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Farmers' perceptions and adoption of digital technologies as information sources in Tshwane, South Africa

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DECLARATION

I, Chantelle Mogashane, declare that the dissertation, which I hereby submit for the degree MAgric: Extension at the University of Pretoria is my own work and has not been previously submitted by me to this or any other tertiary institution.

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Date: 25 August 2024

Approved by

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Signature: ______________

Date: _________________

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DEDICATION

To my parents, Whisky and Steven Makubiana, my aunt Sonica Mogashane, thank you for sacrificing the little resources you have, and all that you are so we could be. This one is for you. Ke a leboga.

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ABSTRACT

Farmers' perceptions and adoption of digital technologies as information sources in Tshwane, South Africa

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This study explores the challenges that smallholder farmers face in South Africa due to limited resources, finances, and access to advanced production technologies, which impede the adoption of good agricultural practices. A mixed- method research approach was used, involving semi-structured questionnaires with 117 farmers and a focus group discussion. Descriptive analysis and frequency counts identified farmers' socioeconomic characteristics, while thematic analysis was applied to the focus group discussions. Binary regression and independent t-tests were used to analyze adoption data. The results showed that 38% of farmers preferred using the internet for information, followed by YouTube (24%) and the Farming Solutions App (6%). While 50% were neutral about whether digital technologies were superior to traditional methods, 37.7% found them easy to use and 44.6% viewed them as time-efficient. Binary regression indicated that access to extension services positively influenced the adoption of digital technologies. The t-test showed no differences in agricultural incomes of adopters and non-adopters of digital technologies, suggesting that adopters used digital tools as supplementary sources rather than primary ones. The study concludes that smallholder farmers are gradually adopting digital technologies despite low and uneven rates. Extension officers play a critical role in promoting these technologies, but traditional information sources remain vital in farming practices. To enhance digital technology adoption in smallholder agriculture, supportive policies should be implemented to improve infrastructure, digital literacy, and financial support. Additionally, impact monitoring, public-private partnerships, and community engagement through farmer cooperatives are essential to advance technology integration and address farmers' challenges.

Keywords: Digital technology, technology adoption, farmer's perception, information sources

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List of acronyms/abbreviations

AMOS	- Analysis of a Moment Structures
ARC	- Agricultural Research Council
APP	- Application
CFA	- Confirmatory Factor Analysis
DETs	- Digital Extension Tools
EU	- European Union
FAO	- Food and Agricultural Organization
GDP	- Gross Domestic Product
GPS	- Global Positioning System
ICT	- Information Communication Technology
IT	- Information Technology
MCTs	- Modern Communication Tools
NEPRO	-National Emergent Red Meat Producers Organization
NGO	- Non-Governmental Organization
SEM	- Structural Equation Modelling
TAM	- Technology Acceptance model
TOE	- Technology, Organisation and Environment framework
TRA	- Theory of Reasoned Action
US	- United States

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CHAPTER 1: INTRODUCTION

1.1 Background

The introduction of agricultural extension services in South Africa dates back to the 19th century. Following the reconstruction of economies after the Second Anglo-Boer War (1899-1902), the agricultural ministry invested in this process by importing trained extension officers from England to provide extension services, share knowledge and improve farming practices. This meant that extension practices at the time were mainly centred on British agricultural methodologies and practices. However, according to Khwidzili and Worth (2019), these government efforts proved unsuccessful due to differences in climatic and environmental conditions between England and South Africa. Following this, the government sent scientists to England in 1944 to learn about agricultural extension and support services (Van der Merwe and Groenewald, 2016). Upon their return, extension support services were divided into three sections, which served White, Black, and Coloured (people of Indian and other origins) farmers separately. The well-trained extension officers, cooperatives, and the private sector supported white farmers; extension services for Black farmers, mainly smallholders, were designed to meet community needs and provide inputs rather than develop farmer capacity (Worth, 2012).

According to van Vuuren (1952), in the early 1940s, the provision of extension services was promoted as a career in South Africa by incorporating it as a discipline in higher learning institutions. The University of Pretoria, Teko College of Agriculture, Fort Cox College of Agriculture and Forestry, the University of Stellenbosch and Eisenberg College of Agriculture were among the earlier institutions. They were followed by the University of Fort Hare, University of Kwa-Zulu Natal, University of Free State, the University of Venda and the University of South Africa throughout 1970's-1990's (DoA, 2008). These universities played a crucial role in expanding agricultural extension education across South Africa, each contributing to the development of the agricultural sector through its unique programmes and focus areas. The academic input into the discipline helped to improve several areas including agricultural extension approaches and adapting to changes in agricultural practices, technological advancements, and socio-economic contexts.

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In the early stages of introducing and developing agricultural extension, the services were characterised by a top-down approach where government agencies or experts disseminated information to farmers without much input from the farmers themselves. At the time, extension programmes focused on improving crop production techniques and introducing new technologies such as irrigation systems, mechanisation, high-yielding varieties, pesticides and chemical fertilizers (Jones and Garforth, 1997). In the mid-20th century, various approaches were introduced such as the training and visit system. The World Bank introduced this system in the 1970s to provide regular, systematic training to extension agents visiting farmers to transfer knowledge. The design of this approach was to ensure the provision of uniform and frequent extension services (Benor and Baxter, 1984). A commodity-focused approach, widely popular in regions where cash crops were economical, was introduced during this era. According to Axinn (1988), this approach focused on specific commodities and aimed at improving production practices through research and extension services.

Agricultural extension services approaches in the 21st century include participatory extension approach, decentralised extension approach, information and communication technology (ICT) based approaches, as well as pluralistic extension systems (Crowder and Anderson, 2002; Anderson, Feder Ganguly, 2006; Birne et al., 2009; Aker, 2011) These approaches emerged as a response to the limitations of top-down methods, emphasising the active involvement of farmers in the extension process, making extension services more responsive to the specific needs of different regions, and providing new tools for communication and information dissemination. Additionally, these approaches recognised that no single method can meet all the diverse needs of farmers, advocating for a mix of public, private, and non-governmental organisations in providing extension services.

As a direct result of discrepancies in rigid methodologies, commercial farmers have invested in privatised extension and advisory services while smallholder farmers mainly rely on government-led extension services. In recent years, extension services have not been able to effectively provide services and disseminate information to farmers who rely on these services (Daff, 2016; Loki 2022). This has resulted in smallholder farmers, like commercial farmers, seeking alternative means of acquiring accurate agricultural information delivered promptly. This led to the introduction of ICT and digital technologies as supplementary sources of agricultural information

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to accelerate farming activities. The introduction of modern-day agricultural development technologies in the agricultural sector made it more knowledge-intensive (Mittal and Hariharan, 2018). The implication is that smallholder farmers must rely on real-time access to accurate agricultural information to facilitate their decision-making processes and keep up to date with agricultural information and market opportunities. Subsequently, information sharing and acquisition have become important factors in developing smallholder farmers globally (Dankwah and Hawa, 2014).

In the early 2000's, smallholder farmers in South Africa relied on basic ICT tools such as radio broadcasts, mobile phones, and text-based messaging services to receive agricultural information (Mittal & Mehar, 2012). These tools provided farmers with essential updates on weather conditions, market prices, pest control, and government policies (Ferris et al., 2014). Over time, the limitations of these simple ICT tools, such as delayed information and lack of interactive features, became apparent. This prompted a shift in the mid-2000's, towards more complex digital technologies that offer real-time data, interactive learning, and decision-support systems (Mittal and Mehar, 2012, Department of Agriculture, Forestry and Fisheries, 2016). Modern technologies now include smartphone applications, GPS-enabled devices, and Internet of Things (IoT) systems that help farmers monitor soil health, track livestock, and optimize irrigation practices (Aker, 2011; Mittal and Hariharan, 2018).

The type of information obtained through these advanced technologies is diverse. Farmers can access weather forecasts, pest management strategies, crop disease diagnostics, soil analysis data, and market prices. They can also receive alerts on potential risks, such as extreme weather events, enabling them to take preventive measures to protect their crops and livestock (Dankwah and Hawa, 2014). These tools enhance the decision-making process by providing farmers with timely, accurate, and actionable information that is essential for modern farming practices. As digital technologies continue to evolve, smallholder farmers are likely to further integrate these tools into their daily operations, thereby improving the productivity and sustainability of their agricultural activities (Mittal and Hariharan, 2018). Against this background, this study will investigate farmers' perception and adoption of digital technologies from ICT tools, such as the Internet, Farming solutions apps, YouTube streaming platform, Farmers' weekly online website, and GPS livestock tracking devices, as complementary sources of information to extension services.

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1.2 Research problem

The agricultural extension and advisory services sector primarily assists farmers with farming activities and information (Swanson, Bentz & Sofranko, 1997). However, the National Policy of Agricultural Extension and Advisory Services document posited that extension services alone could not facilitate the accelerated capacity development of a range of producers (DAFF, 2016, cited by Makamane, 2023). Several researchers (Ajala, Ogunjimi, and Farinde, 2013; Davis and Terblanche, 2016; Hlatshwayo and Worth, 2016) have examined the challenges confronting extension service, including the low extension-to-farmer ratio, outdated knowledge and skills, high levels of illiteracy among farmers, poor ICTs and channels, unavailability, ineffectiveness and inefficiency, and poor stakeholder collaboration and partnership.

Despite this, studies by Zwane, Groenewald and Van Niekerk (2014) and Christiaensen, Demery and Kuhl (2011) posit that extension services have been identified as an important instrument to help accelerate agriculture production and meet the population growth projections by 2050. According to Kassem (2014), the availability and consistent interaction with extension services can help farmers in many ways, including making informed decisions about which crops to produce and identifying markets that can give a farmer the best returns. Baiyegunhi (2014) and Hazell *et al*. (2010) state that smallholder farmers face limited resources, finances, and access to complex production technologies. These constraints hinder the implementation of good production practices such as good seed selection, knowing when to plant and harvest, pest and disease control as well, and access to lucrative markets (Nwafor, Ogundeji and van der Westhuizen, 2020; Autio e*t al.*, 2021). Accessing market information gives farmers various opportunities such as crop diversification, reasonable input costs, increased profits, and an ability to contribute to food security. Phiri, Chipeta and Chawinga (2019) argue that accessing information that is accurate and reliable can assist in overcoming these challenges.

