Effectiveness of ICT Tools in Disseminating Agricultural Information to Enhance Smallholder Farmers' Crop Productivity in Mbombela

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A research dissertation submitted for the Master of Agriculture in Agricultural Extension and Rural Resource Management

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UNIVERSITY OF MPUMALANGA

May, 2026

Declaration

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TITLE OF PROJECT: Effectiveness of ICT tools in disseminating agricultural information to enhance smallholder farmers' crop productivity in Mbombela

DECLARATION:

In accordance with **Rule,** I hereby declare that the above-mentioned dissertation/ thesis is my own work and that it has not previously been submitted for assessment to another University or for another qualification.

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Dedication

This research study is dedicated to myself, in recognition of my tireless academic efforts and personal sacrifices. I also dedicate this study to Leenetse Ntsoane, Edmond Ntsoane, Kingsley Marumo Talane and Ditebogo Kaia Ntsoane. I aspire for my academic journey to motivate them to seize educational opportunities and encourages them to live by the saying “Kodumela moepa thutse, ga go lehumo le letswago kgauswi.” May they always remember the value of hard work, persistence and the importance of education. I love you, and I hope this accomplishment serves as an inspiration for their own future.

Acknowledgements

Firstly, I want to thank the Lord Almighty for His mercy, which has granted me the opportunity to advance my studies and the fortitude to complete my Master's dissertation.

Secondly, I want to express my sincere gratitude to the following:

Academic Supervision

1. The work would not have been possible without the expert direction, endurance, knowledge, and guidance of my supervisors, Dr. JT Ndoro and Professor N. Wayi-Mgwebi. Your unwavering commitment to academic excellence and insightful recommendations have been crucial to the effective conclusion of this research.

Research Support

2. I would like to convey my profound appreciation to Ms Randy Cossa, Mr Mfanufikile Mabuza and Mr Welcome Zondo for their evaluations and scholarly guidance, which facilitated the successful completion of this research study.

Institutional Support

3. I am grateful to the CSIR HCD-Interbursary for their financial support.

4. Gratitude is extended to the agricultural extension personnel and smallholder farmers of Mbombela Local Municipality for their perspectives, patience, and expertise that contributed to this study. Their support facilitated the accomplishment of this study.

Personal Support

5. My parents, Mr Nthekgo Ntsoane and Mrs Kgolane Ntsoane. I am grateful for the opportunities you have provided me with to improve myself, particularly the encouragement of education, and for gift of life.

6. My siblings, Mr Eshley, Ms Punky, Dr. Pearl and Ms Leenetse Ntsoane. May my journey in academia serve as an inspiration to all. You continue to show me the way, and I am grateful for your unwavering love and support.

7. My friends, Ms Prayer Monamodi, Ms Thando Dyanty, Ms Adelaide Magakwe, Mr Mahlatsi Moepya and Mr Lifa Rodney Thabethe who taught me to "keep swimming." When circumstances compelled me to give up, your encouragement and belief in my abilities sustained my determination to succeed.

Abstract

Sustainable improvement in the crop productivity of smallholder farmers is one of the most persistent challenges in agricultural development in South Africa. Despite being acknowledged as the major contributors to local food security and the economy, smallholder farmers' productivity hinges largely on access to accurate and reliable information. Smallholder farmers are characterized as individuals who tend to make uninformed production decisions, resulting in poor yields due to agricultural information asymmetry within rural communities. The knowledge intensity of the agricultural sector requires an adequate flow and sharing of information among agricultural stakeholders. Therefore, it is necessary to encourage the use of information and communication technology tools, as they are a key source of agricultural information. This will help alleviate the shortage of agricultural information among smallholder farmers.

The adoption and utilisation of ICT tools, such as radio, TV, mobile phones, and computers, is rapidly increasing among rural farming communities. However, it is yet unknown how well ICT tools are utilised to disseminate agricultural information to improve agricultural activities. Therefore, this study contributes to the existing literature on the use of ICT among smallholder farmers by investigating the effectiveness of ICT tools in disseminating agricultural information to enhance smallholder farmers crop productivity in Mbombela Local Municipality of South Africa. The study was conducted under the framework of the Uses and Gratification theory to investigate the effectiveness of ICT tools and its impact on crop productivity. The quantitative research used cross-sectional survey and structured questionnaire to collect data from 308 respondents. Respondents were selected using systematic sampling.

The survey results indicated that female smallholder farmers (195) outnumbered their male counterparts. Most respondents were elderly, aged 55 and above (132), and a significant portion (71.8%) had some formal education. The majority of respondents were married (40.6%) and lived in households with 6-10 members. Most owned agricultural land, with farm sizes of less than 5 hectares, and had 6-10 years of farming experience. Additionally, many respondents were members of farmers' organizations. The findings showed that 78.2% produced crops primarily for household consumption and sold surplus for income, with vegetables being the most common crops grown. Regarding ICT use, 62% accessed agricultural information through technologies like radio, TV, and mobile phones, while others relied on fellow farmers and public extension services. Respondents were familiar with ICT farming programs, including Niche Farmers on TV, Ezokulima on radio, Facebook on smartphones, and phone calls on basic cell phones.

Propensity Score Matching findings indicated that the use of ICT tools to access agricultural information resulted in an improvement in agricultural production. This was demonstrated by the higher number of improved crop varieties used, the application of fertiliser and pesticides, achieved yield and generated income in comparison to non ICT users. Descriptive findings indicated mobile phone was perceived effective on ease of use, accessibility, efficient delivery of timely information and feedback with a mean value of over 3.0. In addition, radio was perceived effective in delivering relevant information and easily accessible with a mean value of over 3.0. Empirical results revealed that variables such as language use, ICT literacy and ICT awareness were statistically significant at a p-value of < 0.01 and positively influencing the use of ICT tools by smallholder farmers for accessing agricultural information. Age, educational level and power outages were found statistically significant at a p-value of < 0.01 while cooperative membership was significant at p-value of < 0.05 respectively and inversely influencing the use of ICT tools by smallholder farmers for accessing agricultural information.

Based on the results, the study concludes that smallholder farmers use ICT tools to access agricultural information, with these tools proving to be effective communication channels between farmers and information sources. This is evident from the positive attitudes toward both traditional and modern ICT tools, as well as their beneficial impact on crop productivity and livelihood outcomes. These benefits include improved access to information, increased yields and income, and better input usage. However, socio-economic variables seem to be inversely militate efficient utilisation of ICT tools by smallholder farmers. In order to maximise the advantages of ICT tools in agricultural production and enhance usability, the study suggests that agricultural personnel should initiate agricultural participation campaigns aimed at increasing youth involvement, emphasising their better utilisation of ICT tools and the resultant contributions to the local economy. The study also suggests that agricultural personnel should conduct ICT awareness programs to educate smallholder farmers on the use of accessible and user-friendly ICT tools that can enhance their farming practices.

Keywords: Information Communication Technology, Productivity, Agricultural information, Impact, Enhance and Effectiveness

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Abbreviations and Acronyms

ATT: Average Treatment Effect on the Treated

DARDLEA: Department of Agriculture Rural Development, Land and Environmental Affairs

df: Degree of Freedom

DID: Difference IN Difference

FAO: Food and Agriculture Organization

ICT: Information Communication Technology

IDP: Integrated Development plan

IV: Instrumental Variables

KBM: Kernel-Based Matching

MIS: Market Information System

NGO: Non-Governmental Organisation

NNM: Nearest Neighbor Matching

NS: Non Significant

PHI: Pre-Harvest Interval

PSM: Propensity Score Matching

RM: Radius Matching

SD: Standard Deviation

SLF: Sustainable Livelihood Framework

SLH: Sustainable Livelihood Framework

SMS: Short Messages Systems

SPSS: Statistical Package for Social Sciences

Stats SA: Statistics South Africa

TV: Television

Chapter One: Introduction

1.1 Background of the study

Agriculture plays a crucial role in South Africa's economy, contributing approximately 15% to the Gross Domestic Product and supporting the livelihoods of a significant portion of the population (Kenneth and Onyedikachi, 2021). It is key to economic growth, poverty reduction, and environmental sustainability (Oladele, 2015; Zwane, 2019). However, agricultural development is often hindered by information gaps, which can be addressed by meeting farmers' information needs (Chipfupa and Wale, 2018). Accurate, timely, and relevant information is crucial for farmers to make informed decisions and address farm-related challenges, thereby improving productivity (Acheampong, Frimpong, Adu Appiah, and Asante, 2017; Rust, 2022). Farmers require diverse agricultural information, including climate, agronomy, biotechnology, and inputs such as chemicals or organic (Kacharo, Mvena, and Sife, 2019). For many years, smallholder farmers have relied on interpersonal communication methods, such as extension agents and local networks, to access this information (Shemfe, 2018; Mavhunduse and Holmner, 2019). Despite the availability of multiple information sources, farmers face difficulties in accessing and utilizing them effectively due to challenges like a shortage of extension workers, inadequate infrastructure, and limited funding, which hinder the efficient dissemination of agricultural knowledge (Levi, Kyazze, and Seguya, 2015; United Nations Department of Economic and Social Affairs, 2005). To overcome these challenges, adopting alternative strategies such as incorporating communication technologies into agricultural extension services is crucial (Food and Agricultural Organisation, 2019).

Agricultural ministries in African Countries have made efforts to increase smallholder farmers' access to agricultural information and services by incorporating ICT into agricultural information delivery (Aker, 2010; Akuku, 2014; Ogbeide and Ele, 2015; Consolata, 2017; Emeana, Trenchard and Dehnen-Schmutz, 2020). The integration of ICT tools has become crucial for providing farmers with access to technical and market information, improving efficiency and productivity across agricultural value chains (Hopestone, 2014; Mwantimwa, 2019; Spielman, Lecoutere, Makhija and van Campenhount, 2021). Smallholder farmers are benefiting from the timely information provided by ICT tools, which aids in rural agricultural growth (Demiryürek, 2010; Sithole, Parker, Molotia and Labadarious, 2013). ICT tools have shown to be an effective means of disseminating agricultural information to the farming community. As it facilitates the sharing of knowledge among farmers, which increases crop yields by making information on cutting-edge techniques, sustainable practices, and methods for reducing input and output costs available to farmers. ICT tools in addition to more conventional means of disseminating agricultural knowledge, are considered as a viable option for improving advisory services in the agricultural sector across African nations (Setu, 2021). However, smallholder farmers in rural areas continue to lack a comprehensive access as well as understanding of agricultural knowledge and practices brought by advisory services. This knowledge is intended to assist in the efficient utilisation of production inputs and to introduce farmers to improved farming methods that foster sustainable productivity (Munyua, Adera and Jensen, 2015).

Local economy of African countries is confronted by the constraints associated with enhancing agricultural outputs (Setu, 2021). In South Africa, the crop productivity of smallholder farmers is being restricted by the current slow growth of the local economy, as well as the high costs of agricultural inputs, water scarcity, and limited access to agricultural information (Matlou, 2018). Improving rural farmers' income and crop productivity hinges on timely access to accurate information (Kaske, Mvena and Sife, 2018; Nyarko and Kozari, 2021). According to Wale and Mkuna (2023), in order for smallholder farmers to make informed decisions about their farms and improve crop production and productivity, they require accurate, relevant, and timely information. To help smallholder farmers increase their yields, ICT tools techniques have emerged as crucial in recent years (Spielman, Lecoutere, Makhija and Van Campenhout, 2021). Smallholder farmers that employ ICT tools in their farming have more knowledge about farming and produce more crops. ICT tools are also employed in agricultural distance learning programs to assist smallholder farmers in acquiring new technologies and practices for the purpose of agricultural development in African countries (Chapman and Slaymaker, 2002; Siraj, 2011; Chhachhar, Qureshi, Khushk and Ahmmed, 2014). Considering the increased use of ICT tools in agriculture Oladele (2015), highlighted that smallholder farmers can find an assortment of beneficial agricultural information on several communication channels. However, due to a lack of digital literacy among smallholder farmers, such crucial information is embedded and challenging to locate (Bertolini, 2004).

A lack of knowledge and experience with ICT tools and their applications in farming is one of the main impediments to their widespread use and adoption by smallholder farmers (Kabir, 2015). To ensure that smallholder farmers in South Africa know how to use ICT technologies for farming, agricultural extension agents uses a variety of methods, techniques, and programs to support these farmers (Shemfe and Modirwa, 2018). In 2011, the South African Department of Agriculture, Forestry and Fisheries (DAFF) introduced the Extension Recovery Plan (ERP) to help restore and enhance the availability of extension services and agricultural information. Liebenberg (2015) outlined five guiding principles for the program. The first was to ensure that extension work was responsible and of measurable quality. The second was to ensure that extension workers were competent and that their perspectives on extension and other stakeholders' roles were improved. The third was to recruit and train extension officers in agricultural innovation, reskilling, and re-orientation. Lastly, the program aimed to make internet- and mobile-based ICT infrastructures, including radio, laptops, phones, digital pens, and Extension Suite Online, available to the sector. Despite these efforts, in many South African rural areas there is still agricultural information scarcity and low ICT usage for farming purposes (Mavhunduse and Holmner, 2019; Wale and Mkuna, 2023).

There are a number of elements that determine how the aforementioned ICT technologies are used. For instance, they are most commonly utilised when the kind is well-known, well-understood, and generally accepted throughout societies (Dunne, 2016). According to Karlo (2017), ICT tools have an immense amount of potential for farmers, businesses, and investors to boost agricultural efficiency, production, and access to information. The efficient and coordinated distribution of relevant agricultural information is crucial to ensuring the effectiveness of these tools (Halewood and Surya, 2012). The ability to provide many services simultaneously and facilitate two-way contact makes these tools useful for offering information services (Sife, 2010). By enhancing access to technological advances, production inputs, and market information, ICT tools efficiently improve agricultural activities in terms of saving time and expense of information access. In addition, there are both the direct and indirect effects of the ICT tools on poverty alleviation. Agricultural commercialisation leads to the development of jobs, which is an indirect benefit, and greater earnings from agricultural production, which is a direct benefit (Kaini, 2007; Akere, 2011; Setu, 2021).

1.2 Problem Statement

Meeting smallholder farmers' information needs is a key challenge for agricultural stakeholders (World Bank, 2011). Smallholder farmers in rural areas rely on farming for livelihood, yet they lack the knowledge, techniques, and resources necessary for agricultural production that would allow them to transition from subsistence to commercial farming (Murray, Gebremedhin, Brychkova and Spillane, 2016; von Loeper, Musango, Brent and Drimie, 2016; Saidu, Clarkson, Adamu, Mahammed and Jibo, 2017). The vast majority of smallholder farmers lack access to a single point of contact where they can acquire all the information they need. Radio, television, cell phones, government extension services, and fellow farmers are the most prevalent ways that they get information (Zodidi, 2022). According to the Food and Agriculture Organisation (2017), most smallholder farmers in developing countries do not have access to consistent and reliable information. As a result, they often make decisions based on a mix of different sources, which can be inconsistent, as well as their own traditional knowledge, experience, and estimations.

ICT emerge as pathways that help overcome communication gaps that hinder the rapid transfer of knowledge, necessary for increasing agricultural output and development (Nyareza and Dick, 2012; Akuku, 2014; Chhachhar, Qureshi, khushk and Ahmed, 2014; Adamu, Mohammed and Jibo, 2017; Tadesse and Bahiigwa, 2015). A key constraint on agricultural development and productivity is the relationship between the information needed by smallholder farmers and the time relevance of information usability (Makaula, 2021). Insufficient timely access to relevant agricultural information and services constitutes one of the numerous barriers that hinder smallholder farmers' productivity (Khapayi and Celliers, 2016). This leads to inefficient decision-making, lower adoption of agricultural innovations, and lower income and production in the agricultural sector. As a result, smallholder farmers have challenges in achieving their livelihood outcomes, such as generation of improved income and food security (Food and Agriculture Organisation of the United Nations, 2017).

A rapid increase of ICT tools usage in agriculture is recognised as the potential solution to the agricultural information inconsistency in rural areas, particularly having a negative influence on farmers' attainment of livelihood outcomes (Tumbo, Mwalukasa, Fue, Mlozi, Haug and Sanga, 2018; Nwafor, Ogundeji and van der Westhuizen, 2020; Okello, Keleke, Gathungu, Owvor and Ayuya, 2020). Regardless of the acknowledged advantageous use of ICTs in agricultural development worldwide, research on this area remains limited in South Africa (Mukasi, 2015). Preceding studies concerning utilization of ICT tools within agricultural sector in South Africa focussed on the usage of ICTs as a tool for agricultural transformation and development among smallholder farmers (Shemfe, 2018; Dlamini and Ocholla, 2018; Makaula, 2021; Nkambule and Agholor, 2021; Feju, Malgas and Phiri, 2023). The research scope broadened with a focus on the effects of ICT use in enhancing market participation among smallholder farmers (Nwafor, Ogundeji and Westhuizen, 2020; Zodidi, 2022). However, there is still a lack of literature that thoroughly examines the effectiveness of ICT tools in improving smallholder farmers' crop productivity through the delivery of agricultural information that is timely, relevant, and easily accessible. This study seeks to address this gap in knowledge by examining the effectiveness of ICT tools in dissemination of agricultural information to enhance smallholder farmers' crop productivity in Mbombela Local Municipality, South Africa.

1.3 Aim

To investigate the effectiveness of ICT tools in dissemination of agricultural information to enhance smallholder farmers' crop productivity.

1.4 Objectives

- To assess smallholder farmers' perception on the effectiveness of ICT tools in disseminating agricultural information on crop productivity.
- To evaluate the impact of ICT tools on crop productivity among smallholder farmers.
- To investigate constraints influencing smallholder farmers access to agricultural information through ICT tools.

1.5 Research questions

- What is the smallholder farmers' perception on the effectiveness of ICT tools in disseminating agricultural information on crop productivity?
- What is the impact of ICT tools on crop productivity among smallholder farmers?
- What are the constraints influencing smallholder farmers access to agricultural information through ICT tools?

1.6 Significance of the study

This investigation is significant considering that it differs from previous research conducted in South Africa in numerous respects. Initially, the study is unique for the reason that it is the initial attempt nationwide to comprehensively investigate the effectiveness of ICT tools in the dissemination of agricultural information to improve crop productivity of smallholder farmers. This investigation encompasses all attributes of effectiveness, including the ability to disseminate timely and relevant information, the accessibility and ease of use of the information channels, and the ability to facilitate feedback. Secondly, it surpasses preceding endeavours by conducting counterfactual analysis to evaluate the impact of ICT tools on the productivity of crops of both ICT users and non-ICT users. The objective of the study is to offer insights that can be used to inform effective policies and strategies for smallholder farmers to effectively utilise ICT tools, thereby enhancing their productivity and well-being. The main objective of the research is to investigate about how smallholder farmers' crop productivity is influenced by the information that they get through ICT tools and how various factors affect that access. This study aims to make a substantial contribution to the current body of literature and knowledge base on the use of information and communication technologies in agriculture by exploring the intricate relationship between smallholder farmers who utilise ICT tools to get agricultural information and their counterparts. This research seeks to offer insightful information to policymakers in addition to its academic contribution. Policymakers can promote ICT usage and expand its overall access in the targeted area and rural areas in general by understanding the subtle dynamics of smallholder farmers' ICT usage and its relation to crop productivity. The goal of this research is to help smallholder farmers in rural areas make better use of ICT tools and implement more sustainable agricultural practices for enhanced crop productivity.

1.7 Limitation of the study

The researcher encountered several challenges throughout the course of this study. At the outset, many participants were reluctant to participate in data collection, primarily due to the lengthy and time-consuming questionnaire. Arranging appointments with officials from Mbombela Local Municipality also proved difficult, as scheduled meetings were postponed several times, which delayed the data collection process. Additionally, a significant number of respondents were not fluent in English, requiring interpretation of questions into their native language. This led to occasional uncertainty about the accuracy of translations, and at times, the responses did not align with the expected answers, potentially reflecting certain biases. Furthermore, the study focused on a sample of only 308 smallholder farmers within Mbombela Local Municipality, which does not provide a representative overview of smallholder farmers across Mpumalanga or South Africa as a whole. Therefore, the findings cannot be generalized to smallholder farmers in other regions or municipalities within the country.

1.8 Definition of terms

Smallholder farmer

The definition of smallholder farmers varies across different sources. Some definitions focus on land size, others on production levels, and others on the availability of resources (Mudhara, 2010; Cousins, 2013; Van Averbeke, 2011; Thamaga-Chitja and Morojele, 2014). Cousins (2010), for instance, defines smallholder farmers as those who cultivate small plots of land and supplement their income through other means, such as social grants. Similarly, Nagayets (2005) defines them as farmers who own farms of two hectares or less. Ngemntu (2010) describes smallholders as black rural households engaged in farming activities on small plots. Mvelase (2017) suggests, these farmers live on communal land, with no individual land rights, and primarily produce food for household consumption, rarely for sale. In contrast, Khapayi and Celliers (2016) define smallholder farmers as those actively participating in formal markets and eager to increase their production and sales. According to the South African Department of Agriculture (2015), smallholder farmers produce food both for household use and for market sales, earning steady income from their farming activities, with the potential to expand into commercial farming given the right support in terms of technical, financial, and managerial resources. Smallholder farmers are not a uniform group, and their agricultural practices and needs vary according to their individual circumstances, which makes defining them challenging (Pienaar, 2013; Tshoni, 2015; Fanadzo and Dube, 2018).

Information communication technology

ICT can be described as a combination of hardware, software, and communication tools that facilitate the processing, management, and sharing of information and knowledge (World Bank, 2002; Ajayi, 2009; Syed, Urooj, and Meela, 2016; Olayemi, 2020). Oladele (2015) defines ICTs as all technologies that enable the effective and economical transfer of information. Ologundudu and Eniola (2021) explain that ICTs are technologies that support communication, as well as the electronic handling and distribution of information. According to the World Bank (2011), ICT refers to any device, tool, or application that allows for the transfer or gathering of data through interaction or transmission. ICT encompasses both Internet-based technologies and mobile technologies relying on wireless networks, including devices such as radios, televisions, landline phones, mobile phones, and computers (Pawar and Yadav, 2021). Adejo and Haruna (2010) classify ICT into traditional ICT (such as radio and television) and modern ICT (such as telephones, computers, and the Internet). In agriculture, ICT refers to the networks, mobile technologies, services, and applications that assist in the exchange, management, and processing of data and information for particular groups (Kiambi, 2018).

Agricultural Extension service

Agricultural extension services are organizations created by the Department of Agriculture to guide and advise farmers on effective practices and technologies that enhance production and profitability, ultimately aiming to enhance rural livelihoods (Shemfe, 2018). These services can also be seen as a network of organizations that assist individuals involved in agricultural activities, helping them address challenges and acquire the knowledge, skills, and technologies needed to improve their quality of life (Hlatshwayo and Worth, 2019). Agricultural extension services provide farmers with technical advice and deliver essential inputs and services that support agricultural production. They also share information with farmers and introduce new ideas and innovations developed by agricultural research institutions (Food and Agricultural Organisation of the United Nations, 1985). Extension programs encompass a wide range of topics, including improved crop varieties, better livestock management, efficient water usage, and the management of weeds, pests, and plant diseases. In some cases, agricultural extension may also focus on helping to form local farmers' groups and organizations, enabling them to take advantage of extension services (Danso-Abbeam, Ehiakpor, and Aidoo, 2018).

Agricultural information

Agricultural information is defined as a range of information and messages that are relevant to farming activities, including crop production, animal management, pest control, fertilizer use, access to credit, market prices, and sustainable resource management (Tadesse, 2008; Oduwale and Ikhizma, 2003; Adio, Abu, Yusuf, and Nansoh, 2016; Bonephace, Gui, and Makawia, 2022). In essence, agricultural information refers to agricultural data that has been converted into valuable and actionable insights to support decision-making in farming practices (Adio, Yusufu, Sheriff, and Nansoh, 2016). This type of information enables farmers to adopt new technologies or farming techniques, determine the optimal times for planting and harvesting, decide on suitable crops or livestock to produce, and identify potential markets for their goods. Furthermore, agricultural information helps farmers learn where to obtain financial support, such as loans, and necessary farming inputs, as well as how to manage pest and disease issues. Ultimately, access to such information can lead to higher agricultural yields and an improved quality of life for farmers (Fedelugwuowo, 2020).

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter presents an in-depth review of the literature relevant to the study's objectives. The initial section explores the different sources of agricultural information accessible to smallholder farmers. It then examines the role of ICT in crop production, highlighting the ICT tools available to these farmers. The chapter further discusses the influence of ICT tools on crop productivity among smallholders. Additionally, it explores farmers' perception on the effectiveness of ICTs in delivering agricultural information to enhance crop production. Lastly, the chapter addresses the constraints that hinder smallholder farmers' access to agricultural information through ICT tools.

2.2 Sources of agricultural information available to smallholder farmers

Agricultural knowledge derived from both scientific research and indigenous wisdom. Once information is created, sourced, and collected, it must be effectively shared with users to foster the innovation process (Mburu, 2013). Agricultural information sources play a crucial role in facilitating the exchange of knowledge across various networks within the agriculture sector, including researchers, exporters, extension services and farmers (Jayathilake, 2010).

2.2.1 Fellow farmers as source of agricultural information

Fellow farmers are often a vital informal source of agricultural information for smallholder farmers (Ogidi, 2014). Through daily interactions and the exchange of experiences, farmers share insights on various farming practices, local conditions, and effective crop management strategies (Lwoga et al., 2013). These peer networks enable farmers to learn from one another's successes and challenges, creating a sense of community and mutual support. Moreover, fellow farmers offer practical advice tailored to the specific needs and conditions of the local environment, making it highly relevant (Mburu, 2013). This informal knowledge-sharing system is especially crucial in rural areas where access to formal extension services or digital resources may be limited. As such, fellow farmers play a pivotal role in improving agricultural practices and enhancing productivity within smallholder farming communities (Kunda et al., 2018).

2.2.2 Private extension service as source of agricultural information

Due to the constraints of the governmental extension service, an alternative form of extension service has emerged, referred to as the private agricultural extension service. This include private enterprises, nongovernmental organisations (NGOs), community-based organisations, and faith-based organisations (Nambiro et al., 2005; Rees et al., 2000). These private enterprises are essential in addressing the deficiencies of public services by delivering specific, pertinent agricultural information to smallholder farmers (Shemfe and Modirwa, 2018). These organisations assist farmers in adopting improved agricultural techniques and enhancing productivity through customised training, guidance and resource access (Kunda et al., 2018). Moreover, private extension services typically concentrate on particular regions or agricultural communities, guaranteeing that the disseminated knowledge is contextually relevant. Consequently, private extension systems enhance the long-term viability and profitability of smallholder farming, promoting increased economic growth in rural regions (Efobi et al., 2023).

2.2.3 Public extension service as source of agricultural information

For smallholder farmers, public extension services are an essential regulatory source for agricultural information. Through the organisation of activities such as seminars and field days, the Directorates of Extension Education in Agricultural Extension are tasked with the responsibility of enhancing the quality of information that is available to farmers and making it more accessible to them (Singh et al., 2013). These avenues give farmers the opportunity to experience first-hand the most recent innovations and technology that have been put through rigorous testing and demonstrated to be applicable to farming activities (Mburu, 2013). In addition, the directorate is responsible for organising training programs that are centred on various parts of agriculture, such as crop production, protection, and storage. These programs are open to both men and women who are engaged in farming. These activities not only familiarise farmers with new innovations but also promote the adoption of technology that can boost productivity and ultimately increase their income (Singh et al., 2013).

2.2.4 Higher learning institutions as source of agricultural information

Higher education institutions are essential in providing formal agricultural knowledge to smallholder farmers. The Directorate of Extension Education, in partnership with agricultural universities, regularly organizes discussions where university specialists address current farming practices and agricultural challenges (Singh et al., 2013). These sessions are aired on various radio stations, ensuring they reach a broad audience of farmers. Additionally, researchers host radio and television conversations to engage with rural populations, allowing farmers to participate and inquire about their own farming experiences (Mburu, 2013). Universities also use radio and public television to demonstrate specific agricultural techniques, such as farm field days and farmer training programs. By utilizing these platforms, higher education institutions ensure smallholder farmers have access to the latest agricultural insights, helping them enhance their practices and improve productivity (Shemfe and Modirwa, 2018).

2.2.5 Information and Communication Technology as source of agricultural information

ICT tools, including radio, TV, mobile phones, and computers serves as an essential sources of agricultural information for smallholder farmers offering access to a wide range of resources and knowledge (Nwafor et al., 2020; Olayemi, 2020). Radio and TV programs are commonly used to broadcast essential agricultural updates, such as weather forecasts, market trends, and expert advice, which farmers can use to improve their practices (Pawar and Yadav, 2021; Asenso-Okyere and Mekonnen, 2012). Mobile phones, especially smartphones, offer a more personalized form of information access through agricultural apps, SMS services, and voice calls, allowing farmers to receive real-time updates and guidance on crop management (Gillwald and Stork, 2018; Balkrishna et al., 2020). Additionally, computers provide access to online platforms and resources where farmers can explore research findings, watch instructional videos, and participate in virtual training sessions (Feju et al., 2023). These ICT tools bridge the gap between farmers and agricultural experts, facilitating knowledge transfer and promoting the adoption of new farming techniques (Adesiji et al., 2019). Ultimately, they empower smallholder farmers by giving them the tools to make informed decisions, increase productivity, and improve sustainability (Kiambi, 2018).

2.3 Role of Information and Communication Technology in crop production

Farming carries inherent risks and uncertainties, such as poor soil quality, drought, erosion, and pest or disease outbreaks (Shemfe, 2018). Stienen (2007) suggests that to address these challenges, the primary improvement should be providing farmers with information that can act as an early warning system, helping them optimize production. As agriculture becomes increasingly knowledge-driven with the introduction of new methods, technologies, and inputs, the need for effective information exchange between all stakeholders continues to rise (Mittal and Hariharan, 2018). Information needs emerge at every stage of a farmer’s process, from planting to harvesting (Shemfe, 2018). Many smallholder farmers begin with little to no agricultural knowledge, which often results in production risks that affect both the quality and quantity of their yields (Louw and Jordaan, 2016). Boosting agricultural production is vital for alleviating poverty, as it can significantly increase farmers’ incomes, especially for smallholders with limited resources for both production and marketing (Ireri et al., 2021). This can be accomplished through a well-functioning agricultural value chain, which relies on collaboration among different stakeholders, including farmers, suppliers of inputs, and distributors (Halewood and Surya, 2012).

The effectiveness of value chains relies on the smooth and organized flow of relevant information, which depends on having a reliable and efficient communication system that connects various stakeholders throughout the agricultural value chain (Halewood and Surya, 2012). In this context, ICT is seen as a solution to many of the challenges in value chain development, as it can address information gaps, particularly for the most vulnerable actors in the chain (Kabbiri, 2018; Hoque, 2021; Mapiye, 2021). ICTs encompass a wide range of technologies used to manage information and support communication, including hardware, software, and media tools for gathering, storing, processing, transmitting, and presenting information in various formats such as voice, data, text, and images. These technologies include computers, the Internet, CD-ROMs, email, phones, radio, television, video, and digital cameras (Asense-Okyere and Mekonnen, 2012). Additionally, ICTs serve as valuable sources of information and knowledge for individuals, especially farmers (Herselman, 2003; Balogun, 2016).

The advent of ICT has brought significant changes to agriculture, particularly in how knowledge and information are shared and transferred among farmers through various technologies (Chhachhar et al., 2014). In this context, ICTs offer a valuable opportunity to enhance the adoption of agricultural technologies, provide crop management information, and offer access to market and weather updates (Aker and Mbiti, 2010; Ireri, Awuor, Ogala, and Nzuki, 2021). This helps facilitate the exchange of knowledge for sustainable and inclusive agricultural development, leading to higher agricultural productivity and improved livelihoods for farmers (Asenso-Okyere and Mekonnen, 2012). Supporting this, Soriano (2007); Kallal, Haddaji, and Ftiti (2021) highlight that the use of ICTs brings economic benefits, including increased income and production.

ICTs enhance access to financial services, which, according to a wide range of theoretical and empirical research, can significantly impact economic growth and poverty reduction in developing nations (Burgess and Pande, 2015; Levine, 2015). These services, such as insurance, credit, and savings options, are essential for smallholder farmers to manage risks and boost productivity (Kallal et al., 2021). Through mobile phones and digital platforms, farmers are now able to access financial products that were previously inaccessible due to geographic or financial limitations (Asenso-Okyere and Mekonnen, 2012). This greater access empowers smallholders to invest in improved farming practices, purchase necessary inputs, and safeguard against unexpected events like droughts or crop failures (Ogbonna and Agwu, 2013; Lwesya and Kibambila, 2017). Additionally, digital financial services promote financial inclusion by enabling farmers to establish credit histories and secure loans (Heeks, 2018). In the long term, ICT-enabled financial services help build more resilient and sustainable agricultural practices, driving economic growth in rural areas (Kallal et al., 2021).

ICTs assist extension workers and researchers in adopting and spreading improved agricultural practices to farmers (Balogun, 2016). This is done by providing farmers with relevant agricultural information, including techniques and methods (Aker and Mbiti, 2010). Through mobile phones, radio, and other digital platforms, farmers can receive timely guidance on sustainable practices such as managing soil, controlling pests, and conserving water (Nwagwu and Opeyemi, 2015). These technologies enable the quick dissemination of knowledge, helping smallholder farmers adopt practices that boost productivity while preserving natural resources (Mburu, 2013; Mapiye, 2021). Moreover, ICT tools allow farmers to receive real-time weather updates, aiding them in making well-informed decisions. As a result, ICT not only supports the adoption of sustainable agricultural practices but also strengthens the resilience and profitability of smallholder farming systems (Aker and Mbiti, 2010).

Research has demonstrated that the use of ICTs to provide access to price information in Africa has resulted in income increases of up to 36% for both farmers and traders (Halewood and Surya, 2012). This is due to the fact that ICTs improve the exchange of information and facilitate better communication between buyers and sellers, lowering communication costs and enabling quicker, more affordable information transfer (Aker and Mbiti, 2010).Additionally, the use of ICTs, particularly mobile technologies, benefits agricultural producers who often lack knowledge of commodity prices in nearby markets and depend on traders’ information to decide when, where, and at what price to sell their goods. ICTs provide them with timely and relevant price information (Sife, 2010; van Loeper, 2016). Delays in obtaining accurate information or misinterpretations by middlemen can have serious repercussions for agricultural producers, leading to underpricing or irregular market supply (Aker and Mbiti, 2010; Chavula, 2012).

ICTs play a crucial role in driving agricultural growth by enhancing market interactions and providing real-time information. They achieve this by improving farmers’ access to markets and increasing their bargaining power through online trading platforms and mobile applications (Driouchi et al., 2010). The use of ICTs, particularly mobile and mass media technologies, is said to significantly lower market search costs, enabling crop producers to directly market their products and communicate with customers (Kallal et al., 2021). Moreover, in markets where traders have a local monopoly, increased access to information can challenge this power, benefiting consumers, although potentially diminishing traders' profits (Aker and Mbiti, 2010).

ICT plays a vital and effective role in the development of agriculture, influencing the decisions of farmers across various communities and countries (Taragola and Van Lierde, 2010). By providing valuable and relevant information, ICT helps address the challenges faced by individual farmers and farming communities, allowing them to learn new skills, adopt advanced technologies, and share innovations on a global scale (Kiambi, 2018). This supports the idea that technology-driven agricultural services can enhance crop yields, improve market access, and increase farmers' revenue, thereby improving their livelihoods and contributing to the overall economy. This is particularly true as ICT connects farmers to expertise and information on a wide range of topics, including weather, crop selection, pest control, as well as management and finance (Sife, 2010; Aker and Mbiti, 2010; Mburu, 2013).

