maize varieties in Ethiopia. *Land use policy*, *72*, 270-279

APPENDICES

Appendix 1: Information Consent Form

MURANG'A UNIVERSITY OF TECHNOLOGY

Information Consent for research titled "Determinants of Adoption of Digital Agricultural Extension Services among Smallholder Farmers in Murang'a County, Kenya."

INFORMED CONSENT FORM

Principal investigator

Name: Okello Samwel

Affiliation: Murang'a University of Technology
Phone: +254706945782
Email: okellosamwel2019@gmail.com

Contact of the Ethics Committee

Murang'a University of Technology Institutional Scientific Ethics Review Committee.

Email: iserc@mut.ac.ke

Introduction

I'm Okello Samwel in the Department of Agricultural Extension and Economics, Murang'a University of Technology. I'm carrying out research on determinants of adoption of digital agricultural extension services among smallholder farmers in Murang'a County, Kenya. There are diverse factors that may limit the adoption of digital extension services, and they will be covered in this study. This study will support the formulation of policies, research, and programs in agricultural extension that are relevant to your context

Purpose of the study

The study seeks to examine the determinants of adoption of digital extension services among smallholder farmers in Murang'a County, Kenya

Voluntary participation, confidentiality, and data protection.

Before proceeding with the survey, I kindly ask for your consent to participate. Your involvement is entirely voluntary, and you may choose not to participate or withdraw at any time without any consequences. All responses will be treated with strict confidentiality and used solely for research purposes. The data collected will be anonymized, ensuring that your identity remains protected in accordance with the Kenya Data Protection Act (2019). Furthermore, your personal details will not be shared or stored unnecessarily.

Benefits and risks associated with participation

There is no risk associated with the study; ethical issues are considered. No direct benefit is guaranteed; nonetheless, the study findings will support agricultural extension services and the formulation of policies to support the farmers.

Duration

You are cordially asked to take part in this study by responding to the structured questionnaire or key informant interview. Participation will take approximately 20-30 minutes.

Consent statement

I have read and clearly understood the information provided above on this study. I have had the opportunity to ask questions to enhance my clarity, and all my concerns have been addressed satisfactorily.

☐ I agree to participate ☐ I do not agree to participate

Appendix 2: Letter of Introduction

Okello Samwel
P.O Box, 75 Murang'a
okellosamwel2019@gmail.com
0706945782
11th/04/2026

Murang'a University of Technology
P.O Box, 75-10200,
Murang'a

Dear Respondent,

RE: DETERMINANTS OF ADOPTION OF DIGITAL AGRICULTURAL EXTENSION SERVICES AMONG SMALLHOLDER FARMERS IN MURANG'A COUNTY, KENYA

I'm a postgraduate student in the School of Agriculture and Environmental Sciences at Murang'a University of Technology, pursuing a Master's Degree in Agricultural Extension. As a requirement for the award of a degree in this course, I am required to conduct research. I intend to conduct research on the determinants of adoption of digital extension services among smallholder farmers in Murang'a County, Kenya.

I'm intending to choose participants who engage in crop and livestock husbandry within Murang'a County. As a result, I humbly request that you engage voluntarily in responding to the study questionnaires. All responses will be treated with strict confidentiality and used solely for research purposes. The study will be instrumental in determining factors affecting digital adoption in Murang'a County, Kenya.

Thank You

Yours sincerely
Okello Samwel

Appendix 3: Study Questionnaire

This questionnaire seeks to gather data on the determinants of the adoption of digital agricultural extension services in Murang'a County, Kenya. All responses will be treated with strict confidentiality and used solely for research purposes.

Questionnaire No:

General information

Enumerator	Sub-County
Date	Ward

A: Socio-Economic Information

This section seeks to capture information on the socio-economic characteristics of smallholder farmers in Murang'a.

What is your age in years?.....	1=<30 years 2=30- 44 years 3= 45 - 60 years 4=>60 years
Gender of respondent	1= Male, 0= Female
Indicate the Marital status	1=Single 2=Married 3=Divorced/ Separated, 4=Widowed, 5=Others, specify
Household size	1=1-2 2=3-5 3=6-8 4= >8
What is the highest level of education you have completed	1=No formal education 2=Adult education 3=Primary education 4= Secondary education 5= Tertiary education (college /certificate/diploma) 6=University education (degree or higher)?