Different stakeholders, including the government, have proposed various strategies in attempts to address the challenges that smallholder farmers experience. Furthermore, there are reports on different approaches for accelerating the development of smallholder agriculture in sub-Saharan Africa. Improving agricultural value chains that enhance smallholder farmers' access to information, markets, and inputs, as well as introducing and promoting crop seeds that are high-yielding and resistant to diseases, have not significantly impacted smallholder productivity

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(Samuel and Sharp, 2007). Zylberberg (2013) has suggested incorporating digital technologies in smallholder farming productions. Technologies such as interactive mobile systems (mobile apps and streaming services), mobile internet, and Internet of Things devices (sensors, cameras, and mobile phones) would increase farmers access to agricultural information. Aker (2011) posits that ICT-based delivery methods, social networking, and farmer-to-farmer advice are becoming more prevalent, aligning with global trends. However, there is an evident variation in access to digital technologies between smallholder and commercial farmers, who are generally wealthy (Born *et al*., 2021).

Despite several studies indicating that smallholder farmers rely on agricultural information to improve food quality and access lucrative markets, these farmers still struggle to make informed marketing and production decisions due to the unrealised benefits of integrating digital technologies into their farming operations (Deichmann, Goyal and Mishra, 2016; Muema *et al*., 2018 and Okello, Kirui and Gitonga, 2020). To substantiate this, several studies assert that smallholder farmers in Africa still have limited access to digital technologies (Mutero, Munapo and Seaketso, 2016; Abdulai, Kc and Fraser, 2023). Furthermore, Mushi *et al*. (2022) affirm that many smallholder farmers miss out on development and commercialisation opportunities because they lack essential food production and market information which could be easily acquired from digital technologies. Abdulai *et al*. (2023) reported that the adoption rate of these technologies remains low, particularly in developing countries. This gap persists despite an increase in the ownership of ICT tools like mobile phones and computers, and awareness of various digital technologies (Phiri *et al*., 2019; Nwafor et al., 2020).

Existing research (Katung and Akankwasa, 2008; Foster and Rosenzweig, 2010; Diiro, 2013) on digital technology integration in smallholder agriculture mainly focuses on adoption-related factors, such as determinants, rate, intensity of adoption, and barriers to adoption which include data costs, network coverage, financial resources, farm size, farm characteristics, and accessibility to digital technologies (Kawula, 2019; Smidt, 2021; Fadeyi, Ariyawardana and Aziz, 2022). . Understanding smallholder farmers' perceptions of digital technologies as information sources and assessing agricultural income of farmers who adopt digital technologies as information sources and those who do not is fundamental in the context of agricultural development and socio-

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economic transformation Several studies unpack the importance of this understanding such as Fenyes and Meyer, 2003 and Tshuma, 2014 who detail how perceptions influence adoption decisions regarding new technologies. Mittal and Hariharan (2018) explain how understanding smallholder farmers perceptions can help identify barriers to the effective design and accessibility of digital technologies which are important factors in ensuring that digital tools are not only accessible but also relevant and practical for the adopters. Despite this understanding of the crucial role perceptions play in the adoption of new technologies, studies that concurrently explore digital technology adoption, impact of adoption and farmers' perceptions of these technologies are scarce and empirically underexplored in the South African context creating a gap in literature. This study aims to address this knowledge gap by exploring smallholder farmers' perceptions and the differences in agricultural productivity, measured by income between farmers who have adopted digital technologies and those who have not

1.3 Research objectives

1.3.1. Overall objective

This study's overall objective is to investigate farmers' perceptions and adoption of digital technologies as information sources in Tshwane, South Africa.

1.3.2. Specific objectives

a) Assess smallholder perceptions of digital technologies as sources of information for farming activities

b) Determine the factors influencing the adoption of digital technologies as sources of information for farming activities

c) Assess differences in agricultural incomes between digital technology adopting and non-adopting farmers

1.4 Research questions

1.4.1. What are smallholder farmers' perceptions of digital technologies as sources of information for farming activities?

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1.4.2. Which digital technologies are adopted by smallholder farmers as sources of information for farming activities?

1.4.3. Is there a difference between agricultural incomes of digital technology adopting farmers and non-adopting farmers?

1.5 Research hypotheses

This study will test the following hypotheses:

HA_1: The adoption of digital technologies by smallholder farmers is low

HA_2: There is no difference on agricultural incomes of digital technology adopting farmers and non-adopting farmers

1.6 Significance of this research

This study explores how smallholder farmers in Gauteng perceive and assess the adoption of digital agriculture as a source of information for farming activities. Understanding how smallholder farmers perceive and use digital technologies is a significant aspect of technology adoption. This study can potentially identify barriers and facilitators to accessing vital agricultural information, which can lead to more targeted interventions that improve farmers' access to up-to-date, relevant, and actionable farming information, thereby enhancing productivity. Significantly, this study will contribute to existing literature in the context of digitisation in agriculture. The findings and recommendations of this study will also provide insights to smallholder farmers, agricultural journalism houses, Department of Agriculture policymakers, and extension officers on how to support and promote the use of digital technologies in agricultural production. The goal is to ensure these technologies are palatable and accessible to smallholder farmers in these regions to address the information asymmetries in the South African agricultural sector. The study's findings can serve as a benchmark for measuring progress in adopting digital technologies over time, helping track the effectiveness of interventions and identify areas that need further improvement for researchers working on related or the same topics.

1.7 Organisation of thesis

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This thesis follows a book format comprising six chapters. The introductory chapter provides a background of the study, its objectives, the question it intends to answer, and its significance. Chapter 2 reviews the literature and key terms relevant to this study. It characterises smallholder farmers, examines farmers' use of technology and digital technology, and explores how they are perceived and adopted. The following chapter details the methods and procedures for collecting and analysing data. Chapter 4 presents, reports and discusses descriptive results, while Chapter 5 presents, reports, and discusses the empirical findings. Lastly, Chapter 6 summarises the findings, draws conclusions, outlines limitations, and provides appropriate recommendations and policy implications.

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CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

This chapter thoroughly examines perceptions and adoption of digital technologies based on published literature. This examination begins with a detailed explanation of the key terms used in this study, followed by the characterisation of smallholder farmers in South Africa and an overview of technology adoption and use in the agricultural sector. The chapter also presents a conceptual framework for the study. Through a thorough literature review, this chapter identifies and gives in-depth information on factors that influence perceptions and adoption of digital technologies as information sources. This includes smallholder farmers' attitudes towards the most adopted digital technologies as well as the differences on agricultural incomes between adopting and non-adopting farmers.

2.2. Definition of key terms

Digital technology- Digital technologies are defined as the utilisation of electronic devices, software, and systems to process, store, transfer, and present information digitally. These technologies include social media, digital platforms, websites, cloud computing, and analytics (Giones and Brem, 2017).

Farmer's perception- This is defined as a constructive and physiological process that is generated by the five senses, and its responses can be processed as negative or positive by individuals. The responses can be generated through selection, interpretation, and reaction (Erin and Maharani, 2018).

Technology adoption- Hall and Khan (2003) define adoption as a process of receiving, integrating, and using an invention or innovation that follows different stages. According to Bonabana-Wabbi (2002), adoption is a mental process that progresses from discovering a technology to finally using it. Loevinsohn *et al*. (2013) also explain adoption as the incorporation of new technology into an established practice, which is then followed by a trial and adaptation period.

Information sources- Kim and Sin (2014) define these as entities that provide data, facts, knowledge, or insights on specific subjects. They can be categorized into three main types which

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are primary, secondary and tertiary sources which are original materials presenting new information, analyze, interpret, or summarize information and, compile and summarize information to give an overview. Examples include research reports, article reviews, encyclopaedias, textbooks and databases (Brand-Gruwe and Stadtler, 2011).

2.3 Summary of the reviewed literature

This section presents the main literature reviewed in this chapter by highlighting each paper's study area, core objective, methods and procedures employed, and the main findings.

Table 2.1: Summary of the reviewed literature

Source	Study area	Purpose	Methods and procedures	Main findings
Nakura *et al.* (2017)	India	Assessment of the Role of WhatsApp in agricultural value chains	Quantitative research	WhatsApp is perceived to be a 'convenient' communication application, provides on-time solutions, and solves problems related to farming activities with audio-visuals.
Lamontagne-Godwin *et al.* (2018)	Pakistan	Investigation of preference of agricultural information sources and frequency of use by gender	Quantitative research	There is a difference in the preference and access of information sources between the different genders.
Mwalupaso *et al.* (2019)	Zambia	Investigation of the association between farmers' technical efficiency and the adoption of mobile phones to collect agricultural information.	Quantitative research	A farmer's technical efficiency is significantly and positively associated to their use of mobile phones.
Mwangi and Kariuki (2015)	Developing countries	Determining potential factors that influence agricultural technology adoption in developing countries	Qualitative approach literature review paper	Perception of farmers towards new technology is a key precondition for adoption to occur.
Rahman, Ara and Khan (2020)	Bangladesh	Examining small-scale farmers' information-seeking behaviour and their information needs.	Qualitative research	Many farmers lack awareness of where and how to obtain agro-information.

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Hoang and Drysdale (2021)	Vietnam	Investigation of factors affecting the adoption of mobile phones for marketing of livestock and poultry by smallholder farmers.	Quantitative research	Young smallholders with higher education, and income, tend to adopt mobile phones for marketing of livestock and poultry.
Coggings *et al.* (2022)	India	Assessment of Processes through which DETs have been used/ not used by farmers and other extension actors in low- and middle-income countries.	Qualitative research	The use of DETs is constricted by fifteen common factors.
Smidt *and Jokonya* (2022)	South Africa	Identification of factors that affect the adoption of digital technologies in agricultural value chains by small-scale farmers.	Qualitative approach Systemic literature review	The role of government and institutional support are critical in facilitating participation and collaboration of different actors.
Atsango, Chimoita and Njeru (2022)	Kenya	Evaluation of farmers' perception of use and access of MCTs	Quantitative research	The majority of the tea farmers had acquired basic literacy levels of education to use modern technologies in tea production.

Source: Author, 2023

2.4 Global review of smallholder agriculture

Smallholder agriculture, which entailed farmers practicing traditional methods of cultivation, relying on family labour and local resources, was the dominant form of farming worldwide before the Industrial Revolution (Mazoyer and Roudart, 2006). The shift towards the green revolution resulted in the introduction of high-yielding varieties of crops, chemical fertilisers, and irrigation techniques to many parts of the developing world, significantly increasing agricultural production (Evenson and Gollin, 2003). Smallholder agriculture refers to farming systems characterised by small-scale production, typically on plots of land that are small in size and managed by households or families. In more detail, the concept of smallholder agriculture is defined using various contexts such as economic importance, challenges and constraints, farming size, and infrastructural and landscape characteristics (World Bank, 2007; Tittonell and Giller, 2013). Smallholder agriculture presents several advantages, including crop diversification, job security, and self-sufficiency, which contribute to the resilience and sustainability of local communities.