2.4 Information and Communication Technology tools available to smallholder farmers

2.4.1 Radio

Importance of radio in agricultural production

Radio remains one of the most accessible forms of communication for people in rural areas (Balan and Norman, 2012; Okwu and Daudu, 2011; Mayers, 2008). Its key advantage lies in its broad geographical reach and the use of multiple languages, enabling it to engage a large and diverse audience (Nakabugu, 2011). Through specialized agricultural programs, radio plays a crucial role in improving the crop productivity of smallholder farmers by enhancing their access to vital agricultural information. This information helps them make informed daily decisions, adopt better practices, and increase both crop yields and income (Farm Radio International, 2016). Moreover, radio serves as an important tool for extension services, delivering valuable content related to crop management, farming inputs, and weather forecasts to smallholder farmers (Mugwisi, 2015; Okeke, Nwalieji and Uzuegbunam, 2015; ICFA, 2017; Balamurugan, 2017). It is an affordable, widely accessible platform that fits local contexts and is particularly beneficial for individuals with limited education. Radio also encourages active listener engagement through calls, text messages, and direct interaction with experts (Mugwisi, 2015). Its efficiency in delivering agricultural content is further enhanced by broadcasting in local languages and using participatory methods that involve farmers directly in the learning process (Farm Radio International, 2016). Through various radio programs, smallholder farmers receive timely information on planting seasons, required inputs, and market availability, leading to positive and impactful results (Shemfe, 2018).

Radio Innovations in South Africa that helps smallholder farmers improve production

Farm radio programming on South African community stations faces several challenges, including delays in licensing rural stations, a lack of training in farm broadcasting, and the historical marginalization of farmers prior to democracy (Stone, 2001). According to Stone (2001), some stations that broadcast agricultural content receive scripts and information packages from the Canadian-based Developing Countries Farm Radio Network, while others rely on pre-recorded cassette materials provided by the Department of Agriculture. Macaskill (2022) highlights that AgriSkoops, a widely popular agricultural radio program in South Africa, is broadcast weekdays on 20 community stations. The show covers various topics, ranging from precision farming to food sustainability and current issues impacting farmers. However, Mhlaba and Yusuf (2020) note that many community radios have shifted their focus towards music and advertising, with their editorial agendas sometimes conflicting with journalistic standards. While talk shows on these stations address issues like community affairs, politics, health, youth, and religion, agricultural topics are often neglected. Moreover, the overall number of agricultural programs on South African community radio stations remains quite limited, as shown in the table below.

Table 1: Percentage distribution of programmes per community radio stations by provinces

Programs	GP	WC	KZN	EC	FS	NW	MP	LP	NC
Music (%)	57.9 %	48.3 %	48. 3%	50.9 %	51.4 %	50 %	40 %	45.7 %	48.3 %
Talk (%)	35.8 %	51.7 %	51.6 %	49.1 %	48.5 %	50 %	60 %	54.2 %	51.6 %
Religious (%)	36.1 %	14.7 %	33.3 %	14.2 %	45.4 %	20 %	6.25 %	23.0 %	-

Educational (%)	8.3 %	20.6 %	5.6 %	19.0 %	18.1 %	6.7 %	-	23.0 %	-
Agriculture (%)	-	0.83 %	0.83 %	-	1.19 %	-	-	-	-

Keys: GP-Gauteng; WC-Western Cape; KZN-KwaZulu-Natal; EC-Eastern Cape; FS-Free State; NW-North West; MP-Mpumalanga; LP- Limpopo; and NC-Northern Cape (Mhlaba and Yusuf, 2020).

2.4.2 Mobile phones

Importance of mobile phones in agricultural production

Basic cell phone

Basic mobile phones, also known as feature phones, are devices with limited functionality, typically offering simple calling and texting features (Johnson, 2023). These phones are affordable and easy to use, making them ideal for users who do not require advanced features. They lack internet access, the ability to run apps, and modern camera capabilities (Johnson, 2023). Despite these limitations, the SMS function on basic phones is valuable for delivering important information to smallholder farmers, including updates on meetings, farming tips, weather forecasts, and wholesale crop prices. This presents a unique opportunity to provide rural farmers with crucial information that could significantly enhance their production (van Vark, 2012). According to Magaji (2022), during the COVID-19 pandemic, when in-person interactions between farmers, extension workers, and customers were limited, the calling and SMS functions of basic phones played a vital role in sharing timely agricultural information. This helped smallholder farmers navigate critical periods, ultimately improving their yield and income.

Smart phone

Smartphones are equipped with advanced features such as high-definition cameras, internet connectivity, and the capability to download and use various applications (Johnson, 2023). These devices are primarily used to share and engage with user-generated content, such as opinions, audio, video, and multimedia, which has transformed how smallholder farmers interact and communicate, even in remote areas (Kumar, 2023). Additionally, smartphone apps empower smallholder farmers to utilize ICT in promoting better agricultural practices (Bajpai and Beriya, 2022). The integration of mobile applications into smartphones has simplified the process of accessing and sharing agricultural information (Bajpai and Beriya, 2022). With smartphones, smallholder farmers can quickly find solutions to farming problems. For instance, when a farmer encounters issues with crops or needs agricultural information, they can simply take a photo, upload it, or send a message through an app. Mobile applications like YouTube, social media platforms and Google allow farmers to learn from a broad community of peers and agricultural experts (Dharanipriya and Karthikeyan, 2019). These apps not only assist in improving agricultural productivity but also enhance food security for rural households by facilitating access to critical information (Bajpai and Beriya, 2022). Smartphones also promote the adoption of farming technologies by offering diverse ways to access agricultural content, enriched with audio and visual aids. This, in turn, contributes to more sustainable food production, supporting food security and improved livelihoods (Masuka et al., 2016).

Mobile application innovations in South Africa that helps smallholder farmers improve production

In South Africa, there is a variety of mobile applications that both smallholder and commercial farmers can download to access agricultural information (Research ICT Africa, 2020). Most of these apps are designed to enhance agricultural supply chain integration, offering a wide range of features such as market information, market link facilitation, and improved access to extension services. The user base for these mobile applications is diverse, consisting of farm produce buyers, smallholder and commercial farmers, input suppliers, cooperatives, content providers, and other agricultural sector stakeholders (Kiambi, 2018). Below are some examples of these applications:

PANNAR Sprout

PANNAR, one of Africa’s leading producers and suppliers of field crop seeds, has created a free mobile app to offer technical support to farmers. Released in 2015, the app includes various tools such as a plant calculator, estimated yield calculator, and a hybrid comparison tool. Additionally, it features a crop disease guide, with its most recent update being the ‘Plant Dr’ tool. This new feature allows farmers to upload images of their plants for analysis, notifying them of potential threats in their region (Research ICT Africa, 2020).

Khula

Launched in 2016, the Khula agricultural app is a South African platform designed to help farmers in informal selling stations connect with formal markets. Its primary goal is to support black farmers who have historically been excluded from these markets. The app enables farmers to list their products, forecast production, purchase agricultural inputs, and access reliable suppliers and production information. Currently, Khula collaborates with over 2,000 farmers across South Africa (Research ICT Africa, 2020).

FruitLook

Launched in 2010, FruitLook is a free online tool developed by the Western Cape Department of Agriculture (WCDoA) to support farmers in managing water usage and production through sophisticated satellite data (Research ICT Africa, 2020). By utilizing cutting-edge satellite technology, FruitLook gathers data on crop growth, water usage, and plant stress, allowing farmers to closely monitor their production and address challenges like rising input costs and water scarcity (Kuschke and Cassim, 2020).

Agrisol

Establishment in 2010, Agrisol has developed a sophisticated GIS that gathers grid samples, soil data, satellite imagery, and weather information. This data is then processed to offer farmers independent, timely, and location-specific recommendations. The information is compiled into an easy-to-use platform, accessible from both laptops and mobile phones, allowing farmers to make informed decisions. Additionally, with the farmer's consent, the data can be shared with relevant external providers, connecting them to various products and services such as agricultural resources, as well as financial and insurance options (Research ICT Africa, 2020).

Mezzanine's Connected Farmer

Mezzanine, a division of Vodacom Group, offers a digital platform that grants farmers in Kenya, Tanzania, Zambia, and South Africa immediate access to local services, including credit providers, resellers, and insurers. Launched in 2012, the platform was designed to provide digital solutions tailored to African businesses. The platform operates on mobile GSM networks, making it easy for farmers in remote areas to connect. Among the services available are eVoucher and eVuma. Through eVoucher, Mezzanine helps enhance smallholder farmers' access to essential agricultural inputs in South Africa and Kenya. eVuna, another tool powered by Mezzanine, connects smallholder farmers to vital resources such as information, agricultural inputs, credit, and buyers. This platform aims to boost productivity, increase revenue, and enhance resilience. Serving as a digital marketplace, eVuna also works to reduce risks for businesses and financial service providers when engaging with smallholder farmers (de Vos, 2021; Farmers' Weekly, 2023).

2.4.3 Television

Importance of television in agricultural production

In agricultural sector, TV shows have become one of the most effective ways to disseminate agricultural innovation and technology, as they can reach a wide audience in a rapid manner (Asenso-Okyere, 2009; Olayemi, 2020). Mass media platforms like TV provide an efficient way to communicate agricultural messages in the national language to smallholder farmers (Nazari and Hassan, 2011). The success of these programs in educating rural farmers lies in the unique combination of audio and visual elements, which have been shown to influence behaviour and enhance learning (Nazari and Hassan, 2011). Agricultural TV programs offer smallholder farmers valuable information on various aspects of production, processing, and marketing, encouraging more informed decisions in farming (Chhachhar et al., 2012). The effective use of television also enables farmers in rural areas to access crucial information, raising awareness and expanding knowledge about the latest agricultural technologies to improve productivity (Aker and Mbiti, 2010).

TV program innovations in South Africa that helps smallholder farmers improve production

The South African Broadcasting Corporation (SABC) partnered with the Department of Rural Development and Land Reform to feature a variety of agricultural television programs (Research ICT Africa, 2020). These programs aim to provide relevant information related to agriculture, land reform, and rural development. They also focus on keeping viewers updated on the latest developments in land reform while offering practical knowledge on topics such as irrigation technology, animal health, and vegetable farming (Research ICT Africa, 2020). According to Macaskill (2022) in the AGRI Handbook for South Africa, some of the TV programs that air agricultural content include the following:

African Farming,

African Farming is a TV show that highlights the achievements of successful black farmers while also educating newcomers about the complexities of farming in South Africa. One of its primary goals is to offer a fresh, positive portrayal of the African farmer. The African Farming brand aims to inspire emerging farmers by showcasing some of the top agricultural talent in South Africa, providing them with relatable role models to look up to. Additionally, the show serves as an informative and motivating platform that contributes to agricultural development. It is broadcast on Mzansi Wethu, DStv channel 163, every Thursday at 18:30, with a repeat airing on Sundays at 11:00 (Macaskill, 2022).

Landbouweekliks

Landbouweekliks is a TV program sponsored by AFGRI that provides a comprehensive look at farms across South Africa, showcasing operations that produce both winter and summer grains, livestock, fruit, and wine. The show also features successful empowerment projects, highlighting remarkable farmers and sharing their inspiring stories. It explores what is needed to run a farm and the team required to turn it into a business, with a particular focus on how AFGRI supports food security. This series underscores the significance of the agricultural industry in South Africa. Landbouweekliks airs on Tuesdays at 19:30 on the Afrikaans lifestyle channel, DStv channel 147. Repeated episodes are shown on Wednesdays at 07:30, Thursdays at 12:30 and 18:30, Fridays at 06:30, Saturdays at 07:00 and 07:30, Sundays at 17:00, and Mondays at 05:00 (Macaskill, 2022).

For the love of the land

For the Love of the Land is a television program that highlights the inspiring journeys of South Africa’s new generation of farmers, many of whom are Black, as they navigate the challenges of modern farming. The show showcases how these individuals persist in their farming endeavours despite facing numerous obstacles. Broadcasted on both DStv and Openview, it can be found on People’s Weather (DStv channel 180) and Openview channel 115. The program airs from Monday to Thursday at 18:00, with a repeat of each episode at 21:00 (Macaskill, 2022).

Niche farmers

Niche Farmers is an AGRI-TV series aimed at inspiring Black South Africans who aspire to become farmers. The show emphasizes rural development and explores a wide range of topics affecting rural communities in South Africa. Presented in English, this program airs on e.TV every Thursday at 13:30. It also offers same-week repeats on eXtra and Honey, available on DStv channel 173, with reruns on Mondays at 20:00 (Laeveld Agrochem, 2022).

Living Land

Living Land is a television program designed to support the growth of emerging farmers by tackling important issues related to land reform and agricultural practices. The show provides valuable insights and practical information for those looking to build a career in farming. It airs every Saturday morning at 05:30 on SABC 2 (SABC Education: Living Land, 2022).

Working Land

Working Land is a program aimed at empowering and educating farmers, particularly those who are emerging in the agricultural sector. The show provides valuable knowledge and updates on the latest agricultural trends, innovations, and developments, helping farmers stay ahead in their industry. It airs on SABC 2 every Saturday at 13:30 (Macaskill, 2022).

Plaas TV/ Farm TV

Plaas TV also known as Farm TV is an online television program that provides comprehensive coverage of the agricultural sector in South and Southern Africa. The show features the latest industry news, expert discussions, technical insights, financial updates, weather reports, and information on events, all tailored to the needs of farmers and agricultural professionals. New episodes are typically released on weekdays and can be found primarily on the Plaas Media YouTube channel (Macaskill, 2022).

2.4.4 Computer

Importance of computers in agricultural production

The following information refers to both desktop computers and personal computers, commonly known as laptops. These electronic devices are capable of processing, storing, and retrieving data, making them essential tools for managing information (Lemonaki, 2021). The introduction of computers and their applications has transformed many traditional industries, including agriculture (Mabe, 2011). In agriculture, computers serve various purposes: software applications can predict weather patterns and estimate agricultural production; they are used for record-keeping, tracking production costs, transportation, agricultural processes, and calculating profit and loss; and they facilitate communication between farmers as well as between farmers and agricultural experts. This exchange of information plays a crucial role in guiding farmers to enhance their production and increase profits (Choudhary et al, 2022).

An internet-enabled computer not only provides access to vast information networks but also offers rural farmers a platform for effective communication. This allows them to address and potentially change the negative perceptions surrounding their situations and other community-related issues (Alao, Usadolo, and Brink, 2021). Additionally, the internet serves as a crucial resource for smallholder farmers to access agricultural information, helping to reduce both the cost of information retrieval and the challenges posed by information asymmetry (Zheng and Jia, 2022). Over the years, farming techniques have advanced significantly, transitioning from basic hand-held tools to highly advanced machinery. Many smallholder farmers are now adopting modern practices, which enables them to maximize their potential in various agricultural activities. With the internet, these farmers can gain a deeper understanding of how to utilize and benefit from these modern technologies (Maumbe and Okello, 2013; Aker and Ksoll, 2016). Innovations in computer applications are also accessible on smartphones, further enhancing their reach and impact.

2.5 Impact of Information and Communication Technology tools on crop productivity among smallholder farmers

Impact can be understood as both positive and negative long-term effects resulting from a developmental intervention. These effects can be direct or indirect, and intended or unintended (Garbarino and Holland, 2009). Impact assessment is a type of evaluation designed to measure the outcomes of an intervention in relation to its intended objectives and effects (FAO, 2010). In assessing the impact of ICT on crop productivity, existing literature identifies several key factors that influence agricultural production, including: changes in crop yields, variations in agricultural income, and shifts in input usage, such as the adoption of improved seeds, fertilizer, and changes in pesticide application patterns (Lal, 2010; Syeda, Ahadat, and Rafique, 2015; Adebayo, Olaginju, and Ogundipe, 2016; Das, Munshi, and Kabir, 2016; Kumar, Hudda, Yadav, and Manjeet, 2018; Sennuga, Conway, and Sennuga, 2020; Chandio et al., 2021). This study uses these factors as the basis for assessing the impact of ICT tools on agricultural productivity among smallholder farmers.

2.5.1 Fertiliser use pattern

Chemical fertilizers are commonly used in agricultural production and play a crucial role in boosting crop yields and ensuring food security. However, their overuse has led to several negative consequences, including food insecurity, soil degradation, soil acidification, greenhouse gas emissions, and water eutrophication, which increase the vulnerability of agricultural systems particularly in developing countries (Zheng and Luo, 2020). As such, improving fertilizer management is essential for protecting the environment, enhancing food security, and mitigating climate change (Pan and Zhang, 2018). A significant factor contributing to the overuse of fertilizers in rural areas is the lack of sufficient knowledge about proper fertilizer use. Research has shown that access to conventional extension services can effectively reduce fertilizer overuse (Huang et al., 2012; Jia et al., 2013; Pan et al., 2017; Pan and Zhang, 2018). However, many smallholder farmers are unable to benefit from these services due to limited local government funding (Pan et al., 2017). Furthermore, fertilizer use efficiency, which reflects the balance between fertilizer application and farm productivity, plays a critical role. Improving the efficiency of fertilizer use allows farmers to achieve greater outputs without increasing the quantity of fertilizer applied (Zheng and Luo, 2020).

African smallholder farmers and agripreneurs no longer depend on inconsistent agro-advisory services from overburdened extension agents. Instead, they now leverage ICTs to access crucial information, including weather forecasts and the best prices and locations for inputs such as fertilizers (Lohento and Ajilore, 2015). According to Lehmann et al. (2012), ICTs can help minimize the use of agricultural inputs including fertilizers, energy, and reduce environmental externalities. This explains the increasing interest in ICTs by farms worldwide, which are utilizing large datasets and data analysis to enhance productivity (Bilali and Allahyari, 2018). For instance, ICT tools enable farmers to tailor input usage to meet the specific needs of their crops and land area, which in turn helps to reduce energy consumption and the ecological impact of agriculture. This more efficient use of inputs has a positive effect on both the environment and crop yields (Balafoutis et al., 2017; Schrijver et al., 2016; Bora et al., 2012; Mutchek and Williams, 2010; Saidi, 2013). According to Kumar, Hudda, Yadav, and Manjeet (2018), smallholder farmers rely on ICTs to obtain vital information, such as fertilizer prices, availability, recommended fertilizers for crops, application methods and timing, fertilizer dosage calculations, and crop nutrient requirements, as well as symptoms of nutrient deficiencies in major crops.

2.5.2 Pesticide usage pattern

Pesticide application is a common practice in agriculture, widely used to boost production (Chandio et al., 2023). Smallholder farmers often face significant crop yield losses, up to 80% per season due to pest-related problems (Santana et al., 2019). In low- and middle-income countries, many farmers rely heavily on agrochemicals, including pesticides to manage pest populations (Bebber et al., 2014). Pesticides, which include herbicides, insecticides, nematicides, and fungicides, are chemicals designed to eliminate pests such as insects, rodents, fungi, weeds, and disease carriers (Ngigi and Mureithi, 2021). While agrochemicals have played a key role in improving agricultural productivity and reducing food insecurity in Africa, concerns have arisen about their use. Issues like inadequate regulation, noncompliance, poor enforcement, and limited awareness of the associated risks among farmers and pesticide handlers have led to instances of pesticide poisoning (Loha et al., 2018; Ngigi and Mureithi, 2021).

Many smallholder farmers lack knowledge about the Pre-Harvest Interval (PHI) for the agrochemicals they apply to their crops (Mergia et el., 2021). The PHI is an essential part of chemical pest control, as it dictates the waiting period required after applying chemicals before harvesting the crops (Halimatunsadiah et al., 2016; Moura et al., 2020). If the PHI is not followed, chemical residues may exceed the acceptable levels, posing health risks (Sarkar et al., 2021). Additionally, Musebe and Ogunmodede (2021) suggest that 80% of smallholder farmers are unaware of PHIs and often harvest and sell crops based on market demand, neglecting when the last pesticide application took place. This oversight can have serious health and environmental consequences, highlighting the need for better farmer education, particularly through strategies like information and communication technologies (Mergia et al., 2021).

Smallholder farmers utilize ICT tools to gather information on weed, insect, pest, and disease management, including details on chemical treatments, chemical prices, availability, trade names, stock levels, and preparation methods (Kumar et al., 2018). Moreover, technological advancements, particularly in ICT, influence farmers' decisions regarding pesticide use (Ma et al., 2021). As technology progresses, several innovations, including ICT, have been introduced to help reduce pesticide usage (Chandio et al., 2023; Manjula et al., 2023; Mwenda et al., 2023; Tambo et al., 2023). The rapid advancement of ICT makes information about reforestation and the risks of excessive chemical use more accessible through reliable apps and websites (Shleh et al., 2024). Research by Zhao et al. (2021) shows that internet access has a significant positive effect on reducing pesticide use. Farmers can easily obtain information on environmentally friendly practices, which helps them reduce pesticide application and enhance agricultural sustainability. According to Hou, Huo, and Yin (2019), information technologies like mobile phones, computers, televisions, and radios can deliver timely, relevant information, enabling farmers to make informed decisions that optimize resource use for better productivity and profitability. As a result, these technologies influence smallholder farmers' purchasing decisions, including the quantity of pesticides they buy, by providing critical information on the correct dosages. Ma and Zheng (2021) further note that smartphone usage increases pesticide expenditures, as it provides quick access to information on proper pesticide application, ultimately improving efficiency and reducing pesticide use.

2.5.3 Adoption of new crop varieties

The adoption of agricultural seed technologies plays a key role in boosting crop yields and improving food security (Keyser et al., 2015). These technologies involve using advanced seed varieties designed to boost yields, enhance disease resistance, and improve crop quality. Research has shown that these technologies positively impact smallholder farmers' productivity and the broader agricultural sector (Adeyongo et al., 2022). However, smallholder farmers often rely on traditional information sources, such as fellow farmers, extension agents, and seed vendors, which may not provide the most up-to-date or reliable data on market demand and pricing for agricultural products and inputs (Ayemi et al., 2023). The lack of accurate information on available seed technologies, seed quantities, and the high cost of these technologies limits their adoption, making it difficult for farmers to make informed decisions about which crops to plant and when (World Bank, 2014). Despite this, there has been limited investment from both public and private sectors in improving smallholder farmers' access to reliable ICT-based market information, which could help them secure better prices for their products. Access to ICT-based market data is crucial for increasing the adoption of enhanced agricultural seed technologies among smallholder farmers (Kiiza and Pederson, 2012; Lokeswari, 2016).

The Market Information System (MIS) is an online platform that provides smallholder farmers with real-time data on agricultural prices, demand, and supply, allowing them to make informed decisions on when and where to sell their products. In addition to market insights, the MIS provides guidance on effective seed management and selection, enabling farmers to adopt new seed technologies that can boost yields (Ebisike et al., 2021). Research suggests that access to market information plays a crucial role in the level of adoption of seed technologies. Moreover, it has been found that using ICT to distribute market data and promote agricultural seed technology can lead to increased productivity and improved livelihoods for farmers (Okeke et al., 2020). Ebisike et al. (2022) explored how ICT-based market information influences the adoption of drought-tolerant maize varieties among smallholder farmers. The study showed that when farmers accessed market information through mobile phones, they were more likely to adopt drought-tolerant maize, leading to higher crop yields and increased income. The impact of ICT on agricultural productivity is significant, as it facilitates the adoption of innovative technologies like improved seed varieties by providing farmers with critical information on the latest methods and how to use them effectively. By improving crop yields and productivity, ICT ultimately helps increase farmers' income and economic well-being (Ebisike et al., 2021).

2.5.4 Changes in Yield

The influence of ICT tools on improving production output is widely acknowledged, as these tools enhance communication between smallholder farmers and agricultural agents, ensuring more efficient delivery of extension services and better access to agricultural information (Abdul-Salam and Phimister, 2017; Aker and Ksoll, 2016; Cole and Fernando, 2012; Fu and Akter, 2016; Kiiza and Pederson, 2012; Lio and Liu, 2006; van Campenhout et al., 2017). Evidence on the effect of ICT tools on the production of various food crops confirms that these technologies play a crucial role in boosting agricultural productivity (Ragasa and Mazunda, 2018). Considered as one of the most effective communication methods, ICT tools are integral to enhancing the efficiency and effectiveness of agricultural practices (Cole and Fernando, 2012). With the support of ICT, smallholder farmers can stay informed about the latest developments, including updates on weather, agricultural techniques, and innovative methods for improving crop quality and yield (Nwagwu and Opeyemi, 2015). In developing nations, ICT in agriculture provides farmers with crucial information on planting schedules, pest management, soil fertility, sustainable farming techniques, market conditions, price fluctuations, and weather forecasts, all of which help enhance agricultural productivity (Ogbonna and Agwu, 2013).

ICT tools have a significant impact on the production output of smallholder farmers, leading to notable increases in yields. These tools enhance the adoption and implementation of recommended agricultural practices by providing timely, relevant, and comprehensive agricultural information (Chhachhar et al., 2014; Sennuga, 2020; Chibsa, 2020). They are particularly valuable in offering knowledge on post-harvest handling, pest and disease control methods, and fertilizer application, all of which help to improve yields by preventing post-harvest losses and minimizing the risks associated with poor soil quality and pest infestations (Ali, Jabeen, and Nikhitha, 2016; Lwesya and Kibambila, 2017; Matto, 2018). This information enables smallholder farmers to make informed decisions about the correct dosages and timing of treatments, helping to protect crops from wilting or dying, ultimately maximizing yields and reducing production losses (Sekabira and Qaim, 2017). Zhang, Wang, and Duan (2016) argue that with the continued development of ICT, agricultural practices have shifted from traditional to modern methods. The availability of appropriate ICT tools supports enhanced agricultural productivity, optimizes the agricultural value chain, and reduces waste in agricultural production (Fu et al., 2018). Furthermore, ICT tools improve smallholder farmers' decision-making abilities, which boosts production by providing essential information on crop selection, planting times, input choices, harvest quantities, market locations, and pricing (Chibsa, 2020). When smallholder farmers have access to the right information on how to enhance yields, their productivity tends to increase, leading to better working conditions and greater food security on their farms (Ragasa and Mazunda, 2018).

2.5.5 Changes in income

ICT tools are innovative communication platforms that connect smallholder farmers with agricultural researchers and extension agents, helping to bridge the communication gap between them (Sekabira and Qaim, 2017). These tools offer a cost-effective way to enhance smallholder farmers' access to market information (Nwagwu and Opeyemi, 2015). Additionally, they provide farmers with a dependable platform to check the best prices for their products in local markets, as well as receive daily updates to ensure they get fair returns (Mashangwa, 2018). By strengthening the connection between farmers and traders, ICT tools open up new opportunities for farmers to find profitable markets, which can help increase their income (Jain, Alka, and Usha, 2010; Nwagwu and Opeyemi, 2015). Research by Agrilinks has shown that ICT tools can boost smallholder yields by as much as 70%, leading to an average income increase of 40%. These tools enable farmers to stay well-informed about market conditions by providing complete, relevant information, ensuring they can sell their produce at the best prices (Sife, 2010; Casaburi et al., 2014). When smallholder farmers are well-informed about key market aspects, their participation in the market improves (Ingabire et al., 2018). Enhanced market participation creates opportunities for smallholder farmers to access better income prospects and achieve more sustainable livelihoods (Machete, 2016; Ingabire et al., 2018).

Many smallholder farmers live in remote areas where poor infrastructure and limited access to market information hinder their ability to reach output markets, leading them to engage in direct trade with consumers (van Loeper, 2016). As a result, many farmers end up selling their produce in informal markets or to middlemen, who often exploit them by offering low prices for their goods (Mashangwa, 2018). ICT tools provide essential market information that helps smallholder farmers plan their sales more effectively, ensuring they can secure better prices and avoid being exploited by middlemen who take advantage of the information gap (Anoop et al., 2015). By reducing the number of intermediaries involved in the marketing process, ICT tools help lower transaction costs within the food supply chain (FAO, 2013; Berti and Mulligan, 2015; Sylvester, 2015; Conway, 2016; FAO, 2017). These tools are now considered crucial for rural and agricultural development, as they help smallholder farmers cut down on costs, time, and risks associated with traveling for purchases and sales (Sife et al., 2010; Martin and Abbott, 2011; Heeks, 2018). Through various ICT channels, farmers can advertise their products and reach a wider customer base, increasing their potential returns (Heeks, 2018). Moreover, ICT tools improve smallholder farmers' access to market information and financial services, facilitating changes in market structures by eliminating intermediaries and introducing farmers to supply-chain contracting (Goyal, 2010; Kikulwe et al., 2014; Baumüller, 2015; Munyegera and Matsumoto, 2016; Baumüller, 2018).

By contributing to increased income, ICT tools enhance farming households' capacity to adapt to various challenges and opportunities in farming, particularly by improving flexibility in agricultural production. This is achieved by encouraging crop diversification, the adoption of advanced farming practices, and the support of multiple income streams, while also expanding market options by enabling sales to different markets (Kirui et al., 2013; Manfre and Nordehn, 2013; Baumüller, 2015; Sekabira and Qaim, 2017). ICT tools enable smallholder farmers to approach profitable markets, enhancing their sales by providing localized market information and improving their access to the domestic food supply (Nwagwu and Opeyemi, 2015; OECD and FAO, 2015; Nkandu and Phiri, 2022).

2.6 Smallholder farmers' perception on the effectiveness of Information and Communication Technology tools in disseminating agricultural information on crop productivity

Effectiveness refers to the capacity to achieve success and deliver desired outcomes (Adokiye, 2020). In the context of this study, it represents the result of farmers' use of various ICT tools, indicating that the adoption stage has been completed. Specifically, effectiveness is the capacity of ICT tools to effectively deliver agricultural information that addresses the needs of smallholder farmers. Key factors that help assess the effectiveness of these tools include relevance, timeliness, accessibility, ease of use, and feedback (Kante, Oboko, and Chepken, 2018; Tata and McNamara, 2018; Shemfe and Modirwa, 2018; Tamubula, Sseguya, Miiro, and

Okry, 2019; Kumar and Philip, 2019; Adokiye, 2020; Manjuprakash, Philip, and Sriram, 2020; Raza, Khan, Shahbaz, and Saleem, 2020; Sule, Datsu, Abubakar, and Tauheed, 2021; Ahmad, Ali, Shahbaz, and Siddiqui, 2021; Wale and Mkuna, 2023). The perception of smallholder farmers towards the effectiveness of ICT tools in disseminating information significantly affects their efficient use of these tools (Manjuprakash, Philip, and Sriram, 2020; Haque and Hoque, 2021).

Smallholder farmers have varying perceptions regarding the information they need and its level of importance (Makaula, 2021). The central theme behind these differences is that farmers require a comprehensive set of information that addresses their specific needs, which evolve throughout the production cycle (Ireri, Awuor, Ogala, and Nzuki, 2021). These needs are met when the information provided is timely, relevant to their situation, complete, and affordable (Milovanovic, 2014; Manjuprakash, Philip, and Sriram, 2020; Setu, 2021; Makaula, 2021; Mdoda and Mdiya, 2022). To assess smallholder farmers' perceptions of the effectiveness of ICT tools in accessing agricultural information, this study will focus on elements such as the timeliness and relevance of information, accessibility and ease of use of ICT tools, as well as the feedback acquired from the ICT tools.

2.6.1 Smallholder farmers' perception on the relevancy of agricultural information received through Information and Communication Technology tools

Access to relevant agricultural information is vital for enhancing productivity, raising income, and reducing poverty among food producers in disadvantaged communities (Rodriguez, 2008; Makaula, 2021). However, aligning the information provided with the specific needs of the community is a significant challenge. Researchers emphasize the importance of assessing the information needs and its relevance in the farming community before delivering agricultural extension services (Kumar and Best, 2006; Alao, Usadolo, and Brink, 2021). The relevance of the agricultural information depends on how applicable and beneficial it is to the farmer's specific circumstances (Siyao, 2012). The information should not only be timely but also address the unique challenges of the particular farming system practiced in the area (Levi, 2015).

ICT tools are recognized for their ability to help deliver relevant agricultural information and advice to smallholder farmers, addressing their daily farming needs in rural areas (Okayere and Mekonnen, 2012). Kante, Oboko, and Chepken (2018) highlight that the relevance of ICT-based farm information is essential for its adoption by smallholder farmers. Correct and necessary information can empower farmers, helping them gain profit from their agricultural activities (Msoffe and Ngulube, 2016). However, when the information does not align with the farmers' environment, capabilities, and available resources, it leads to a reluctance to use ICT tools, as farmers are of a view that they are unacknowledged (Tata and McNamara, 2018).

Studies on ICT use in agricultural development have shown that smallholder farmers often perceive agricultural content from ICT tools as inappropriate or incomplete for their specific farming conditions (Meera, 2004; Wang and Peng, 2008; Palmer, 2014; Kante, Oboko, and Chepken, 2018; Usadolo and Brink, 2021). Lwoga (2010) also reported that inadequate provision of relevant and local agricultural content is a barrier to ICT adoption among smallholder farmers. Despite these challenges, Osondu and Ibezim (2015) observed that many farmers hold a positive view of ICTs in extension services, noting their potential to enhance rural development by increasing contacts, saving time, accelerating progress, and providing cost-effective services (Abubakar, 2021). This positive perception can drive farmers to embrace ICT tools, ultimately boosting agricultural productivity (Mahmud and Ahsan, 2016).

2.6.2 Smallholder farmers' perception on the timeliness of agricultural information received through Information and Communication Technology tools

The timely delivery of agricultural information is essential for the success of smallholder farmers (Ahmad, Ali, Shahbaz, and Siddiqui, 2021). Farmers must receive agricultural information at the right time to effectively apply it in their daily farming practices and enhance farm productivity (Levi, 2015). According to Rodriguez (2008), Makaula (2021), and Mdoda and Mdiya (2022), the timely availability of agricultural information is essential for the successful execution of key farm management tasks such as planning, organizing, leading, and controlling. A major challenge for agricultural development lies in the gap between the information smallholder farmers need and its timely relevance, which limits its usability (Makaula, 2021). Access to up-to-date and relevant information, such as proper sowing techniques, soil fertility management, pest control methods, and market prices, strengthens farmers' decision-making capabilities across various agricultural activities. Furthermore, issues like climate change and its impacts on agriculture, along with pest and disease outbreaks, significantly influence the information required by smallholder farmers in rural areas (Lokeswari, 2016).

Parmar (2019) pointed out that ICT-based sources play a crucial role in meeting the agricultural information needs of smallholder farmers. By accessing current information through ICT, farmers are able to make informed decisions that enhance their agricultural output. The intention of smallholder farmers to use ICT is greatly influenced by its ability to provide timely agricultural information (Demiryurek, 2010; Palmer, 2015). Furthermore, the timeliness of the agricultural information provided can be evaluated based on the seasonal activities for which ICT tools can serve as valuable resources (Aldosaria et al., 2019). Timely information delivery means that smallholder farmers receive information at a moment when they can put it to use (Siyao, 2012). For instance, receiving timely information about rainfall helps farmers plan the right time for preparing their farms (Siyao, 2012). This information also enables them to choose the appropriate crop varieties based on the expected rainfall for the season. Similarly, timely information about pest outbreaks allows farmers to take proactive measures to mitigate losses (Levi, 2015). When crucial information, such as weather forecasts, market trends, agricultural policies, or warnings about pests and diseases, is not provided on time, smallholder farmers face losses and may lose trust in ICT tools, deeming them unreliable (Macire Kante, 2016).

Smallholder farmers generally have a positive view of the timeliness of agricultural information delivered through ICT tools, as it is current and can be used when needed (Levi, 2015; Makaula, 2021). However, they also believe that the timing of agricultural broadcasts on various ICT platforms is inconsistent, and there is a lack of proper promotion for agricultural programs. It would be beneficial if upcoming agricultural topics were advertised in advance, allowing farmers to know the schedule and content so they could prepare questions (Chhachhar et al., 2014). Key challenges related to accessing agricultural information through ICTs include limited air time, outdated content, and the fact that agricultural programs are often not the primary content of interest for farmers (Ramli, 2013).