If you completed secondary education, did you study agriculture as a subject in school?	1=Yes 0=No
What is your current employment status (select one)?	1.Unemployed 2=Fulltime employment 3=Part-time employment 4=Formally employed (with contract). 5=Self-employment
What are your two main sources of livelihood? (Please select TWO main options)?	1) Farming/livestock (own farm, family farm or leased land) 2)Agricultural wage labor (working on others' farms for pay) 3) Off-farm formal employment (salaried job with a contract, e.g., teacher, government NGO, company) 4) Off-farm informal employment (Casual labor, vending, boda boda, tailoring, domestic work, etc.) 5) Entrepreneurship – SMEs, business 6)Other (Specify
Are you currently engaged in any form of farming or agricultural activity?	1=Yes, please specify 0=No
. How many years have you been involved in farming/agricultural activity?	(Number of years)
. How would you describe the scale of your farming operation? (Select one)	1. Subsistence (mainly for home consumption) 2. Small-scale commercial (small surplus for sale) 3. Medium-scale commercial (regular sales, moderate income) 4. Large-scale commercial (significant production for markets/business)

12. Please provide your average monthly income range (KES) (Select one option)

1=Less than 10,000 2=10,001 – 20,000 3=20,001 – 30,000 4=30,001 – 40,000 5=40,001 – 50,000 6=50,001 – 75,007=75,001 – 100,000 8=Over 100,000 9=Prefer not to say

13. What is your average monthly food expenditure in KES?

14. Indicate monthly non-food expenditure in Ksh (school fees, leisure, clothing, fuel, airtime, rent, etc.)

Institutional factors affecting the adoption of DES

Resources	**Response**
Do you have access to agricultural land (including owned, inherited, or leased land?	1=Yes 0=NO
If yes, what is the total land size you use for agricultural activities (in acres)	
What is the status of land tenure for the land?	1=Owned (with title deed) 2=Owned (without title deed) 3=Inherited 4=Leased 5=Communal land 6=Other, please specify
Would you consider the soil on your farm to be fertile?	1=Yes 0=NO
Have you had access to credit/loan in the last 12 months?	1=Yes 0=NO
If yes, what are the primary sources of credit (main 2)	1= Mobile-based sources (e.g. mobile money loans) 2=non-governmental organization (NGO), 3=Formal lender (bank/financial institution), 4=Informal lender (e.g., money lenders like shylock) ,5=Friends/relatives, 6=Group-based microfinance (e.g.,

	SACCOs), 7=Informal credit systems (e.g., merry-go-rounds)
Have you accessed the agricultural extension services in the last 12 months	1= YES 0= NO
Have you received any agricultural training in the last 12 months?	1= YES 0= NO
If yes, kind of topics covered *(Select all that apply)*	1=Livestock management 2=Crop production and agronomy 3=post-harvest handling and value addition 4= Marketing and Market survey 5=Climate-smart agriculture and agroecology 6. Use of digital tools and ICT for agriculture 7=Group management/cooperative governance 8= Financial literacy or record-keeping 9=Youth and women empowerment 10= Other (specify)
What is the distance to the nearest agricultural market (KM)	
Indicate the name of the market	
On average, how much time (in minutes) does it take you to reach this market?	1=Less than 15 minutes 2=15–30 minutes 3=31–60 minutes 4=More than 1 hour
Have you received any government support for agriculture– NAVCDP, seeds, fertilizer, training?	1=Yes 0=No, if yes, specify

SECTION C: AWARENESS OF DIGITAL EXTENSION SERVICES

15. Are you aware of any digital extension service for agricultural information? 1=Yes 0 =No

16. If YES, how did you first learn about Digital Extension Services? (Select all that apply)

i) Farmer organizations – groups, associations and cooperatives
ii) Agricultural extension officers
iii) Social media or mass media (e.g., radio, TV, newspapers, Facebook, Twitter, LinkedIn)
iv) NGO or development project
v) Training/workshops or agricultural expos
vi) Mobile service providers (e.g., SMS alerts, mobile apps)
vii) Peers/neighbors/family
viii) Other (please specify)

C 2: Awareness, Level of Awareness, and Use of Digital Agricultural Extension Services.