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It is important to note that this agricultural sector significantly differs between developed and developing countries, driven by variations in economic development, infrastructure, access to technology, and policy environments. This distinction is evident in the economic and infrastructural context, whereby smallholder farmers in developed countries savour the benefits of well-developed and better-functioning infrastructure, such as roads and storage facilities, while their counterparts in developing regions are disadvantaged by poor infrastructure, which limits access to transportation and storage facilities. Correspondingly, the Organisation for Economic Co-operation and Development (OECD) (2015) and Lowder, Skoet, and Raney (2016), state that in developed countries, smallholder farms tend to be more mechanised and technologically advanced, with the use of precision farming techniques, advanced machinery, and information technology enhancing productivity and efficiency. In contrast, smallholder farms in developing countries often rely on manual labour and traditional farming practices and need more access to modern technology and machinery, which constrains productivity (Hazell *et al*., 2010).

2.5 Characteristics of farmers in South Africa and Implications for the Adoption of Digital Technologies

The e agricultural sector in South Africa is dualistic (Vink and Kirsten, 2003; Mmbengwa *et al*., 2012). According to Aliber and Hart (2012), this sector comprises approximately 35,000 commercial white farmers responsible for 94% of the agricultural output and four million black smallholder farmers occupying only 13% of the agricultural land compared to 87% of the commercial farms. The sector remains highly unequal in various aspects, such as accessing markets, acquiring and distributing economic resources, income, and infrastructure which play a crucial role in determining the adoption of digital technologies in agriculture. The characteristics of smallholder farmers, particularly those in the former homelands**,** present both challenges and opportunities for the adoption of digital technologies. These farmers are mainly concentrated in the former homelands and plays a significant role in rural development, food security, and poverty alleviation (Zantsi, Mack and Mann, 2020). This sector, however, faces a plethora of challenges, including poor infrastructure, limited access to arable land and water resources, inconsistent extension and advisory support, and limited market access, with many smallholders struggling to transport their produce to markets, which affects their income, livelihoods and willingness to invest in new technologies (Magingxa and Kamara, 2003; Von Loeper *et al*., 2016).

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Various literature sources have categorised smallholder farmers based on factors such as farm size, farmer characteristics, and income (Aliber *et al.*, 2009; Tshuma, 2014). Louw (2013) stated that smallholder farmers are commonly characterised by their labour-intensive small farms which rely greatly on traditional production methods which can hinder the adoption of advanced digital tools. Chabalala (2016) also stated that livestock smallholder farmers generally lack appropriate tools for grazing management which suggests a potential demand for digital technologies that provide real-time data on pasture conditions and animal health monitoring. .

One of the critical barriers to adopting digital technologies among smallholder farmers is their demographic profile. Studies (Fenyes and Meyer, 2003; Tshuma, 2014) indicate that 80% of smallholder farmers farm primarily for household food security, with only a small proportion actively participating in formal markets. Additionally, many smallholder farmers are elderly women with low educational levels, which limits their digital literacy and capacity to engage with modern farming technologies (Fenyes and Meyer, 2003). Despite these challenges, the characteristics of smallholder farmers also reveal opportunities for digital technology adoption. For example, farmers who rely on traditional methods could benefit from mobile applications that provide simplified agricultural advice, market information, and weather updates in local languages. Additionally, the inconsistency of extension services suggests that digital advisory platforms could play a vital role in bridging the information gap and reaching more farmers in remote areas (Dankwah and Hawa, 2014).

2.6 Global evolution of extension and advisory services

Historically, extension services catered for white commercial farmers who received substantial support, including subsidies, technical advice, and access to resources, to ensure high levels of production and efficiency (Nel and Davies, 1999; Ngomane, Thomson and Radhakrishna, 2002; Oladele and Mabe, 2010; Van Niekerk *et al.*, 2011; Ndoro, Mudhara and Chimonyo, 2014). All of this while black smallholder farmers in homelands received minimal assistance and were largely excluded from formal agricultural support systems (Hall, 2004). The end of apartheid in 1994 signified a shift towards inclusivity and support for smallholder farmers represented by a concerted effort to redress historical inequalities; this included the introduction of the Comprehensive Agricultural Support Programme (CASP) aimed at providing funding, training, and resources to

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smallholder farmers, to enhance the productivity and sustainability of small-scale farming operations (Aliber and Hall, 2012).

Agricultural extension services are an organisational framework aimed at assisting and enabling individuals in agricultural production by helping them acquire the necessary information, skills, and techniques to solve their problems and enhance their success (Anderson, 2008). Agricultural extension approaches have evolved significantly over the years, adapting to changes in agricultural practices, technological advancements, and socio-economic contexts. Notable among these are the Traditional top-down approach, whereby government agencies or experts disseminated information to farmers without much input from the farmers themselves (Jones and Garforth, 1997); the World Bank's Training and Visit system aimed at ensuring that extension services were uniform and frequent; the commodity-focused approach, and the decentralised T&V approach aimed at making extension services more responsive to the specific needs of different regions (Anderson *et al.*, 2006; Crowder and Anderson, 2002). Maoba (2016) states that farmers in the eastern region of the Gauteng province found training and demonstrations valuable. More recently, methods like the farmer field school model, ICT-based delivery, farmer-to-farmer advice, fee-for-service models, and social networking have been introduced to keep up with the ever-growing challenges of the agricultural industry (Van den Berg and Jiggins, 2007; Birne *et al.*, 2009; Aker, 2011).

Various challenges currently characterise the government-led extension services. According to a report by The South African Extension Recovery Implementation Plan (2008), there is a significant shortage of extension services in the country, revealing a ratio of one extension officer to 500 farmers. Because of this core issue, extension systems are frequently viewed as ineffective in addressing the needs of poor farm households, even though they have significant potential to drive agricultural sector transformation (World Bank, 2010 and Davis, 2008). Additionally, factors like low morale, limited mobility, and low salaries were identified as contributing factors to the high turnover rates in extension services and the difficulty in attracting new recruits (Belay and Abebaw, 2004; Kaimowitz, 1991).

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2.7 The evolution of agricultural technology

The growth and development of the agricultural sector have resulted in the need for advancement, where technology is at the forefront. The introduction of technology into agriculture has evolved over centuries, transforming farming practices and boosting productivity. The 20th century saw the introduction of technologies for disseminating agricultural information to broader audiences as supplements to extension services. Earlier technologies included the radio, television, and print media, which perpetuated programmes that focused on farming techniques, weather forecasts, and market prices, which in turn helped improve farm productivity and decision-making (Chapman *et al.*, 2003). Mugwisi, Ocholla and Mostert (2012) state that print media is still the most preferred source of information among smallholder farmers. According to Jones (1989) and Wolfert, Ge, Verdouw and Bogaardt (2017), the introduction of computers, the internet and email revolutionised information sharing and management in agriculture.

The introduction of technologies such as the Geographic Information System (GIS), Global Positioning System (GPS) and sensors in the early 2000s enabled farmers to collect spatial data while accelerating precision farming (Mulla, 2013). These technologies have proven to be advantageous to farmers as they allow site-specific management, optimise input use and improve crop yields (Bongiovanni and Lowenberg-DeBoer, 2004). In developing countries, the proliferation of mobile phones provided farmers with real-time access to market prices, weather forecasts, and advisory services. This resulted in the emergence of mobile-based platforms and applications that offer tailored information to farmers (Aker, 2011). A study in Pakistan by Raza et al. (2020) shows that mobile phones, television and the radio are easily accessible due to their low capital investment, ease of use and ability to provide access to accurate and reliable agricultural information.

Recent years have seen the introduction of more complex technologies such as drones and unmanned aerial vehicles (UAVs), which are fast becoming valuable technological tools for monitoring crop health, assessing field conditions, and collecting high-resolution data for precision agriculture (Zhang and Kovacs, 2012). According to Li, Lan and Ma (2020) and Chlingaryan, Sukkarieh and Whelan (2018), Internet of Things (IoT) devices, Artificial Intelligence (AI) and machine learning are gaining momentum in the agricultural industry. These technologies are interconnected systems that connect various aspects of farm operations, such as soil moisture sensors, weather stations, and automated irrigation systems, to provide real-time data and

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automation. A paper by Peter and associates (2020) outlines that agriculture is an ideal sector for integrating AI and machine learning (ML) technologies as it can benefit from the potential of AI and ML to improve productivity, sustainability, and profitability in farming operations.

2.8 Socioeconomic factors influencing the use of digital technologies

There are varied factors that constitute how an individual perceives an object or subject. These factors can be on the perceived object or subject, on the environment, and on the situation where the perception is made by the perceiver. For the perceiver, the characteristics could be personal interests, expectations, self-concept, and attitudes. Rogers (2004) states that the adoption of new technologies is influenced by five sequential processes in his theory of innovations. These processes are economic profitability, compatibility, trialability, complexity, and observability. For the adoption of new technology by farmers, Bayih *et al*. (2022) note that factors such as cultural acceptability, the beneficial attributes of using the technology, farmers' perceptions of the technology after observation, the effectiveness of the technology after its trial, and the economic status of the farmer all influence technological adoption. Singh *et al*. (2021) argued and concluded from surveys of 200 rural farmers in four different agro-climates in India that infrastructural development, geography, type, and agro-climatic state of the land influence the adoption of new technologies by farmers. Furthermore, they stated that these factors shape farmers' perceptions of the practicality**,** effectiveness**,** and suitability of new technologies, ultimately affecting whether they decide to adopt them.

Aker, McWilliams and Zilberman (2005) analysed the adoption of computers for farming practices using a Tobit model to establish factors influencing the rate of technology adoption among 449 farmers in the United States. The analyses depicted that the educational levels of farmers and being in the age group of 30-40 influenced the rate at which digital agricultural technologies are adopted. In corroboration, Mdoda (2017) states that farmers' ability to process information from varied information sources relies greatly on their level of education. Several studies also affirm that the age of farmers has a paramount influence on their access to agricultural information, showing that male farmers over 35 years old have greater access to agricultural information when compared to younger farmers (Lawal, Oladele and Alabi, 2017; Mtega, Ngoepe and Dube, 2016). When the adoption of digital technology by smallholder maize farmers in Nigeria was studied, it was shown that other factors such as the attributes of the technology (complexity and compatibility) and the

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characteristics of the farm (access to resources, farm size, education and literacy levels) directly influence adoption decision (Mwangi and Kariuki, 2015; Sennuga, Fadiji and Thaddeus, 2020).