2.6.3 Smallholder farmers' perception on the accessibility of Information and Communication Technology tools used to access agricultural information

ICT access refers to the ways in which individuals, communities, and institutions engage with and utilize ICTs, considering aspects like affordability, availability, ease of maintenance, and portability (Levi, 2015; Ekeanya et al., 2018). For ICT tools to be effective, access is essential (Mousavi et al., 2018). In agriculture, easy access to ICT tools is critical for their effective use (Kante et al., 2018). Mwombe et al. (2014) highlighted that the accessibility of ICT tools is key to ensuring smallholder farmers can equitably access information. However, for the tools to benefit farmers, they must be supported within the farmers' environment. Abubakar (2021) found that while many smallholder farmers have access to ICT tools, only a few can use them to obtain agricultural information. He also noted that farmers' use of ICTs for information retrieval is limited, suggesting reluctance despite having access. Furthermore, farmers believe that the cost of ICT tools does not justify their benefits, likely due to challenges such as limited electricity, high costs, and poor network access in rural areas (Osondu and Ibezim, 2015). Nonetheless, Gbughemobi et al. (2021) emphasized the crucial role ICTs can play in delivering agricultural information, though many rural African communities still have minimal or no access to these technologies.

Various studies have highlighted the digital technologies available to smallholder farmers in South Africa in regions such as North West, KwaZulu-Natal, Eastern Cape, and Gauteng, with mobile phones, television, and radio being among the most common (Makaula, 2021; Oladipo and Wynand, 2019; Dlamini and Ocholla, 2018; Maumbe, 2010; Otiso and Moseley, 2009). Additionally, more advanced technologies such as GIS, Radio Frequency Identification, Precision Agriculture, and GPS have been noted by Zantsi and Nkunjana (2021). However, these tools are not widely adopted within the smallholder farming sector. Other frequently used technologies include personal computers, the internet, videos, and email (Akinsola, 2014; Migiro and Kwake, 2007; Woodburn, 1994). Enwelu et al. (2014) also found that access to modern ICT tools is limited for many smallholder farmers. The most commonly used and accessible ICTs are mobile phones, radio, personal computers, laptops, and television (Olayini, 2013; Rimi and Chudi, 2017; Freeman and Mubichi, 2017; Adokiye, 2020). These technologies are often preferred due to their ease of use, ability to facilitate personal interaction, improve literacy, and save time in information searches. However, they also require resources like energy, data, airtime, batteries, network connectivity, and subscriptions. Despite these challenges, their portability is a key advantage, allowing farmers to access agricultural information even in remote fields without electricity, which is particularly important in Africa where farms are often located far from homes (Mwombe, 2014).

2.6.4 Smallholder farmers' perception on the ease of use of Information and Communication Technology tools used to access agricultural information

Ease of use of an information channel refers to how simple or difficult it is perceived to understand and use (Rogers, 2003; Loukis et al., 2016). A more complex information channel makes it harder for users to integrate it into their daily lives, ultimately slowing progress (Kapoor et al., 2014). According to Tarhini (2015), perceived ease of use is the extent to which users find technology effortless, and the simpler they believe it is to operate, the more likely they are to adopt and use it. For smallholder farmers, developing a positive attitude toward ICT requires not only frequent use and access on the other hand, also a clear understanding of how to operate the tools effectively (Lokeswari, 2016). Knowledge of how to use ICT tools to gather timely and relevant information is crucial to improving productivity. However, many farmers face challenges in understanding the functions of ICT tools, such as texting, uploading attachments, sharing, downloading, and saving files (Kumar and Philip, 2019). Despite using various ICT tools daily, few smallholder farmers have a deep understanding of their functionality (Mwakaje, 2010). The complexity of ICT tools significantly impacts their utility for smallholder farmers, as noted by Devaraja (2011). Kumar and Philip (2019) also highlighted that some farmers find certain ICT tools complicated, particularly when they require specific mobile apps to access agricultural information. Rural farmers often struggle with the installation and use of these apps.

The complexity of information technology poses a significant barrier to the use of many mobile and web-based innovations (Kumar and Philip, 2019). Featherman and Pavlou (2003) and Kotze et al. (2016) argue that, alongside acceptance and adoption processes, farmers' risk perceptions play a crucial role in influencing their decisions when engaging with complex technologies. Additionally, factors such as lack of skills, old age, low education, and language barriers, particularly in smallholder farming systems, further complicate farmers' ability to effectively use ICT tools. Misaki et al. (2018); Trendov et al. (2019) emphasize that innovations aimed at farmers must be simple and tailored to their specific circumstances. For instance, older and illiterate farmers would benefit from basic, text-based solutions in local languages rather than sophisticated applications. Furthermore, technologies like smartphones, the internet, and computers are often perceived as difficult to use due to their complex features, causing smallholder farmers to view them as less useful compared to simpler methods, such as contacting agricultural extension services by phone (Kapoor et al., 2014). To address these challenges, innovations should clarify unfamiliar terminology and present information in a way that aligns with users' existing understanding. Providing resources like FAQs, tooltips, and tutorial videos can also support users in understanding how to navigate and use these technologies (Loukis et al., 2016).

2.6.5 Smallholder farmers' perception on the feedback provided by Information and Communication Technology tools used to access agricultural information

The speed at which ICT tools provide feedback is a crucial factor in their effectiveness for disseminating agricultural information to smallholder farmers (Okello et al., 2020). Feedback is vital, as demonstrated by agricultural programs that often include contact details such as phone numbers, emails, and websites, enabling farmers to reach out to information managers (Mwombe et al., 2014). Farmers have a preference for ICT tools that allow them to share their opinions, ask questions, and receive timely responses (Palmer, 2015). Receiving feedback helps farmers better apply the information shared, as it addresses any doubts or queries they may have (Zewge and Dittrich, 2017). Furthermore, smallholder farmers often seek clarification on agricultural content shared through ICT tools (Mtega, 2018). While radio has been less favoured due to its limited time for listener calls and the large audience, some farmers still appreciate the instant feedback it provides, which encourages them to seek further clarifications from agricultural programs (Okello et al., 2020; Mtega and Msungu, 2013). Radio is particularly effective in providing immediate feedback since it allows for communication in real-time, with both the broadcaster and the audience typically in the same setting (Min, 2007; Mtega, 2018).

Smallholder farmers often find that the feedback they expect from agricultural TV programs is either delayed or absent, which discourages them from seeking further clarifications (Mtega, 2018). According to Kelly (2014), agricultural TV programs typically display contact information such as social media handles, websites, and office numbers at the end, allowing farmers and viewers to voice their opinions and ask for clarification. These platforms are then used to address their questions and acknowledge their feedback. Additionally, mobile applications accessible through smartphones and computers provide a valuable opportunity for engaging audiences to share informed perspectives. When used effectively, these applications enhance communication with target audiences and facilitate real-time interactions and learning, something traditional media often lacks (Kelly, 2014).

2.7 Constraints influencing smallholder farmers access to agricultural information through Information and Communication Technology tools.

The distribution of agricultural information across farmers and extension services remains a significant challenge in many African countries (Chukwunonso et al., 2012). One of the primary obstacles to agricultural development, especially for smallholder farmers, is limited access to agricultural information (Hailu et al., 2017). The introduction of ICT tools in the agricultural sector, which are intended to enhance the dissemination of agricultural knowledge, has been seen as a solution to this issue, helping to bridge the information gap for smallholder farmers (Chhachhar et al., 2014). Despite this potential, smallholder farmers face several challenges in effectively utilizing ICT tools for agricultural activities, limiting the ability of these tools to improve crop production and increase income (Berhanudaniso, 2017). Insufficient agricultural knowledge among smallholder farmers directly affects their farm productivity and income, making it harder for them to sustain their livelihoods. These challenges are tied to various constraints within the sustainable livelihood framework, including physical, financial, human and natural factors that hinder farmers' access to vital agricultural information (Chhachhar et al., 2014; Yaseen et al., 2020).

The sustainable livelihoods framework (SLF) focuses on individuals, particularly marginalized groups, and highlights the interconnections among varied factors that influence livelihoods (Scoones, 2015). This framework was chosen for the study, which examines the factors that rural farmers face in accessing agricultural information through ICT tools. Limited access to agricultural knowledge and information leads to reduced crop production, lower income, poorer well-being, and increased food insecurity, all of which negatively impact rural farmers' livelihoods (Okello et al., 2012; Chikaire et al., 2017; Yaseen et al., 2020; Mdoda and Mdiya, 2022). The SLF emphasizes the importance of having a range of assets to achieve positive livelihood outcomes (Scoones, 2015). This study will explore how farmers' assets or capital endowments affect their access to agricultural information through ICT tools, which are essential for improving their livelihoods.

2.7.1 Physical constraints

Physical assets include essential infrastructure and production tools that are crucial for supporting livelihoods (Scoones, 2015). Infrastructure involves changes in the physical environment that help individuals meet basic needs and increase productivity, while producer goods refer to the tools and equipment that enhance work efficiency (UNDP, 2017). However, in many African countries, infrastructure development is still in its early stages (Barakabitze et al., 2017; Mugwisi et al., 2015; Barakabitze et al., 2015; Kiambi, 2018; Otene et al., 2018; Magesa et al., 2017; Awuor et al., 2017). This issue is particularly prevalent in rural communities, where access to electricity and reliable network connectivity is often limited (Makuala, 2021). Since a large portion of farmers live in these rural areas, the lack of technological infrastructure significantly hinders the adoption and use of ICT (Kiambi, 2018).

This section of the study will examine how physical assets, whether benefit or limit smallholder farmers' access to agricultural information through ICT tools.

Network towers

A large proportion of the rural population consists of smallholder farmers, but fewer than one-third have access to reliable and fast network connectivity, primarily due to the lack of network towers (Kitooma et al., 2018). These farmers often struggle with poor network coverage, which hinders their ability to effectively use ICT tools such as mobile phones and computers. As a result, they are often required to be physically present in locations with better network or internet connectivity (Makuala, 2021). While smallholder farmers may have access to necessary farming resources, poor network coverage remains a significant barrier to utilizing ICT tools for agricultural purposes (Milovanovic, 2014). Consequently, farmers in rural areas, where mobile network availability is inconsistent, often lose interest and patience with these tools (Magesa and Michael, 2014; Kitooma et al., 2018).

Stable network coverage is rare in rural regions, as Internet service providers tend to prioritize urban areas over rural ones (Masuki et al., 2010). Even when communication services like telephone networks are available, limited bandwidth defined as the amount of data an internet connection can transfer in a given time presents a substantial barrier to efficient network use. Providing electronic services to farmers in rural areas is challenging due to the high bandwidth demands of internet services in these regions (Milovanovic, 2014). Many smallholder farmers struggle with network issues, particularly in remote farming locations. Poor network coverage and frequent interruptions have significantly contributed to the reluctance of South African smallholder farmers to adopt technology (Mdoda and Mdiya, 2022).

The advancement of technology has made it possible to access radio and TV through smartphones and computers (Mtega and Msungu, 2013). However, poor network coverage in some rural areas limits access to these technologies, especially when there is weak or no signal at all (Byres et al., 2011). These challenges are mainly due to the absence of network towers, which directly impacts the availability of agricultural information that should be accessible through ICT tools (Mtega and Msungu, 2013). Research by Akullo and Mulumba (2016) and Obidike (2011) found that rural farmers face difficulties in accessing agricultural information through radio and TV, largely due to poor reception and the lack of antennas, as well as environmental factors. The quality of the signal significantly affects the effectiveness of these technologies as reliable sources of agricultural knowledge (Mtega, 2018).

Electricity supply

Rural areas are often characterised by a population that is dispersed, which makes it difficult to provide essential services such as electricity, modern ICT tools, infrastructure, and public utilities (Kiambi, 2018; Jose et al., 2014). Electricity, a crucial resource for ICT services, is notably scarce in many of these areas (Torero, 2014). Masuki et al. (2010) observed that frequent power outages in rural communities across Africa hinder smallholder farmers' ability to charge phones, computers, and operate devices like radios and TVs. This issue has led many farmers to rely on batteries and solar systems, which are not always reliable, further discouraging ICT tool usage (Mdoda and Mdiya, 2022).

In South Africa, the problem of power outages and rolling blackouts is particularly severe (Mdoda and Mdiya, 2022). A consistent electricity supply is essential for operating ICTs, ranging from mobile phones and internet access to more advanced technologies like Artificial-Intelligence and Internet-of-Things (Research ICT Africa, 2020). If South Africa's electricity supply were more reliable, the use of both basic and complex ICTs in agriculture could increase significantly. Most smallholder farmers in the country turn to national radio or TV broadcasts for agricultural information, with high television penetration rates of 85% in urban areas and 70% in rural areas, along with 71% and 61% access to radio, respectively (Gillwald et al., 2018). However, the effectiveness of agricultural programming is being undermined by load shedding and unreliable electricity (Research ICT Africa, 2020).

Furthermore, smallholder farmers often struggle to access or discover agricultural information and technological advancements due to the lack of electricity. In South Africa, 60% of rural residents and 31% of the total population still lack electricity access (Jamal, 2015), limiting their ability to use ICT devices and services for agricultural purposes. This electricity shortage has been identified as a key barrier to ICT access and effective usage among smallholder farmers, as noted by Chhachhar et al. (2014).

2.7.2 Financial constraints

Financial assets refer to the monetary resources individuals use to accomplish their livelihood goals (Scoones, 2015). These assets come from two primary sources: first, from available stocks like savings, livestock, and jewellery; and second, from consistent income streams such as wages, pensions, and remittances (UNDP, 2017). This part of the study will examine how financial assets, whether positively or negatively, impact smallholder farmers' ability to access agricultural information through ICT tools.

Household income

In rural areas, income levels tend to be lower than in urban settings, making it difficult for most rural households to afford modern ICTs such as computers, smartphones, and internet access (Asenso-Okyere and Mekonnen, 2012). The availability of income plays a significant role in determining whether individuals can acquire the necessary tools and skills to use various technologies (Gillwald and Stork, 2010; Hafkin and Odame, 2002; Hafkin and Taggart, 2001). According to Titilope (2020), the slow adoption of ICTs by smallholder farmers and their limited use of ICT tools to access agricultural information can be attributed to their low or non-existent income. A major constraint for smallholder farmers in accessing more complex and efficient technologies is the high cost, as lack of stable income prevents them from investing in these tools. In South Africa, for instance, this financial barrier results in a marked difference in ICT usage between smallholder and large commercial farmers (Chisasa and Makina, 2012).

Research by Gillwald and Stork (2010) revealed that ICT diffusion, including mobile phones, radio, internet, and television, is uneven, with income serving as a major barrier to access and usage. Additionally, ICT operators are often hesitant to provide services in rural areas due to high infrastructure, operational, and programming costs, as well as the inability of rural populations to afford these services (Souter et al., 2005). Kinuthia and Mabaya (2017) also highlight that smallholder farmers are typically slower to adopt new technology, largely because of constraints related to their low farm and off-farm income. Lapple (2015) adds that farmers with stable incomes are more likely to embrace new technologies, as they have the financial means to invest in them. The use of ICT tools comes with high operational costs, such as maintenance, mobile data, electricity, batteries, and installation of systems like satellite dishes e.g., DSTV, all of which are often unaffordable for smallholder farmers (Byres, 2011; Akullo and Mulumba, 2016).

Cost of ICT tools

One of the key challenges hindering the adoption and use of ICTs by agripreneurs and agricultural stakeholders in African countries is the high affiliated costs. While advancements in infrastructure and the availability of more affordable devices have reduced the costs of accessing ICT services, the expenses of owning devices and maintaining connectivity remain significant barriers. Shemfe (2018) highlighted that the high cost of ICT tools and data usage are major factors that restrict smallholder farmers from using these technologies for agricultural information. This challenge is particularly pronounced in developing countries, where the high costs of ICTs hinder their widespread use for farming purposes (Milovanovic, 2014). Many smallholder farmers, who primarily rely on income from farming and social grants, struggle to afford ICT tools for agricultural use (Mdoda and Mdiya, 2022). Fors and Moreno (2002) and Galloway and Mochrie (2005) pointed out that the cost of personal computers and other ICT equipment makes them unaffordable even for middle-class families in many developing nations, limiting the number of people who can utilize these tools to improve agricultural productivity.

The expense of ICT tools has been widely recognized as a significant barrier to smallholder farmers' access to agricultural information through these channels (Barakabitze, 2015; Wulystan and Andrew, 2013; Haug and Tumbo, 2018; Kilima et al., 2016). For those who rely on mobile applications for agricultural information, the operational costs often prove to be prohibitively high (Palmer, 2014). Mahant et al. (2012) noted that some technology developers focus more on innovation rather than cost-effectiveness, which may lead to the neglect of more traditional technologies that are similarly effective but more affordable. The push for increasingly advanced technologies also drives up costs, as these innovations require greater infrastructure and resources to function, making them more expensive for users (Barakabitze, 2015).

Furthermore, the affordability issue extends to the need for financial resources to maintain and repair ICT tools, which many smallholder farmers lack (Antim et al., 2021). In contrast, radio remains one of the most affordable means of accessing agricultural information, particularly compared to newer technologies like television and modern ICTs. Its affordability makes it more accessible to rural and low-income communities, where it serves as an essential medium for overcoming challenges such as isolation and illiteracy (Fraser and Estrada, 2023; Jemal, 2013).

2.7.3 Human constraints

Human capital encompasses the skills, knowledge, labour capacity, and health that collectively empower individuals to pursue various livelihood strategies and meet their livelihood goals (Scoones, 2015). At the household level, the availability of human capital is determined by the quantity and quality of labour, which can differ based on household size and the skill sets of its members. Human assets include factors such as education, expertise, skills, and the ability to work and adapt (UNDP, 2017). This section of the study will examine how these human assets, whether beneficial or limiting, impact smallholder farmers' ability to access agricultural information through ICT tools.

Level of education

Education plays a vital role in enhancing the ability to understand, interpret, and evaluate valuable agricultural information (Jemal, 2010). A positive correlation between education and the adoption of technology has been observed, with smallholder farmers who have higher educational levels generally having better access to essential information for farming compared to those with lower education levels (Mwangi and Kariuki, 2015; Munasinghe and Kanchanamala, 2018). The successful application of innovation often depends on literacy, as higher levels of literacy enable better use of technology (Gundu, 2006). A significant barrier for many smallholder farmers is inadequate literacy, which directly impacts their ability to effectively use ICT tools to access agricultural information (Abebe and Mammo-Cherinet, 2019). Additionally, educational constraints alongside socioeconomic factors further limit the capacity of farmers to use technology efficiently (Gillwald, 2010; Hafkin and Odame, 2002). Studies reveal that the inability to read and write is a primary obstacle for smallholder farmers, hindering their ability to understand and implement agricultural information (Sanga, Kalungwizi, and Msuya, 2013; Kaddu, 2011; Barakabitze et al., 2017).

The high illiteracy rate among smallholder farmers exacerbates the issue, as many are unable to comprehend or apply the information provided to them (Lamptey et al., 2016). Furthermore, agricultural information is often presented in English or the national language through ICT platforms, creating a language barrier that leads to misinterpretations and the adoption of incorrect farming practices (Mbagwu, 2018). The use of languages such as English, which do not consider local cultural contexts, further complicates the access to farming information through ICT tools like mobile phones, TV, and computers (Asenso-Okyere and Mekonnen, 2012; Schalkwyk et al., 2017). Mtega (2018) highlighted that agricultural programs broadcast in foreign languages, particularly English, are often incomprehensible to farmers, making it difficult for them to grasp the message being conveyed. This underscores the need for agricultural broadcasts to be in languages that are widely understood by farmers.

Even when the potential of ICTs is acknowledged, the lack of content in local languages remains a major barrier in rural Africa. Tembo (2005) emphasized that local language content is essential for ICTs to make a real difference in people's lives. The language barrier continues to prevent smallholder farmers from fully utilizing ICTs to access valuable agricultural information (Chhachhar et al., 2014). This suggests that developing ICT tools and services that support local languages would significantly improve smallholder farmers' access to agricultural knowledge, boosting their productivity and market access as this information is increasingly available through digital platforms (Makaula, 2021).

ICT literacy

Digital literacy involves the ability to effectively use technology in a secure, creative, and critical manner to meet the demands of living, learning, and working in a digital environment (Letshela, 1999). In rural Africa, it is projected that up to 80% of farmers are unable to operate modern ICT tools like smartphones and computers (Jeffery et al., 2019). Abebe and Mammo-Cherinet (2019) identify inadequate knowledge and skills for using ICT applications as key factors limiting smallholder farmers' access to these tools. Accessing and utilizing ICT effectively is crucial for adopting agricultural information (Ireri et al., 2021).

Low ICT skills remain a significant barrier to the use of technology in agricultural information. Despite the growing availability of ICTs, smallholder farmers' ability to use and access them is hindered by insufficient technical skills (Ayim et al., 2022). A report by GSMA (2015) also notes that the lack of technical expertise is a major challenge in adopting ICT tools for agriculture. While ICTs have the potential to improve farm technologies and increase productivity and income, the challenge persists because many rural farmers lack the basic knowledge to use essential ICT tools like computers and the internet (Eskia, 2019; Nwafor, 2020; Omotayo, 2005). Additionally, many smallholder farmers struggle with basic digital tasks, such as navigating menus, typing, downloading apps, and accessing hyperlinks (Milovanovic, 2014). This lack of skills not only impedes the adoption of ICTs but also limits the farmers' ability to access real-time agricultural information and services (Henze and Ulrichs, 2016; ITU, 2020; Misaki et al., 2018).

Age

Farmers' age is a key factor that affects how they acquire and use information provided through ICT tools (Fahad et al., 2019). Studies by Sikundla (2018) and Bryan and El Didi (2019) emphasize that age is an important socio-economic characteristic affecting smallholder farmers' use of these technologies. According to Muhammad et al. (2012), the age of farmers influences their attitudes toward accessing and applying agricultural information through ICT tools. Ekepu and Tirivanhu (2016) also pointed out a link between age, technology adoption, and usage, suggesting that older farmers, with years of experience, are often more capable of evaluating agricultural information than younger farmers. However, other studies, such as those by Dhraief (2018) and Mittal and Mehar (2016), suggest that as people age, they may become more resistant to adopting and utilizing modern technologies. In addition, Asif, Uddin, Dev, and Miah (2017) observed that older individuals often find it challenging to operate advanced technologies like mobile phones, computers, and televisions, in contrast to younger generations, who are generally more comfortable with these devices. The older generation often prefers sticking to traditional technologies like radios, thus distancing themselves from newer, more complex tools (Jeffery et al., 2019). On the other hand, younger rural populations are increasingly engaging with a wide range of ICT tools and applying them in modern agricultural practices (Aker, 2011).

ICT awareness

Awareness refers to an individual's knowledge of the existence of an innovation. This awareness often sparks interest, encouraging the individual to explore the innovation further, potentially leading to its adoption (Kimbowa, 2013). The successful and efficient use of ICT tools in rural areas hinges on the readiness of the rural population, which is influenced by their understanding and attitude toward these technologies (Raghuprasad et al., 2012). Despite recognizing the importance of ICT and having a positive attitude toward it, rural communities often experience low ICT adoption, largely due to a lack of knowledge. Many farmers continue to rely on traditional methods and peer recommendations, as they are unaware of the specific services offered by ICT and how to access them (Kumar and VijayaKumar, 2015). Although various ICT services are available, their use remains limited because farmers lack awareness (Hasan et al., 2019). Ajaji et al., (2018) noted that farmers' general awareness of ICT is low, likely due to insufficient knowledge and a lack of interest in ICT use. This gap in awareness impacts how farmers apply ICT to their everyday activities (Hasan et al., 2019). Overall, many stakeholders in the agricultural sector lack a deep understanding of how ICT can enhance productivity and profitability (Kimbowa, 2013). This lack of understanding hampers ICT investment in agricultural education, institutions, and the sector as a whole. Some successful agripreneurs, unaware of the additional benefits ICTs can provide, do not see the value in using or investing in these technologies (Kimbowa, 2013). Furthermore, while ICTs could boost farming productivity, challenges like inadequate comprehension of smallholder farmers' needs and limited knowledge about ICT's role make it difficult for them to effectively incorporate these tools into their farming practices (Chukwunonso et al., 2012).

2.7.4 Natural constraints

Natural capital refers to the resources from nature that contribute to sustaining livelihoods (Scoones, 2015). These resources range from intangible elements like biodiversity and the atmosphere to tangible assets, such as land and trees, which are directly used in production (UNDP, 2017). In this section, the study will explore the natural resources that can either positively or negatively impact smallholder farmers' ability to access agricultural information through ICT tools.

Land

Land ownership and its size are recognized as significant factors that can both positively and negatively influence the adoption and utilization of agricultural management practices (Baumgart-Gretz et al., 2012). The use of ICT tools in agriculture is seen as a technological innovation that helps disseminate valuable agricultural information, enabling smallholder farmers to improve their productivity. Ojo and Oluwatusin (2017) pointed out that farmers with smaller farms are more likely to embrace new technologies, including ICT tools, with the expectation that access to agricultural information will help them improve their agribusiness and increase their returns. This indicates that larger land areas can positively influence a farmer's access to agricultural information through ICT tools, supporting their efforts for personal and business growth. Conversely, farmers without secure land tenure are less likely to invest in ICT tools or consider them as long-term assets for acquiring agricultural information or improving their physical infrastructure (Wreford et al., 2017). Armstrong and Ghandi (2012) further emphasized that land ownership typically allows farmers to earn more income, which could be used for purchasing ICT tools and enhancing their farming practices.

2.8 Theoretical framework

This study employed the Uses & Gratification theory as its theoretical framework. The fundamental idea behind this theory is that individuals actively choose a media that satisfy their needs and lead to satisfaction (Lariscy et al., 2011). By applying this theory, the research aims to offer a more detailed and comprehensive understanding of why smallholder farmers utilize ICT tools to address their agricultural information needs.

Historical development

In the 1940s, Herzog (1944) introduced the Uses and Gratifications (U&G) theory, exploring reasons individuals listened to the radio. She identified four key motivations: self-rating, competitive, sporting, and educational. Resulting in three primary gratifications: emotional release, wishful thinking, and advice. This theory was later extended to print media by Berelson (1949), who suggested that newspapers met readers' needs for a sense of security, shared conversation topics, and daily routine structure. Blumber and McQuail (1969) further explored the theory by examining audience motives for watching televised political programs during the 1964 English elections, categorizing the motives into four groups: diversion, personal relationships, personal identity, and surveillance. Katz et al. (1974) broadened this research by investigating gratifications from various media, including radio, television, newspapers, books, and films. More recently, the theory has been applied to new media, such as video games, the internet, and cell phones (Foregger, 2008), and has become crucial for understanding the growing role of new media and information technologies in communication (Foregger, 2008).

Basic assumptions of the theory and its application to the study

1. Users play an active role in the media environment. In the context of agricultural ICT, smallholder farmers engage with various ICT tools to address their intrinsic farming needs, such as accessing agricultural information that supports crop productivity. When using ICT tools to access information, smallholder farmers do not simply passively receive information; rather, they actively participate. They contribute by sharing their experiences, raising questions, and seeking clarification. In this study, smallholder farmers are considered active participants in the media environment, as they engage directly with the information source by interacting, asking for clarification, and exchanging experiences.

2. Users are driven by specific goals, purpose, and motivation. In the context of the Uses & Gratification theory and ICT in agriculture, smallholder farmers as media users, are driven by a clear purpose to use ICT tools for accessing agricultural information, engaging with various information sources, promoting their products, and communicating with customers. This study highlights that smallholder farmers are motivated to use ICT tools that effectively meet their information needs, such as receiving timely, relevant information, easily navigating the tools to access it, and getting immediate feedback.

3. Media competes with other sources to satisfy needs: Smallholder farmers in the agricultural context turn to different sources for information, such as traditional media, modern technologies, and agricultural experts. Each of these sources has its own strengths and weaknesses in how they distribute information. In this study, smallholder farmers choose a particular source based on its ability to meet their information needs and provide effective

communication. Important factors in determining the effectiveness of a source include the relevance and timeliness of the information, ease of access, and the feedback they receive.

4. Audience members can evaluate the value of media content and the gratifications obtained from media usage: In this study, smallholder farmers who utilize ICT tools to obtain agricultural information are able to assess the value of the content they receive. They determine this value by considering whether the information is timely (current) and relevant to their daily farming activities. Farmers gain satisfaction when they experience enhanced access to useful information, feel content with the quality of the content, and are able to interact effectively with customers and other stakeholders in the agricultural value chain.

The U&G theory suggests that media consumers, in this case, smallholder farmers, recognize their own needs and choose the media that can best fulfil them. Essentially, users take an active role in selecting the media that fits their requirements (Katz et al., 1974). This theory has been widely applied in studies of traditional media, and it seems reasonable to extend its use to more modern platforms (Browning and Sanderson, 2012). In the context of the Fourth Industrial Revolution, particularly in agriculture, smallholder farmers deliberately and actively choose ICT tools, setting expectations and achieving gratification. The application of this theory to new forms of computer-mediated communication is appropriate, as it emphasizes an active audience (Foregger, 2008; Logan, 2014). Ruggiero (2000) notes that, since some ICT tools are interactive, the distinction between sender and receiver is becoming less clear, particularly with devices like smartphones, basic cell phones, and sometimes radio, where both roles can be interchanged. This interactivity strongly supports the U&G concept of active users, defined as "the degree to which participants in the communication process have control over and can exchange roles in their mutual discourse" (Williams et al., 1988; Moon, 2016).

The assumptions of the theory are closely aligned with the framework of this research study. This study explored major ICT tools, including mobile phones, radio, the internet, television, and computers. In rural communities, farmers not only provide for their families but also produce food for the broader society, which gives them a unique and crucial role within the community. In line with this theory, the study examined the possession and usage of ICT tools, as well as farmers' perceptions of their effectiveness. This investigation aimed to understand how these tools might help meet their information needs in the future. The theory is relevant to the study, as it underscores how smallholder farmers use various ICT tools to fulfil their agricultural information needs. For ICT tools to effectively address these needs, they must align with the key components of effective information technology. The study identified the ability to provide timely and relevant information, ease of access and use of the tools, and the feedback provided as critical elements of effective ICT tools. As a result, smallholder farmers experience primary gratifications such as enhanced access to information, better utilization of agricultural inputs, and increased crop yields and income.

2.9 Conceptual framework

The use of ICT tools to provide relevant agricultural information can significantly accelerate the development of smallholder farmers by offering them the knowledge needed to enhance their farming practices and link them to more profitable markets. When farmers have access to essential farming information and resources, crop farming can greatly contribute to agricultural progress in rural areas. As shown in Figure 1, ICT plays a key role in spreading agricultural information, thus boosting the crop productivity of smallholder farmers. These farmers use ICT tools such as television, radio, smartphones, basic cell phones, and computers to access various types of agricultural data. By utilizing these tools, smallholder farmers can acquire valuable information on market trends, weather conditions, agricultural practices, innovative inputs, pest and disease control, and financial resources all of which support their farming operations.

The wealth of information provided through ICT tools has a positive impact on crop productivity, adoption of improved seeds, fertilizers, and pest control methods, which in turn leads to better yields and higher incomes. As a result, smallholder farmers can achieve better livelihood outcomes, including enhanced access to agricultural information, increased farm profits, improved food security, greater crop production, sustainable use of natural resources, and stronger connections to lucrative markets. Additionally, the effectiveness of ICT tools in disseminating agricultural information depends on how relevant and timely the information is, the accessibility and ease of use of these tools, and the farmers' overall satisfaction. These factors determine the extent to which smallholder farmers are motivated to use and continue using ICT tools for acquiring agricultural knowledge.

However, smallholder farmers face various challenges when accessing agricultural information through ICT tools. These barriers, which can be categorized into physical, financial, human, and social constraints, impact the efficient flow of information and ultimately hinder the improvement of the farmers' livelihoods.

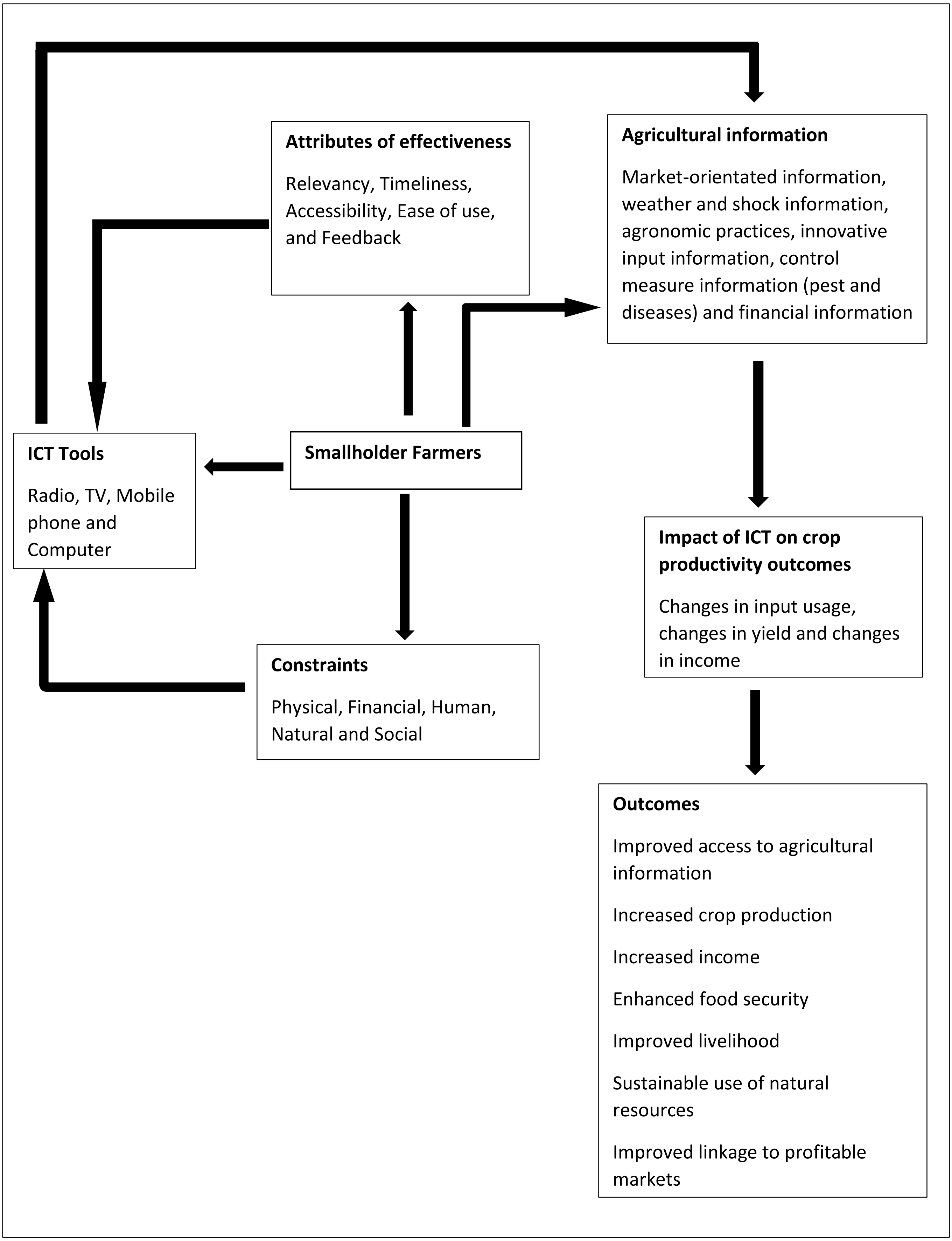
2.10 Research paradigm

A research paradigm refers to the philosophical framework that guides a study by shaping how reality is viewed, how knowledge is constructed, and the methods used to investigate a phenomenon (Adil and Khalid, 2016). According to Husam and Abraham (2020), it consists of underlying assumptions about the nature of reality (ontology), how knowledge is gained (epistemology), and how research should be conducted (methodology). Selecting an appropriate paradigm provides direction, coherence, and legitimacy to the research process. Various paradigms exist within social science research (Adil and Khalid, 2016). Positivism is based on the belief that reality is objective and measurable, favouring structured, quantitative approaches to establish causal relationships (Yoon, Konge and Anthony, 2020). Interpretivism, in contrast, assumes that reality is socially constructed and best understood through the lived experiences and perceptions of individuals, often utilising qualitative methods to explore meaning (Husam and Abraham, 2020). Pragmatism blends elements of both, acknowledging that multiple perspectives may explain reality and allowing the researcher to choose methods that best address the research questions (Kaushik and Walsh, 2019).