For each digital platform or service listed below, please:

- Indicate if you are **aware** of it (1 = Aware, 0 = Not Aware)
- Rate your **level of awareness** on a scale of 1 to 5 *(1 = Not aware at all, 5 = Very much aware)*
- Indicate if you have **used** it to access agricultural information (1 = Yes, 0 = No)

Type of digital extension service/platform	**Aware 1=Yes 0=No**	**Level of awareness 1-5**	**Use/Access 1=Yes, 0=No**
Mobile phone services (e.g., calls, SMS alerts, push messages)			
Mobile apps (e.g., iShamba, KALRO App)			
Digital Green Video Programmes			

Social media platforms (e.g., TikTok, WhatsApp, Facebook, X)			
Government platforms (e.g., e-kilimo)			
Digital TV or radio for farmers e.g., Shamba Shape-Up, Mugambo wa Murimi (the 'Farmer's Voice)			
Marketing platforms (E-soko, M-farm)			
Weather Information platforms (e.g., KARLO Weather App)			
Internet Searches e.g., Google)			
. Use of AI tools (e.g., ChatGPT)			
. Online portals/websites (e.g., ministry or NGO websites)			
. Other, Specify			

17. How do you primarily access the internet when you want digital extension information (**select only one option)? 1=**Mobile purchased data bundles 2=Wi-Fi 3=Shared hotspot from another device 4=Cyber Cafe

18. On a scale of 1-5, 1=Strongly Disagree and 5=Strongly Agree, to what extent do you agree or disagree with the following statements regarding digital extension services

Statement	**Rate (1-5)**
Internet cost is affordable	
I possess enough skill to navigate the digital extension service.	
I feel confident in using digital tools	
I have access to digital devices	

SECTION D: UTILIZATION OF DIGITAL EXTENSION SERVICES

19. How long have you been using digital extension services? 1=Less than 1 year 2=1 to 3 years 3=4 to 5 years 4=More than 5 years

20. Which type of agricultural information do you usually seek through digital extension services?

Agricultural information	**1=Yes, 0=No**
Financial advice	
Weather information	
Best farming technologies/ practices	
Market information – prices, quality etc.	
Crop specific advice, such as pest and disease control	
Access to farm inputs	
Value addition information	
Post-harvest handling and storage	
Government subsidies/policies	

34. To what extent has information obtained from digital extension services influenced your decision-making in farming? 1=Not at all 2=Somewhat 3=Moderately 4=Very much 5=Extremely much

35. Using a scale of 1-5, to what extent to agree or disagree with the following statements about digital agricultural extension service?

Statement	**Rate (1-5)**
Digital extension services (DES) can reduce overreliance on the traditional extension system.	
DES provides personalized agricultural information.	
DES provides timely agricultural information.	
DES has improved my farm income.	
DES is reliable	
DES is more cost-effective than conventional extension services.	

36. What challenges have you encountered that hinder your awareness, access and utilization of digital extension services? **(Select three main ones)**

1=High internet cost 2=Skepticism in digital tools 3=Limited access to smartphone 4=Limited digital literacy 5=Lack of timely updates 6=Poor mobile connectivity 7=Language barrier 8=Lack of electrical power 9=Privacy concerns 10=Insufficient knowledge of existing services 11=Limited trust in digital information 12=No challenge 13. Other, specify

37. What would make it easier for you to use digital extension services more frequently? Specify

Thank the respondent and leave

Appendix 4: Approval for research

MURANG'A UNIVERSITY OF TECHNOLOGY
Office of the Director, Postgraduate Studies
E-mail: bps@mut.ac.ke
Website: www.mut.ac.ke
P.O. Box 75-10200
Murang'a, Kenya

Ref: MUT/ARP/PGS/19/2020 /VOL.1 **Date:** 5th May, 2026

Mr. Samwel Okello – GR402/5181/2024,
School of Agriculture and Environmental Sciences,
Murang'a University of Technology,
P.O. Box 75-10,200
Murang'a.

Dear Mr. Okello,

RE: APPROVAL OF RESEARCH PROPOSAL AND SUPERVISORS.

I am pleased to inform you that the Directorate of Postgraduate Studies on 23rd April, 2026 considered and approved your Master research proposal entitled ***"Determinants of Adoption of Digital Agricultural Extension Services Among Small Holder Farmers in Murang'a County, Kenya."*** and appointed the following as supervisors:

1.Dr. George Mose - Murang'a University of Technology

2.Dr. Marther Ngigi - Murang'a University of Technology

You may now proceed with your collection subject to obtaining research permit from NACOSTI, if required. You should also begin consulting your supervisors and submit through them quarterly progress reports to the Director Postgraduate Studies through your CoD and School Dean. Progress Reports forms can be accessed in the Student Portal.