According to Kaur and Singh (2021), farmers' experience, age and level of education significantly influence how they perceive digital technologies. At the same time, these factors determine perceptions, such as income, land size, gender, and household size do not. Contrarily, Meijer *et al*. (2015) stated that characteristics such as gender and income influence perceptions. They also noted that farmers' marital status, age, and educational level are significant factors in shaping their perceptions. In Pakistan, a study conducted by Aldosari *et al*. (2019) aimed to identify the farming community's perceptions of digital communications such as radio, the Internet and television. This study discovered a significant relationship between the age of farmers, their level of education and the application of information from digital sources. These findings concur with those of Boz and Ozcatalbas (2010), who also found that the educational levels of farmers significantly influence the application of information from radio sources. Mohammed *et al.* (2012) contradict the relationship between the age of farmers and the application of information from digital sources.

When Coggings *et al*. (2022) studied how farmers in Sub-Saharan Africa and Southeast Asia used digital extension tools, using real voices from the users and developers, they concluded that the use of digital technologies in agricultural settings is discriminatory and does not favour low-income farmers, such as those with low educational levels and woman farmers. Supporting this, Hoang and Drysdale (2021) reported that in Vietnam, while women and men are equal participants in farming activities, male farmers have a significant advantage in using mobile phones as sources of information for their marketing and food production needs. It was also reported that women farmers in Pakistan have limited access to digital technologies and, consequently, to agricultural information that is accurate and reliable (Lamontagne-Godwin *et al*., 2018).

2.9 Farmers' perceptions of digital technologies as sources of information

Understanding farmers' perceptions is fundamental in the development and dissemination of new technology. This is because the perception of a technology ultimately determines its sustained adoption (Gerli *et al.,* 2022). Studies conducted globally conclude that there are varied determinants influencing the level of perception of digital technologies (Pishnyak and Khalina, 2021). In a study conducted in the Port St Johns and the Ingquza Hill municipalities of South

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Africa, an evident pattern was observed whereby older age, and a bigger household size were associated with increased negative perceptions towards digital technologies (Bontsa, Mushunje and Ngarava, 2023). Da Silveira *et al*. (2023) argued that the negative perceptions of digital technologies as sources of information among older farmers stem from their unreceptive attitude towards change and a strong reliance on indigenous knowledge systems.

Aldosari *et al*. (2019) reported that 38.3% of the 183 respondents in their study perceived the Internet as a useful source of agricultural information, while the majority (65.6%) found television as a useful source. Additionally, 23.5% of the farmers further indicated that information from television programmes maximises agricultural productivity. Bontsa *et al.* (2023) reported that farmers with smaller farm sizes as well as farmers engaged in sales and marketing, exhibit positive perceptions towards the use of digital technologies. Furthermore, farmers have strong perceptions which are associated with the cost of adoption, adaptation to the knowledge of these technologies and existing inequalities. The literature and studies indicate that certain socioeconomic factors of farmers affect their perceptions of digital technologies.

Since its launch in 2014, the uber-like tractor service called Hello Tractor has had an overwhelming reception from Nigerian farmers, who report an exponential increase in production yields of up to 200 per cent (Daum *et al.*, 2021). Daum *et al*. (2021) further reported that farmers perceive this network of smart tractors as convenient and easy to use, as they can utilise mobile money services and SMS to request and pay for tractors. In the context of willingness to use digital agriculture for marketing purposes, Chand (2016) noted that farmers in India have expressed how the National Agriculture Market online trading portal alleviates distress selling. In contrast, Jouanjean *et al.* (2020) reported that the uncertainty surrounding the governance of digital technology data influences how farmers perceive the adoption of agricultural technologies in their farms. This uncertainty affects policymaking due to limitations in the availability of agricultural data from farmers. Similarly, the unwillingness of farmers to use the available digital technologies hinders the development of innovations and services for agriculture.

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2.10 Farmers' utilisation id digital technologies as information sources

An article published by Tara Nathan (2023), the executive vice-president of MasterCard in the World Economic Forum, explicitly details how many farmers in India use digital technologies in several of their farm functions. A digital platform known as Farm Pass is used by farmers to sell their farm produce digitally by connecting with buyers. This platform is cost-efficient for both parties involved. The platform also helps millions of farmer's access financial credit for business expansion purposes not only in India but also in Africa. In a study aimed at determining whether digitalisation in agriculture is a strategy for survival or a marketing risk, it was revealed that over 200 rural farmers achieved a 36 per cent increase in production yields because of using digital technology as a source of information. These farmers from Kenya were able to access real-time accurate information regarding their farming systems, a benefit that was only afforded to commercial farmers before the establishment of Ujuzikilimo. This agri-tech company gathers and combines information from soil and farms using sensors and big data to generate analytical insights and readily avail them to farmers through their website (Chaham, Bosire and Ricau, 2019).

2.11 Impact of adopting digital technologies as information sources

According to Nakura *et al*. (2017), communication and digital information technologies present opportunities to enhance information sharing between agricultural researchers, farmers, and extension personnel. Furthermore, they postulate that common digital technologies like web portals, mobile phones, print media, video streaming, and social media can improve the information dissemination structure in agriculture and offer opportunities for acquiring information on farm operations when properly utilised. In Zambia, a study by Mwalupaso *et al*. (2019) analysed the impact of agricultural information on technical outcomes. The conclusion was that smallholder farmers in the region frequently use their mobile phones to connect with agri-support organisations, leading to a positive correlation between the use of mobile phones for acquiring production information and technical efficiency. Mwangi and Kariuki (2015) revealed that institutional costs associated with technology acquisition and maintaining operations are beyond the financial means of smallholder maize farmers in Nigeria, which makes adoption rates of digital technologies low.

The continuous digital development in the farming county known as Changzhou in China has led to the introduction of a digital technological service that integrates finances, technology, and

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various resources among the government, farmer cooperatives, and efficiency of field inspection efficiency. Farmers and farm managers use the information gathered by this digital agricultural service application to monitor seedlings, diseases, and insects. This application was particularly beneficial during the pandemic as it enabled farmers to regularly track progress in farm activities and monitor crop growth from the comfort of their homes (Xie, Luo and Zhong, 2021). Australian farmers are considered highly receptive to information acquired through a digital agriculture platform founded through collaborative efforts of the country's national farmer's Federation. According to Hansen *et al*. (2022), local farmers have access to tools that provide real-time information and optimise input costs. Mkenda, Mbega and Ndakidemi (2017) also observed that farmers frequently use mobile phones to acquire production information due to perceived convenience.

2.12 Theoretical and conceptual framework

A theoretical framework is an essential component of research that provides a structured approach to understanding and investigating a research problem. It links the study to existing theories, guiding the formulation of research questions, hypotheses, and the interpretation of findings, thereby enhancing the overall rigor and validity of the research (Anfara and Mertz, 2014). In contrast, a conceptual framework as described by Antonenko (2015), is an original description of a researcher's construction of the research. It is independent of existing empirical and theoretical publications.

2.12.1 Theoretical framework

The framework of this study is developed by drawing from and combining various theories of technology and innovations adoption; namely, the Theory of Reasoned Action (Ajzen and Fishbein, 1975), the theory of Technology Acceptance Model (Davis, 1985), and the Technology-Organization Environment (TOE) Framework developed by Tornatzky, Fleischer and Fleischer (1990). The Theory of Reasoned Action (TRA) posits that individual behaviour is driven by behavioural intentions where these intentions are a function of an individual's attitude toward the behaviour and subjective norms. In the context of this framework, attitudes towards digital technologies are influenced by perceptions of ease of use, access to markets, complexity, and affordability. The Technology Acceptance Model (TAM) builds on the foundation of TRA and introduces two specific factors that influence technology acceptance: perceived ease of use and

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perceived usefulness. In this framework, ease of use and access to markets (representing perceived usefulness) are critical perceptions. Lastly, the Technology-Organization Environment (TOE) framework identifies three contexts that influence technology adoption: technological context, organisational context, and environmental context. Here, the focus of this study is on the technological context (ease of use, complexity, affordability) and the organisational context represented by the farmer's characteristics (age, gender, level of education, number of farming years and household size). Based on these interrelationships, the following conceptual framework was developed for this study.

2.12.2 Conceptual framework

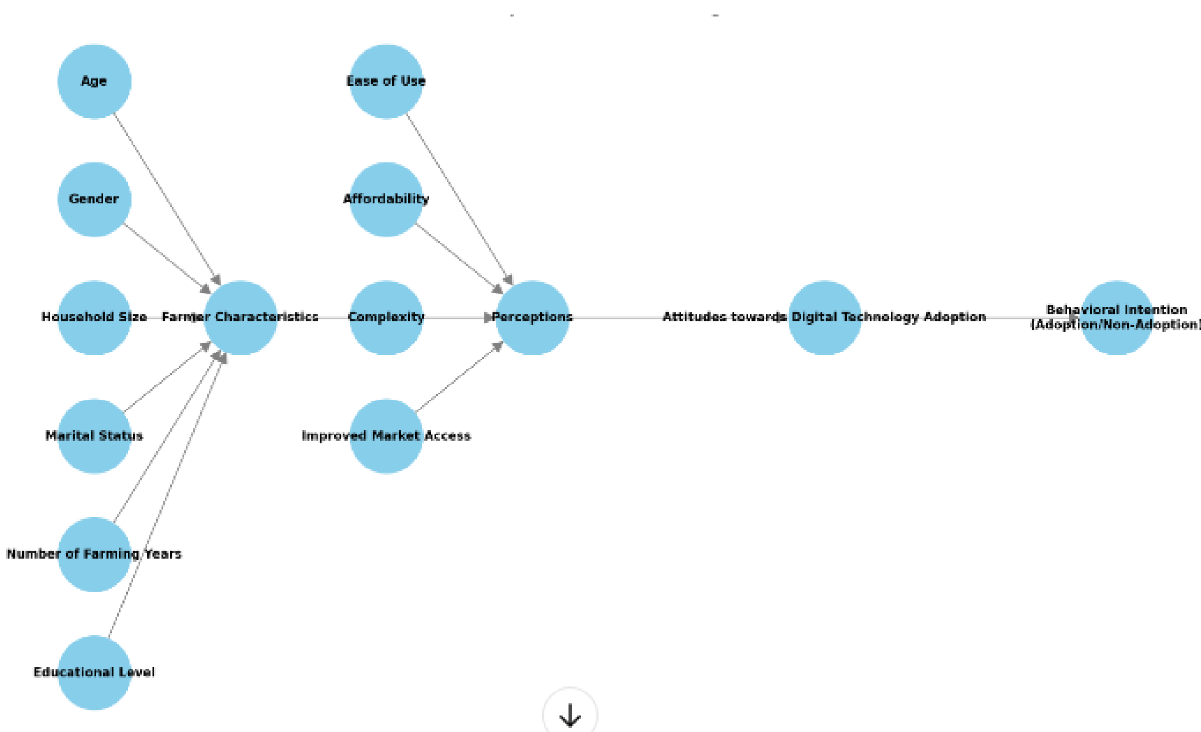

Figure 2.1: Conceptual framework

Source: Adopted from Geng, Li and Xue, 2022

2.13 Literature summary

The literature relevant to this study highlights the complex interplay of socioeconomic factors, perceptions, and attitudes influencing the adoption of digital technologies by smallholder farmers. The agricultural sector in South Africa is highly dualistic and marked by significant inequality.