This study is underpinned by a positivist paradigm. The focus was on examining the effectiveness of ICT communication tools through observable and quantifiable indicators such as extent of use, perception, constraints, and impact on crop productivity among smallholder farmers in the Mbombela Municipality. Positivism is appropriate because the study aims to establish patterns, relationships, and measurable outcomes, rather than relying on subjective interpretations of reality. Quantitative data collection through structured questionnaires allowed the researcher to obtain reliable and generalisable findings, consistent with positivist assumptions. The methodological implications of adopting a positivist paradigm include that it supports the use of quantitative research design, use of standardised data collection instruments, and statistical analysis (Yoon et al., 2020). It reinforces the emphasis on validity, reliability, and replicability in measuring ICT effectiveness and associated constraints. Additionally, it positions the researcher as an independent observer who does not influence the responses of participants.

Further details on how the positivist paradigm shaped the practical aspects of the study are presented in the research Methodology Chapter 3, including the sampling approach, survey design, and quantitative statistical techniques used to analyse the data. By aligning the research objectives and design, this paradigm ensures that the study produces evidence-based insights that are relevant for agricultural extension stakeholders and policy makers seeking to improve ICT utilisation among smallholder farmers in the region.

Figure 1: Conceptual framework of effectiveness of ICT tools in dissemination of agricultural information to enhance crop productivity



Chapter summary

This chapter has presented a literature review related to the effectiveness of ICT tools in disseminating agricultural information to smallholder farmers in enhancing crop productivity. It began by exploring the various sources of agricultural information available for smallholder farmers in rural areas and the role of ICT in agriculture. Followed by an examination of various ICT tools employed by smallholder farmers, such as radio, television, mobile phones, and computers. The chapter also looked at the different channels these farmers use to access agricultural information through ICT platforms. Additionally, it discussed how ICT tools influence crop productivity, focusing on changes in input usage, yield, and income. The review also assessed the effectiveness of ICT tools in spreading agricultural information, considering seven key attributes: the relevance and timeliness of information, the accessibility and user-friendliness of the tools, and the feedback provided to farmers. The literature highlighted several challenges smallholder farmers face when accessing agricultural information through ICT tools, which impede their effective use. These challenges include factors such as farmers' age, gender, educational level, farm size, membership in cooperatives, the use of foreign languages on the tools, electricity availability, network connectivity, the cost of tools, ICT literacy, and awareness.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This section outlines the methodology for assessing how effective ICT tools are in dissemination agricultural information to improve crop productivity among smallholder farmers in the Mbombela local municipality of the Ehlanzeni district. It includes a comprehensive overview of the study area, data collection methods, sampling approach, research tools employed, data analysis procedures, and the validity and reliability of the study's instruments.

3.2 Study area

The study was carried out in the Mbombela local municipality within the Ehlanzeni district. The name "Mbombela" translates to "a lot of people together in a small space" (Municipalities of South Africa, 2012-2023). Established in 2000, the municipality was formed through the merger of the Hazyview, Nelspruit, and White River Local Councils, as well as the amalgamation of the former Mbombela and Umjindi Local Municipalities. It is one of four local municipalities in the Ehlanzeni District as shown in Figure 2 (Municipalities of South Africa, 2019). Located in the north-eastern part of South Africa within the Lowveld sub-region of the Mpumalanga Province, the municipality spans approximately 7,139 square kilometres (City of Mbombela final Integrated Development Plan (IDP), 2019). It is divided into four regions: The Northern Region (Hazyview), the Eastern Region (Nsikazi, White River, Kabokweni, Malekutu), the Central Region (Mbombela, Kanyamazane, Pienaar, Daantjie, Nelsville, Mataffin, Elandshoek), and the Southern Region (Barberton, Lowscreek, Matsulu). The municipality is made up of 45 wards and includes 10 Traditional Authorities located in the Southern, Northern, and Eastern Regions (City of Mbombela Local Municipality: Spatial Development Framework, 2018).

According to Statistics South Africa (2011), based on the 2016 municipal boundaries, the Mbombela municipal area had a total population of 695,913, which makes up 39.6% of the total population of the Ehlanzeni District. The municipality has approximately 206,136 households, with the majority of the population residing in peri-urban and rural areas. Around 75% of the population lives in communal areas on the eastern side of the city, far from economic centers (Mbombela Local Municipality Integrated Development Plan, 2019). Data from the City of Mbombela Local Municipality: Spatial Development Framework (2018) reveals that the municipality has a relatively young population, with 61% being under the age of 29. The working-age group, which includes individuals aged 15-64 years, makes up 64% of the population. In terms of gender, females have outnumbered males in the municipality since the 1996 Census and the most recent 2016 Community Survey. The majority of the population is Black (96%), followed by White (2.69%), with smaller percentages of Coloured and Indian populations. The most commonly spoken language is Swati (79%), followed by Afrikaans (7%), English (5%), Tsonga (4%), and other languages (5%) (Mbombela Local Municipality Integrated Development Plan, 2019-2020; Statistics South Africa, 2011).

The Mbombela Local Municipality is characterised by varying socio-economic conditions that influence farmers' access to and use of ICTs. While education and employment challenges exist within the area, the most relevant aspect for this study is that many smallholder farmers operate in contexts of limited digital skills and uneven ICT infrastructure. These conditions shape how farmers adopt and utilise ICT tools, making it important to understand the municipality's basic socio-economic context when assessing ICT effectiveness among smallholder farmers (Community Survey, 2016). Agriculture in Mbombela is on the decline, contributing less to the local economy than other sectors, though there is still potential for growth through new farming methods that address land scarcity and adapt to climate change (City of Mbombela Local Municipality: Spatial Development Framework, 2018).

The region has mild winters and summer rainfall, characterized by a subtropical climate. It receives an average annual rainfall of between 300mm and 500mm. The main crops grown in the area include macadamia nuts, vegetables, citrus, grains, avocados, and other nuts (Mbombela Local Economic Development Strategy Review, 2015). Smallholder farmers in the Mbombela municipality plant crops based on planting calendars provided by the local Department of Agriculture, Rural Development, and Environmental Affairs through its extension services. These crops include maize, vegetables, groundnuts, and soybeans (City of Mbombela Integrated Development Plan, 2017-2022).

The Community Survey (2016) highlighted that the municipality has made 16.6% improvement in access to piped water since 2001. This progress reflects broader infrastructural developments in the area, which are important to consider as access to basic services often correlates with improved opportunities for ICT uptake and utilisation among smallholder farmers. Additionally, the municipality expanded access to electricity, which reached 92.2% in 2016, marking it as the most improved basic infrastructure. However, the Mbombela Local Municipality Integrated Development Plan (2019-2020) noted that the current infrastructure is limited and cannot adequately serve all residents, and much of it is outdated and in need of upgrading. The report also pointed out that outdated infrastructure, the rural digital divide, limited access to reliable internet, and high ICT costs are barriers to ICT access, especially in rural areas (Van Greunen and Fosu, 2022). In Mbombela Local Municipality, the use of ICT by farmers is generally restricted, with many smallholder farmers mainly relying on basic ICT services, such as mobile phones for communication. There are considerable challenges in accessing more advanced agricultural information platforms, including issues such as poor internet connectivity, low digital literacy, and limited access to smartphones. Nonetheless, efforts are underway to encourage greater ICT adoption among farmers through programs aimed at providing training and improving access to relevant agricultural information platforms. Despite these challenges, there is a growing effort to integrate ICT into agriculture. Smallholder farmers in the municipality are utilizing various ICT tools, including radio, TV, mobile phones, and apps such as Farmbook, Farmer's Weekly, and Smartfarm, to enhance their knowledge and farming practices. Agricultural extension workers also utilise ICT tools, such as mobile phones and radios, to directly share useful information with farmers (Agholor et al., 2024).

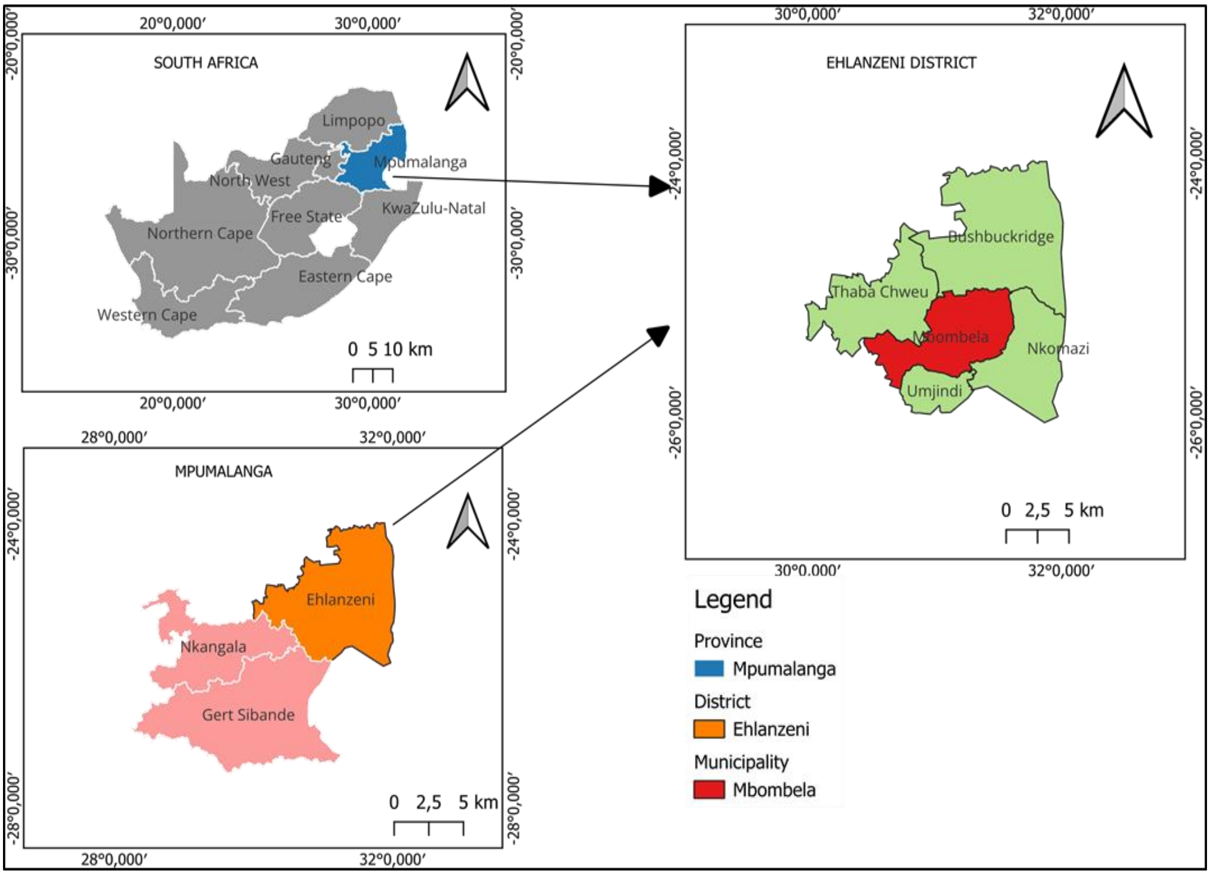


Figure 2: City of Mbombela Local Municipality Map

Source: QGIS, 2025.

3.3. Research design

The study was conducted using a quantitative research design, also referred to as a survey research design, which is commonly used to investigate a broad range of issues and challenges (Suhaila, 2021). This approach involves analysing social or human problems by testing theories through the measurement and analysis of various variables using statistical methods (Creswell, 1994). Quantitative design is employed to collect and analyse data in numerical form. It can help identify trends and averages, predict future outcomes, test causal relationships, and generalize findings to a larger population (Castellan, 2010).

One key strength of this research design is its repeatability, as it involves predefined data collection protocols and clear descriptions of conceptual ideas (Castellan, 2010). This allows the study to be replicated in different ethnic contexts, at different times, or with a new group of participants. Statistical comparisons can then be made between results (Suhaila, 2021). Another advantage is the use of large sample sizes, which enables the gathering and analysis of data in a consistent and accurate manner through quantitative methods (Powell, 2019). However, Chetty (2016) points out that the quantitative research approach has certain limitations, the most significant being its tendency to yield restricted findings due to the reliance on structured questionnaires with closed-ended questions.

3.4 Sampling

3.4.1 Target population

In this study, the target population consisted of smallholder crop farmers within the Mbombela Local Municipality, specifically those from rural communities in the area. This group included both smallholder farmers who use ICT tools such as radio, TV, computers, and mobile phones for accessing agricultural information, as well as those who do not. The target population of the study refers to the group being studied, as well as those to whom the results may be applicable or transferable (Casteel and Bridier, 2021). Zhao, Tian, Claggett, and Wei (2013) also describe this group as the study's intended audience.

3.4.2 Sampling method

The study employed a probability sampling method, which involves selecting a sample from a population based on the principle of randomization, also known as random selection (Sharma, 2017). Probability sampling ensures that every individual in the population has an equal chance of being chosen (Singh and Masuku, 2014). This method is commonly used in quantitative research to produce results that are representative of the entire population. Some advantages of probability sampling include its cost-effectiveness, higher reliability of research findings, and its simplicity and ease of use (Etikan and Bala, 2017). However, it also has some drawbacks, such as being more complex and time-consuming to implement (Singh and Masuku, 2014).

3.4.3 Sampling technique

The study employed a systematic sampling technique to select units from the target population. Systematic sampling is a probability sampling method where study units are chosen from a larger population starting from a randomly selected point, with a consistent, periodic interval between selections. This interval, known as the sampling interval, is calculated by dividing the population size by the desired sample size (Thomas, 2020). Systematic sampling is straightforward to perform and easy to understand. It assumes that the results will accurately represent the majority of typical populations, ensuring that the entire population is sampled evenly (Hayes, 2022). This technique relies on a sampling frame, which is a list of individuals from which the sample is drawn, ideally representing the entire population (Villegas, 2023).

The study used the systematic sampling technique to select 337 crop smallholder farmers from the sample frame. This method involved randomly selecting a starting point, referred to as the first subject. For this study, the number two was chosen as the starting point (Thomas, 2020). To determine the sample interval, the study applied the recommended formula, which resulted in 1343/308 = 4. Thus, four was used as the constant difference between consecutive numbers in the sequence. Sampling occurred at an interval of four, meaning that after counting three names of smallholder farmers in the sample frame, starting from the selected point, the next individual was included in the sample (Thomas, 2020). This technique was employed to ensure that everyone in the target area had an equal chance of being selected and to prevent biases related to factors such as gender and distance.

3.4.4 Sampling size

To determine the sampling units, the study used Slovin’s formula. This formula is commonly applied in random sampling to estimate the sample size, especially when the researcher lacks sufficient information about the population’s behaviours (Stephanie, 2013). One of the benefits of using this sampling method is that it enables the researcher to estimate the necessary sample size to ensure the results are reasonably accurate, while also allowing for precise sampling of the population (Singh and Masuku, 2014).

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

Where:

n = Number of samples

N = Total population

e = Error tolerance (level)

e= 1- confidence level. Confidence level refers to the degree of certainty the researcher has that the data collected accurately reflects the overall population (Singh and Masuku, 2014).

In this study, there is a 95% likelihood that the sample results represent the true characteristics of the population within a specified accuracy range, leaving only a 5% chance that they do not.

According to the Mbombela Local Municipality farmers' database, there are 1,343 crop smallholder farmers across the municipality's communities.

n= 1343 / (1 + 1343 (0, 05) $_2$)

n= 308

3.4.5 Data Collection

A structured questionnaire was used to gather data for the study. In a structured questionnaire, the questions are prepared in advance, ensuring that all respondents are asked the same questions in the same order (Cheung, 2014). The questionnaire consists of questions with predefined answers, which may be either closed or prompted (Marsden and Wright, 2010). One advantage of using structured questionnaires is that they require less cognitive effort from respondents, as they minimize the need for critical thinking to answer the questions. This often leads to higher response rates and more accurate data. Consequently, the researcher finds it easier to code and analyse the responses (Chipeta, 2020). However, one limitation of this method is that the design of the questionnaire makes it difficult to explore complex issues or opinions, as the questions do not allow for in-depth exploration (Chetty, 2016).

For this study, enumerators and translators who were familiar with the local languages, SiSwati in their respective communities, were employed to assist with the questionnaire. Since a large number of people understood SiSwati, it was chosen as the primary language to explain the English-language questions to respondents. During the survey, the researcher and trained enumerators personally administered the questionnaire to respondents and remained present throughout the process to address any questions or concerns that arose.

3.5 Data Analyses

Objective one: To evaluate the impact of ICT tools on crop productivity among smallholder farmers.

The study assessed the impact of ICT tools on the crop productivity of smallholder farmers. The decision of whether farmers use ICT is not random; it is influenced by factors such as the farmers' characteristics, their families, and the region, making it a self-selecting process. The variation in crop productivity between ICT users and non-users may result in selection bias, potentially undermining the reliability of the estimated results. To address this, previous studies have employed various econometric models, including the instrumental variable method, Heckman's two-step method, difference-in-difference (DID) matching, and propensity score matching (PSM). However, the Heckman two-step method is limited by the assumption that unobserved variables are normally distributed (Becerril and Abdulai, 2010). The IV method faces challenges in identifying an appropriate instrument variable for the selection model, and it also relies on a functional form in estimating the outcome equation (Ali and Abdulai, 2010). While the DID matching method provides reliable, unbiased estimates by correcting for selection bias, it is only suitable for studies using panel data (Ali and Abdulai, 2010), which this study does not include. To overcome the limitations of these methods, the study uses the PSM method proposed by Rosenbaum and Rubin (1983) to address selection bias in a cross-sectional dataset

This study used propensity score matching (PSM) to evaluate the impact of ICT tools on the crop productivity of smallholder farmers. PSM was first introduced by Rosenbaum and Rubin (1983), with Heckman (1997) also contributing to the development of the method. When assessing impact, it is necessary to estimate the counterfactual, which compares the actual outcomes with what would have occurred in the absence of an intervention. This is done by comparing control groups with the treatment group. The control group should be similar to the treatment group, except for their participation in the intervention. Therefore, selecting an appropriate counterfactual is essential for impact assessment. In this study, the counterfactual is defined as what would have happened if smallholder farmers in the targeted area had not used ICT tools to access agricultural information for improving their crop productivity. The treated group consists of smallholder farmers who use ICT tools to access agricultural information, while the control group includes those who do not use ICT tools for this purpose.

PSM involves matching treatment and control units that have similar propensity scores, and possibly other covariates, while excluding any unmatched units. It is typically used to compare two groups, though it can be applied to studies with more than two groups (Rosenbaum and Rubin, 1983). According to Diaz and Handa (2004), PSM is most effective when the survey instrument used to measure outcomes is consistent for both treatment and control groups. Thus, the success of PSM largely depends on the quality of the data available and the variables selected for matching.

Rosenbaum and Rubin (1983) describe PSM as a method that compares the outcomes of program participants with those of non-participants who are similar in all observed characteristics. Since the only difference between the two groups is program participation, any variations in outcomes can be attributed to the program. The estimated propensity score for an individual represents the likelihood of receiving a specific treatment based on a set of observed covariates, as outlined by Rosenbaum and Rubin (1983).

$e(xi), (i = 1…, N)$ ……………………………….. (1)

$e(xi) = Pr (zi = 1 \mid xi)$ ……………………………. (2) and

$Pr(Zi, \ldots, X1, \ldots Xn) = \sum e\ N\ i{=}1\ \{Xi\}\ Zi\{1 - e\{X\}\}\ 1{-}Zi$……………………….. (3)

Where: zi= 1 for treatment

zi= 0 for control

xi= the vector of observed covariates for the ith subject

The propensity score is a probability that ranges from 0 to 1. In this study, PSM was applied to assess how ICT tools affect crop productivity among smallholder farmers in the Mbombela local municipality. PSM allows evaluators to determine the average treatment effect on those who received the treatment. To measure productivity, changes in yield (including vegetables, agronomic crops, and overall yield in tonnes), changes in income, and patterns of input usage were used as proxies. The treatment impact is calculated as:

$\Delta = Y1 - Y0$ ………………………………………… (4)

Where: Y1 denotes the potential outcome conditional on participation

Y0 denotes the potential outcome conditional on non-participation, Pan and Bai (2015) describe four steps in the PSM process: (a) estimating the propensity scores using a logistic or Probit model, (b) matching the propensity scores to form a comparison group, (c) assessing the quality of the matching, and (d) evaluating the results of the outcomes.

The study will apply three matching algorithms to compare the treatment and control groups when estimating the average effects of a program or treatment using cross-sectional data: nearest neighbor matching (NNM), kernel-based matching (KBM), and radius matching (RM). The nearest neighbor matching method pairs each treated individual with the control individual whose propensity score is closest (Becerril and Abdulai, 2010). In kernel-based matching, each treated individual is matched with a weighted average of all control individuals within the region of common support (Heckman et al., 1997). The radius matching algorithm, on the other hand, matches a treated observation with a control observation that falls within a specified range of propensity scores, called the calliper (Zeweld et al., 2015). If the results from the different matching methods are consistent, the estimated outcomes will be considered robust.

In this study, the propensity score matching estimator was obtained through logit regression, using individual socioeconomic status to create matched pairs of individuals with similar characteristics. The dependent variable was the impact of ICT among farmers in the Mbombela Local Municipality, while the independent variables included age, gender, marital status, education level, years of farming experience, farm size, household size, cooperative membership, and the purpose of farming.

Independent variables

Gender: Gender was assessed based on the participant's sex, with a value of 1 representing male and 0 representing female. In this study, gender was anticipated to have an uncertain effect on the likelihood of using ICT tools.

Age: Age was determined by counting the number of years from the respondent farmer's birth to the time of the survey. It was recorded in years. In this study, age was expected to have an uncertain impact on the likelihood of using ICT tools.

Marital status: Marital status was determined based on whether the respondent farmer was married or not. The categories used to record marital status included single, married, divorced, and widowed. In this study, marital status was anticipated to have an uncertain effect on the likelihood of using ICT tools.

Educational level: Education level was measured based on the respondent's ability to read, write, or their participation in formal education. It was represented by the number of years of schooling completed. Education levels were categorized by the highest level attained, including no formal education, primary, secondary, ABED, diploma, and degree. In this study, it was anticipated that higher education levels would positively influence the likelihood of using ICT tools.

Farming experience: Farming experience was assessed by counting the total number of years the respondent farmer had engaged in farming activities up to the time of the survey, based on their response. It was recorded in full years, with no consideration given to partial years. In this study, farming experience was expected to have an uncertain effect on the likelihood of using ICT tools.

Farm size: The effective farm size of the respondent farmer was measured by the total number of hectares cultivated. In this study, farm size was expected to have an uncertain impact on the likelihood of using ICT tools.

Household size: The family size of the respondent farmers was measured by counting the total number of individuals in their household. This included the household head, their spouse, children, parents, and other dependents who lived and shared meals together during the survey. In this study, household size was expected to have an uncertain impact on the likelihood of using ICT tools.

Cooperative membership: Cooperative membership for the respondent farmer was assessed based on whether they belonged to formal or informal farmers' groups, or if they were not a member. In this study, it was anticipated that cooperative membership would positively influence the likelihood of using ICT tools.

Purpose of farming: The purpose of farming was assessed based on the type of farming practiced by the respondent, such as smallholder farming, as defined by the National Policy on Extension and Advisory Services (2016). Smallholder farming is categorized into household consumption, where the farmer produces for personal use and sells any surplus; and profit generation, where the farmer grows crops specifically for sale. In this study, it was anticipated that the purpose of farming would have a positive impact on the likelihood of using ICT tools.

Dependent variables

The dependent variable in this study is the effect of ICT tools on the crop productivity of smallholder farmers. It was measured in three aspects: a) the change in crop yield compared to the previous cropping season, b) the change in income from agricultural crops in the last season, and c) the change in the usage of inputs. The impact was evaluated by comparing the responses of the treated group and the control group.

Changes in crop yield: The changes in crop yield of the respondents were measured by comparing yield in tonnes between treated and control groups. The crops included vegetables, and agronomic crops.

Changes in income from agriculture: The change in income was measured by evaluating the variation in total income derived from vegetables and agronomic crops in the most recent cropping season. The annual production turnover of smallholder farmers ranges from R50,000 to R1 million (National Policy on Extension and Advisory Services, 2016).

Changes in input usage: The change in input usage was calculated by considering variations in the adoption of new agricultural crops varieties, fertilizer and chemical use, and comparing these changes between the treated and control groups.

Objective two: To assess smallholder farmers' perception on the effectiveness of ICT tools in disseminating agricultural information on crop productivity.

In this study, descriptive statistics were used to analyse the data for the second objective. Descriptive statistics help summarize and provide a clearer understanding of a data set by offering an overview of the sample and key data measures (Murray et al., 2009). The most commonly used descriptive statistics, such as mean, frequency distribution, and percentages, express the range of values, including the maximum and minimum values in a dataset (Zyphur and Pierides, 2017). The mean, standard deviation, and ranking were calculated to describe the various perception statements and were presented in tables to highlight the differences and opinions of the respondents, forming the basis for further discussion.

To aid in the analysis, participants' responses were measured using a 5-point Likert scale ranging from 1 to 5. This scale was used to assess the perceptions of smallholder farmers regarding the effectiveness of ICT tools in delivering agricultural information. The scale ranged as follows: 1 = Strongly disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly agree. The response values were summed and then divided by 5 to obtain a mean score of 3.0, which was considered the baseline for effectiveness. Perception statements with mean scores of 3.0 or higher were considered as effective by the smallholder farmers, while those with mean scores below 3.0 were considered ineffective.

The study also used ordinal scale ranking to indicate the smallholder farmers' order or priority and preference of the perceived effectiveness of ICT tools in disseminating agricultural information. This type of ranking is commonly used in social sciences and agricultural surveys to assess priority or preference among multiple options. This ordinal ranking method enabled the study to capture not only the most preferred choice but also secondary and tertiary priorities, providing a more nuanced understanding of farmers' perspectives.

Objective three: To investigate constraints influencing smallholder farmers access to agricultural information through ICT tools.

In the study, to model constraints influencing access to agricultural information, a univariate binary model (logit or Probit) could be suitable due to the dichotomous nature of the dependent variable (Greene, 2008). Constraints encountered by smallholder farmers when using ICT tools has a dichotomous choice of yes or no estimating experiencing the constraints and not experiencing the constraints when using ICT tools, respectively. Establishing a distribution assumption dictates whether to use the Probit or Logit regression model. Numerous researchers prefer to apply the Logit model in practice due to its relatively straightforward mathematical nature (Greene, 2008). However according to Sirak and Rice (1994), when the predictor variables are non-normally distributed, mixed-type (continuous and categorical), or not easy to handle, the Logit regression model is generally preferred due to its greater power, convenience, and flexibility. Considering this study combines both continuous and categorical predictor variables, it employs a binary Logit regression model to determine the constraints that smallholder farmers confront when seeking to use ICT tools to acquire agricultural information. A binary regression model is an extension of linear regression in which the dependent variable is binary (Harrell, 2015). This model predicts one of two possible outcomes, typically "yes" or "no." Therefore, the predicted outcomes are either positive or negative, reflecting the expected relationship between the dependent variable and the independent variables (Finney, 1952). This approach helps to identify significant factors (Xi) influencing the target variable (Y) and to understand the nature of the relationship between these factors and the dependent variable (Patel, 2021).

According to Greene (2003), The model is set as follows:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + ... \beta n + \mu i \text{ .... } (1)$$

Where: β0=intercept term

$\beta 1$, $\beta 2$, $\beta 3$.... βn= slope of the model's parameters or regression coefficients, which measures a unit change in explanatory variables.

Ui = Error or disturbance term.

Y = Dependent variables: The depended variable is a dummy variable, which takes a value of 1 indicating usage of ICT tools to access agricultural information and 0 for otherwise.

X1, X2…. Xn = Independent variable: Gender, age, educational level, years of experience in farming, land ownership, land size, cooperative membership, household size, network connectivity, power outage, electricity supply, cost of ICT tools, language use, ICT literacy, ICT awareness.

Table 2: Description and expected sign of hypothesized variables in the usage of ICT tools to access agricultural information

Variables	**Values**	**Expected sign**
Dependent variables		
ICT use	Dummy 1- ICT use 0= otherwise	
Independent variables		
Age	Continuous	+/-
Gender	Dummy	+/-
Educational level	Categorical	+
Household size	Continuous	+/-
Farm size	Continuous	+/-
Farming experience	Continuous	+/-
Language use	Categorical	+
ICT literacy	Categorical	+
ICT awareness	Categorical	+

Cost of ICT	Categorical	-
Network coverage	Categorical	+
Power blackouts	Categorical	+

Explanation of the independent variables presented in table 2

Age: Age was treated as a continuous variable in this study. The age of respondent farmers was calculated by determining the number of years from their birth to the time of the survey, expressed in actual years. According to Asif, Uddin, Dev, and Miah (2017), older individuals often face challenges in using ICT tools effectively compared to younger individuals. They also noted that older generations are more likely to stick to older technologies and avoid adopting newer ones. Therefore, in this study, age was anticipated to have an uncertain effect on the use of ICT tools.

Gender: Gender was coded as a dummy variable, with 1 representing male and 0 representing female. Zodidi (2022) observed that farmers' decisions regarding technology adoption are primarily influenced by resource availability, such as land, water, labour, and capital, rather than by gender. As a result, in this study, gender was expected to have an uncertain impact on the use of ICT tools.

Educational level: The educational level was treated as a categorical variable with nine categories, based on varying literacy levels. The study anticipated that farmers with education beyond primary school would be more productive and more inclined to adopt technology in their farming activities. Educational level is expected to have a positive effect on the use of ICT tools.

Household size: Household size was treated as a continuous variable, reflecting the number of individuals living in a household. Zodidi (2022) pointed out that larger households tend to be poorer than smaller ones, which may limit family members' access to ICT tools. Therefore, this study anticipated that household size would have an uncertain effect on ICT use.

Farm size: Farm size was measured as a continuous variable, indicating the total area of land owned in hectares. Mwangi and Kariuki (2015) suggested that farm size has a mixed impact on technology adoption. While a larger farm is often seen as beneficial for adopting new technologies, it can also present challenges. According to Ojo and Oluwatusin (2017), smaller farms tend to adopt new technologies more readily, as they hope to improve their agricultural practices and increase their returns. As a result, farm size was expected to have an uncertain influence on ICT usage.

Farming experience: Farm experience was considered as a continuous variable, representing the number of years the farmers has spent farming. A positive link is often observed between farming experience and the adoption of new technologies, as experienced farmers are typically more willing to take risks and explore innovative solutions to enhance production and marketing (Aker and Mbiti, 2010). However, Asif et al. (2017) noted that experienced farmers may become set in their ways, showing reluctance to change their established farming practices, which could make them less inclined to use alternative information sources. As such, the study expected farm experience to have an uncertain impact on ICT usage.

ICT literacy: Technical skill was assessed as a categorical variable, where the household indicated how likely a lack of digital skills would affect their ability to use ICT tools. It was anticipated that having technical skills would positively influence the use of ICT tools.

Power blackouts: Power blackouts were measured as a categorical variable, where households indicated how likely they were to be impacted by a lack of electricity when using ICT tools. Muhammad et al. (2019) argued that the effectiveness of ICT tools relies on access to electricity, and households must have electricity to use these tools effectively. Consequently, this study expected that access to electricity would have a positive impact on the use of ICT tools.

Network coverage: Quality network coverage was assessed as a categorical variable, where households indicated how likely poor network coverage would affect their ability to use ICT tools. Owusu et al. (2018) also pointed out that inadequate network coverage can hinder the delivery of agricultural information to farmers. Therefore, the study anticipated that better network coverage would positively influence the use of ICT tools.

Cost of ICT tools: The cost of ICTs was evaluated as a categorical variable, with households indicating how likely high costs would influence their use of ICT tools. Mammo and Girma (2017) highlighted that many smallholder farmers struggle to afford mobile phones due to economic challenges, even when lower-cost options are available in the local market. Thus, the study anticipated that the cost of ICT tools would negatively affect their use.

Language use: The language used for delivering agricultural information through ICT tools was assessed as a categorical variable. Respondents were asked to indicate how likely the language used in ICT tools would affect their ability to access agricultural information. It was anticipated that the choice of language would have a negative impact on the use of ICT tools.

ICT awareness: Awareness of the use of ICT tools in agriculture and their benefits for crop production was assessed as a categorical variable. Respondents were asked to indicate how likely they were to be influenced by knowing about the use of ICT tools in agriculture. It was expected that awareness of ICT tools would positively influence their use.

3.6 Ethical Considerations

The study attained ethical clearance from the University of Mpumalanga Ethics Committee, under the protocol reference number: (UMP/Ntsoane/219040508/MAGR/2024) as seen on appendix 7.4 Ethical Clearance certificate. The study followed all essential ethical guidelines required for conducting research. It fully complied with the ethical standards outlined in the University of Mpumalanga's code of ethics. The study was mindful of the diverse expectations and experiences of the respondents during data collection. Confidentiality, anonymity, and the well-being of the respondents were prioritized throughout the process. Participants were fully informed about the research protocols and procedures before taking part, fostering trust, respect, fairness, and preventing any misrepresentation or fabrication of data. The responses provided by the participants were used exclusively for the research purposes and were not utilized against them in any other context.

3.6.1 Informed consent

Informed consent is the process of providing research participants with key details about the study and what their involvement will entail, allowing them to make an informed decision about whether to participate (Bhandari, 2022). This information typically covers aspects such as the potential benefits and risks of the study, the source of funding, institutional approval, and the estimated time commitment (Heider et al., 2020). The study adhered to this principle by clearly explaining to participants what was expected of them, how their involvement would contribute to the research, and informing them about any associated risks. Participants were then asked to sign a consent form, ensuring their voluntary participation.

3.6.2 Anonymity

Anonymity is an ethical research principle that helps guarantee the privacy of participants' personal data, ensuring their protection (Novak, 2014). It is considered a key aspect of safeguarding privacy and providing individuals the option to remain unidentified (Sieber and Tolich, 2013). To uphold this principle, the study refrained from collecting any personally identifiable information, including names, addresses, email addresses, phone numbers, government-issued IDs, photographs, or IP addresses, to prevent linking responses to specific participants.

3.6.3 Confidentiality

Confidentiality refers to the practice of a researcher knowing a participant's identity but taking measures to keep that information private from others (Graham et al., 2006). In terms of data confidentiality, this means removing or altering any identifiable information about participants, such as their names (Kaiser, 2009). To uphold this principle, the study ensured that participants' personal information remained concealed and could not be linked to their responses by anyone else. This was achieved by assigning a unique code to each participant, known only to them, ensuring that their identities were not connected to their answers throughout the research.

3.6.4 No harm

This principle covers various forms of potential harm to participants, including psychological harm, which can result from sensitive or personal questions that may cause negative emotions like shame or anxiety (Bhandari, 2022). Social harm is another consideration, where participating in the study could expose individuals to social risks such as embarrassment or stigma. Physical harm, such as injury or pain during the research process, is also a possible risk (Graham et al., 2006). To follow this principle, the study made every effort to minimize harm to participants, ensuring that any risks were kept as low as possible. Participants were also given the freedom to withdraw from the study at any time if they chose to do so. Additionally, all potential risks were communicated to the participants before the study began. In case any issues arose, the study's supervisors were available to provide assistance in mitigating any harm to participants.