It is the policy and regulations of the University that you observe deadlines. The guidelines on Postgraduate supervision can be accessed in the post graduate Handbook.

Your responsibilities as a student will include, among others;

i. Maintain regular consultation with your supervisor(s), at least once a month
ii. Submit quarterly reports on time, through your supervisors, CoD, Dean and to the Director of Postgraduate Studies;

iii. Ensure quality work all through;
iv. Present your research findings at 2-3 seminars/conferences prior to thesis examination.
v. Publish one article from your research findings in a refereed journal prior to thesis examination.

For any further clarification please contact the undersigned.

Yours Sincerely,

Prof. Geoffrey Muchiri, PhD
Director, Postgraduate Studies
GM/MMK

DIRECTORATE OF POSTGRADUATE STUDIES
MURANG'A UNIVERSITY OF TECHNOLOGY
0 6 MAY 2026
P. O. Box 75 - 10200, MURANG'A
Tel: 0771453515, Email: info@mut.ac.ke

Copy to:
1. Registrar, Academics, Research and Students Affairs
2. Dean, School of Agriculture and Environmental Sciences

Appendix 5:MUT ISERC

OFFICE OF INSTITUTIONAL SCIENTIFIC ETHICS REVIEW COMMITTEE
MURANG'A UNIVERSITY OF TECHNOLOGY
Website: www.mut.ac.ke ; Email: iserc@mut.ac.ke

Ref: **MUT-ISERC/A/026** 9TH FEBRUARY 2026

OKELLO SAMWEL
Reg. No: GR402/5181/2024

Dear Samwel,

RE: Determinants of Scaling Digital Agricultural Extension Services among Smallholder farmers in Murang'a County, Kenya (P027/1/2026)

This is to inform you that the Murang'a University of Technology Institutional Scientific Ethics Review Committee (MUT-ISERC) has reviewed and **approved** your above research proposal. The approval period is **9th February 2026 to 8th February 2027.**

This approval is subject to compliance with the following requirements:

a) Only approved documents (informed consents, study instruments, advertising materials etc) will be used.
b) All changes (amendments, deviations, violations etc) are submitted for review and approval by MUT-ISERC before implementation.
c) Any adverse events (death, life-threatening problems) whether related or unrelated to the study, must be reported to the MUT-ISERC within 72 hours of occurrence.
d) Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to MUT-ISERC within 72 hours.
e) Clearance of export of biological specimens must be obtained from relevant institutions.
f) Submission of Progress reports at a regular interval, at least every 6 months.
g) Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. (*Attach a comprehensive progress report to support the renewal).*
h) Submission of an *executive summary* report within 90 days upon completion of the study to MUT-ISERC.

Prior to commencing your study, you will be expected to obtain a research license from NACOSTI, and other clearances as applicable.

Yours sincerely

Dr. D. Otieno, PhD
Chairman, Murang'a University of Technology ISERC

INSTITUTIONAL SCIENTIFIC ETHICS REVIEW COMMITTEE
MURANG'A UNIVERSITY OF TECHNOLOGY
09 FEB 2026
CHAIRMAN

MUT IS ISO 9001: 2015 & ISO/IEC 27001

Appendix 6: NACOSTI permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **461374**

Date of Issue: **19/February/2026**

RESEARCH LICENSE



This is to Certify that Mr.. SAMWEL OKELLO of Murang'a University of Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Muranga on the topic: DETERMINANTS OF SCALING DIGITAL AGRICULTURAL EXTENSION SERVICES AMONG SMALLHOLDER FARMERS IN MURANG'A COUNTY, KENYA: TRENDS, ACCESS, AND POLICY CONTEXTS for the period ending : 19/February/2027.

License No: **NACOSTI/P/26/4185271**

461374

Applicant Identification Number

Ag. Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix 7: Publication

This thesis has produced the following publication:

Okello, S, Mose, G. N. & Ngigi, M. (2026). Analysis of Current Landscape and Emerging Trends in Digital Agricultural Extension Services among Smallholder**.** Farmers in Kenya. East African Journal of Agriculture and Biotechnology, 9(2), 316332. https://doi.org/10.37284/eajab.9.2.5430