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While approximately 35 000 commercial white farmers produce 94% of agricultural output, about four million black smallholder farmers occupy only 13% of the agricultural land (Pienaar and Traub, 2015). These smallholder farmers face considerable barriers in accessing markets, resources, and infrastructure. Technological advancements in agriculture, such as automation, robotics, and precision farming, have the potential to enhance efficiency and economic benefits. The literature reveals that digital and communication technologies offer significant opportunities for improving information dissemination among farmers, researchers, and extension personnel. Technologies like web portals, mobile phones, and social media can enhance information flow and farming efficiency. However, institutional costs and financial constraints limit adoption rates among smallholder farmers.

The adoption of various digital technologies has demonstrated significant positive impacts on farmers' productivity and market access in countries such as Kenya, China, Vietnam and, Nigeria. However, concerns over data governance and the reluctance to adopt digital technologies can hinder innovation and policy development. The research reviewed in the literature relies on data that was mainly collected through surveys. Zwane, Biyase and Rooderick (2022) argue that surveys do not provide substantial data for analytical purposes, suggesting that there are still critical gaps in the information available from these studies. Consequently, there is still a limited number of publications addressing the perceptions and adoption of digital technologies and innovations in South Africa. There is also a notable gap in research concerning the opinions of South African smallholder farmers on using digital technologies as a source of information. This study aims to address and fill this gap.

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CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

In research, methodology is an indicator of the direction the research will take from inception to completion and reporting. This aspect of research encompasses comprehensive processes that a researcher takes before the inception of a research project (Leedy and Ormrod, 2010; Williams and Hoell, 2011). This chapter outlines the methods and procedures such as the research design, study area, sampling technique, sampling size, tools for data collection as well as the data analysis tools that this study will employ in addressing the research problem, answering the research questions and generating accurate results that can be applied in decision making processes (Carpenter, 2011; Legesse, 2014).

3.2 Research design

Yin (2009) defines research design as a comprehensive strategy used to integrate the varied aspects of a study in a clear and consistent manner ensuring that the research problem is thoroughly investigated. According to Creswell (2009), the three approaches in research are, 1) the qualitative research approach 2) the quantitative research approach, and lastly the pragmatic research approach, which this study follows. Bryman (2012) explains the pragmatic approach as a mixed methods technique that employs varied methods to give accurate and principled answers to a research question, by collecting, analysing, and reporting both qualitative and quantitative data. This approach was taken as this study seeks to simultaneously generates both qualitative and quantitative data and analyse them independently. The findings of this study will be contrasted and compared using this approach to provide meaningful answers to the research questions and deduce a generalised conclusion (Maxwell, 2016).

3.2.1 Quantitative approach

The quantitative approach quantifies and analyses variables in research. This approach mainly involves the analysis of numerical data using statistical tools to deduce and answer how, when, who, where and what questions (Aliaga and Gunderson, 2002). According to Williams and Hoell (2011), the quantitative approach in research begins with the identification of a research problem, followed by the development of research questions and hypotheses. These hypotheses are then tested and answered using quantitative analysis methods. This approach employs tools such as surveys and experiments to acquire statistical data (Williams and Hoell, 2011; Creswell and

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Creswell, 2017). In this study, this approach was mainly employed through the questionnaire tool, which collected both numerical and non-numerical data, such as farmers' annual agricultural income, age and gender.

3.2.2 Qualitative approach

This research approach is mainly concerned with exploring social issues as well as human and group perceptions, opinions and views on these issues (Morris and Burkett, 2011). To thoroughly address this study's objectives, the qualitative approach was predominantly used to capture the perceptions of smallholder farmers regarding digital technologies. This approach employed data collection tools, semi-structured interviews and focus group discussions to gain an in-depth understanding and insights into their perceptions, both individually and in group settings.

3.3 Study area

This research study was carried out in the City of Tshwane district municipality in the city of Pretoria, situated in the north of the Gauteng province of South Africa. This is the largest metropolitan municipality in the province but accounts for the smallest human population of 3 555 741 compared to other municipalities. The population is composed of more women (50.5%) than men (49.5%). Reports show that there are 1 136 876 households, with 16.4% residing in informal settlements. The main economic activities in the City of Tshwane are community services and finance, with agriculture being among the least significant, accounting for only 1% of employment. When compared to all the other municipalities in the province, this municipality has the highest number of smallholder farmers. This is because this municipality has a large agricultural area in Region 7 (Bronkhorstspruit) and Region 5 (Cullinan), which exhibit the best soil qualities for thriving agricultural productions (Department of Agriculture, Land Reform & Rural Development, 2021; Department of Cooperative Governance and Traditional Affairs, 2020).

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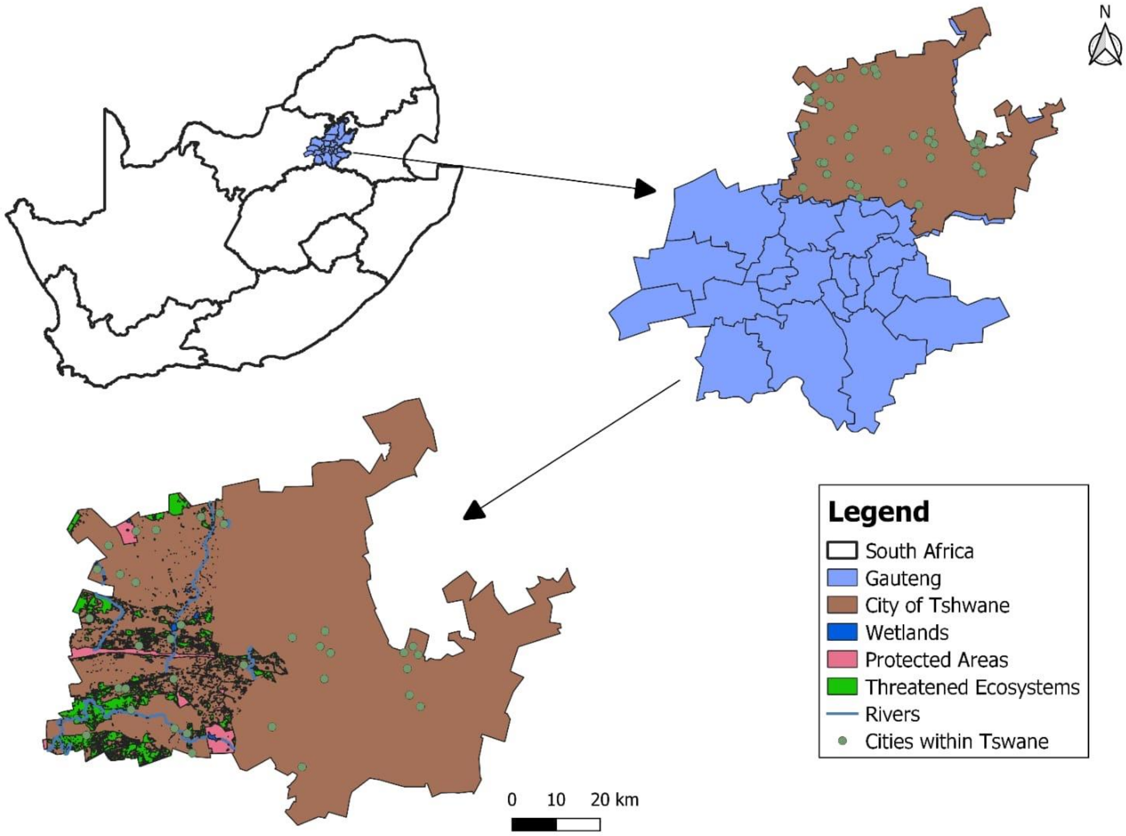

Figure 3.1: Map of the study area

3.3.1 Criteria for selecting a study area

The study unit of this research project was smallholder farmers which formed the basis for the selection criteria of selecting a study area. When compared to all the other municipal regions in Gauteng province, the City of Tshwane municipality accounts for a total of 462 smallholder farmers, representing the majority of smallholder farmers in the province. Literature suggest that the use of technology is often associated with farmers practising their farming activities in urban landscapes, making this area particularly suitable for the study.

3.4 Sampling strategy

3.4.1 Target population

To effectively address the objectives of this study, smallholder farmers in the City of Tshwane municipality were targeted as the population. This population was chosen because it displays characteristics that align with the study's objectives. The following criteria were used for target selection:

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- Be of legal age

- Practice farming activities in any region of the City of Tshwane municipality

- Engage in farming any agricultural commodity

- Farm for business, household consumption or any other reasons

3.4.2 Sampling frame

A sampling frame is a list that a researcher uses to select participants that will constitute a sample for their study using a predetermined method. To frame all relevant members of the study population, a list of all smallholder farmers engaged in various commodities was acquired from the City of Tshwane municipality extension officers. This list consisted of contact details of 462 smallholder farmers, with a gender distribution of 198 male farmers to 264 female farmers. Each farmer in the list was allocated a unique identifier and method of contact.

3.4.3 Sampling technique

According to Bhardwaj (2019), sampling is a selection process of a symbolic part of a population as an integral representation of the entire population. To determine farmers' perceptions of digital agriculture, this study used a multi-sampling technique, including systematic and snowballing methods. According to Onwuegbuzie and Collins (2007), systematic sampling imitates random sampling by selecting participants in randomised sampling intervals. A sampling interval is determined by dividing the population by the desired sample size (Thomas, 2022). A list of smallholder farmers in the City of Tshwane from the Department of Agriculture in the province was obtained for sample selection. A desired sampling size was determined, and the farmers on the list were allocated identification numbers. A sampling interval was calculated, and a random starting point was chosen. The snowballing sampling technique was implemented due to the marginalised nature of the study area, which posed challenges for an outside researcher (Cohen and Arielli, 2011).

3.4.4 Sample size

According to the Department of Agriculture, Land Reform & Rural Development (DALRRD) (2021), 462 registered smallholder farmers are in the City of Tshwane district municipality. This study applied Slovin's formula, developed in 1960 by Slovin, to determine the sample size.