3.7 Instrument validity

According to Mugenda and Mugenda (2003), the reliability and validity of the data collection instruments are crucial for ensuring the accuracy of the collected data. Orodho (2010) pointed out that validity is concerned with ensuring that the questionnaire accurately measures what it is intended to measure. Robinson (2002) defined validity as the extent to which the data analysis results truly represent the phenomenon being investigated. In this study, validity was achieved by including objective questions in the questionnaire. Furthermore, content validity was ensured through an extensive literature review, which guided the development of the questionnaire and survey guides. Additionally, face validity was confirmed by the supervisors and the Faculty Ethics Committee panel within the Faculty of Agriculture and Natural Sciences.

3.8 Instruments reliability

Reliability refers to the degree to which research instruments produce consistent results (Mugenda and Mugenda, 2003). In this study, reliability was ensured by conducting a pilot test of the questionnaire with a selected sample from various communities within the Mbombela Local Municipality that shared similar characteristics. The pilot study allowed the researcher to become familiar with the research process and helped identify areas in the questionnaire that needed adjustment. The feedback from the pilot study allowed for corrections to be made, ensuring the instruments accurately measured what they were intended to.

Chapter summary

This chapter outlined the methods used to achieve the study's objectives. It began with a description of the study area, followed by an overview of the research design, which was quantitative in nature. The chapter also covered the sampling procedure, including the selection of crop smallholder farmers as the target population, the use of systematic sampling to choose participants, and the application of a structured questionnaire with predefined questions for data collection. Additionally, it discussed the various data analysis techniques employed, including propensity score matching to assess the impact of ICT tools on crop productivity, descriptive statistics to analyse smallholder farmers' perceptions of ICT tools' effectiveness, and binary logistic regression to examine the constraints influencing smallholder farmers' access to agricultural information through ICT tools.

Chapter 4: Research Results and Discussion

4.1 Introduction

The results of the study are presented in this chapter. Results of the respondent's descriptive statistics are presented and explained in the first section, with a focus on percentages and frequencies. The study's data and their interpretation are presented in the second section.

4.2 Respond Rate

Direct administration of the survey questionnaire was carried out with the participants. Table 3 hereunder provides a summary of the response rate.

Table 3: Respondents rate

Questionnaires	Frequencies	Percentage
Returned	308	100
Unreturned	0	0
Distributed	308	100.0

Source: Survey data, 2024.

Out of the 308 respondents who were targeted, the study obtained a response rate of 100%. A response rate of 50% is sufficient for analysis and reporting, while a rate of 60% is satisfactory and a response rate of 70% or higher is exceptional (Mugenda and Mugenda, 2003). The high response rate was a result of the following: the direct administration of the questionnaire to the respondents, the confirmation of respondents' availability two days prior to the commencement of the survey. Additionally, both the researcher and trained enumerators present throughout the survey.

4.3 Socio-economic characteristics of the respondents

The initial section delineates the socio-economic characteristics of the respondents in order to establish a foundation for the subsequent discussion of the findings. Gender, age, marital status, education level, agricultural certificate, years of farming experience, land ownership, farm size, household size, cooperative membership, purpose of farming, and on-farm and off-farm source of income are among the characteristics that are outlined.

4.3.1 Gender

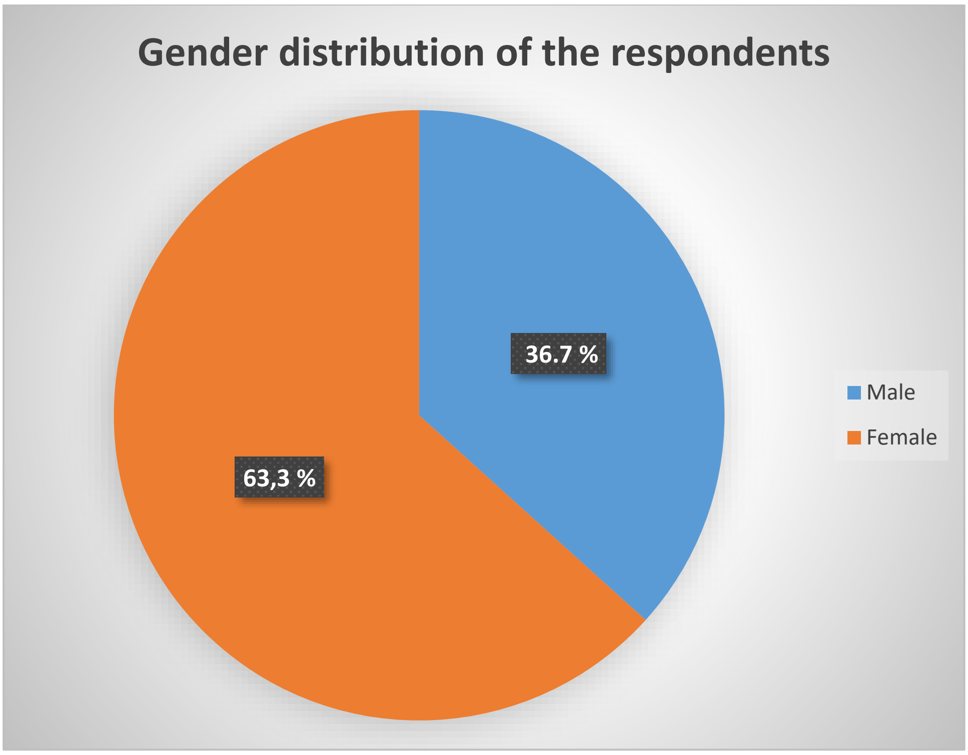


Figure 3: Gender of respondents

Source: Survey data, 2024.

Figure 3 reveals that, from a total sample of 308 respondents in Mbombela Local Municipality 133 males participated constituting 36.7% of the total. The results indicated that women predominately engage in smallholder farming within the Mbombela Local Municipality. Agholor et al., (2024) also discovered that in Mbombela South Africa, smallholder farmers are more likely to be female (74.7%) than male (25.3%). Lubisi and Agholor (2023) also discovered that in Mpumalanga Driekoppies, female farmers outnumber male farmers 55.4% to 46%, therefore the findings are consistent with theirs. These findings contrast with those of Zondo and Ndoro (2024), who reported that men made up 51.6% of the smallholder farmers in Nkomazi Mpumalanga. This shift over time could be explained by changes in societal factors where men migrating for work and increased women participation in the agricultural sector. In another study, Janavi et al. (2021) observed that gender plays a significant role in innovation adoption, with men more frequently using social media as an information and communication technology tool compared to women. This may be attributed to the generally lower engagement of women with technology. Adejo et al. (2013) further support this by noting that men have greater access to radio, television, computers/internet, and GSM connectivity than women.

4.3.2 Age

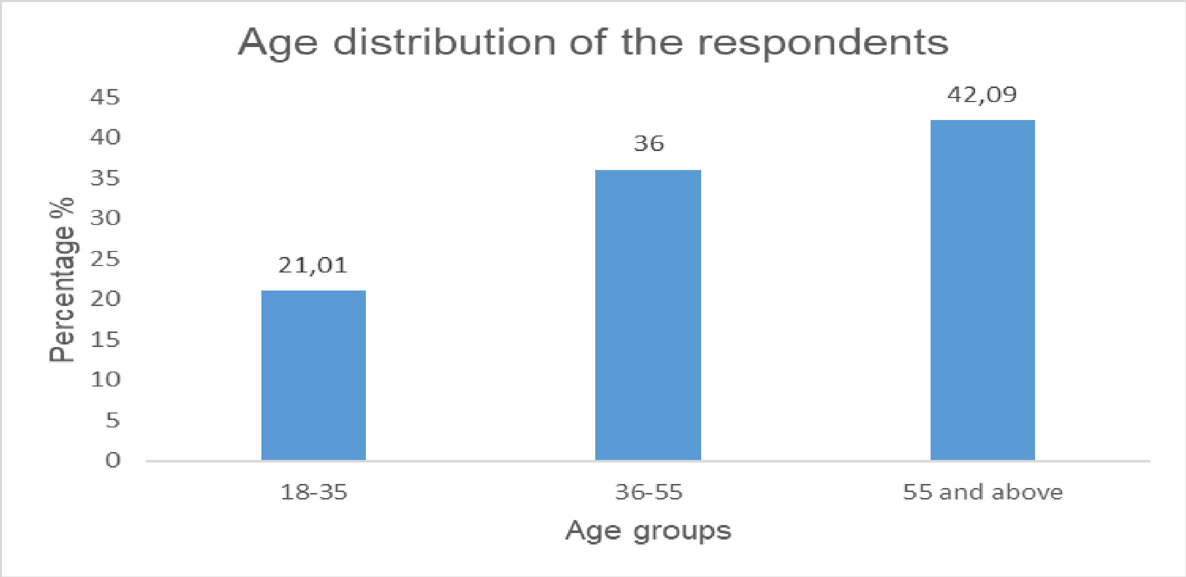


Figure 4: Age of the respondents

Source: Survey data, 2024.

Figure 4 presents the distribution of respondents across different age groups. In the survey, 65 (21.1%) were in the 18–35 age bracket, 111 (36%) were in the 36–55 age bracket, and 132 (42.9%) 55 and up. According to the data, smallholder farmers in the research region are of a very even age distribution, with a slight majority being 55 and up. The findings are consistent with the research conducted by Agholor et al. (2024), which determined that in Mbombela, elderly people were more engaged in farming than their younger counterparts. The results are also corroborated by the findings of Shemfe and Modirwa (2018), who found that the elderly population continues to engage in farming at a higher rate than the younger population. Cele's (2016) research found that youth individuals show little interest in farming, as they perceive it to be a profession suited for older generations. This highlights the need to encourage youth participation in farming to support rural development sustainability. Mittal and Mehar (2016) observed that older smallholder farmers tend to avoid exploring new innovations and emerging information resources, leading to a limited reliance on diverse information sources. However, these findings contrast with those of Zondo and Ndoro (2024), who reported that in Nkomazi, Mpumalanga, smallholder farmers aged 20–39 are the primary participants in agricultural activities and are also able to utilize social media as a component of an ICT tool.

4.3.3 Marital status

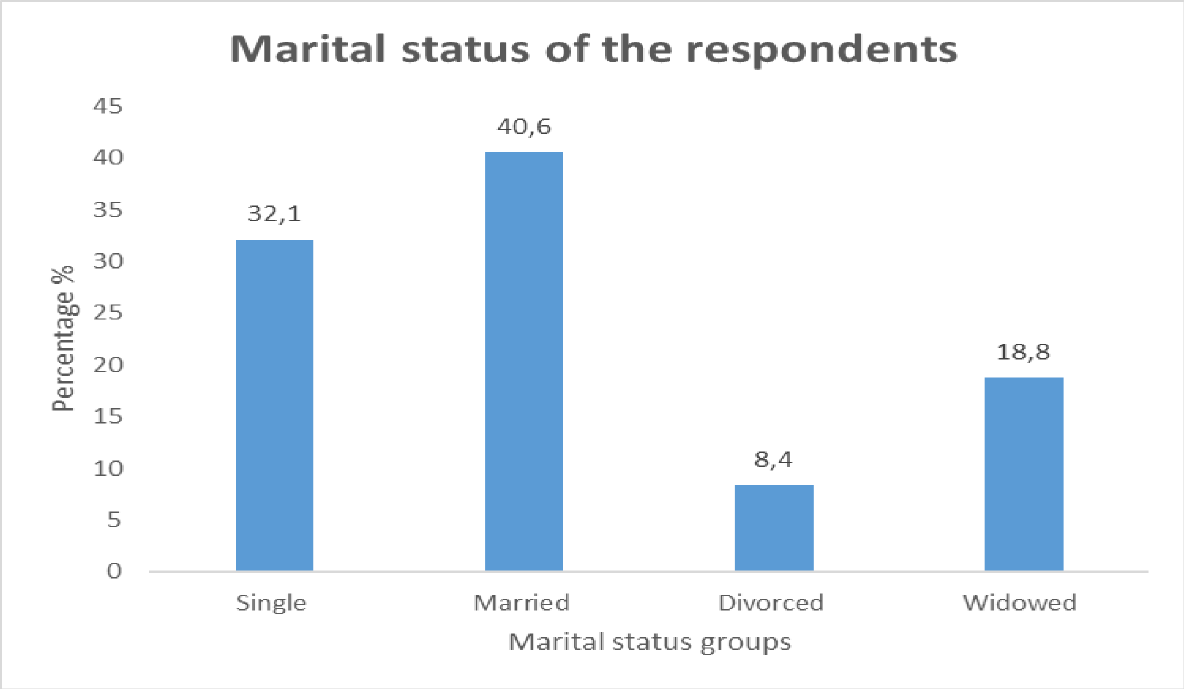


Figure 5: Marital status of the respondents

Source: Survey data, 2024

As illustrated in Figure 5, approximately 125 (40.6%) of the respondents are married, 99 (32.1%) are single, 26 (8.4%) are divorced, and 58 (18.8%) are widows or widowers. This suggests that the agricultural activities in the region are primarily dominated by married individuals, as opposed to other categories. The results are also consistent with the findings of Shemfe and Modirwa (2018), who found that the vast majority of small-scale farmers in the Northwest were married, as opposed to those who were unmarried and divorced. Hosseini, Fatemifar, and Rahimzadeh (2015) found that married couples tend to adopt ICT more than single males and females, possibly due to their shared decision-making process. Similarly, Levi et al. (2015) observed that married couples often have similar television viewing preferences, including an interest in educational programs related to agriculture. This shared interest can increase access to agricultural information. However, if one partner is not interested, they may choose to watch different content, such as music, which may reduce the chances of accessing agricultural information. Other studies show that married farmers use information and communication technologies more than those who are single, divorced, or widowed (Adepoju, 2017; Muhammad et al., 2019; Okwusi et al., 2010). These studies suggest that married farmers make logical decisions and understand the value of ICT for farming. Tambo et al. (2019) and Mdoda and Mdiya (2022) reached similar conclusions. In contrast, Agholor et al. (2024);

Zondo and Ndoro (2024); and Lubisi and Agholor (2023) found that farming communities in Mpumalanga are primarily composed of single smallholder farmers.

4.3.4 Educational level

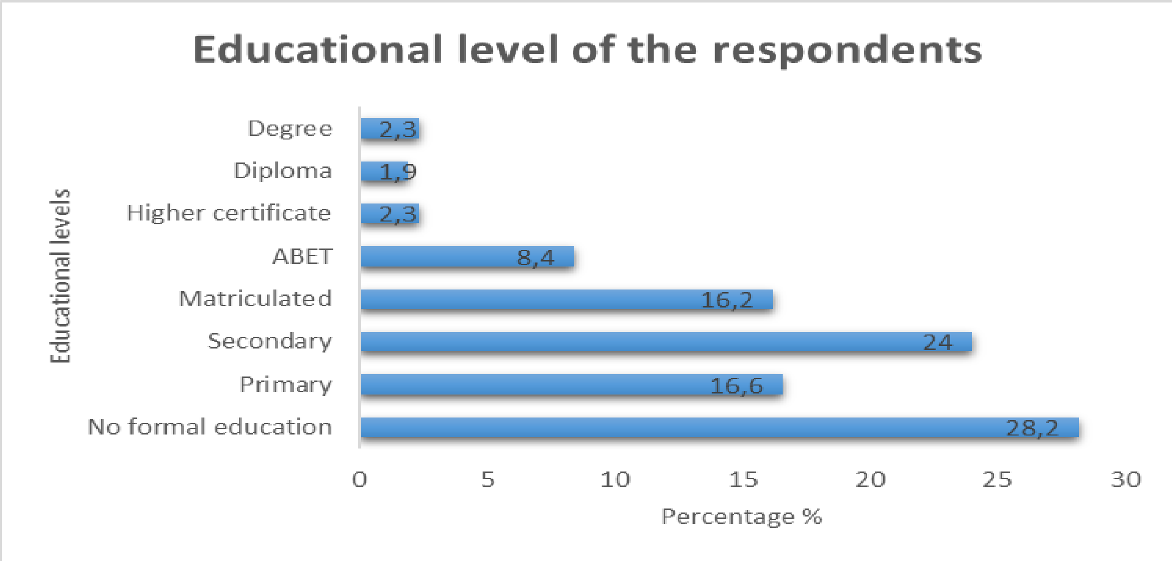


Figure 6: Educational level of the respondents

Source: Survey data, 2024.

Figure 6 shows that 87 (28.2%) of the respondents lacked any formal education, 74 (24.0%) completed secondary education, 51 (16.6%) achieved primary education, 50 (16.2%) obtained matriculation, 26 (8.4%) participated in ABET, and 20 (6.5%) attended higher education institutions. The results indicate that the majority of smallholder farmers surveyed have achieved a certain level of formal education, with most having completed at least high school. This conclusion is in line with previous research showing that a higher percentage of smallholder farmers have completed secondary education (Zondo and Ndoro, 2024; Lubisi and Agholor, 2023). Muhammad et al. (2019) corroborated these results and found that among farmers surveyed, 55.0% had completed primary school, 12.5% had completed secondary school, 7.5% had completed university education, and 25.0% had not completed any formal education at all. This suggests that a large percentage of farmers in the area are literate, which supports their ability to use ICT to improve their farming practices. A well-educated farmer will find it easier to navigate and make use of the new information and technology available through ICT. Siulembe and Moodley (2014) also noted that small-scale farmers with formal education are better equipped to adopt modern agricultural technologies. However, a 2016 community survey in Mpumalanga found that most smallholder farmers had only completed secondary education or none at all. The majority of South African smallholder farmers are illiterate, which hinders their ability to access official institutions that offer technical knowledge (DAFF, 2012).

4.3.5 Years of farming experience

Table 4: Distribution of respondents years of farming experience

Farming experience in years	Frequency	Percentage %
≤ 5 years	101	32.8
6-10 years	113	36.7
11-20 years	60	19.5
≥ 21 years	34	11.0
Total	**308**	**100**

Source: Survey data, 2024.

Table 4 summarises the survey outcomes, showing a substantial proportion of respondents 113 (36.7%) had farming experience of 6-10 years, while 101 (32.8%) had farming experience of 5 years or less. Furthermore, the lowest percentage of respondents 34 (11.0%) had 21 years or more of agricultural experience, while 60 (19.5%) had 11-20 years of farming experience. The findings indicate that households had an average of 10 years of agricultural experience or less. The results contradict the findings of Muhammad et al. (2019), who determined that the majority of farmers engaged in farming for a substantial duration. This finding aligns with the research of Ajayi et al. (2016), who indicated that their respondents have engaged in agricultural production for a prolonged duration. Asif et al. (2017) observed that an increase in a farmer’s years of experience results in a significant decline in the use of mobile phones as ICT tools for accessing agricultural information. Experienced farmers are often hesitant to change their established agricultural practices, leading to a reduced interest in exploring alternative information-gathering methods. Mishra et al. (2023) noted that farmers with extensive farming experience tend to be more progressive, adaptable, and skilled at evaluating new technology, which helps them make more efficient decisions. They also emphasized that these farmers are keen to improve agricultural practices, enabling them to learn more about applying ICT in farming. This finding aligns with Vosough et al. (2015). Ghosh et al. (2022) argued that more farming experience leads to lower ICT technology use. This may be due to the fact that experienced farmers feel more confident in their existing knowledge, while beginners in farming, who require additional information, tend to use ICT to acquire it.

4.3.6 Land ownership

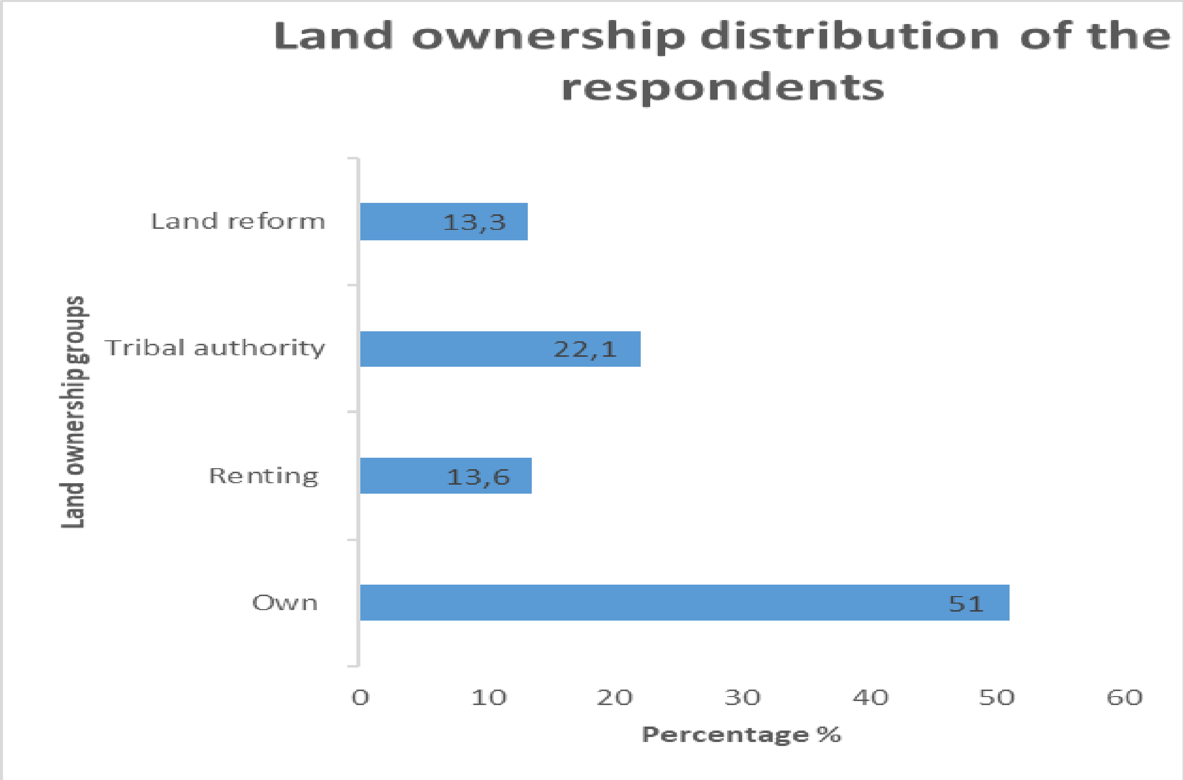


Figure 7: Land ownership of the respondents

Source: Survey data, 2024.

It is evident from Figure 7 that most respondents 157 (51.0%) own the land on which they farm, followed by 68 (22.1%) who access farming land from the local tribal authority. Additionally, 42 (13.6%) respondents rented their land, while the smallest group 41(13.3%) acquired their land from the department of agriculture and land reform. The data indicate that land ownership among farmers in the study area is generally dispersed, with a majority being landowners themselves. The findings are consistent with the Municipalities of South Africa (2021), which reported that approximately 84% of households involved in agriculture own the land they cultivate. These results also align with Aldosari et al. (2017), who found that 42.6% of respondents were landowners engaged in agricultural activities. Tenants made up 32.3%, while owner-occupants and tenants together accounted for 25.1%. Additionally, Ghosh et al. (2022) demonstrated that farmers who own land for cultivation have better access to ICT tools than those without personal land.

4.3.7 Farm size

Table 5: Distribution of farm size of the respondents

Farm size in ha	Frequency	Percentage %
≤ 5ha	186	60.4
6-10 ha	117	38.0
≥ 11	5	1.6
Total	**308**	**100**

Source: Survey data, 2024.

According to Table 5, the majority of respondents 186 (60.4%) possess a farm size of 5 hectares or less, while 117 (38.0%) have a farm size ranging from 6 to 10 hectares. Only a small number of responders 5 (1.6%) possess a farm size of 11 hectares or greater. This indicates that the majority of respondents in the research area possess small farm sizes. The results align with Zondo and Ndoro (2024), highlighted that a significant proportion of smallholder farmers possessed land measuring 5 hectares or less. The findings are corroborated by FAO (2012), which indicated that smallholder farmers manage smaller land areas compared to livestock farmers. The findings align with those of Shemfe and Modirwa (2018), who demonstrated that the majority of respondents in their study area possess small farm sizes. The Consultative Group to Assist the Poor (CGAP, 2016) conducted a study in Mozambique, indicating that the predominant proportion of small-scale farmers (31%) operated on farms measuring 1-2 hectares, whereas only 20% managed farms of 3-5 hectares, which represented the largest farm sizes in the survey. Munyua (2007) asserts that small-scale farmers in Africa possess limited farm sizes, which may result in diseconomies of scale and an inadequate foundation of knowledge. This finding is consistent with Suleiman’s (2017) research, which indicated that respondents are smallholder farmers operating at a subsistence level, which may shape their use of ICTs. Feju et al. (2023) confirm that the amount of land a farmer cultivates determines the use of mobile applications, as also noted by Mittal and Mehar (2016) and Diaz et al. (2021). Mittal and Mehar (2016) found that farmers with larger farm sizes tend to seek information from various sources, including ICTs, and are more open to adopting new ICT tools to improve production.

4.3.8 Household size

Table 6: Distribution of household size of the respondents

Household size	Frequency	Percentage %
≤ 5	92	29.9
6-10	144	46.8
≥ 11	72	23.4
Total	**308**	**100**

Source: Survey data, 2024.

Findings in Table 6 reveal that most respondents belong to households with 6-10 individuals 144(46.8%), while 92 respondents (29.0%) have households of 5 members or fewer. The smallest proportion, 72 respondents (23.4%), belongs to households with 11 or more members. The results indicate that smallholder farmers have an even household size, which may influence farm labour intensity. The results align with the findings of Agholor et al. (2024), which indicate that the majority of homesteads (133) have 6-10 household members. The findings are inconsistent with those of Shemfe and Modirwa (2018), who reported that no households exceeded 14 people, with the majority comprising 4 to 6 individuals. Moreover, it was suggested that household size may serve as a mechanism for improving production through labour. Ajani and Ashagidigh (2008) asserted that a household's contribution to productivity may be contingent upon individual perspectives of interest. A surge in household size leads to heightened household expenditure, hence reducing the annual income of farmers. In relation to this study, Tijjan et al. (2017) discovered that the household distribution in their study area is broad, which in turn provides additional labour for farming. Furthermore, the large size of the household may facilitate the acquisition of additional agricultural information through various ICT tools. Leng et al. (2020) corroborated this by demonstrating that households with numerous family members may utilize various ICT tools available within the home, thereby promoting the adoption and utilization of ICT in their agricultural practices. In support of these findings, Muhammad et al. (2019) observed that smallholder farmers often have larger households, which allows them to rely on family labour to reduce production costs. As a result, these farmers seek better production information, which encourages the use of ICT to improve agricultural output. This is consistent with the findings of Ojo et al. (2010), who noted that large family sizes in agricultural communities provide an ample and low-cost labour force.

4.3.9 Cooperative membership

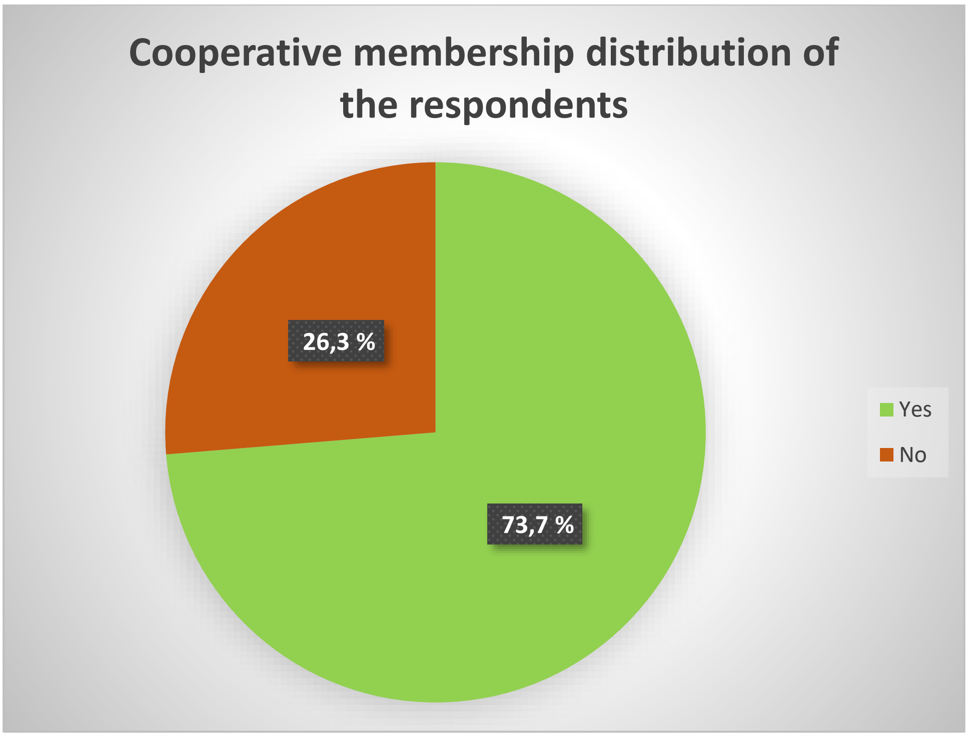


Figure 8: Cooperative membership of the respondents

Source: Survey data, 2024.

Figure 8 demonstrate that a large proportion of respondents 227 (73.7%) are members of smallholder farmers' organizations, whilst 81 (26.3%) are not. This suggests that the majority of respondents belong to farmers' associations designed to address the essential needs of farmers. The results align with the findings of Tamako et al. (2022), who reported that around 48.4%, the majority, indicated a tendency to participate in farmer cooperatives as a primary information platform. Farmers frequently engage in various official and informal social structures, such as cooperatives, which offer them access to scientific knowledge that might enhance yield output. Moreover, the social connections formed by cooperative participation enable farmers to exchange knowledge with one another. It was further clarified that cooperative meetings were typically scheduled through telephone. The results are corroborated by research by Efobi et al. (2023), which indicated that in their study region, the majority (89.2%) of respondents were affiliated with various cooperative organizations, whereas 10.8% were not members of any cooperative society. This suggests that the substantial membership of cooperatives may provide a means to get agricultural information and insights regarding the advantages of utilizing ICT tools. This discovery corroborates the findings of Chikaire et al.

(2017), Onyeneke (2017), and Mbah et al. (2016), who determined that the majority of participants in their research were associated with cooperative organizations.

Nevertheless, the findings are in direct opposition to Zodidi (2022), who stated that 34.6% of the South African population in KZN is a member of a farmers' organization, while 65.4% is not. This is further supported by the fact that 11.4% of respondents expressed disinterest, 39.5% reported a lack of awareness, 0.8% deemed the organizations to be ineffective, and 0.4% were still establishing themselves in the agricultural industry. Conley and Udry (2010) verified that participation in community organizations, such as cooperatives, enhances an individual's ability to acquire and access critical knowledge and information regarding innovations and new technologies, as well as the advantages that result from mutual interests and interactions. It enhances the chance of smallholder farmers utilizing social media to enhance their knowledge, information access, and sharing, as well as their awareness. Additionally, Zeweld et al. (2017) highlight the significance of farmer social organizations in the dissemination of agricultural knowledge, as farmers are the most well-equipped to witness how it is applied in practice. Additionally, farmers acquire new knowledge through a variety of practices that can be disseminated through farmer social networks

4.3.10 Purpose of farming

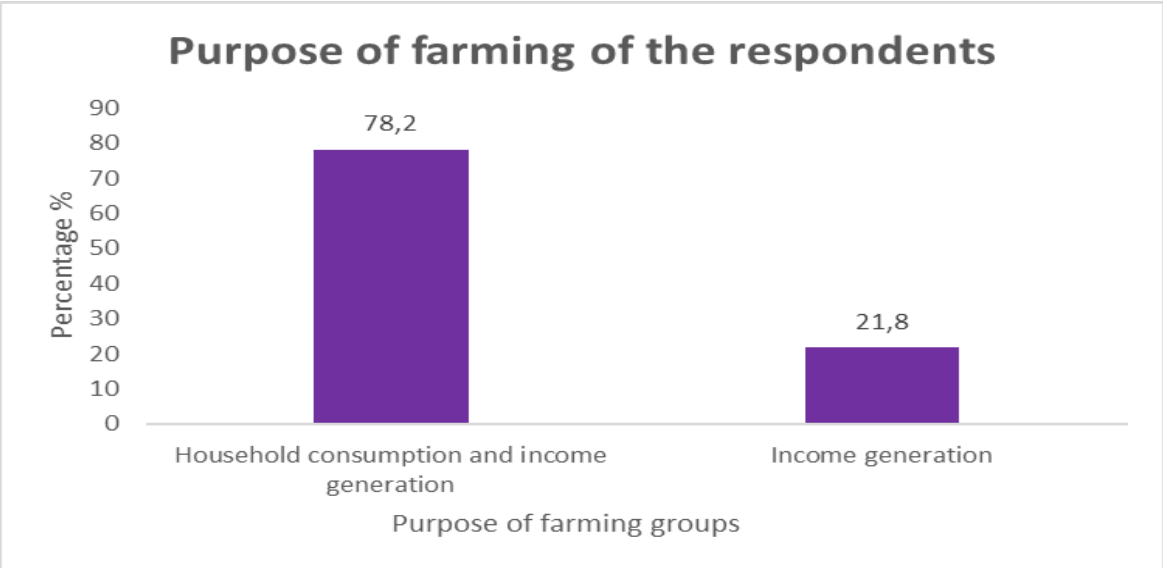


Figure 9: Purpose of farming of the respondents

Source: Survey data, 2024.

Based on the results displayed in Figure 9, the majority of the respondents 241 (87.2%) engage in farming for household consumption and sell surpluses to generate income. Conversely, 67 (21.8%) respondents engage in farming exclusively for income generation. This suggests that a significant number of households in the studied area engage in farming activities to improve the availability of food at the household level and generate income. The findings align with the World Bank (2018) and Sibhatu and Quim (2017), who stated that most farmers engage in agriculture primarily to supply food for their families, thereafter, selling any surplus to generate revenue. This finding aligns with Suleiman's (2017) research, which indicated that smallholder farmers engaged in subsistence-level production for home use and selling surplus. Moda and Gidi (2023) demonstrated that farmers primarily cultivate for personal use, selling excess produce to create revenue that supplements government-provided social security, thereby sustaining their households and agricultural operations. Jannat et al. (2015); Feju et al. (2023), found a larger number of farmers engaging in agricultural activities for income generation compared to those engaging in subsistence farming, which contradicts the current results. This data suggests that the majority of local respondents engaged in agricultural pursuits for profit. Kanf et al. (2022) examined the role of ICT investments in revenue generation. Research results identified that a key factor in the amount of money spent on ICT adoption is the farmers' income.

4.3.11 Source of on-farm income

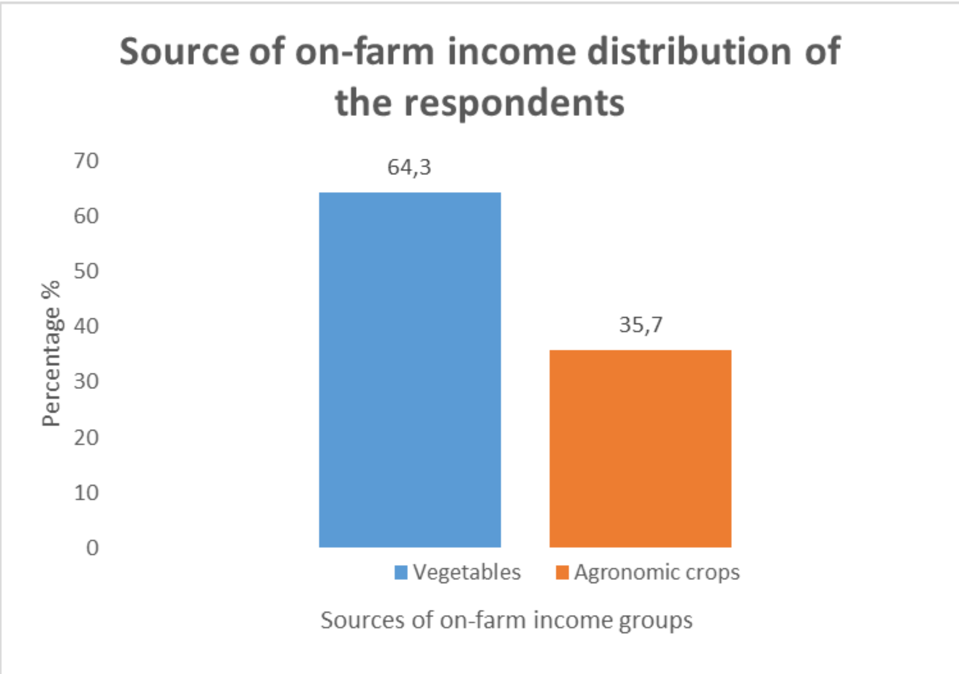


Figure 10: Sources of on-farm income of the respondents

Source: Survey data, 2024.