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N = N/ [1 + N $\times e^2$]

Where:

n = represents the sample size

N = represents the total population size (462 smallholder farmers)

e = According to Altares *et al*. (2003), e signifies a probability that is acceptable for making a mistake in the process of selecting a sample size. This study used a probability of 8%

n = N/ [1 + N $\times e^2$]

n = 462/ [1+ 462 × 0.08^2]

n = 117

Because this study used a systemic sampling technique, the following guideline was used for determining the sampling interval:

Sampling interval: i = N/n

N = Population size

N = desired sample size

i = N/n

i = 462/ 117

i = 4

A random number was chosen between **1** and **4** (the interval). This ensures the starting point is random within the first group. The random number was **2,** this means the first individual selected was the **2nd person** in the population list. Subsequent selections occurred at every 4th interval: 2, 6, 10, 14, etc.

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3.5 Data collection

This research process involved various techniques that were applied in collecting data from the research sample. This cross-sectional study employed semi-structured interviews, questionnaires, and focus group discussions for collecting data.

3.5.1 Preparation for data collection

A visit to an extension officer at the Department of Agriculture was undertaken, and a list of smallholder farmers was acquired. The farmers on the list were contacted to arrange meetings for interviews and group discussions. The objectives and significance of this study were outlined to prospective participants. Two participants pre-tested the questionnaires to ensure validity, which is recommended by Sekaran and Bougie (2016). Travel arrangements for researcher and enumerators were made and the process of data collection commenced.

3.5.2 Data collection instruments

3.5.2.1 Semi-structured interviews

Semi-structured interviews are a blend of rigidly structured and unstructured interviews. Hofisi, Hofisi and Mago (2014) state that semi-structured interviews are generally flexible and allow interviewees to express their opinions explicitly; however, they are still guided by a set thematic framework. A list of questions was prepared for the interviewees, who were afforded leeway when responding. The interviews were voice recorded, and interview notes were written during the whole process. These recordings and notes were used as instruments to gather data on smallholder farmers' sociodemographic characteristics and their adoption of digital technologies as sources of information.

3.5.2.2 Likert- scale instrument questionnaires

A questionnaire is a set of questions that are used with the intention of generating information from respondents. This study employed Likert-scale questionnaires ranging from 1 to 5 to gather perceptions of digital technologies as sources of information among smallholder farmers. Using this scale, smallholder farmers rated their level of agreement with questions regarding the attributes of the different technologies such as ease of use, efficiency, complexity, reliability and affordability (Joshi *et al*., 2015).

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3.5.2.3 Focus group discussions

This method of collecting data involves a group of participants with similar experiences and characteristics that will answer research questions in a moderated setting. Because this study was cross-sectional, employing this method was beneficial for efficient time use (Vanderstoep and Johnston, 2009). Four participants were grouped and met through the facilitation of an extension officer at their convenience to discuss their perceptions of digital technologies as sources of information for markets and food production. The participants were selected randomly from the list acquired through the City of Tshwane municipality extension officers.

3.5.3 Data collection process

During this process, most of the farmers were visited in their homes. The objectives and significance of this study were communicated to enforce a clearer understanding of the information needs. The questionnaire and interview questions were written in English and translated into Setswana/Sepedi. The data collection was conducted only after obtaining clear consent and willingness to participate from the farmers. For clarification and translation purposes, every questionnaire was completed in the presence of an enumerator. The data was collected within the following categories:

Demographic characteristics of farmers- This section employed categories and continuous variables to capture the gender, age, level of education, ethnicity and marital status of the farmers

Farm characteristics- To understand if farmers own the land they farm on, how big the land is, the commodity farmed is, and the revenue generated from their agricultural activities.

Extension services- This aspect established if the farmers are aware, have access and use any of the extension services provided by the government.

Technology adoption and use- This section explored the ownership, access and use of ICT tools in acquiring farming information. Furthermore, it probed into whether the farmers knew and used any of the five studied digital technologies.

Perceptions of digital technologies- Using a Likert-scale questionnaire style, the farmers ranked how they perceived the different digital technologies.

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3.5.4 Ethical considerations

Ethics primarily concern morality (Lutabingwa and Nethonzhe, 2006). During the construction of questionnaires, interview processes and data collection, several ethical concerns were carefully considered. Ethical clearance was obtained from the ethics committee of the University of Pretoria. Before the process of collecting data began, written and verbal consent was obtained from the participants. In the focus group discussions and interviews, an environment that encouraged openness and a willingness to converse was facilitated. This enabled participants to share as much information as they could without feeling invaded. In both processes, only questions relevant to the study were asked, and personal questions were deliberately excluded. The information gathered was treated with strict confidentiality, and anonymity was ensured.

3.5.5 Anonymity and Confidentiality

Anonymity and confidentiality are crucial ethical principles to protect participants' privacy and ensure their data is handled responsibly.

In research, anonymity involves collecting data without identifiers that could reveal the participant's identity, such as names, addresses, or unique personal characteristics (Saunders, Kitzinger, and Kitzinger, 2015). For the qualitative aspect of this study, identifying information was recorded and then given unique identification during the data-cleaning process for analysis, discussion and presentation purposes. According to Wiles *et al*. (2008), confidentiality entails protecting participants' identities and data from being accessed or disclosed inappropriately, which is critical for maintaining trust between researchers and participants and ensuring the ethical integrity of the research process. To maintain confidentiality, raw data was securely stored, IDs were used in place of real names, and access to the data was restricted to authorised personnel only (Kaiser, 2009).

3.6 Data analysis

Data analysis is a process of using the collected data to summarise, deduce, and provide answers to research questions. Successful analysis of data is achieved through a process of cleaning, inspecting, modelling, and transforming the data through statistical or analytical tools (Pouyanfar *et al.,* 2018). The collected data was cleaned by allocating the 117 smallholder farmers' unique identifiers using Microsoft Excel before commencing with the analysis. This section outlines the tools adopted by this study for analysis purposes.

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3.6.1 Choice of analytical tools and variables used

3.6.1.1 Objective 1

Descriptive analysis and frequency counts

To determine the characteristics of the farmers in Gauteng, descriptive analysis and frequency counts were used. This approach helps to succinctly summarise the general attributes of the study population from the collected data sets and gives insights into how the population is dispersed based on their characteristics. Descriptive statistics help to describe and understand the features of a specific data set by giving short-term summaries of the sample and measures of the data.

Mean: $\tilde{x} = \frac{\sum x}{n}$ (1)

Where $\tilde{x}$ is the mean of the data

Standard deviation: $S = \sqrt{\frac{\sum(x - x^{x})^2}{n}}$ (2)

Where x represents the mean of each of the values and n is the sample size of the score

3.6.1.2 Objective 2

Thematic analysis

From the interview recording and notes gathered during the process of data generation, thematic analysis framework was used to search, formulate, name, and define themes to determine perceptions (Braun and Clarke, 2006). This was s was followed by the writing up of a logical report, which was detailed and accounted for the data generated and analysed.

3.6.6.3 Objective 3

Binary logistic Regression

The predictive modelling tool of binary regression was used to model the relationship between the set of independent variables, which are the socioeconomic factors of smallholder farmers, and the dependent variable, which is diverse and was modelled as a logit of ***p*** that represents a probability of the dependent variable, which are perceptions and adoption taking a value of 1 (Harrell and Harrell, 2015). An exploratory analysis was conducted, and the following statistical model was used, followed by a likelihood test. An analysis was done using R Studio to test the hypotheses of this study. The following equation was used to model:

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$$\log\left(\frac{p}{1-p}\right) = b_o + b_1X_1 + \cdots + b_kX_K \quad (1)$$

Where p is the probability that $y = 1$ given x, y represents the dependent variable, $x_{1},x_2, \dots, x_k$ represent the independent variables. Lastly, $b_{1},b_2, \dots, b_k$ represent the parameteres of the model. The following table represents the variables that were modelled in the logit regression with their expected outcomes.

Table 3.1: Variables used in the binary regression model

Dependent variable	**Measure**	
Adoption of any digital technology	1 if the farmer has adopted any digital technology, 2 for non-adoption	
Adoption of the internet	1 if farmer has adopted, 2 for non-adoption	
Adoption of farmers weekly website	1 if farmer has adopted, 2 for non-adoption	
Adoption of farming solutions app	1 if farmer has adopted, 2 for non-adoption	
Adoption of GPS	1 if farmer has adopted, 2 for non-adoption	
Adoption of YouTube	1 if farmer had adopted, 2 for non-adoption	
Independent variables	**How it is measured**	**Expected outcome**
Age groups	Categorical – 20 years and less = 0; 21- 35 years = 1; 36-50 years = 2; 51-65 years =3; 66 years and older = 4	+
Farming experience	Continuous- year	-
Gender	Male = 1; Female = 0	-
Level of education	No education = 1; Primary = 2; Secondary = 3; Tertiary = 4	+
Own farming land	Yes = 1; No = 2	-
Government support	1 = Yes; 0 = No	+
Access to extension services	1 = Yes; 0 = No	+

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3.6.6.3.1 Age

The age was categorised into five groups and modelled to assess its impact on the adoption of digital technologies as information sources. This variable was expected to have a positive coefficient and therefore have statistical significance in relation to the adoption of digital technologies. The tested hypothesis was that the younger the farmer, the more likely they were to adopt digital technologies. This hypothesis was informed by literature and the theory that older farmers are less receptive to the introduction of new technologies in their farming activities when compared to younger farmers (Bester, 2008; Sikwela, 2013).

3.6.6.3.2 Gender

The impact of being a male or female on the adoption of digital technology was modelled in the binary regression. This variable was expected to show a negative relationship with the adoption of digital technologies, indicating that gender had a negative effect on the likelihood of adopting digital technologies. The expected outcome was contradictory to literature that showed otherwise (Tiwari *et al.*, 2008; Shongwe *et al*., 2014; Gebrehiwo, 2017). This literature showed that female smallholder farmers are less likely to adopt new innovations compared to their male counterparts.

3.6.6.3.3 Farming experience

Farmers' experience in farming was included in the binary regression to assess the impact of being an experienced farmer on the adoption of the various technologies. The expected outcome was a negative coefficient which would depict that farming experience has no effect on the likelihood of digital technology adoption. Ndlazilwana (2022) found that farming skills acquired through longer farming experience affected farmers' decisions to adopt innovations that differed from traditional methods used in their farming activities.

3.6.6.3.4 Level of education

The farmer's level of education was included in the binary regression model to assess the effect of the various educational levels on the adoption of different digital technologies. The expected outcome was positive, meaning that the level of education variable would have a positive coefficient relative to digital technology adoption. The tested hypothesis was that farmers with higher educational levels are more likely to adopt digital technologies than farmers with lower

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educational levels. This hypothesis was built on literature (Hagos and Hadush, 2017; Oyetunde-Usman *et al*., 2022; Ndlazilwana, 2022 and theory which depicts that education is a significant enabler of adopting innovations that improve farming activities and results in increased productivity. This literature theorises that farmers with formal education are highly likely to adopt and incorporate technologies and sustainable farming techniques into their farming activities.

3.6.6.3.5 Own farming land

This variable was included in the model to determine the effect of farmers owning farming land on the adoption of digital technologies as information sources. The expected outcome was negative which would depict that ownership of farming land has no effect on the adoption of digital technologies.

3.6.6.3.6 Government support

The model analysed the variable of government support on the adoption of digital technologies which had an expected positive outcome. This expectation would depict that government support has an effect and increases likelihood of farmers adopting digital technologies.

3.6.6.3.7 Access to extension services

This variable was incorporated in the regression model to assess the impact of accessing and not accessing extension services on the dependent variable. The expected outcome was a positive coefficient which would suggest that access to extension services has an effect on the adoption of digital technologies by smallholder farmers.

3.6.6.4 Objective 4

To assess the difference in agricultural incomes between adopting and non-adopting farmers, a t-test for independent samples was used. According to Mishra *et al.* (2019) and Trajkovski (2016), this test is used to compare means between two groups while observing the unique p-value of each to determine whether the differences in the means between the two groups are statistically significant. Agricultural income assumed the place of the test variable, while the adoption of digital technology was the grouping variable. The grouping variable was categorised into YES, I have adopted, and NO, I have not adopted. The analysis was done on the SPSS software, and the following equation was assumed:

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$$t = \frac{x_1 - x_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \tag{1}$$

Where x_1 represents mean of first sample and x_2 mean of the second sample. n_1 Represents the sample size of first sample and n_2 represents the sample size of the second sample. s_1 Represents the standard deviation of the first sample, s_2 represents the standard deviation of the second sample.

The calculated t value is then compared to the critical t value from the t distribution table with degrees of freedom

$$df = \frac{\left(\frac{s_1^2}{n_1} - \frac{s_2^2}{n_2}\right)^2}{\frac{1}{n_1-1}\left(\frac{s_1^2}{n_1}\right)^2 + \frac{1}{n_2-1}\left(\frac{s_2^2}{n_2}\right)^2} \tag{2}$$

And a chosen confidence level of 95%. If the calculated $\boldsymbol{t}$ value is greater than the critical $\boldsymbol{t}$ value, then the null hypothesis is rejected.

3.7 Chapter Summary

This chapter detailed the procedures and methods adopted to collect and analyse data. Firstly, the study area was described and mapped to depict its geographical characteristics and reason for selection. Secondly, the research design, which included both the quantitative and qualitative research approaches, was detailed. This chapter also outlined the various techniques utilised for data collection and analysis in this study. Data was gathered using questionnaires and focus group discussions, and analysis was conducted using descriptive statistics, binary regression, themes, and t-tests. The study employed a multi-sampling technique for participant selection, with a sample size of 117 smallholder farmers determined using Slovin’s formula. The data was collected in the City of Tshwane, where consent was obtained from participants, and the collected data was handled with confidentiality.

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CHAPTER 4: DESCRIPTIVE RESULTS

4.1 Introduction

This chapter reports the findings and explains the demographic and socio-economic characteristics of smallholder farmers in the regions of the City of Tshwane municipality. It also describes the characteristics of their farms, their access to extension services, and their digital devices. This aspect of the results is important in addressing this study's first objective, which will facilitate the analysis of the subsequent objectives.

4.2 Demographic characteristics

This section explains the characteristics of the smallholder farmers, such as farmer age, gender, educational level, marital status, and the commodity produced, household size and farming purpose. These characteristics are represented as frequencies, percentages, means and standard deviations, as detailed in Table 4.1.

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Table 4.1: Demographic characteristics of farmers in Tshwane

Variables Demographic	Frequencies N	 %
Age group		
18-25	4	3.4
26-35	21	28.1
36-45	42	36.2
45-55	28	24.0
56+	21	28.1
Gender		
Male	54	46.2
Female	63	53.8
Educational level		
No formal education	6	5.2
Primary	16	13.9
Secondary	66	57.4
Tertiary	27	23.5
Purpose of farming		
Commercial	31	26.5
Household consumption only	33	28.2
Both	53	45.3
Commodity		
Crop	64	56.6
Livestock	40	35.4
Mixed	9	8.0
Variables	**Mean value**	
Household size	5.94	
Farming years	8.15	

Source: field survey (2023)

4.2.1 Age group

In this study, the 35-45 age group accounted for 36.2% smallholder farmers, followed by the 26-35 and the 56+ age groups, accounting for 28.1% of the smallholder farmers. This depicts that smallholder farming in these regions is dominated by middle-aged farmers. Kaur and Singh (2021) reveal that a farmer's age is a significant socio-economic factor influencing their perception of digital technologies. In line with this, a study in India highlighted that age is a crucial factor in

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determining a farmer's choice of information sources (Mittal and Mehar, 2016). Oluwarotimi *et al.* (2006) characterised farmers over the age of 40 as less likely to adopt technologies.

4.2.2 Gender

The dispersion of the 53.8% female to 46.2% male ratio in this study corroborates findings from various socioeconomic-centric surveys (GHS, 2016; DAFF, 2016; StatsSA, 2017), which delineate that the South African smallholder farming sector is predominately female-dominated. A study conducted in the Eastern Cape by Gidi (2013) also showed that 70% of smallholder farmers were females. . According to Kaur and Singh (2021), gender is not considered a significant factor in the determination of perceptions relating to digital technology.

4.2.3 Educational level

Most (94.8%) of these smallholder farmers are considered literate, with 57.4% having achieved secondary education and 23.5% having completed tertiary education. This indicates that farmers can read information related to their farming activities. This finding aligns with the sentiments of Oyewole and Sennunga (2020) that being educated is an important factor in the adoption of innovative farming techniques. It is also consistent with Kaur and Singh (2021) who state that a farmer's level of education affects their perception of digital technologies.

4.2.4 Purpose of farming

A significant portion, 45.3% of smallholder farmers in Tshwane, stated that they farm for both household consumption and commercial purposes. This indicates that despite various challenges that these farmers encounter, they are still able to achieve production for dual functions (Ortmann and King, 2006). This finding agrees with the observation that such farmers do not produce for the sole purpose of markets but also for personal consumption (Van Averbeke and Khosa, 2007). This contrasts with the OECD (2015) which defines smallholder farmers as the type of farmers who produce solely for their own consumption.

4.2.5 Commodity

Crop farmers (56.6%) predominate the smallholder farming sector in the study area with only 35.4% livestock farmers and 8% mixed farmers. This distribution supports the characterisation that the regions in the municipality of Tshwane display exceptional soil qualities ideal for crop production (DALRRD, 2021; Department of Cooperative Governance and Traditional Affairs, 2020).

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4.2.6 Household size

The average household size is six members, and this also serves as a source of labour on their farms (Yusuf, 2018). A study by Kaur and Singh (2021) states that the number of household members is not a significant determiner of farmers' perceptions of digital technologies. When the characteristics of technology adopters and non-adopters were assessed, it was revealed that non-adopters were mainly farmers with household sizes of over ten members (Oluwarotimi *et al*., 2006).

4.2.7 Number of farming years

When asked to state their farming experience, an average of eight years was recorded. This suggests that these farmers are informed on various aspects of farming, such as climatic conditions, and are experienced in dealing with them (Muthelo, 2018). Oluwarotimi *et al.* (2006) argue that farming experience has no impact on the adoption of digital technologies, as adopters and non-adopters in Nigeria share the same years of farming experience.

4.3 Socio-economic characteristics

This section reports on the socio-economic characteristics of the farmers, such as ownership of farming land, source of labour, and farming practices, presented in terms of frequencies and percentages.

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Table 2.2: Socio-economic characteristics of smallholder farmers in Tshwane

Variables	**Frequencies**	
Socio-economic characteristics	**N**	**%**
Non-farm income		
Yes	45	39.1
No	70	60.9
Agricultural income		
> 50 000	69	84.1
50 000 – 100 000	10	12.2
100 000 – 150 000	2	2.4
150 000 – 200 000	1	1.2
Own farming land		
Yes	54	50.0
No	54	50.0
Source of labor		
Family	81	71.1
Hired	33	28.9
Nature of farmer		
Full time	104	90.4
Part time	11	9.6
Challenges		
Access to markets	12	12.8
Finances	31	33.0
Farming support and training	10	10.6
All of the above	18	19.1
Others	23	24.5

Source: field survey (2023)

4.3.1 Non-farm income

Most farmers (60.9%) do not have any income outside of their agricultural earnings. This finding contradicts the WRC report by Manona *et al.* (2008) which states that smallholder farmers rely on other income streams unrelated to their farming activities. In relation to digital technology perceptions and adoption, a farmer's income is an insignificant factor in determining their perceptions of digital technology (Kaur and Singh, 2021).

4.3.2 Agricultural income

Most smallholder farmers, 84.1%, generate an annual income of less than R50 000 from their agricultural production, while only 1.2% earn between R150 000 and R200 000. This variable

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directly represents production yield in this study, indicating that these farmers generally produce in limited quantities.

4.3.3 Ownership of farming land

Table 4.2 shows that 50% of smallholder farmers own the land they farm on, and the other 50% do not. Among those who do not own the land, 50% acquired it through inheritance, 25.9% through a lease, and 19% farm on communal land. Oluwarotimi *et al.'s* (2006) assessment of technology adopters and non-adopters found that land ownership was not a significant factor, as both these groups exhibited similar land ownership patterns.

4.3.4 Source of labour

Smallholder farms are characterised by sourcing their labour from their household members, and 71.1% of farmers in these regions are no exception to this characterisation. However, 28.9% of the farmers utilise hired labour. A study in Nigeria by Oluwarotimi *et al.* (2006) showed that farmers who rely on family and household members for farm labour are less likely to adopt technology.

4.3.5 Nature of farmer

The majority, 90.4%, of the farmers farm on a full-time basis and spend most of their days annually tending to their farming activities.

4.3.6 Challenges

When asked about the challenges encountered in their farming activities, 33% of the smallholder farmers stated that finances pose the biggest constraints in their farming activities. These findings are consistent with Loki *et al*. (2016), who identified financial support as one of the biggest challenges smallholder farmers encounter. According to the study, 24.5% of the farmers reported facing "other" challenges, such as adverse weather conditions, livestock theft and diseases. Consistent with this finding, Rajkhowa and Qaim (2021) noted that adverse climatic conditions and lack of information are among the prevailing challenges encountered by smallholder farmers. Additionally, 12.8% and 10.6% of farmers cited difficulties accessing markets and obtaining farming support and training, respectively. Furthermore, 19.1% of smallholders reported experiencing these challenges periodically and simultaneously.