The agricultural activities of the smallholder farmers in the research region predominantly involve the cultivation of vegetables (198, 64.3%) and agronomic crops (110, 35.7%). The results indicate that smallholder farmers primarily cultivate staple food crops in the study area. The results are consistent with the findings of Stats SA (2017), which indicated that the Ehlanzeni District has a greater number of vegetable cultivators. In contrast, Lehohla (2016) discovered that maize is one of the most frequently cultivated commodities in the Mpumalanga province. Muhammad et al. (2019) also found that many farmers in the study area cultivated key staple foods. Therefore, if these farmers adopt information and communication technologies to access improved farming methods, it would significantly enhance both their crops and their livelihoods. This finding aligns with the research of Ibrahim and Onuk (2010), who revealed that the majority of respondents in their study area engage in staple food crop production. Feju, Malgas, and Phiri (2023) confirm the findings, indicating that the predominant crops cultivated by farmers during the interview period were cabbage and spinach, as these were cited by the majority of farmers. Melaine and Nonvide (2023) found that agricultural households in Benin predominantly consist of smallholder farmers engaged in polyculture, frequently accompanied by small animals. Maize and vegetables constitute the primary staple foods cultivated in the country.

4.3.12 Source of off-farm income

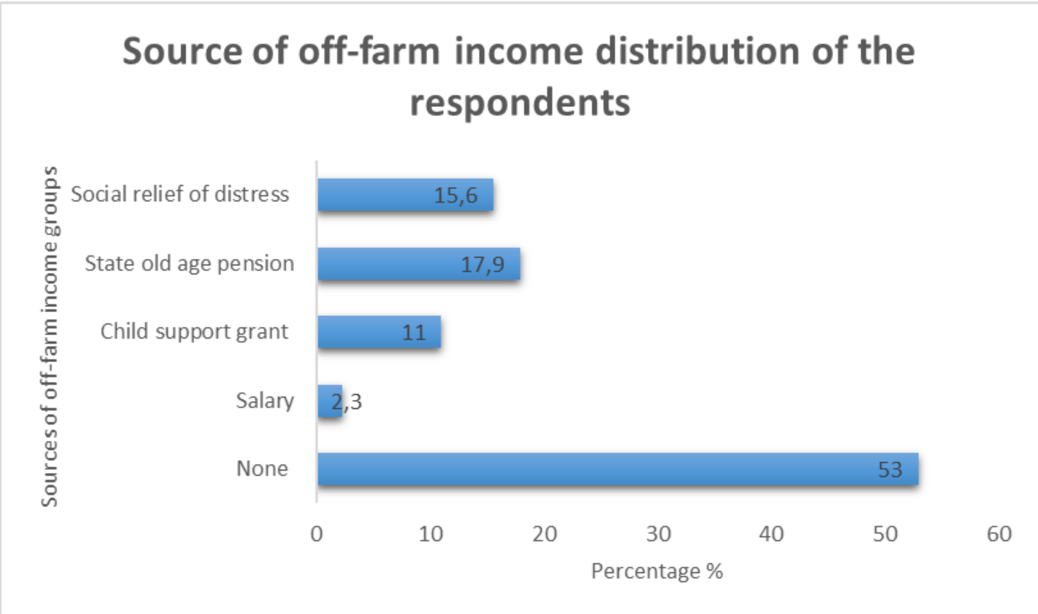


Figure 11: Sources of off-farm income

Source: Survey data, 2024.

Insights from Figure 11 show that most respondents 164 (53%) are entirely dependent on farming and do not have any off-farm income. In the group of respondents with off-farm income, a substantial proportion of 55 (17.9%) receive a state old age pension, while 48

(15.6%) receive social relief of distress. 34 (11.0%) of the respondents receive child support grand, and the least number of respondents (7.3%) receive a salary. This suggests that the majority of farmers in the studied area are solely dependent on farming for their livelihood, as some alternatively rely on governmental grants to sustain their livelihoods. The results align with the findings of Raza, Khan, Shahbaz, and Saleem (2020), which indicated that the majority of farming communities are depended on agriculture (79.3%). The data indicate that farming serves as the primary occupation for farmers in the research area, with only 20.7% depending on off-farm income sources. The findings align with Feju, Malgas, and Phiri (2023), who contended that the primary objective of most farmers is to cultivate in order to sustain their livelihoods. Läpple et al. (2015) noted that farmers with a stable off-farm income are more equipped to adopt new and enhanced technology due to their adequate financial resources. Tamako, Thamaga-Chitja, and Mudhara (2022), demonstrated that farmers rely on a variety of economic streams to keep their families afloat. Findings showed that pension payouts are the primary source of income for 57.1% of the farmers surveyed. The next highest percentage, 26.9%, of farmers rely on government social grants to support their families. Most farmers were able to receive these subsidies because their monthly household incomes were between 1,500 and 3,500 rand (South African Social Security Agency [SASSA], 2020, 2021).

4.3.13 Distribution of ICT tools used by the respondents

Table 7: ICT tools used by smallholder farmers

	Frequency of using ICT tools			**Ratings**	
ICT tools	**Frequently**	**Occasionally**	**Not at all**	**Mean score**	**Ranking**
Radio	15(40.5)	22(59.5)	0(0.0)	1.41	3rd
TV	1(25.0)	3(75.0)	0(0.0)	1.25	4th
Smart phone	89(67.4)	43(32.6)	0(0.0)	1.67	1st
Basic cell phone	8(44.4)	10(55.6)	0(0.0)	1.44	2nd
Computer	0(0.0)	0(0.0)	0(0.0)	N/A	N/A

Source: Survey data, 2024.

The data reveals significant differences in the frequency of use across the various ICT tools, providing valuable insights into the preferences and behaviours of the respondents concerning their media consumption habits. Smartphones are the most frequently used ICT tool, with

67.4% of respondents reporting frequent usage. This tool has the highest ranking (1st) in terms of usage frequency, followed by basic cell phones (2nd) and radio (3rd). TV ranks 4th, with a lower frequency of use compared to smartphones, basic cell phones, and radio. Computers were not used by any respondents, as no data was available for the tool. The results imply that the most commonly used ICT tools among the respondents are mobile-based devices (smartphones and basic cell phones), followed by traditional media (radio and TV).

The results align with the findings of Falola and Adewumi (2011), Gillwald and Stork (2018), and Ogunniyi and Ojebuyi (2016), which indicate that 85% of South Africans possess a mobile phone, emphasizing the significance of mobile phones for agricultural businesses, particularly in communication as well as advertising. In the same way, Okoedo-Okojie and Omoregbee (2012) and Muhammed et al. (2018) found that, in addition to radio, the mobile phone (GSM) was the most utilized ICT tool. The utilization of computers, email, and the internet was minimal. Muhammad, Adesiji, Tyabo, Muhammed, and Loko (2019) affirm that mobile phones and radios are the predominant ICT tools utilized by farmers, likely due to their accessibility, portability, and affordability. This study concurs with the findings of Henri-Okoha, Chikezie, and Osuji (2012), which indicated that farmers utilized mobile phones, radio, and television to obtain agricultural knowledge. The results contradict the conclusions of Adegbidi et al. (2012), who determined that radio was the most popular medium in their survey. Investment in radio endures, as approximately 35.0% of respondents in the surveyed communities own one. Approximately 14.0% had televisions, whereas a mere 2.0% owned computers.

The findings align with those of Levi, Kyazze, and Sseguya (2015) and Kameshwari et al. (2011), who discovered that in certain communities, television surpassed radio in popularity due to its audiovisual characteristics. However, it remains underutilized for acquiring essential agricultural information, being primarily regarded as a medium for entertainment, particularly for viewing films and soccer. They discovered that television is primarily utilized for entertainment purposes, despite the consistent airing of agricultural programs. This is in line with what Sife et al. (2010) found, which states that the absence of electricity is the primary barrier to television access in rural Tanzania. Accessing information on television is challenging for farmers due to the necessity of power. Luqman, Yaseen, Ashraf, Mehmood, and Karim (2019) corroborate the findings about the frequency and scope of ICT tool utilization in agriculture, indicating that respondents utilized ICTs for less than 2 hours daily. They expressed in an informal talk that they are information searchers who utilize ICTs to obtain the necessary information. Mtega and Msungu (2013) obtained same findings indicating that farmers acquired agricultural information using ICTs. Approximately 21.3% of respondents were classified as medium level users, use ICTs for 3 to 4 hours daily. Fourteen percent had utilized ICTs for over five hours daily. Participants in the casual communicate remarked that they utilized ICTs for many purposes, including information and fun. Consequently, they dedicate considerable time to ICTs.

4.3.14 Distribution of sources of agricultural information used by respondents

Table 8: Sources of agricultural information used by smallholder farmers

Sources of Information	**Frequency (No of respondents)**	**Percentage**	**Mean score**	**Ranking**
Personal locality sources				
Fellow farmer	32	27.35%	0.55	2nd
Cosmopolite Sources				
Public extension service	71	60.68%	1.21	1st
Private extension service	0	0%	0	4th
Community based organisations	14	11.97%	0.24	3rd

Source: Survey data, 2024.

Table 8 display that public extension service is the most frequently used source of information, with 71 respondents (60.68%) relying on them. They have the highest mean score of 1.21 and are ranked 1st in terms of usage frequency. Fellow farmers are the second most common source, with 32 respondents (27.35%) using them. They have a mean score of 0.55 and are ranked 2nd. Community-based organizations (CBOs), though used less frequently, are still a relevant source for 14 respondents (11.97%). They have the mean score of 0.24 and are ranked 3rd. Private extension service are not used at all, with 0 respondents relying on them for information, giving them a mean score of 0 and ranking them 4th. This finding implies that formal sources like public extension service are the most important for the respondents, followed by informal, peer-based sources like fellow farmers, while community-based organizations and private extension service are much less relied upon.

Consistent with previous research, this study's findings show that farmers without access to ICT tools still rely on informal and official sources of agricultural knowledge such as field days, other farmers, and neighbors, as well as extension workers. Additionally, Ogidi (2014) discovered that the majority of agricultural knowledge in Nigerian rural farming communities is disseminated through interpersonal routes, such as friends, relatives, and neighbors. The study found that most people relied on the radio as their primary source of agricultural information, indicating a lack of use of mass media. Research conducted by Kunda et al. (2018), Lwoga et al. (2013), and Babu et al. (2011) found that farmers sought out agricultural information from a variety of sources. These included government agriculture extension officers, social gatherings, relatives, other successful farmers, primary agricultural cooperative banks (PACBs), groups representing farming associations, meetings with village leaders, representatives from nongovernmental organizations (NGOs), and agricultural exhibitions. In support of this view, Efobi, Nwalieji and Ahaneku (2023) showed that smallholder farmers rely on informal and interpersonal contacts for agricultural information. This is likely due to the fact that these contacts are readily available, they interact frequently, and they are cheap and easy to obtain. Shemfe and Modirwa (2018) assert that an increase in the number of information sources utilized by respondents correlates with a decreased likelihood of employing ICT, likely due to the respondents' tendency to not depend on a singular information source, which may originate from concerns regarding the accuracy and accountability of their information requirements.

4.3.15 Programs and functions smallholder farmers are familiar with and use to access agricultural information through ICT tools.

Table 9: Programs and functions smallholder farmers use to access agricultural information through ICT tools

Measures	Frequency	Percentage
Radio programs		
None	229	74.4
Ezokulima	77	25.0
Agriskoop	2	0.6
TV programs		
None	290	94.2
African farming	7	2.3
For the love of the land	1	0.3
Niche farmers	9	2.9
Living land	1	0.3
Mobile applications		
None	176	57.1
WhatsApp	24	7.8

Facebook	74	24.0
LinkedIn	6	1.9
YouTube	28	9.1
Agricultural mobile apps	0	0
Basic cell phone functions		
None	190	61.7
Phone call	118	38.3
SMS	0	0.0

Source: Survey data, 2024.

The survey results shown in Table 9 illustrate the programs, applications, and functions utilized by smallholder farmers in the target area through ICT technologies. This study aimed to determine the programs, apps, and functions that farmers recognize and utilize to obtain agricultural information. Respondents were provided with opportunities to select additional programs, applications, and functionalities that they utilize in combination with the primary tool employed to acquire agricultural information. The results indicate a substantial proportion of mobile application usage with 132 respondents (42.8%) utilizing programs including WhatsApp (24, 7.8%), Facebook (74, 24.0%), LinkedIn (6, 1.9%), and YouTube (28, 9.1%), alongside additional agricultural applications not selected by respondents. Respondents utilize fundamental cell phone features for accessing agricultural information with 118 (38.3%) employing phone calls and 0 (0.0%) utilizing SMS. Additionally, 79 (25.6%) get agricultural information through radio programs including Ezokulima 77 (25.0%) and Agriskoop 2 (0.6%). A minimum of 18 respondents (5.8%) utilizes television shows for agricultural knowledge including African Farming 7 respondents (2.3%), For the Love of the Land 1 respondent (0.3%), Niche Farmers 9 respondents (2.9%), and Living Land 1 respondent (0.3%).

The results are consistent with the findings of prior research conducted by Kumar and Karthikeyan (2019) and Feju, Malgas, and Phiri (2023). However, these studies do not inherently imply that agricultural apps are attainable to all farmers. Additionally, Feju, Malgas, and Phiri (2023) contended that South Africa was the country with the highest number of agricultural applications developed in Africa, with a total of 4 (4.9%) applications out of the total number of apps discovered during the search. Out of the total number of applications discovered during the search, Kenya, Liberia, and Tanzania each accounted for one (1.21%). Additionally, it was discovered that 55.6% of farmers were aware of the extant agricultural mobile applications, while 44.4% of farmers were unaware of them. Additionally, Balkrishna et al. (2020) evaluated the usability of the agricultural applications and identified areas for future enhancement. They identified that farmers' lack of awareness and the unfriendliness of mobile applications were the reasons for their limited use. Nevertheless, those discoveries do not suggest that all farmers worldwide are facing comparable constraints, as the challenges they encounter are contingent upon their social orientation and geographic context.

Feju, Malgas, and Phiri (2023) found that minimal app usage was observed among farmers, regardless their awareness of the technology. Out of the total number of those involved, only four (22.2%) farmers were found to employ mobile applications in their agricultural operations. WhatsApp (11.2%), Facebook (8.1%), Linked-In (1.2%), YouTube (1.1%), mobile finance (1.1%), and GPS (1.1%) are all utilized by farmers. The Khula app (2.3%), GPS treble (1.1%), and tillo app (1.2%) were also mentioned by the participants as agricultural mobile applications. The results are consistent with the reports of Nazir et al. (2018), Sharma et al. (2020), and Kumar (2021), which indicated that farmers' utilization of mobile applications in agricultural operations was minimal. This is due to the fact that a farmer may possess knowledge of a specific extant agriculture mobile application, but the application is not critical to their farming system. This conclusion is consistent with the findings of Nwokoye et al. (2019), who found that consequently, there is a high level of awareness but low usage. Contrary to this, Levi, Kyazze, and Sseguya (2015) discovered that farmers may have implemented ICT tools such as mobile phones to facilitate the dissemination or provision of information more rapidly. For example, the voice call feature of a mobile phone facilitates a rapid exchange of information between a farmer and a client. Small-scale producers may have utilized social media applications extensively as a result of their higher penetration and simpler user interfaces. In social media applications, farmers and customers have the ability to engage in conversations regarding farm-related matters in their preferred language (Suchiradipta and Raj, 2018; Mwombe et al., 2014; Makhawula, 2020).

4.4 Impact of Information and Communication Technology tools on crop productivity

This section delineates the results derived from the model evaluating the impact of ICT tools on crop productivity. Productivity has been assessed by the utilization of input values (fertilizer application, pesticide usage, and the adoption of improved crop varieties), yield attained, and revenue generated from agricultural sales. A Probit regression model was employed to evaluate the model fit in the study. The propensity score matching estimator was derived using logit regression, employing individual socioeconomic status to create matched pairings based on similar observational characteristics. The study utilized the propensity score matching method (PSM) with the psmatch2 command to evaluate the average treatment impact (ATT) of ICT tools on crop productivity. Probit regression, Propensity Score Matching (PSM), and Average Treatment Effect on the Treated (ATT) were executed using Stata version 18.0.

4.4.1 Factors influencing smallholder farmers' use of Information and Communication Technology tools

The propensity score matching approach commences with the determination of the likelihood of being assigned to the treatment group. The control groups are composed of individuals who do not use ICT tools, whereas the treatment groups consist of individuals who do. A logistic regression model was employed to determine the propensity score matching between users of ICT tools and non-users.

Table 10: Factors influencing smallholder farmers' use of ICT tools

ICT use	Coef.	Std. Err.	Z	P>|z|
Gender	-.075	.290	-0.26	0.796
Age	-.958	.249	-3.84	0.000***
Marital status	-.402	.153	-2.62	0.009***
Educational level	.102	.097	1.05	0.295
Years of experience	-.184	.164	-1.12	0.262
Farm size	.559	.275	2.03	0.042**
Household size	-.186	.188	-0.99	0.320
Cooperative membership	-.744	.323	-2.31	0.021**
Purpose of farming	-1.074	.398	-2.70	0.007***
Constant	5.664	1.094	5.18	0.363

Pseudo R squared = 0.6320, p-value: < 0.001, log likelihood = -162.40926. *** significant at 1%, ** significant at 5%, * significant at 10% respectively. Source: Survey data, 2024.

Table 10 shows the results of the Probit model, which showed that nine factors had significant impacts on how smallholder farmers used ICT tools. A high Pseudo-R2 of approximately 0.6320 was computed by the model, suggesting that the predictors adequately describe the likelihood of involvement. Adding to that, the Chi-square statistics show that the model is very significant (p-value < 0.001), indicating that the model's variables together strongly explain the variation in the probability of ICT participation. Gender, age, marital status, education, experience, farm size, household size, membership in a cooperative, and the aim of farming all have a role in the likelihood of utilizing information and communication technology instruments.

Age

The findings in Table 8 indicate that age exerted a negative influence on ICT usage, with a coefficient of -0.958, which was statistically significant at the 1% level. An increase in respondents' age is correlated with a 0.958 reduction in the likelihood of utilizing ICT tools. The results align with the findings of Lubisi and Agholor (2023), which indicate that an increase in household age reduces the likelihood of ICT adoption by 0.040. Mishra, Sigdel, Devkota, and Devkota (2023) corroborate these findings, indicating that for each additional year of age in respondents, the likelihood of utilizing ICT diminishes by 1.1 percent. This may be attributed to the decline in learning behavior among farmers as they age; they tend to anticipate risk and choose simplicity. Consequently, there is reluctance in the acceptance of new technology. This outcome aligns with Vosough et al. (2015). Feju et al., (2023) contended that the age group of farmers exhibited a positive significant correlation with the utilization of the internet as an ICT tool component. The results align with those of Mdoda and Mdiya (2022), who discovered that the age of farmers affects their propensity to utilize ICT tools. This may be attributed to the fact that elderly farmers possess extensive knowledge and expertise in agricultural practices, leading them to perceive little necessity for contemporary agricultural information. The youth, being inexperienced in agriculture, seeks new insight to enhance food production.

Marital status

The research identified a substantial negative correlation between marital status, with a coefficient of -0.402, and the probability of utilizing ICT tools for acquiring agricultural information, achieving statistical significance at the 1% level. The results indicate that married smallholder farmers who dominate farming activities, are less likely to utilize ICT tools for obtaining agricultural information in contrast to their unmarried counterparts. Awoyemi (2015) contradicts this finding. He stated that the farmer's marital status (married) was positively significant (p=0.05), indicating that being married enhances the likelihood of utilizing ICT by 3.9%. Nevertheless, the results align with the conclusions of Chhachhar et al. (2012) who established a strong correlation in the use of ICT tools, such as television, and program preferences between married individuals and singles, with singles favoring entertaining content. The married individual may also convey the information broadcasted if one partner was unable to view the show due to other commitments. Both spouses can possess mobile phones due to their relatively inexpensive cost, enabling them to independently access agricultural information at their convenience, hence increasing the likelihood of getting the necessary details. Neves et al., (2012) also revealed that marital status was relevant in the adoption of ICTs and new technologies in their study. Nwafor, Ogundeji, and van der Westhuizen (2020) and Anim-Dankwa (2014), argued out that marital status does not significantly affect the utilization of ICT in agriculture. Furthermore, Henri-Ukoha et al. (2012) posited that marital status was not a major factor in their research on ICT utilization among livestock producers.

Farm size

The research indicated a positive and substantial correlation between farm size and ICT utilization among smallholder farmers, with a coefficient of 0.559 and significance at the 5% level. This positive and substantial effect suggests that a larger farm size increases the likelihood of farmers utilizing ICT tools for agricultural information. The results align with the findings of Lubisi and Agholor (2023), indicating that larger farm sizes correlate with an increased likelihood of smallholder farmers adopting innovative technologies (ICT). The results align with the findings of Shemfe and Modirwa (2018), which indicate that an increase in farm sizes is likely to enhance the utilization of ICT. This suggests that the respondents' farm sizes may hinder their use of ICT, as those with smaller farms tend to have lower production outputs, potentially diminishing their income and consequently making it challenging for them to acquire ICT tools. Bello, Baiyegunhi, and Danso-Abbeam (2021) assert that farm size is a crucial factor in the adoption of diverse agricultural technologies. The size of a farm positively and significantly influences the adoption of innovations, as an increase in farm size boosts farmers' productivity, with returns on adoption being scale-dependent (Bello et al., 2021; Baiyegunhi, Majokweni, and Ferrer, 2019). This study contradicts Kalema's (2017) conclusion, which indicated that farm size negatively influenced ICT adoption, as farmers with larger farms were thought to already possess a target market and hence did not require ICT to connect with consumers, contrasted with farmers with smaller farm sizes. Ojo and Oluwatusin (2017) observed that small farmers are more inclined to adopt new technology, anticipating enhancements in their agriculture and an increase of their profits.

Cooperative membership

Membership in smallholder farmers' organizations negatively influenced the utilization of ICT tools by smallholder farmers, with a coefficient of -0.744, and was statistically significant at the 5% level. This indicates that members of smallholder farmers' organizations in the study area are less likely to adopt ICT tools for obtaining agricultural information compared to non-members. The results show that these respondents rely more on traditional and interpersonal communication channels such as extension agents and peer knowledge sharing rather than ICT tools. The data reveal the actual behavioral patterns in smallholder farming communities rather than expected theoretical benefits that cooperative membership offer. The results contradict findings of Nwafor, van der Westhuizen, and Ogundeji (2020) found, which is that there is a strong correlation between using information and communication technology (ICT) and being a member of a farmer cooperative. This could mean that farmers who are part of a cooperative are more likely to be familiar with and make use of information and communication technology (ICT)-based resources. Zondo and Ndoro (2024) adversely contended that participation in a cooperative significantly influenced the adoption of social media as an information and communication technology tool component, with a positive effect with a $p = 0.023$. Preceding research by (Deji, 2005; Meena, Dudi and Sharma, 2013; Heffernan, Thomson and Nielsen, 2008; Kithendu, 2018) has similarly shown a favorable and statistically significant association between cooperative membership and adoption of innovation. Research by Conley and Udry (2010) confirmed that joining a social group, such as cooperative, increases one's chances of learning about and gaining access to key information regarding technological advancements. It raises the awareness of social media and encourages smallholder farmers to use it to their advantage by expanding their horizons in terms of information exchange, data access, and overall knowledge. The researchers Kanf, Ullah, Jiao, and Zheng (2022) concluded that farmers' adoption of ICT is positively and significantly correlated with cooperative membership. This might be for the reason that agricultural cooperatives are more likely to employ ICT as they are in the business of providing information services through channels like mobile phones and networks, and a larger population means a higher demand for information. There are parallels to the work of Liu (2018) and Wang and Huo (2014).

Purpose of Farming

The study demonstrated a negative correlation of -1.074 between smallholder farmers' farming objectives and the utilization of ICT tools, which was statistically significant at the 1% level. The findings suggest that smallholder farmers who cultivate crops for household consumption and sell limited surpluses to generate income are less likely to employ ICT tools to acquire agricultural information than those who cultivate crops solely for income generation. This also suggests that farmers who prioritize household consumption are less motivated to adopt ICT tools as their production goals do not strongly depend on market information, price updates, or advanced advisory services. In contrast, farmers who produce primarily for income generation are more likely to rely on ICT platforms for market intelligence, technology updates, and productivity-enhancing knowledge. The findings align with Kanf, Ullah, Jiao, and Zheng (2022), who determined that overall family earnings significantly and positively influence farmers' adoption of ICT. mainly, rural households with higher annual incomes are more likely to utilize ICT. This may be due to high-income households showing the economic capacity to acquire and implement new technology. Myhammad, Adesiji, Thabo, Muhammed, and Loko (2019) discovered that farmers in the study region were economically disadvantaged, which could adversely affect their ICT utilization due to selling a little amount of their produce and consuming most of it. This data corroborates the research of Loko et al. (2017), which indicated that the majority of those who participated in their study were people with low incomes. Luqman, Yaseen, Ashraf, Mehmood, and Karim (2019) revealed that the results substantiate the correlation between respondents' income levels and their utilization of ICTs. The results indicate that when farmers' income levels increase, the utilization of ICTs would rise to enhance benefits. The elevated income level of the farmer may encourage them to adopt modern ICTs to address their information requirements. The results revealed by the Syiem and Raj (2015) indicated a substantial association between income of farmers with the adoption of ICTs. Tijjan, Anaeoto and Emerhirhi (2017), revealed that farmers that practice farming for generating income likely to earn more. Farmers with higher incomes could easily provide three meals daily, educate their family members, and access more ICT facilities compared to those with less earnings.

4.4.2 Estimating Propensity Score

The propensity score represents a singular value that signifies the likelihood of obtaining treatment. Smallholder farmers in the treatment group (utilizing ICT tools) were matched with those in the counterfactual group (not utilizing ICT tools) based on closeness of their propensity scores for participation, which were derived by the logit regression model. The analysis excluded all other farmers whose propensity scores for participation differed from the range of scores for the intervention of smallholder farmers. Considering the following, we examined productivity measures across smallholder farmers who were more comparable in terms of their use of fertilizer and pesticides, adoption of improved crop varieties, yield, and income. Table 11 displays the estimated propensity scores. The propensity scores of treated smallholder farmers range from 0.120 to 0.986, with a mean of 0.076, whereas those of the control group range from 0.027 to 0.898, with a mean of 0.219. Consequently, the common support falls within the range of 0.120 to 0.986. Potential matches are indicated by observations within this common support range, while those outside of it are not.

Table 11: Propensity score estimates

Groups	**N. Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Control	117	.4692821	.21976	.0274275	.8984702
Treated	191	.7160554	.2099628	.1200107	.9857852
Total farmers	308	.6223136	.2447933	.0274275	.9857852

Source: Survey data, 2024.

4.4.3 Common support graph

To assess the accuracy of the matching, it is necessary to compare the individuals' distinctive features before and after matching, taking into consideration the propensity score, in order to identify any disparities. Thus, balancing tests are designed to evaluate how well the propensity score achieves balance. Balancing tests aim to determine if a certain attribute displays common distributions for the treatment and control groups at each propensity score value (Callendon and Kopeinig, 2008). A common support graph was constructed to further assess the quality of the match for balancing purposes. This presumes that treatment observations are accompanied by comparison observations. Implying that there are control persons with extremely similar observable traits as the treatment individuals. This enables the study to compare analogous treatment and control subjects. This test is helpful since it visually illustrates the overlap of propensity scores between the treated and control groups. A greater degree of overlap indicates a favorable correspondence between treated and control cases (Dehejia and Wahba, 2002). The graph below indicates a significant overlap in propensity scores between the treatment and control groups, suggesting that the match is effective and balanced.

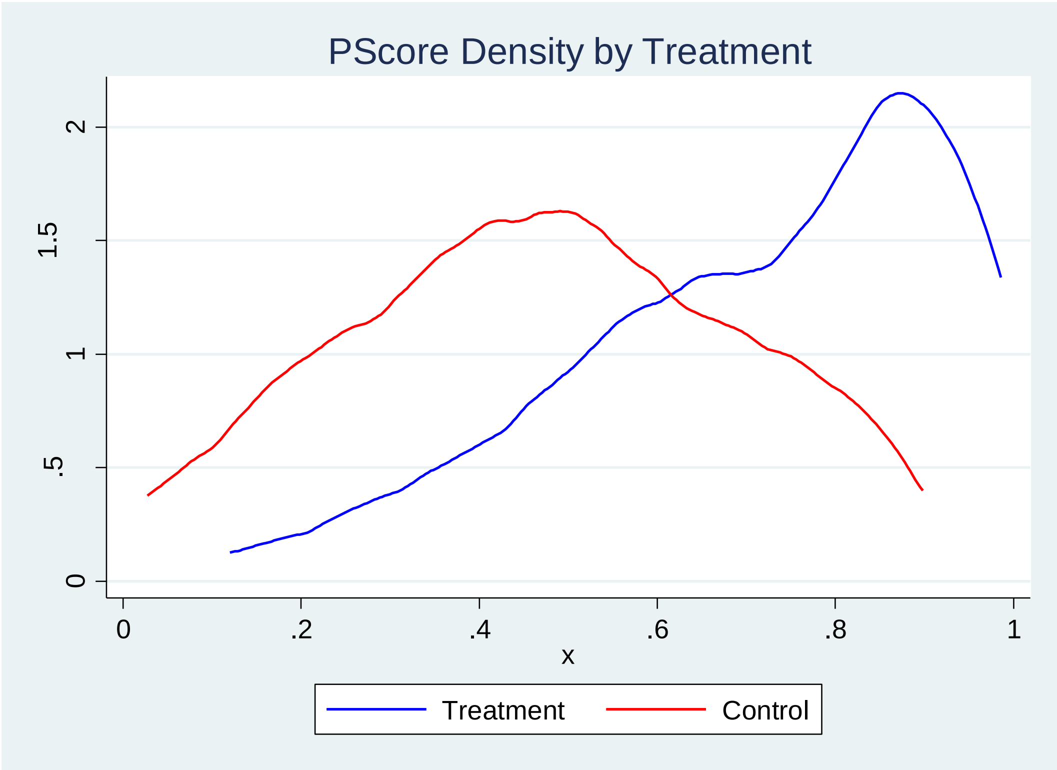


Figure 12: Common support graph

Source: Survey data, 2024.

4.4.4 Estimating average treatment effect on treated

The average treatment effect (ATT) measures how much different the treatment and control groups' mean outcomes are. The Radius matching approach, Kernel-based matching (KBM), and Nearest Neighbor matching (NNM) were used to acquire the results. Kernel matching finds a weighted average of the control subjects inside the common support region and matches them with each treatment subject. The weights are inversely proportional to the gap between the control group and the treated group propensity scores (Heckman, Ichimura and Todd, 1997). According to Becerril and Abdulai (2010), the nearest neighbor matching estimator is designed to pair each treatment individual with the control individual whose propensity score is closest. Using a set of predetermined propensity ratings called the caliper, the radius matching algorithm compares a treatment observation to its equivalent control observation (Zeweld et al. 2015).

4.4.4.1 Impact of Information and Communication Technology tools on Fertilizer usage

The distribution of agricultural inputs is a key indicator of crop productivity in this study. The influence of ICT tools on fertilizer application patterns among respondents was assessed by analyzing the variation in kilograms utilized by smallholder farmers per hectare of farmland in the previous cropping season.

Table 12: Average impact estimates of PSM of ICT tools on fertilizer usage pattern

Fertilizer usage pattern measured in kg	Matching algorithm	Treated	Control	ATT	S.E	t-stat
NPK	Nearest neighbor	291.985	736.489	-444.504	54.811	-8.11
	Kernel	291.985	723.164	-431.179	53.166	-8.11
	Radius	291.985	803.846	-511.861	19.437	-26.33
LAN	Nearest neighbor	506.107	1311.908	-805.802	87.156	-9.25
	Kernel	506.107	1279.539	-773.432	82.360	-9.39
	Radius	506.107	1381.624	-875.517	31.148	-28.11
CAN	Nearest neighbor	501.908	1425.648	-923.740	90.557	-10.20
	Kernel	501.908	1385.589	-883.681	86.531	-10.21
	Radius	501.908	1500	-998.091	32.451	-30.76
Lime	Nearest neighbor	1729.921	2285.354	-555.433	256.783	-2.16
	Kernel	1730.469	2222.514	-492.045	235.691	-2.09
	Radius	1729.921	2127.876	-397.955	98.476	-4.04

ATT is the average treatment effect on the treated. No asterisk on t-stat denotes statistical significance at 5% level and ns is not significant. Common alpha level $\alpha = 0.05$. Degree of Freedom df = 308. Critical value = -1.96. Source: Survey data, 2024.

The influence of ICT tools on fertilizer use among smallholder farmers was evaluated using the Average Treatment Effect (ATT), as presented in Table 12. To calculate the Average Treatment Effect on the Treated (ATT), three distinct matching techniques were employed: nearest neighbor matching, radius matching, and kernel matching. The findings indicate that the ATT of the fertilizers NPK, LAN, CAN, and Lime for all matching algorithms was adversely and statistically significant, as the T-stat values exceeded -1.96 of the critical value.

With a Degree of Freedom (df) of 308, a standard alpha level (α) of 0.05, and a critical value of -1.96, significance is shown at the 5% level.

The study assessed fertilizer usage by focusing on the most commonly applied fertilizers in the study area: NPK, LAN, CAN, and lime. These fertilizer types were selected following the pilot testing of the questionnaire, during which farmers consistently reported using these products to improve soil fertility and crop yields. Other less commonly used fertilizers were filtered out during data cleaning to maintain focus on the fertilizers most relevant to the majority of smallholder farmers. Focusing on these fertilizers allowed the study to capture the key nutrient management practices adopted by farmers and to assess the role of ICT tools in informing fertilizer selection, application timing, and dosage.

Table 12 indicates that users of ICT tools generally utilize fewer fertilizers than non-users, as evidenced by the mean difference or ATT. Fertilizers comprise NPK with values of -444.504kg, -431.179kg, and -511.861kg; LAN with values of -805.802kg, -773.432kg, and -875.517kg; CAN with values of -923.740kg, -883.681kg, and -998.091kg; and Lime with values of -555.433kg, -492.045kg, and -397.955kg in nearest neighbor, Kernel, and Radius matching respectively. Results reveal that users of ICT tools tend to utilize a lesser amount fertilizer per hectare compared to non-ICT users. This outcome may also suggest that ICT users experience lower fertilizer expenses than non-users.

The results are aligned with the research of Lehmann (2012) and Bilali and Allahyari (2018), which indicated that ICT tools minimize the use of chemical fertilizers among smallholder farmers. This is accomplished by disseminating agricultural knowledge regarding the necessary quantity of input utilization for the crops. Conversely, the study by Adebayo, Olagunju, and Adeyemi (2016) revealed that households engaged in the ICT (GESS) intervention exhibited an increase in fertilizer usage, with an average application rise of 2.02 and 1.17 bags of inorganic fertilizer, respectively, compared to households in the counterfactual group. GESS intervention is responsible for this variation since it encouraged households to reinvest in their farm business in order to maintain their agro enterprise through improved market outcomes. Van Campenhout et al. (2021) indicated that the three ICT components Interactive Voice Response (IVR), SMS, and Video were employed to facilitate agricultural extension on maize cultivation techniques. Agricultural techniques enhanced by ICT components included fertilizer application, which augmented corn production by over 10%. Huang et al. (2012), Jia et al. (2013), Pan et al. (2017), and Pan and Zhang (2018) assert that enhanced knowledge of fertilizers contributes to the mitigation of their excessive application.

4.4.4.2 Impact of Information and Communication Technology tools on Pesticides application

The distribution of agricultural inputs is a key indicator of crop productivity in this study. The influence of ICT tools on pesticide application patterns among respondents was assessed by analyzing the variation in the quantity of bags and bottles measured in liters/milliliters utilized by smallholder farmers per hectare of farmland.

Table 13: Average impact estimates of PSM of ICT tools on pesticides application pattern

Pesticide application pattern (no of bottles in l/ml used)	Matching algorithm	Treated	Control	ATT	S.E	t-stat
Insecticide (ml)	Nearest neighbor	368.345	857.793	-489.448	49.354	-9.92
	Kernel	368.345	860.472	-492.127	47.216	-10.42
	Radius	368.345	873.932	-505.587	23.943	-21.12
Herbicides (1)	Nearest neighbor	5.182	12.336	-7.154	1.725	-4.147
	Kernel	5.182	13.933	-8.751	1.664	-5.259
	Radius	5.182	14.623	-9.441	0.535	-17.647
Fungicides (ml)	Nearest neighbor	315.152	317.936	-424.469	34.915	-12.16
	Kernel	315.152	726.108	-410.956	32.589	-12.61
	Radius	315.152	754.274	-439.122	15.609	-28.13

ATT is the average treatment effect on the treated. No asterisk on t-stat denotes statistical significance at 5% level and ns is not significant. Common alpha level $\alpha = 0.05$. Degree of Freedom df = 306. Critical value = -1.96. Source: Survey data, 2024.

The results in Table 13 demonstrate the mean difference, referred to as ATT, across several matching techniques. The outcomes of the matching algorithms are consistent and produced similar results, demonstrating the robustness of the findings. The ATT across all matching methods demonstrates a negative and statistically significant effect on pesticide usage, considering all T-statistics exceed -1.96 of the critical value. The Degree of Freedom (df) is

308, with a common alpha level (α) of 0.05, a critical value of -1.96, and a significance level of 5%.

The study assessed pesticide usage by focusing on the three most commonly applied pesticide categories globally and within smallholder farming systems: insecticides, herbicides, and fungicides. These categories were selected following the pilot testing of the questionnaire, during which farmers identified pest and weed infestations, as well as crop diseases, as the primary challenges affecting crop productivity. The pesticides used to address these production constraints fell predominantly within these three groups. By focusing on these major pesticide types, the study aimed to capture the most significant chemical crop protection practices adopted by smallholder farmers and the application pattern to examine the extent to which ICT tools support decision-making related to their use.

ATT in Table 13 reveals that ICT tools users tend to apply less insecticides compared to non-users as shown by -489.448ml in nearest neighbor, -492.127ml in Kernel and -505.587ml in Radius matching. Results shows less application of herbicides between ICT tools user and non-users by -7l, -8l and -9l in nearest neighbor, Kernel and Radius matching respectively. Furthermore, there was less application of fungicides among users and non-users by -424.469ml in nearest neighbor, -410.956ml in Kernel and -439.122ml in Radius matching. Results shows that in the last cropping season ICT tools users applied lower variety of pesticides compared to the non-users. The findings indicated that non-ICT users frequently exceeded the recommended pesticide application rates per hectare.

The findings align with the research by Zhao et al. (2021), which shown that internet usage significantly influences the reduction of pesticide application. The capacity of farmers to access knowledge regarding eco-friendly production and sales over the internet substantially decreases pesticide usage and enhances agricultural sustainability. According to Subramanian et al. (2022), the use of ICT tools to facilitate interaction among farmers and extension officers has resulted in the enhancement of farm practices, including the application of herbicides, the planting of crops, and the post-harvest management of crops. According to Ma and Zheng (2021), the expenditure on pesticides is substantially elevated by the utilization of smartphones. As a result of prompt dissemination of information regarding the appropriate application of pesticides, the likelihood of pesticide reduction is enhanced. Hou and Yin (2019) asserted that the capacity of ICT tools to provide applicable and swift information aids in the development of a more comprehensive understanding of the sale points of pesticides, the types of pesticides necessary for different crops, and the appropriate dosage.

4.4.4.3 Impact of Information and Communication Technology tools on number of improved crop types adopted

In this study, the adoption of enhanced crop types is also considered a proxy for crop productivity. The propensity score matching method was employed to estimate the impact of ICT tools on the number of improved crop type adopted in the last cropping season.

Table 14: Average impact estimates of PSM of ICT tools on the adoption of improved crop type

No of crop types adopted	Matching algorithm	Treated	Control	ATT	S.E	t-statistics
Spinach	Nearest neighbor	6.182	3.085	3.097	0.176	17.64
	Kernel	6.287	2.990	3.295	0.199	16.51
	Radius	6.182	3.171	3.010	0.127	23.70
Cabbage	Nearest neighbor	6.964	3.486	3.479	0.180	19.31
	Kernel	7.021	3.551	3.469	0.189	18.28
	Radius	6.964	3.547	3.417	0.131	26.14
lettuce	Nearest neighbor	5.714	2.257	3.457	0.258	13.41
	Kernel	5.888	2.036	3.853	0.380	10.13
	Radius	5.714	2.25	3.464	0.194	17.83
Chillies	Nearest neighbor	6.455	2.691	3.764	0.211	17.87
	Kernel	6.667	2.491	4.176	0.271	15.44
	Radius	6.455	2.667	3.788	0.158	24.04
Tomato	Nearest neighbor	6.111	2.378	3.733	0.250	14.91
	Kernel	6.272	2.313	3.959	0.311	12.74
	Radius	6.111	2.583	3.528	0.179	19.72
Maize	Nearest neighbor	6.978	3.476	3.502	0.191	18.30
	Kernel	6.918	3.467	3.451	0.201	17.19

	Radius	6.978	3.521	3.457	0.151	22.83
Ground nuts	Nearest neighbor	7.44	2.992	4.448	0.208	21.37
	Kernel	7.353	2.996	4.357	0.287	15.18
	Radius	7.44	2.956	4.483	0.143	31.43

ATT is the average treatment effect on the treated. No asterisk on t-stat denotes statistical significance at 5% level and ns is not significant. Common alpha level α = 0.05. Degree of Freedom df = 306. Critical value = -1.96. Source: Survey data, 2024.

The results presented in Table 14 demonstrate the mean differences documented as ATT in the number of improved crop varieties that smallholder farmers adopted during the most recent cropping season. The ATT was determined using three matching methodologies, and it was statistically significant for all crops examined in the study. The T-stat values of all the methods were greater than -1.96, which was supported by the Degree of Freedom df of 308, common alpha level α = 0.05, critical value of -1.96, and significance level of 5%. The results are robust, as evidenced by the consistent and similar ATT estimates across all crops and matching methodologies. In order to estimate the impact of ICT tools on the adoption of improved crop varieties, the study adapts the study of Lelisho (2024); Hirko et al. (2018), which employs only the Kernel matching method when the results are consistent across all matching methods. According to the research, Kernel matching is the optimal matching method due to its ability to estimate the effect with greater precision, thereby reducing variance.

The findings indicate that smallholder farmers in the study area predominantly cultivate vegetable crop types such as spinach, cabbage, lettuce, chillies, and tomatoes, along with staple crops like maize and groundnuts. These crops were selected for the study as they were repeatedly mentioned by farmers during the pilot study as the most commonly grown and economically relevant crops in the community. Concentrating on these major crop types enabled the study to effectively assess the role of ICT tools in supporting production-related decision-making for crops that contribute significantly to household livelihoods in the area.

ATT in Kernel matching respectively show that ICT tools users in the last cropping season adopted 3 spinach, 3 cabbage, 4 lettuces, 4 chillies, 4 tomatoes, 3 maize and 4 ground nuts improved varieties as compared to their non-ICT counterparts. The results indicate that the adoption of improved crop varieties among smallholder farmers is significantly enhanced by ICT tools.

Findings from this study are in accord with those of Jannat, Ulla, and Islam (2015), who found that respondents in the study group were more likely to adopt new varieties than those in the control group. Further indicated that, it is justifiable to assume that the respondents' use of ICT media may have played a role in the significant shifts observed in the study group. In yet another study, it was discovered that farmers in rural Nigeria were equipped with acquiring new varieties of maize by engaging in interactions with experts that were facilitated by the internet (Adekunle and Alluri, 2006). The present study's findings are clearly corroborated by the aforementioned literature. In addition, the results are solidified by the research conducted by Ogutu, Okello, and Otieno (2014), who discovered that the utilization of enhanced seeds increased by Ksh 285.41 to Ksh 359.21 as a result of their involvement in the ICT-based MIS project. This outcome is in accordance with the discovery made by Kiiza et al. (2011), which indicated that the intensity of the adoption of modified maize seed is enhanced by access to ICT-based MIS. In 2023, Efobi, Nwalieji, and Ahaneku demonstrated that farmers require information regarding enhanced crop varieties. This could be the result of a lack of awareness regarding the existence of such varieties or a lack of capital to purchase the enhanced seeds. This is consistent with the results of Benard, Dulle, and Ngalapa (2014), who observed that the majority of farmers in their study were unaware of enhanced seeds, resulting in their continued use of the unprofitable recommended varieties.

4.4.4.4 Impact of Information and Communication Technology tools on crop yield

The study used agricultural value of output, commonly referred to as yield, as a proxy for crop productivity. Propensity score matching was also used to quantify the impact of information and communication technology tools on farmers who grow agronomic crops and vegetables. The study was able to gauge the impact by comparing the yields of different crops, measured as tons procured per hectare of land.

Table 15: Average impact estimates of PSM of ICT tools on vegetable output (ton/ha)

Output (Kg/ton/ha)	Matching algorithm	Treated	Control	ATT	S.E	t-statistics
Spinach	Nearest neighbor	10.139	4.4	5.739	0.234	24.53
	Kernel	10.118	4.355	5.763	0.262	22.03
	Radius	10.139	4.429	5.710	0.128	44.58

Cabbage	Nearest neighbor	13.118	8.114	5.004	0.454	11.03
	Kernel	13.118	8.015	5.102	0.484	10.54
	Radius	13.118	8.396	4.721	0.231	20.42
lettuce	Nearest neighbor	12.417	5.65	6.767	0.474	14.26
	Kernel	12.417	5.573	6.843	0.4777	14.33
	Radius	12.417	5.75	6.667	0.398	16.74
Chillies	Nearest neighbor	10.556	5.067	5.489	0.429	12.81
	Kernel	10.286	5.523	4.763	0.591	8.06
	Radius	10.556	5.067	5.489	0.243	22.63
Tomato	Nearest neighbor	11.786	5.243	6.543	0.461	14.18
	Kernel	11.818	5.028	6.789	0.564	12.04
	Radius	11.786	4.917	6.869	0.318	21.62

ATT is the average treatment effect on the treated. No asterisk on t-stat denotes statistical significance at 5% level and ns is not significant. Source: Survey data, 2024.

The calculated average treatment effect on the treated (ATT) reveals that the utilisation of ICT tools has a statistically significant impact on crop productivity as displayed in Table 15 at 5% level of significant. The statistical significance is supported by the critical value which is acquired by the Degree of Freedom df of 89, significant common alpha level $\alpha = 0.05$ and critical value of 2.00. when conducting a two-tailed test. T-stat values of all the matching algorithm ranges of 24.53, 22.03 and 44.58 are greater than the critical value of 2.00. The estimates suggested that the use of ICT tools leads to an increase in spinach productivity, by 5.73 tons in the last cropping season as compared to non-users.

The ATT on the use of ICT tools to improve cabbage production is positive and statistically significant at 5% level of significant when conducting a two-tailed test. This is confirmed by the Degree of freedom df of 144, significant common alpha level $\alpha = 0.05$ and critical value of

1.984. T-stat values of all the matching algorithm ranges of 11.03, 10.54 and 20.42 are greater than the critical value of 1.984. The estimates suggested that the use of ICT tools leads to an increase in cabbage productivity, by 5 tons in the last cropping season as compared to non-users.

Table 15 shows that there was significant positive difference in each of the matching algorithm of the changes in lettuce yield. The differences or ATT in all the three matching algorithms were significant at 5% when conducting a two-tailed test, given Degree of Freedom df of 45, significant common alpha level α = 0.05 and Critical value of 2.042. T-stat values of 14.26, 14.33 and 16.74 are greater than the critical value of 2.042. The estimates suggested that the use of ICT tools leads to an increase in lettuce productivity, by 6 tons in the last cropping season as compared to non-users.

ATT for chillies yield relative to the control group is statistically positively significant at 5% level in Table 15. The significance level was determined by the Degree of Freedom df of 44, significant common alpha level α = 0.05 and critical value of 2.042 when conducting a two-tailed test. The matching methods T-stat values of 12.81, 8.06 and 22.63 are greater than 2.042. The difference in mean of lettuce yield was found to be 5.49 tons in nearest neighbor and Radius, while 4.76 in Kernel matching. Treated group have positive yield difference per ha over the control group in the last cropping season.

Table 15 display the results of ATT on tomato yield. The results indicated that the ATT was significant and consistent among the three-matching algorithm at a yield of 6 tons per ha as compared to the control group in the last cropping season. The significance level is supported by the Degree of Freedom df of 45, significant common alpha level α = 0.05 and critical value of 2.042 when conducting a two-tailed test. The T-stat values of 14.18, 12.04 and 21.62 are greater than 2.042 indicating significance level at 5%.

Table 16: Average impact estimates of PSM of ICT tools on agronomic crops output (tons/ha)

Output (ton/ha)	Matching algorithm	Treated	Control	ATT	S.E	t-statistics
Maize	Nearest neighbor	11.190	4.238	6.952	0.275	25.31
	Kernel	11.190	4.296	6.895	0.277	24.91

	Radius	11.190	4.417	6.774	0.212	32.00
Ground nuts	Nearest neighbor	7.647	3.541	4.106	0.269	15.264
	Kernel	7.647	3.547	4.1	0.289	14.187
	Radius	7.647	3.434	4.213	0.226	18.642

ATT is the average treatment effect on the treated. No asterisk on t-stat denotes statistical significance at 5% level and ns is not significant. Source: Survey data, 2024.

The ATT reveals that the utilisation of ICT tools has a statistically significant impact on maize productivity as displayed in Table 16 at 5% level of significant. The statistical significance is supported by the critical value which is acquired by the Degree of Freedom df of 100 and significant common alpha level α = 0.05 and critical value of 1.984 when conducting a two-tailed test. T-stat values of all the matching algorithm ranges of 25.31, 24.91 and 32.00 are greater than the critical value of 1.984. The estimates suggested that the use of ICT tools leads to an increase in maize productivity, by 6 tons in the last cropping season as compared to non-users.

Table 16 shows that there was significant positive difference in each of the matching algorithm of the changes in ground nuts yield. The ATT in all the three matching algorithms were consistent and significant at 5% when conducting a two-tailed test, given Degree of Freedom df of 55, significant common alpha level α = 0.05 and Critical value of 2.002. T-stat values of 15.264, 14.187 and 18.642 are greater than the critical value of 2.002. The estimates suggested that the use of ICT tools leads to an increase in lettuce productivity, by 6 tons in the last cropping season as compared to non-users.

In summary, the results from Tables 15 and 16 show that smallholder farmers who use ICT tools have higher crop yields than those who do not. This is based on the average treatment impact of the treatment. A positive ATT signifies that the agricultural productivity of smallholder farmers has enhanced in the previous cropping season due to the utilization of ICT tools. This suggests that the utilization of ICT tools in agriculture correlates with enhanced access to quality agricultural information essential for improving crop output.

These findings are in line with those of Jannat et al. (2015), who also discovered that the study group experienced a greater increase in vegetable yield compared to the control group. Participants' usage of information and communication technology (ICT) in the study group may have played a role. This study's findings are supported by Ozaki et al. (2013), who found that vegetable yields in Bangladesh improved significantly when farmers participated in the Income Generation Project for Farmers utilizing ICT. The results also coincide with those of Das, Munshi, and Kamir (2016), which clearly show that the output of maize from the ICT service area has improved more than that of the non-ICT area. According to Sennuga et al. (2020), smallholder farmers' agricultural output was positively and significantly affected by information and communication technology (SMS text reminders). Also, 92% of the participants said the SMS text reminders were helpful, and they were more likely to use the suggested GAP technologies after that. 89% said that having access to reliable information could significantly boost yields. This finding suggests that smallholder farmers' agricultural output could be enhanced when they are provided with trustworthy information through SMS text reminders. Adebayo, Olagunju, and Adeyemi (2016) discovered that households that took part in the GESS intervention, which involved information and communication technology, had a 109.24 kg/ha improvement in maize production compared to households that did not. The results support what was found in the research of (Awotide, 2012). According to Mdoda and Mdiya (2022), households that have access to ICTs are more likely to increase their agricultural production. This is due to these households having better access to information focused on market, climatic information. knowledge regarding new technologies, financial data, and agricultural practices. Farmers will be able to improve their crop yields with the use of this information.

4.4.4.5 Impact of Information and Communication Technology tools on income generated

The empirical results of the impact of ICT tools on income for vegetable and agronomic commodities in the study area are presented in Tables 17 and 18. Crop income is a value that is derived and comprises of monetary earnings generated from a variety of on-farm activities. These activities are classified jointly based on the sources of on-farm income, which include the vegetables enterprise and the agronomic enterprise.

Table 17: Average impact estimates of PSM of ICT tools on vegetable income (Rands)

Income (Rands)	Matching algorithm	Treated	Control	ATT	S.E	t-statistics
Spinach	Nearest neighbor	30875	15244.444	15630.556	1180.854	13.24
	Kernel	30955.882	15196.702	15759.18	1264.059	12.47

	Radius	30875	15128.57	15746.429	317.333	49.62
Cabbage	Nearest neighbor	38490	18131.373	20358.824	1086.744	18.73
	Kernel	38490.196	18042.003	20448.193	1257.208	16.26
	Radius	38490.196	18433.962	20056.234	243.022	82.53
lettuce	Nearest neighbor	30916.667	21983.333	8933.333	855.826	10.44
	Kernel	30916.667	31862.298	9054.369	863.084	10.49
	Radius	30916.667	22375	8541.667	583.832	14.63
Chillies	Nearest neighbor	20888.889	11733.333	9155.556	784.101	11.68
	Kernel	20428.571	11935.355	8493.217	1186.015	7.16
	Radius	20888.889	11633.333	9255.556	352.619	26.25
Tomato	Nearest neighbor	14125	5840.625	8284.38	1419.15	5.84
	Kernel	16500	6140.16	10359.84	2355.95	4.40
	Radius	14125	5200	8925	1266.07	7.05

ATT is the average treatment effect on the treated. No asterisk on t-stat denotes statistical significance at 5% level and ns is not significant. Source: Survey data, 2024.

ICT tools significantly and positively impacted smallholder farmers’ spinach income. The significance level is determined by the Degree of Freedom df of 89, significant common alpha level $\alpha = 0.05$ and critical value of 2.00 when conducting a two-tailed test. The T-stat values of 13.24, 12.47 and 49.62 are greater than the critical value of 2.00 indicating significance at 5% level. The average treatment effect on the treated estimates in Table 17 shows the ATT difference between treated and control is R15630.556 in nearest neighbor matching, R15759.18 in Kernel and R15746.429 in Radius for spinach income.

ATT for cabbage income compared to the control group is statistically, positively significant at 5% level in Table 17. The significance level was determined by the Degree of Freedom df of 144, significant common alpha level $\alpha = 0.05$ and critical value of 1.984 when conducting a two-tailed test. The matching methods T-stat values of 18.73, 16,26 and 82.53 are greater than 1.984. The difference in mean of cabbage income was found to be R20358.82 in nearest neighbor, R20448.19 in Kernel matching and R20056.234 Radius matching. Treated group have positive income difference per ha over the control group in the last cropping season.

Table 17 shows a significant difference in income incurred for the production of lettuce between ICT tools users and non-users. The significance of ATT is backed by the Degree of Freedom df of 44, significant common alpha level α = 0.05 and critical value of 2.042 when conducting a two-tailed test. The T-stat values of 10.44, 10.49 and 14.63 are greater than the critical value of 2.042 showing significance level at 5%. The ICT tools users incurred higher income for lettuce of R8933.33 in nearest neighbor, R9054.37 in Kernel and R8541.67 in Radius matching.

The results reported in Table 17 show statistically significant mean differences between ICT tools users and non-users in terms of their chillies income. The significance level is demonstrated by the Degree of Freedom df of 44, common alpha level α = 0.05 and critical value of 0.042 when conducting a two-tailed test. The T-stat values of 11.68, 7.16 and 26.25 are greater than the critical value of 0.042 which shows significance at 5% level. The chillies income obtained by treated group is R9155.556 in nearest neighbor, R8493.217 in Kernel and R9255.556 in Radius matching is higher than that of control group.

Table 17 indicate that smallholder farmers who use ICT tools have high tomato income of R8284.38 in nearest neighbor, R10359.84 in Kernel and R8925 in Radius matching than their non-ICT counterparts. The study also found a positive significant level in the differences of ATT among the matching algorithms. The significance level is determined by Degree of Freedom df of 45, significant common alpha level α = 0.05 and critical value of 0.042 when conducting a two-tailed test. The T-stat values of 5.84, 4.40 and 7.05 are greater than the critical value of 0.042 showing a significant level of 5%.

Table 18: Average impact estimates of PSM of ICT tools on agronomic crops income (Rands)

Income (Rands)	Matching algorithm	Treated	Control	ATT	S.E	t-statistics
Maize	Nearest neighbor	30023.809	15693.933	14329.876	800.442	17.90

	Kernel	30023.809	15588.756	14435.054	811.331	17.79
	Radius	30023.809	16035.688	13988.122	233.738	59.85
Ground nuts	Nearest neighbor	16647.059	9894.118	6752.941	543.876	12.42
	Kernel	16647.059	9236.727	7410.331	673.859	11.00
	Radius	16647.059	10130.435	6516.624	172.375	37.80

ATT is the average treatment effect on the treated. No asterisk on t-stat denotes statistical significance at 5% level and ns is not significant. Source: Survey data, 2024.

ATT for maize income compared to the control group is statistically, positively significant at 5% level in Table 18. The significance level was determined by the Degree of Freedom df of 100, significant common alpha level α = 0.05 and critical value of 1.984 when conducting a two-tailed test. The matching methods T-stat values of 17.90, 17.79 and 59.85 are greater than 1.984. The difference in ATT of maize income was found to be R14329.88 in nearest neighbor, R14435.05 in Kernel matching and R13988.12 Radius matching. Treated group had positive income difference per ha over the control group in the last cropping season.

The results reported in Table 18 show statistically significant differences in ATT between ICT tools users and non-users in terms of their ground nuts income. The significance level is demonstrated by the Degree of Freedom df of 55, common alpha level α = 0.05 and critical value of 2.00 when conducting a two-tailed test. The T-stat values of 12.42, 11.00 and 37.80 are greater than the critical value of 2.00 which shows significance at 5% level. The ground nuts income obtained by treated group is R6752.94 in nearest neighbor, R7410.33 in Kernel and R6516.62 in Radius matching is higher than that of control group.

Tables 17 and 18 provide a summary of the results, which demonstrate that smallholder farmers who use ICT tools have an increased crop income compared to those who do not. A positive ATT also clearly shows that the use of ICT tools boosted smallholder farmers' crop income in the last cropping season. This suggests that smallholder farmers can gain better access to high-quality agricultural information, which is essential for improving their revenue, when they employ ICT tools in agriculture.

These findings are in line with those of Levi et al. (2015), who also discovered that the majority of farmers believe that the information they receive through three forms of ICT (radio, television, and mobile phones) helps them improve their farming practices, which in turn increases their profits due to the high quality of their crops. Jannat et al. (2015) found that respondents in the study group saw greater gains in agricultural income compared to those in the control group. This difference could be explained by the fact that the study group made more use of information and communication technology (ICT) media. Farmers' profit margins increased by 86% after participating in the DrumNet project, an ICT-based market information service, according to Okello (2010). Their participation in the DrumNet project resulted in better incomes from selling of their crops. It was also shown that farmers' earnings were significantly higher and more consistent after they joined the DrumNet initiative compared to previously. Raj et al. (2011) found that in the Nagapattinam district of India, a mobile phone service that taught farmers how to use nutrients correctly increased their income by 15% compared to the control group. This was because the intervention group used less expensive seeds and nutrients. The present study's findings are substantially supported by the literature stated above.

These findings corroborate those of Sennuga et al. (2020), which found that the treated group achieved more earnings during the 2016 cropping season following the implementation of the ICT intervention (SMS text reminders) than the control group. It was further explained that this is because smallholder farmers were given agricultural knowledge through SMS text reminders and other forms of information and communication technology. Participating families in the information and communication technology (GESS) intervention had higher overall incomes compared to their counterfactual counterparts among maize farmers, according to research by Adebayo et al. (2016). The improvement in cash earnings can be directly linked to the GESS intervention's emphasis on supporting smallholder farmers in the study area, which aligns with the intervention's transformation agenda aimed at developing profitable and resource-efficient agro-enterprises that capitalize on present market opportunities rather than merely selling surplus from subsistence farming.

4.5. Smallholder farmers' perception on the effectiveness of Information and Communication Technology tools

This section provides the findings regarding smallholder farmers' perceptions on the effectiveness of ICT tools. The aim of this study was to examine the farming community's perception of ICT tool utilization in agriculture. Various statements were provided to evaluate this perception, and the findings are displayed in the tables below. This has been accomplished using measures of effectiveness, including timeliness, relevance, accessibility, ease of use, feedback, satisfaction, and complementarity of the ICT tools. Descriptive statistics were employed to examine the study's data in order to derive the mean, standard deviation, and ranking for the perception statements. The study used SPSS version 27 for data analysis.

4.5.1 Distribution of respondents on their perceptions on the timeliness of the information received on Information and Communication Technology tools

Table 19: Comparative timeliness of the information received on ICT tools as perceived by respondents

Perception statements	**Options**					**Ratings**	
	Strongly agree	**Agree**	**Un-decided**	**Disagree**	**Strongly disagree**	**Mean**	**Rank**
Provide agricultural information that is up to date	124(64.9)	67(35.1)	0 (0)	0(0)	0(0)	4.65	1
Provide agricultural information at the time of need	115(60.2)	76(39.8)	0(0)	0(0)	0(0)	4.60	3
Allow access to agricultural information at time of convenience	121(63.4)	68(35.6)	0(0)	1(0.5)	1(0.5)	4.61	2

Scale: 1 = Strongly disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly agree. Note: Mean ≤ 3.0 = Not effective, Mean ≥ 3.0 = Effective. Figures in parentheses are percentages. Source: Survey data, 2024.

The analysis of the perception of the timeliness of information received on ICT tools in Table 19 reveals that majority of the smallholder farmers agreed with the statements that ICT tools provide agricultural information that is up to date (100%), agricultural information at the time of need (100%), and allow access to agricultural information at time of convenience (99%). The statements were ranked 1st, 3rd and 2nd respectively. All the perception statements recorded mean scores above 3.0. The mean values in Table 19 suggest that ICT tools are effective in ensuring that agricultural information is available in a timely manner to smallholder farmers.

The results are in line with Levi et al. (2015); Mitta et al. (2010); Ogbeide (2015), who found that ICT tools enhance the timely delivery of agricultural information to farmers, with widespread coverage through regular agricultural programs and quick access to information that saves time and reduces costs. In addition, these technologies are sources of up-to-date information, that help and allows smallholder farmers to make informed decisions and enhance agricultural production (Levi et al., 2015; Mitta et al., 2010; Ogbeide, 2015). Research by Levi et al. (2015) confirms that ICT tools provide timely information to smallholder farmers, with many preferring these tools for their convenience and accessibility at home or on the farm. Additionally, Sife et al. (2010) highlighted the effectiveness of ICT tools in reaching rural populations, primarily due to their wide coverage.

4.5.2 Distribution of respondents on their perceptions on the relevance of information received on Information and Communication Technology tools

Table 20: Comparative relevancy of the information received on ICT tools as perceived by respondents

Perception statements	**Options**					**Ratings**	
	Strongly agree	**Agree**	**Un-decided**	**Disagree**	**Strongly disagree**	**Mean**	**Rank**
Convey agricultural information suitable for farmers' context	87(45.5)	60(31.4)	0 (0)	38(19.9)	6(3.1)	3.96	2
Provide agricultural information that is reliable	84(44.0)	60(31.4)	0(0)	31(16.2)	16(8.4)	3.86	3
Provide agricultural information that is complete	112(58.6)	71(37.2)	1(0.5)	6(3.1)	1(0.5)	4.50	1

Scale: 1 = Strongly disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly agree. Note: Mean ≤ 3.0 = Not effective, Mean ≥ 3.0 = Effective. Figures in parentheses are percentages. Source: Survey data, 2024.

The current research measures the relevance of agricultural information provided to farmers through ICT tools by evaluating the potential for distributing standard information and its effect improvements in agricultural productivity. Table 20 indicates that majority of the smallholder farmers agreed that ICT tools provide agricultural information that is complete (95.8%) and it was ranked 1st. The farmers also agreed that ICT tools convey agricultural information suitable for farmers' context (76.9%) and it was ranked 2nd, also provide agricultural information that is reliable (75.4%) and it was ranked last. Whereas 23%, 24.6% and 3.6% disagreed with the statements respectively. All perception statements recorded mean scores above 3.0. The results in Table 20 indicate that ICT tools are effective in conveying relevant agricultural information to smallholder farmers, given that all mean values exceed 3.0. The findings align with those of Levi et al. (2015), who found that over 45% of farmers ranked ICT tools as the most relevant for receiving agricultural information. While only 9.6% of respondents used ICT tools for agricultural communication, 11.45% preferred ICT tools with visual and auditory features, which farmers found effective for content adoption. However, Churi et al. (2012) observed that farmers felt certain ICT tools were disorganized and unsuitable for accessing agricultural information, although many still considered them valuable, with both local and external stations meeting the information needs of rural farmers in some districts. Furthermore, Usadolo and Brink (2021) argued that agricultural information content acquired from varied ICT tools is perceived as inappropriate to farming situation and incomplete by smallholder farmers. According to Levi et al. (2015), there is evidence that information accessed through various forms of ICT is relevant to farmers' situations and useful. Specifically, they found that smallholder farmers always used the information to guide their daily basis farming practices. Research indicates that farmers find ICT tools more useful than other sources of information as they can select relevant, reliable, and accurate information. Additionally, ICT tools that broadcast in local languages are highly valued by farmers for accessing agricultural information and financial services, as the information is easy interpreted and implemented (Benard et al., 2019; Okello et al., 2020).

4.5.3 Distribution of respondents on their perceptions on the accessibility of Information and Communication Technology tools used to access agricultural information

Table 21: Comparative accessibility of ICT tools as perceived by respondents

Perception statements	Options					Ratings	
	Strongly agree	**Agree**	**Un-decided**	**Disagree**	**Strongly disagree**	**Mean**	**Rank**
Cheaper source of information	30(15.7)	56(29.3)	0 (0)	79(41.4)	26(13.6)	2.92	3
Portable	93(48.7)	59(30.9)	1(0.5)	8(4.2)	30(15.7)	3.93	2
Requires supplementary operations	115(60.2)	76(39.8)	0(0)	0(0)	0(0)	4.60	1

Scale: 1 = Strongly disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly agree. Note: Mean ≤ 3.0 = Not effective, Mean ≥ 3.0 = Effective. Figures in parentheses are percentages. Source: Survey data, 2024.

Results presented in Table 21 show that majority of the participants contended that ICT tools requires supplementary operations (100%), 79.6% agreed that ICT tools are portable whereas 19.9% disagreed with the statement. However, majority 55% disagreed with the statement that ICT tools are cheaper source of information whereas a least percentage of 45% agreed with the statement. ICT tools were perceived effectively accessible in relation to portability and requirements of supplementary operations as the mean scores were above 3.0 and ranked 1st and 2nd respectively. ICT tools were not perceived effective as cheaper sources of information with a mean score less than 3.0 and ranked last.

The findings are supported by Churi et al. (2012), who found that most farmers have access to affordable and user-friendly ICT tools, enabling them to access services like money transfers and communicate with agricultural stakeholders, enhancing knowledge transfer. Similarly, Levi et al. (2015) highlighted that the wide availability and low cost of ICT tools in rural areas facilitate the accumulation of agricultural information, although solar power and alternative energy sources for using ICT tools like television are expensive. Sife et al. (2010) further noted that many farmers' low incomes prevent them from purchasing costly ICT tools, limiting their exposure to valuable agricultural broadcasts. Further research conducted by Fawole and Olajide (2011) indicated that farmers cited the high cost of utilizing ICT tools such as mobile phones, the internet, and television as the main reason they do not use these sources of information. In addition, Raza et al. (2020) found that respondents considered ICT tools, particularly those with visual and auditory features, to be the most effective and affordable source of information, which contrasts with the current study's findings. While ICT tools were seen as a cost-effective source of information, mobile devices, especially smartphones, were considered more expensive, and many farmers faced challenges in accessing them due to affordability and infrastructure issues. Inadequate infrastructure, such as limited access to electricity for charging mobile devices, further hindered farmers' ability to access timely agricultural information, as highlighted by Wyche and Steinfield (2015).

4.5.4 Distribution of respondents on their perceptions on the ease of use of Information and Communication Technology tools

Table 22: Comparative ease of use of ICT tools as perceived by respondents

Perception statements	**Options**					**Ratings**	
	Strongly agree	**Agree**	**Un-decided**	**Disagree**	**Strongly disagree**	**Mean**	**Rank**
Easy to use when accessing agricultural information	104(54.5)	86(45.0)	0 (0)	1(0.5)	0(0)	4.53	1
User friendly	77(40.5)	111(58.4)	0(0)	1(0.5)	1(0.5)	4.38	3
Align with farmers literacy capability	99(51.8)	84(44.0)	0(0)	7(3.7)	1(0.5)	4.43	2

Scale: 1 = Strongly disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly agree. Note: Mean ≤ 3.0 = Not effective, Mean ≥ 3.0 = Effective. Figures in parentheses are percentages. Source: Survey data, 2024.

The results of the analysis on the perception of the ease of use of ICT tools by smallholder farmers when accessing agricultural information in Table 22 showed that majority of the farmers agreed that they find it easy to use ICT tools when accessing agricultural information (99.5%) and it was ranked 1st. 95.8% agreed that ICT tools align with farmers' literacy capability and ranked 2nd, whereas 98.9% agreed that ICT tools are user friendly and was ranked last. All the perception statements recorded mean scores above 3.0. With mean values more than 3.0, the data shown in Table 22 suggest that all of the described ICT technologies are successful in making information easily accessible. The findings align with those of Levi et al. (2015), who identified ICT tools as a practical means for farmers to access and share information. This is supported by Shemfe and Modirwa (2018); Muhammad et al. (2019); Benard et al. (2019), who found that ICT tools are user-friendly and accessible for rural smallholder farmers seeking agricultural information. Additionally, Feju, Malgas, and Phiri (2023) suggest that farmers' familiarity with and ease of use of ICT tools, including social media applications, increase their likelihood of usage, with Raza et al. (2020) noting that the most important characteristics of ICT tools are ease of use and high efficiency. Chhachhar et al. (2014) further emphasize that farmers cite the easy access to information on ICT tools as a key reason for their effectiveness. Farmers rated ICT tools, such as television and mobile phones as easier to use compared to other forms of communication technology (Raza et al. 2020). Sanga et al. (2013) and Ekoja (2003) also found that ICT tools are effective and accessible sources of information, helping to reach larger audiences. Farmers perceived that ICT tools are user-friendly for tasks such as making calls, sending texts, and exchanging audio-visual information, which encourages farmers to use them for accessing agricultural knowledge (Makaula, 2021).

4.5.5 Distribution of respondents on their perceptions on the feedback received on Information and Communication Technology tools

Table 23: Comparative feedback received on ICT tools

Perception statements	**Options**					**Ratings**	
	Strongly agree	**Agree**	**Un-decided**	**Disagree**	**Strongly disagree**	**Mean**	**Rank**
Provide an avenue to get clarity through provision of contact details of agricultural information source	107 (56.0)	82 (42.9)	0 (0)	1(0.5)	1(0.5)	4.53	1
Provide fast feedback	36(18.8)	66(34.6)	0(0)	72(37.7)	17(8.9)	3.17	3

Foster interactive feedback through engagement between agricultural information source and audience	84(44.0)	82(42.9)	0(0)	15(7.9)	10(5.2)	4.13	2

Scale: 1 = Strongly disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly agree. SD = Standard deviation. Note: Mean ≤ 3.0 = Not effective, Mean ≥ 3.0 = Effective. Figures in parentheses are percentages. Source: Survey data, 2024.

The results in Table 23 show that, majority of the farmers agreed that ICT tools provide an avenue to get clarity through provision of contact details of agricultural information source (98.9%), was ranked 1st. Farmers also agreed that using these technologies foster an interactive feedback by engaging in the audience and the source of agricultural information (86.9%), where as 13.1% disagreed with the statement. Additionally, 53.4% agreed that ICT tools allows them to get faster feedback whereas 46.6% disagreed with the statements. The statements were ranked 2nd and last respectively. All the perception statements recorded mean scores above 3.0. This Justify that ICT tools were perceived effective in terms of provision of feedback to smallholder farmers. These findings align with Levi et al. (2015), who found that ICT tools enable one-on-one communication and active participation, which accelerates problem-solving. Okello et al. (2020) further suggested that respondents benefit from the convenience of ICT tools, which provide direct communication and quick feedback on agricultural transactions. Contrary to the findings of Mtega and Msungu (2013), Okello et al. (2020) showed that ICT tools with limited time for listener interaction, such as radio programs, restrict the number of participants able to provide input, which leads farmers to rely less on these sources for agricultural information. Mtega (2018), similarly found that farmers often experience delayed or absent feedback when trying to clarify information from agricultural TV programs through contact details. These findings suggest that, despite the initial preference for ICT tools for immediate responses, farmers' reliance on them may diminish due to limited interaction and delayed feedback.

4.6 Binary regression analysis of respondent's constraints influencing access to agricultural information through Information and Communication Technology tools

This section delineates the outcomes derived from the logistic regression model to evaluate the constraints influencing smallholder farmers' use of ICT tools towards accessing agricultural information. This considers the physical, human, natural and financial elements that influence smallholder farmers' utilisation of ICT tools. The analysis utilised SPSS version 27 to generate the logistic regression outcomes.

Table 24: Binary logistic regression model results on smallholder farmers' constraints influencing the use of ICT tools

Independent variables	B	Std. Error	Wald	df	Sig	Exp(B)	95% Confidence Interval for Exp(B)	
							Lower	Upper
Gender	-.458	.438	1.090	1	.296	.633	.268	1.494
Age***	-.713	.300	5.641	1	.018	.490	.272	.883
Educational level***	-.659	.163	16.462	1	.001	.517	.376	.711
Farm size	.357	.360	.983	1	.322	1.429	.705	2.895
Cooperative membership**	-.983	.471	4.356	1	.037	.374	.149	.942
Network connectivity	-.495	1.606	.095	1	.758	.609	.026	14.192
Power outage***	-1.948	.556	12.289	1	.001	.143	.048	2.424
Electricity supply	-.238	.614	.150	1	.698	.788	.237	2.624
Cost of ICT tools	-3.482	3.377	1.063	1	.302	.031	.000	23.012
Use of foreign language***	2,660	.551	23.289	1	.001	14.298	4.854	42.119
ICT literacy***	1.278	.520	6.050	1	.014	3.590	1.297	9.941
ICT awareness***	4.520	.880	26.392	1	.001	91.864	16.375	515.371
Constant	.490	.117	17.428	1	.001	1.613		
Overall percentage			88.0%					

Number of observations(N)	308
-2 Log-likelihood	183.120[a]
Cox & Snell R Square	.520
Nagelkerke R Square	.707
Hosmer and Lemeshow Test	Chi-square 5.823 df 8 Sig. 0.667

*P < 0,1, **P < 0.05, *** P < 0.01; ns: not significant

A binary Probit regression model was calculated to assess the influence of various explanatory variables on the likelihood of smallholder farmers utilising ICT tools. The factors that influence smallholder farmers' utilisation of ICT tools for accessing agricultural information were examined using the Probit model. The smallholder farmers in the sample were either non-users or users of ICT tools. Therefore, the dependent variable that indicates the utilisation of ICT tools by smallholder farmers was binary, denoting a value of 1 when present and 0 otherwise. The model contained twelve explanatory variables. The summary of the variables that may affect the usage of ICT tools in agriculture by smallholder farmers is shown in Table 24. A method for evaluating the model's goodness of fit is the log-likelihood value of regression. This was done using data from the Omnibus testing of the model coefficient, where X^2 (df, N = 308) was equal to 225.904 $P < 0.001$. Logistic regression fits the data nicely and is appropriate for predicting the impact of the independent factors on the use of ICT tools, according to the results. This model accounts for 61% to 83% of the variation in the dependent variables, as indicated by the 71% Nagelkerke R Square and 52% Cox & Snell R Square. The model is considered significant ($P = 0.001$, $P < 0.001$) based on the results of the Hosmer and Lemeshow test. The effect of each independent variable on the dependent variable is represented by the positive and negative signs of each logistic regression coefficient.

4.6.1 Age

The age of the respondents influenced ICT usage, with $\beta = -0.713$, and was statistically significant at a p-value of 0.01, where $P < 0.01$. These data indicate that each additional year in the age of farmers will reduce the likelihood of utilising ICT tools for accessing agricultural information by a factor of 0.713. The findings indicate that older farmers are less inclined to accept and utilise ICT tools than their younger counterparts. These findings are consistent with those of Lubisi and Agholor (2023), Irungu, Mbugua, and Muia (2015), Anim-Dankwa (2014), and Sekabira, Bonabana-Wabbi and Narathius (2012), who discovered that young individuals are more inclined to embrace ICT than their older counterparts. The results are in direct opposition to the findings of Nkambule and Agholor (2022) study, which posited that an increase in the average age of smallholder farmers would lead to a 1.071-unit increase in the likelihood of adopting ICT. Consequently, it is posited that an individual's age has an impact on their ability to access various sources of information (Mittal and Mehar, 2016). Contrary to these findings, Wale and Mkuna (2023) discovered that the age of smallholder farmers has no significant influence on adoption. However, further concluded that it is clear that the most likely innovators and early adopters of ICT are younger smallholder farmers.

4.6.2 Educational level

The findings of the study demonstrated that the level of education was statistically significant (p-value = 0.001, $P < 0.01$) and had a negative influence on the use of ICT ($\beta = -0.659$). These findings suggest that the likelihood of utilising ICT tools to access agricultural information will decrease by 0.659 times as the level of education among the respondents' increases. The results contradict the previous findings of Kabir (2015), which indicated that a higher level of education is a stronger predictor of ICT use. Nkambule and Agholor (2022) discovered that an increase in educational attainment enhances the likelihood of ICT adoption by a factor of 0.565. Farmers with higher literacy and education levels are more proficient at assimilating new information and expertise, enabling them to seek out diverse agricultural technologies that enhance their farming operations (Yokamo, 2020; Aldosari et al., 2019). The findings also do not align with those of Shemfe and Modirwa (2018), which demonstrated a favourable statistical correlation between educational level and ICT usage. Indicating that more educated respondents are more likely to take advantage of and utilise ICT technologies efficiently to access crucial information that could enhance agricultural activity. Fadeyi, Ariyawardana, and Aziz (2022) assert that smallholder farmers with any type of education, regardless of official or informal, exhibit a higher likelihood for adopting agricultural technology. The understanding and intricacy of agricultural technologies are more accessible to smallholder farmers having better education and literacy levels.

4.6.3 Cooperative membership

The data presented in Table 24 demonstrates that the membership of cooperatives was determined to be statistically significant, with a p-value of 0.037, where $P < 0.05$. Furthermore, the membership had a negative influence on the utilisation of ICT, as indicated by a β value of -0.983. The majority of those who participated in the survey were members of local farmer's organisations, according to the findings of the survey. According to these findings, there is a 0.983 times decrease in the utilisation of ICT for the purpose of gaining access to agricultural information for every unit increase in cooperative membership among farmers. These findings are in agreement with the findings of van Averbeke et al. (2011), who discovered that there is a lack of statistical significance ($p = 0.479$) regarding the utilisation of social media as a component of ICT and membership in irrigation schemes. The findings are in contradiction to the findings of Zondo and Ndoro (2024), who discovered that the probability of a smallholder farmer adopting social media was 7.36 for every unit increase in the variable social cooperative membership. Kithendu (2018) and Dudi and Sharma (2013) discovered that there is a positive and significant association between membership in a cooperative and the adoption of innovations.

4.6.4 Power outage

Power outage had a negative influence on ICT use at a $\beta = -1.948$ and was statistically significant at p-value = 0.001 where $P < 0.01$. These results suggest that increased power outage results in the decreased use of ICT tools by farmers to access agricultural information by 1.948 times. The results are consistent with the findings of Mdoda and Mdiya (2022), who determined that the electricity disruption was statistically significant at a 5% level and had a negative impact. This implies that there is actually an inverse correlation between the use of ICT and the occurrence of electricity outages. This suggests that the probability of utilising ICT tools will decrease by 0.9 for every 1% increase in electricity outages experienced by farmers. Further indicated that it is this challenge that the country is currently confronting as it is experiencing a high rate of electricity supply failures which has resulted in the damage of numerous appliances. Electricity outages have a significant impact on smallholder livestock producers, as they are reliant on batteries and solar systems to ensure that their phones are operational and that they can watch television at any hour of the day. The results are further corroborated by Ajani and Agwu (2012); Shankariah and Swamy (2012), who discovered that farmers' utilisation of ICTs was impeded by irregular power failures. The results further suggest that farmers perceived electricity shortages in rural locations as the main constraint to their access to information. According to Mutambara and Munodawafa (2014), the electricity shortage is the most significant challenge that the majority of respondent encounter. As a result, producers are forced to resort to traditional production methods and experience frequent load-shedding. Otene et al. (2018) found that the use of mobile phones by farmers was significantly impacted by unreliable electricity supply and inadequate network

4.6.5 Language use

The variable use of foreign language was found significant with a p-value = 0.001 where $P < 0.01$ and $\beta = 2.660$ which indicates that it is positively associated with the use of ICT tools. These results indicate that for every unit increase in the use of foreign language during dissemination of information on ICT tools, there is an increase in ICT usage by 2.660 times. Consistent with previous research by Alam, Mushtaq, Khatun and Mamun (2019), who shown that individuals with a formal education are better able to use ICT products that are not set up in their native language without experiencing any language difficulties. The findings contradict those of Muricho (2013), who discovered that the language barrier limited the usage of ICT due to the preponderance of English-language electronic content. This suggests that most farmers, even the more educated ones, may favour speaking the native tongue. Another challenge that smallholder farmers face when using mobile phone technology to access farming information is the use of a foreign language that include English for communication, which fails to factor cultural context into account sufficiently (Ireri, Awuor, Ogalo and Nzuki, 2021). According to Asenso-Okyere and Mekonnen (2012), understanding a foreign language might be challenging. As a result, the accessible data may have been misused (Schalkwyk et al., 2017).

4.6.6. Information and Communication Technology literacy

The variable ICT literacy was found significant with a p-value = 0.014 where $P < 0.01$ and $\beta = 1.278$ which indicates that it is positively associated with the use of ICT tools. These results indicate that for every unit increase in the operational skills of ICT tools among farmers, there is an increase in ICT usage by 1.278 times. The results align with the findings of Anim-Dankwa (2014), which indicated that farmers who obtained ICT training and possessed technological literacy considerably increased their utilisation of ICT tools. Yakubu et al. (2013) corroborate this finding and highlighted that the acceptance of ICTs is expected to be enhanced by training in their use. Morrow (2002) asserts that small-scale farmers lack access to computers, sufficient telecommunication infrastructure, and the computer literacy necessary to comprehend digital content. Mutisya (2016) confirmed that the degree of digital knowledge influences the effective utilisation of mobile phones by farmers, indicating that a rise in a farmer’s digital knowledge enhances the likelihood of mobile phone usage. Luqman, Yaseen, Ashraf, Mehmood, and Karim (2019) demonstrated that smallholder farmers lack the abilities to sort out relevant, accurate, valid, and useful information from the vast variety of information that is accessible online. Shankariah and Swamy (2012) observed similar findings, indicating that farmers have limited practical experience in utilising ICTs for information acquisition. According to Lawal-Adebowale (2015), although farmers possess ICT devices like mobile phones and computers, they lack the necessary skills and expertise for utilising and maintaining such technological equipment.

4.6.7 Information and Communication Technology awareness

The results obtained indicated that ICT awareness was found to be significant with a p-value = 0.001 where $P < 0.01$ and had a positive influence on the use of ICT with a $\beta = 4.520$. These results imply that any increase in ICT awareness among farmers will result in the increase in the probability of using ICT tools to access agricultural information by 4.520 times. The findings are in agreement with the findings of Lubisi and Agholor (2023), who discovered that there is a substantial positive link between awareness of ICT and using ICT. In addition, it was shown that farmers who are more informed about the advantages of ICT tools are more inclined to adopt new technologies than farmers who are not aware of these advantages. These findings are consistent with the findings of Shemfe and Modirwa (2018), who discovered that there is a significant and substantial association between the awareness of ICT tools and its use among smallholder farmers. This suggests that the majority of respondents are aware of the use of ICT tools for the delivery of extension services and have a likelihood to make use of one of the ICT instruments that are within their capabilities in order to gain access to information concerning farm and management activities.

Chapter 5: Conclusion and Recommendations

5.1 Introduction

This chapter presents a comprehensive summary of the study. It commences with a summary of the study's major findings pertaining to its observed chapters, followed by an overall conclusion and recommendations derived from the findings of the research.

5.2 Conclusion

This paper investigated the effectiveness of ICT tools in disseminating agricultural information to improve crop productivity of smallholder farmers in Mbombela Local Municipality of Mpumalanga province. Socio-economic characteristics of the smallholder farmers were examined as they form the foundation of the study results and influences use of ICT tools. The study results showed that in the study area female farmers dominate farming activities as compared to their male counterpart. Age analysis has shown that smallholder farmers of age range of 55 and above are the dominating group in the study area. The results also displayed that majority of the smallholder farmers are married. Regarding educational level, results indicated that majority have a form of formal education or are literate. Furthermore, majority of the smallholder famers did not have agricultural certificates, implying they have not attended any agricultural trainings and workshops. Majority of the respondents had six to ten years of farming experience and less than five hectares of land. Land distribution of the respondents showed that majority own the lands they were practicing agriculture on. Majority of the smallholder farmers had a household size of 6-10 members per homestead in the community. The results have further shown that majority of the respondents participate in local smallholder farmers' organisations. Majority of the farmers practice agriculture for household consumption and to generate income. This indicates that the smallholder farmers in the study are predominantly smallholder oriented, producing mainly to support household food security and only selling surplus produce when available. As commercial activities are limited, there is reduced urgency to adopt ICT tools that provide market information, price updates and advanced advisory services. Therefore, smallholder-based farming objectives contribute to the lower likelihood of ICT utilization, as farmers rely more on traditional knowledge and localized communication systems rather than digital platforms. A great percentage of the smallholder farmers in the targeted area produce vegetable crops but do not have source of off farm income. Furthermore, results indicated that majority of the farmers uses ICT tools for agricultural information access with smartphone and radio being the most used tools. Smallholder farmers who do not use ICT tools are depended on public extension services and have less yield as well as income.

The study also examined the perceived effectiveness of ICT tools in disseminating agricultural information to improve crop productivity of smallholder farmers. From the research findings, it is demonstrated that ICT tools are perceived effective by respondents on various measures of effectiveness such as relevance, timeliness, accessibility, ease of use, feedback and complementarity. The results further showed that basic cell phone and radio were perceived effective on ease of use of the tools, accessibility which implies affordability and being satisfied with the quality of agricultural information accessed from the tools. Basic cell phone is also perceived by the respondents to be effective in providing immediate feedback that is complete. The results also showed that smartphone is perceived by the respondents to be disseminating agricultural information that is timely. Furthermore, basic cell phone and smartphone were perceived effective on complementarity as an individual can access functions of one tool in another. It can be deduced from the results that smallholder farmers who uses ICT tools were more familiar with the conventional ICT tools such as basic cell phone, radio and television as compared to the contemporary ICT tools such as smart phone and computer.

This study assessed the impact of ICT tools on smallholder crop productivity taking to account fertilizer usage, pesticide application, adoption of improved crop varieties, crop yield and income. The propensity score matching results firstly, showed that to compute matching Probit logistic regression was carried out where smallholder farmers socio economic characteristics between users and non-users were tested to measure the probability of an individual to use ICT tools. Age, marital status, farm size, cooperative membership and reason of farming were found statistically significant and reducing the probability of using ICT tools for agricultural information access. The logistic regression results were used to generate propensity scores which were used to conduct matching to generate average treatment effect on the treated (ATT). Based on the results of this study, ATT showed that agricultural information accessed on ICT tools assist smallholder farmers to reduce over-use and over-application of fertilisers as well as pesticides. ATT generated also showed that participants who uses ICT tools adopted more improved crop varieties, acquired more yield and generated more income as compared to their non-ICT counterparts. Therefore, this study guided by the results demonstrate that agricultural information acquired from various ICT tools aid in improving crop productivity taking to account increased crop yield and income respectively.

The current study further examined constrains affecting smallholder farmers' utilisation of ICT tools for acquiring agricultural information to enhance crop productivity. The binary logistic regression results of the study revealed that majority of the smallholder farmers use ICT tools to access agricultural information. However, in accessing the agricultural information smallholder farmers are mainly faced with constraints which hamper optimal utilisation of the tools. The results also showed that among the twelve factors tested against ICT tools use such as gender, age, educational level, farm size, cooperative membership, network connectivity, power blackouts, electricity supply, cost of ICT tools, ICT literacy and ICT awareness only seven factors were found significant. Factors that were found statistically significant included age, educational level, cooperative membership, power blackouts, language barrier and ICT awareness. Based on the results, this study demonstrates that an increased unit in ICT literacy, ICT awareness and language used to communicate agricultural information increases the use of ICT tools whereas an increase unit in age, educational level, cooperative membership and power blackouts reduces the use of ICT tools.

Disseminating accurate and timely agricultural information to smallholder farmers is crucial for promoting the adoption and implementation of sustainable and advanced farming techniques. In this modern digital era, information and communication technology is acknowledged as a tool that enables smallholder farmers communicate and share agricultural information. According to the study's findings, smallholder farmers in the targeted area uses ICT tools to access agricultural information with the mostly used ICT tools being mobile phones and radio. The findings also showed that through the use of various ICT tools smallholder farmers are able to improve their crop productivity. The mentioned ICT tools are perceived by smallholder farmers to be easy to use, easily accessed, have fast feedback, disseminate timely and relevant information, and satisfied with the quality of information received. It also emerged that a statistical positive and as well as negative relationship exists between smallholder farmers' socio-economic factors, institutional factors and the use of ICT tools. This implies that factors that have a statistical negative relationship reduces smallholder farmers use of ICT tools whereas positive statistical relationship increases use of ICT tools.

5.3 Recommendations

Local extension officers and diverse agricultural information sources need to consider the context and socio-economic characteristics of smallholder farmers when planning, packaging, and disseminating agricultural information. Consideration should be given to ICT tools that are predominantly accessible to smallholder farmers, content that aligns with their context, language, and ICT tools that are compatible with the users' literacy levels when communicating with specific groups of farmers. This will enhance the acquisition and implementation of agricultural information.

The government and agricultural information providers should develop strategies to address issues that are currently hindering farmers' access to agricultural information on ICT tools. Age and power outages were identified as constrains to ICT utilisation among smallholder farmers in the current study. Consequently, it is imperative to enhance the utilisation of radio and mobile phones as ICT tools for disseminating agricultural information, as these are the most favoured and accessible mediums, particularly among elderly smallholder farmers. Additionally, the government should strive to establish a reliable power supply in all rural areas to promote the utilisation of ICT tools.

Local extension officers in collaboration with community leaders and farmers' organisations, should promote participation in adult literacy programs offered by the Department of Education for smallholder farmers who are illiterate. Consequentially, this will improve smallholder farmers' capacity to understand information obtained through ICT tools.

Modern ICT tools, including smartphones and computers, were regarded as less effective regarding ease of use and accessibility due to their costly nature and complexity. Consequently, the study recommends for collaboration between local agricultural extension officers and NGOs notably NEMISA, which implement technological literacy programs in rural communities. Extension officers should motivate smallholder farmers to participate in such programs to enhance their utilisation and operation of ICT tools. The government should subsidise smallholders' acquisition of ICT tools and their supplementary operational needs. This can also be achieved by providing farming ICT channels accessible at no cost to smallholder farmers.

The research highlighted the necessity to enhance agricultural information accessibility for smallholder farmers, commencing with the improvement of factors that adversely affect information access in the study area. The study recommends for the enhancement of existing agricultural information dissemination platforms to facilitate better access to information for smallholder farmers. This encompasses the analysis and monitoring of the effectiveness of platforms to ensure the adequate dissemination of agricultural information. A comprehensive understanding of farmers' informational requirements and sources could enhance the selection of specific farmer groups for suitable interventions in extension and agricultural programs.

The study recommends policymakers, in collaboration with local extension officials, to initiate additional educational programs aimed at encouraging smallholder farmers to use ICTs to enhance agricultural productivity. This can be accomplished by investing in campaigns, roadshows, information sessions in local languages, that promote knowledge sharing and awareness of ICT utilisation in agriculture. This will equip smallholder farmers with knowledge, skills and familiarity regarding various ICT tools to effectively utilise their benefits for accessing agricultural information.

Suggestion for future research

This study offered an analysis of the efficacy of ICT tools in improving crop productivity among smallholder farmers in Mbombela Local Municipality. The slow acceptance of ICT tools as pathways to access agricultural information has been recognised as a significant constraint for smallholder farmers. Due to resource limitations, this study collected data exclusively in one municipality within the Mpumalanga province. Consequently, future studies should incorporate smallholder farmers from various municipalities within the province to achieve more comprehensive results.

Further studies may be undertaken to investigate the efficacy of other ICT tools not encompassed in this study, yet recognised for their advantages to smallholder farmers. The study indicates that ICT tools effectively disseminate agricultural information to smallholder farmers thus, it is essential to illuminate other tools utilised by these farmers for accessing agricultural information.

The research assessed mobile applications utilised by smallholder farmers to obtain agricultural information. However, the study identified that smallholder farmers lack access to and knowledge of agricultural mobile applications. Further research is required to examine user-friendly agricultural mobile applications accessible to smallholder farmers in rural South Africa. Critically assessing the barriers and prospects associated with the adoption of agricultural mobile applications.

When assessing the impact of ICT tools on the crop productivity of smallholder farmers, the study gathered data once for the most recent cropping season in 2023, taking into account both those who used and those who did not use ICT. Further studies should be conducted implementing baseline and follow-up survey methodologies to obtain more robust findings regarding the impact of ICT on crop productivity.

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7. Appendix

7.1 Participants consent form

CONSENT FORM

1. I _______________________________________agree to and am voluntarily taking part in this research project.
2. I understand that I have the right to withdraw from the study at any time, and may choose no longer to participate without having to explain myself.
3. I am aware that the information I provide on the questionnaire is for educational / academic purposes.
4. I understand that my name will not be recorded.
5. I have been provided with, have read, the information leaflet regarding this research study.
6. I have had the opportunity to ask any questions related to this study, and received satisfactory answers to my questions, and any additional details I wanted.
7. I agree to answer the questions to the best of my ability.
8. I understand that I may refuse to answer any questions that I do not feel comfortable answering.
9. By signing this letter, I give free and informed consent to participate in this research study.

Date			
Participants Signature			
Researcher Name		Research Signature	

This research is being conducted by Melga Meta Ntsoane.

Telephone: [redacted] E-mail: [redacted]

If there are any further question about the research study or the questions itself, please contact the Supervisor Dr. JT Ndoro at UMP. The Supervisor's contact details are as follows:

Supervisor

Tel: [redacted] E-mail: [redacted]

7.2 Research questionnaire

SECTION A: Demographic information

NB: Tick or cross the appropriate answer

NO	QUESTION	OPTIONS							
1	Gender	◯ Male	◯ Female						
2	Age	◯ 18-35	◯ 36-55	◯ 55 and above					
3	Marital status	◯ Single	◯ Married	◯ Divorced	◯ Widowed				
4	Educational level	◯ No formal education	◯ Primary level	◯ Secondary level	◯ Matriculated	◯ ABET	◯ Higher Certificate	◯ Diploma	◯ Degree
5	Years of experience in farming	◯ ≤ 5 years	◯ 6 - 10 years	◯ 11 - 20 years	◯ ≥ 21 years				
6	Land Ownership	◯ Own	◯ Renting	◯ Tribal authority	◯ Land reform				
7	Farm size	◯ ≤ 5ha	◯ 6 – 10ha	◯ 11 – 20ha	◯ 21 – 30ha	◯ 31- 40ha	◯ ≥ 41ha		
8	Household size	◯ ≤ 5	◯ 6 – 10	◯ ≥ 11					
9	Cooperative membership	◯ Yes	◯ No						
10	Purpose of farming	◯ Household consumption	◯ Income generation						

		and income generation							
11	Main source of off-farm income	◯ None	◯ Previous employers' pension	◯ Salary	◯ Remittances	◯ Child support grant	◯ Disability grant	◯ State old age pension	◯ Care dependency grand
		◯ Social relief of distress grant	◯ Grand in aid						
12	Main source of on-farm income	◯ None	◯ Vegetables	◯ Agronomic crops					
13	Do you use ICT Tools to access agricultural information	◯ Yes	◯ No						
14	Source of agricultural information (If you selected Yes on question 13 skip this question)	◯ Fellow farmers	◯ Community based organisation	◯ Private extension service	◯ Public extension service	◯ Higher learning institutions			
15	ICT tools used to access agricultural information (If you selected No on	◯ Radio	◯ TV	◯ Computer	◯ Smart phone	◯ Basic cell phone			

	question 14 skip this question)								
16	Frequency of using ICT tools to access agricultural information	◯ Frequently	◯ Occasionally	◯ Rarely	◯ Never				
17	Radio programs used to access agricultural information	◯ None	◯ Vuka sambe	◯ Ezokulima	◯ Agriskoop				
18	TV programs used to access agricultural information	◯ None	◯ African Farming	◯ Landbouweekl iks	◯ For the love of the land	◯ Niche farmers	◯ Living land	◯ Working land	
19	Applications used to access agricultural information	◯ None	◯ PANNAR Sprout	◯ Khula	◯ Lindsay Africa's FieldNET	◯ FruitLook	◯ Agrisol	◯ Mezzanine's Connected Farmer	◯ WhatsApp
		◯ Facebook	◯ LinkedIn	◯ YouTube					
20	Basic cell phone functions used to access agricultural information	◯ None	◯ Phone call	◯ SMS	◯ USSD	◯ MMS			

SECTION B: Impact of ICT tools on crop productivity of smallholder farmers

21) Fertilizer usage pattern

NB: Fill the appropriate boxes with the information of the last cropping season 2023

Item	Last cropping season	
	Cultivated area (ha)	Applied dosage per Kg
◯ NPK		
◯ LAN		
◯ Lime		
◯ CAN		

22) Pesticides usage pattern

NB: Fill the appropriate boxes with the information of last cropping season 2023

Item	Last cropping season	
	Cultivated area (ha)	Applied dosage per l
◯ Insecticides		
◯ Herbicides		
◯ Fungicides		
◯ Nematicides		

23) Changes in the number of adopted new varieties of agricultural crops

NB: Fill the appropriate boxes with the information of the last cropping season 2023

Item	Last cropping season
	Number of adopted new varieties of agricultural crops
Vegetables	
◯ Spinach	
◯ Cabbage	
◯ Lettuce	
◯ Chillies	
◯ Tomatoes	
Agronomic crops	
◯ Maize	
◯ Ground nuts	

24) Changes in yield of agricultural crops

NB: Fill the appropriate boxes with the information of the last cropping season 2023

Item	Last cropping season	
	Cultivated area (ha)	**Yield (tonnes)**
Vegetables		
◯ Spinach		
◯ Cabbage		

◯ Lettuce		
◯ Chillies		
◯ Tomatoes		
Agronomic crops		
◯ Maize		
◯ Ground nuts		

25) Changes in income from agricultural crops

NB: Fill the appropriate boxes with the information of the last cropping season 2023

Item	Income generated (Rands)
Vegetables	
◯ Spinach	
◯ Cabbage	
◯ Lettuce	
◯ Chillies	
◯ Tomatoes	
Agronomic crops	
◯ Maize	
◯ Ground nuts	

SECTION C: Smallholder farmers' perception on the effectiveness of ICT tools in disseminating agricultural information on crop productivity.

NB: Tick or cross the appropriate box

NO	QUESTION	OPTIONS				
Perception statements		◯ Strongly Agree	◯ Agree	◯ Undecided	◯ Disagree	◯ Strongly Disagree
Smallholder farmers' perception on timeliness of the information received through ICT tools						
26	ICT tools provide agricultural information that is up to date					
27	ICT tools provide agricultural information at the time of need					
28	ICT tools allow farmers to access agricultural information at their time of convenience					
Farmers perception on the relevancy of information received through ICT tools						
29	ICT tools convey agricultural information suitable for farmers' context					
30	ICT tools provide agricultural information that is reliable					
31	ICT tools provide agricultural information that is complete					

Farmers perception on the accessibility of ICT tools to acquire agricultural information						
32	ICT tools are affordable					
33	ICT tools are portable					
34	ICT tools require supplementary operations e.g. data, airtime, aerial, batteries, DSTV subscription, network, electricity					
Farmers perception on the ease of use of ICT tools to access agricultural information						
35	ICT tools are easy to use when accessing agricultural information					
36	ICT tools navigation is easy to understand					
37	ICT tools align with farmers literacy capability					
Farmers perception on the feedback received on ICT tools						
38	ICT tools provide farmers with an avenue to get clarity through provision of contact details of agricultural information source					
39	ICT tools provide farmers with fast feedback					
40	ICT tools foster interactive feedback through engagement between agricultural information source and audience					

SECTION D: Constraints influencing smallholder farmers access to agricultural information through ICT tools.

(Tick or cross the appropriate box)

NO	QUESTION	Options	
Which of the following constraints have an influence on your access to agricultural information through ICT tools?		◯ YES	◯ NO
Physical constraints			
41	Inadequate network connectivity influences farmers effective utilization of ICT tools		
42	Constant power blackouts influence farmers use of ICT tools		
43	Insufficient electricity supply influences farmers use of ICT tools		
Financial constraints			
44	High cost of ICT tools influence farmers access of ICT tools		
45	High operational cost of ICT tools influences farmers usage of the ICT tools		
46	Insufficient access to contemporary ICT tools influences farmers utilization of efficient ways of accessing agricultural information		
Human constraints			
47	Language barrier influences farmers access to agricultural information on ICT tools		
48	Inadequate operational skills influence farmers ability to use ICT tools		
49	Insufficient ICT awareness influences farmers adequacy to use ICT tools		

THANK YOU FOR YOUR COOPERATION!

7.3 Topic approval certificate

UNIVERSITY OF MPUMALANGA

FACULTY OF AGRICULTURE AND NATURAL SCIENCES

Postgraduate Studies Committee

Certificate of Approval – Research Proposal

Date of this Approval:	**21 August 2023**

Student Details

1	Student Name:	Ntsoane, M
2	Student Number:	219040508
3	School	School of Agricultural Sciences
4	Degree Registered for:	MAgric
5	Date of First Registration:	2023
6	Supervisor(s):	Dr JT Ndoro & Prof N Wayi-Mgwebi

The research proposal entitled '**Effectiveness of ICTs in disseminating agricultural information to enhance smallholder farmers' crop productivity in Mbombela, South Africa**' has been evaluated and approved by the Postgraduate Studies Committee of the Faculty of Agriculture and Natural Sciences.

Chairperson: Prof. Victor Mlambo

Signature:

UNIVERSITY OF MPUMALANGA

FACULTY OF AGRICULTURE AND NATURAL SCIENCES

Date & Official Stamp:

7.4 Ethical clearance certificate

UNIVERSITY OF MPUMALANGA

Creating Opportunities

B Maoneke (PhD)

School of Computing and Mathematical Sciences

Mbombela Campus.

Dear Melga Meta Ntsoane

Protocol Reference Number: UMP/Ntsoane/219040508/MAGR/2024

Project Title: Effectiveness of ICT Tools In Disseminating Agricultural Information To Enhance Smallholder Farmers' Crop Productivity In Mbombela.

Approval Notification: In response to your application received on **15/01/2024**, The Research Ethics Committee Faculty Research Ethics Committee has considered the above mentioned application and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interviews Schedule, Informed Consent form, Title of the project, Location of the study, Research Approach and methods must be reviewed and approved through the amendment/ modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be stored securely in the School/ division for a period of 5 years.

The Ethical Clearance certificate is only valid for a period of 3 years from date of issue. Thereafter, Recertification must be applied for on an annual basis.

Wishing you the best with your study.

Yours faithfully,

....

B Maoneke (Chair)

Cc: Faculty Research & Innovation Committee Chair: ....M Bombe

DECLARATION OF INVESTIGATOR(S)

I/We fully understand the conditions under which I am/we are authorised to carry out the abovementioned research and guarantee to ensure compliance with these conditions. I agree to completion of a yearly progress report.

....05/03/2024...........

Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

7.5 Permit to conduct research

agriculture, rural development, land & environmental affairs
MPUMALANGA PROVINCE
REPUBLIC OF SOUTH AFRICA

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Litiko Letekulima, Kutfutfukiswa Kwetindzawo Tasemakhaya, Temhlaba Netesimondzawo

Departement van Landbou, Landelike Ontwikkeling, Grond en Ongewing Sake

umNyango weZelimo UkuThuthukiswa kweeNdawo zemaKhaya, iNarha neeNdaba zeBhoduluko

Enq: Ms. Bester Masuku
Ext: 6728

Ms Ntsoane Melga Meta
Stand No. 10222
Lesetsi ,Ga Mphahlele
0762

Per email: 219040508@ump.ac.za

RE: PERMISSION TO CONDUCT A STUDY IN THE DEPARTMENT OF AGRICULTURE, RURAL DEVELOPMENT, LAND AND ENVIRONMENTAL AFFAIRS

The request for Ms Ntsoane Melga Meta to carry out a study on **The Effectiveness of Information and Communication Technology (ICT) tools in disseminating Agricultural information to enhance smallholder farmers' crop productivity within the Mbombela Local Municipality,** is hereby granted.

Take note that this authorisation is based on a mutual understanding that the Department of Agriculture, Rural Development, Land and Environmental Affairs and the departmental officials' names will not be mentioned anywhere in the study. Additionally, no information in the study will enable a third party to identify the name of the Department. The information provided by the employees or any other means (such as confidential archived documents or reports) of the Department is purely for academic purposes and cannot be used for any other purposes.

Regards

MR. C.M. CHUNDA
HEAD: AGRICULTURE, RURAL DEVELOPMENT, LAND AND ENVIRONMENTAL AFFAIRS
DATE: 10/10/23

MPUMALANGA
THE PLACE OF THE RISING SUN