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4.4 Extension services

This section reports on the exploration of government support and extension services in the City of Tshwane regions, with a focus on their availability, utilisation, and general perceptions of them by smallholder farmers in these regions.

Table 4.3: State of extension services delivery as perceived by farmers

Variables	**Frequencies**	
Extension services	**N**	**%**
Government support		
Yes	31	27.7
No	81	72.3
Awareness of extension services		
Yes	66	60.0
No	44	40.0
Access to extension services		
Yes	41	38.3
No	66	61.7
Frequency of extension visits		
Bi-weekly	1	1.9
Monthly	8	14.8
Annually	8	14.8
Other	37	68.5
Helpfulness of extension officers in info sharing		
Yes	37	91.1
No	9	8.9
Can reach extension officers for information needs		
Yes	22	20.0
No	14	25.5
Sometimes	19	36.2
Quality of extension services in relation to info sharing		
Poor	6	12.8
Neutral	12	25.5
Good	17	36.2
Very good	12	25.5

Source: field survey (2023)

4.4.1 Government support

As shown in Table 4.3, only 27.7% of smallholder farmers in this region receive support from the government in their farming activities which is relatively low compared to the 72.3% who do not

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receive any support. This is in line with the report by Aliber and Hall (2012) asserting that there is limited government support for smallholder farmers. The inability of government to support this sector results in poor production performance (Obiechina, 2012). Furthermore, 41.9% of these farmers stated that they get resources as a form of support from the government, followed by advisory services at 38.7%. Nyaga *et al*. (2021) and FAO (2022) state that the lack of government support is a significant factor contributing to the uneven access to and adoption of digital technologies.

4.4.2 Awareness of extension services for information needs

Sixty percent of the farmers are aware of the extension services available for their farming needs. This awareness positions these farmers at a better chance of accessing such services. Mgbenka, Mbah and Ezeano (2015) report that a general lack of awareness about extension services among smallholder farmers, which often stems from low literacy levels, contributes to a lag in the adoption of technologies.

4.4.3 Access to extension service

Despite 60% of farmers being aware of extension services, only 38% have access to them. Similarly, Midamba *et al.* (2022) highlight that only 42.50% of smallholder farmers in Uganda had access to extension services. This contrasts with the findings of Loki and Mdoda's (2023) survey which showed that 78% of smallholder farmers in the Eastern Cape had access to extension services. A significant portion of farmers (49.1%) further elaborated that their lack of access to these services was due to not knowing how to reach the extension officers and their offices.

4.4.4 Frequency of extension visit

In Table 4.3, 14.8% of smallholder farmers stated that extension officers visit monthly, while another 14.8% stated that visits occur annually. Only 1.9% of the farmers mentioned that visits happen bi-weekly. For 68.5% of the farmers, visits are inconsistent and do not follow a discernible pattern, leading them to be classified as "other". Additionally, 57.9% of smallholder farmers further indicated that they are not satisfied with the frequency of these visits, corroborating the findings of a study by Ndlazilwana (2022) in the Eastern Cape, which highlighted widespread dissatisfaction among smallholder farmers with the frequency of extension visits.

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Extension services delivery was negatively impacted in South Africa during and post- COVID-19 outbreak due to its reliance on face-to-face interactions, which compromised smallholder farmers' access to information (Karubanga *et al.*, 2016, Yusuf, Popoola and Yusuf, 2022).

4.4.5 Helpfulness of extension officers in sharing farming information

When it comes to sharing farming information, 91.1% of smallholder farmers found extension officers to be helpful. This aligns with the findings of Loki and Mdoda (2023), who noted that extension officers are very helpful in disseminating information that is relevant to farming activities and helping farmers stay informed. Contrary to this, Maoba's (2016) study found extension services ineffective and inefficient in-service delivery.

4.4.6 Can you reach extension officers for information needs?

Regarding Table 4.3, 34.5% of smallholder farmers stated that they can only sometimes reach extension officers for information, while 25.5% stated they cannot reach them for their information needs. This suggests that farmers cannot acquire farming information from extension officers when they need it. Similarly, Maoba (2016) reports that smallholder farmers in the Gauteng province consider extension officers insufficiently visible.

4.4.7 Quality of extension services in relation to information sharing

Using a Likert scale ranging from 1-5, with 1 being "very poor" and 5 "very good", 36.2% of the farmers rated the quality of extension services for information sharing as "good". This was followed by "neutral" and "very good" ratings from 25.5% of the farmers. Only 12.8% of smallholder farmers rated the quality of extension services as "poor" with regard to information sharing. This finding contradicts the results of Loki *et al*. (2022), who reported that smallholder farmers generally receive poor information delivery from extension officers..

4.5 Technology use as information source and importance of information

This section reports on the state of access to and ownership of digital devices used for accessing information, general knowledge of digital technologies and the perceptions of information needs among smallholder farmers. The findings are represented in the form of frequencies and percentages.

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Table 4.4: Technology use and information access by farmers in Tshwane

Variables	Frequencies	
Technology use	**N**	**%**
Own a computer		
Yes	23	24.5
No	71	75.5
Access to a computer		
Yes	43	45.7
No	51	54.3
Know how to use farmers weekly website		
Yes	24	26.1
No	68	73.9
Own a smartphone		
Yes	73	73.0
No	27	23.0
Access to a smartphone		
Yes	43	45.7
No	51	54.3
Know You Tube can be used as an information source		
Yes	46	48.9
No	48	51.1
Preferred source of information		
Extension officers	16	20.5
Digital technologies	17	21.8
Other farmers	34	43.6
All of the above	11	41.1
Is it important to access real-time information		
Yes	69	95.8
No	3	4.2

Source: field survey (2023)

4.5.1 Ownership and access to a computer

Table 4.4 shows that the majority of smallholder farmers (75.5%) do not own computers, and 54.3% of these farmers do not have access to one. This leaves only a minority (45.7%) of the farmers with the opportunity of using digital technologies that can be accessed using digital

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devices such as a computer. Evangelista, Guerrieri and Meliciani (2014) argue that farmers' access to ICT tools does not ensure adoption of digital technologies.

4.5.2 Know how to use the farmers' weekly website

Despite the majority of farmers expressing familiarity with the Farmer's Weekly print magazines, 73.9% of them stated that they do not know how to use the Farmer's Weekly website to acquire agricultural information. Only 26.1% of the farmers indicated they knew how to navigate the website for information acquisition. Evangelista *et al.* (2014) argued that the availability of digital technologies to smallholder farmers is an insignificant factor in the knowledge and skills required to adopt and utilise these technologies, which is consistent with the findings of this study.

4.5.3 Ownership and access to a smartphone

This study showed that 73% of smallholder farmers own a smartphone, and only 23% do not. Furthermore, 71.8% of these farmers have access to a smartphone. This finding supports the results of Abdulai *et al*. (2023) that smallholder farmers have access to digital devices that are generally considered simple, such as mobile phones, which serve as a bridge to accessing digital resources. Aker and Fafchamps (2015), Shimamoto, Yamada and Gummert (2015) and Aker and Ksoll (2016) highlight that farmers' use of mobile phones positively impacts market participation, income, input and selling costs, as well as overall farm productivity.

4.5.4 Know that YouTube can be used as a resource for farming information

Table 4.4 shows that 48.9% of the farmers know that YouTube can be used to acquire agricultural information, while 51.1% do not.

4.5.5 Preferred source of information

The results of this study show that 43.6% of the farmers prefer using other farmers to acquire information. These farmers stated that this preference is due to the trust and familiarity they have with these individuals. In line with this finding, a European study by Kernecker *et al*. (2020) shows that peer-to-peer communication is the preferred source of information for smallholder farmers. Meanwhile, 21.8% of farmers prefer digital technologies due their availability and time efficiency, while 20.5% prefer acquiring information from extension officers because they are experienced, trained and qualified to disseminate agricultural information effectively. Lastly, 41.1% of the smallholder farmers state that they prefer all of the above-mentioned information sources. This indicates that farmers who rely on other farmers and extension officers for information also consult

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digital technologies, which represents a positive change in the use of these technologies for information acquisition. This finding is consistent with the views of Mavhunduse and Holmner (2019) that the adoption of digital technologies should be used to enhance traditional methods of disseminating agricultural information.

4.5.6 Is it important to have access to real-time farming information?

Almost all (95.8%) the smallholder farmers state that it is important to access real-time farming, with only 4.2% holding a different sentiment. This is a positive perspective for smallholder farmers as their development relies on access to real-time agricultural information.

4.6 Chapter Summary

This chapter used descriptive statistics, frequencies, percentages and mean values to highlight key aspects of smallholder farmers, including demographic characteristics, socioeconomic characteristics, access to extension services, and access and ownership of digital devices. These are essential factors in examining smallholder farmers' perceptions and adoption of digital technologies and, ultimately, the impact of these technologies on agricultural income. The chapter also showed that smallholder farming is female-dominated in these regions and is mainly comprised of middle-aged farmers who rely mainly on agricultural production as a means of income.

The chapter also explored the challenges encountered by farmers, their knowledge and awareness of digital technologies that are commonly used for farming information as well as their thoughts on access to agricultural information to the high value placed on real-time agricultural information reflects a positive attitude towards adopting digital technologies as information sources. Understanding the findings outlined in this chapter is crucial for devising targeted interventions to support and enhance the productivity and sustainability of smallholder farming in the region.

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CHAPTER 5: EMPIRICAL RESULTS

5.1 Introduction

This chapter presents findings and reports on the analysis conducted to address the following objectives:

1. Assess smallholder perceptions of digital technologies as sources of information for farming activities

2. Determine the adoption of digital technologies as sources of information for farming activities and the effect of smallholder farmer characteristics on adoption

3. Assess agricultural incomes between adopting and non-adopting farmers

5.2 Farmers' perceptions of digital technologies as information sources

This section of the chapter reports on smallholder farmers' perceptions of information sources for farming activities using descriptive and Likert-scale ratings. Assessing perceptions is important in understating the adoption and non- adoption decisions.

Table 5.1: Farmers' perceptions of digital technologies as information sources

Farmers' Perceptions of digital technologies as information sources	Strongly Agree %	Agree %	Neutral %	Disagree %	Strongly disagree %
Complicated to use	15.1	4.1	32.9	27.4	20.5
Costly	19.7	23.9	33.8	16.9	5.6
Easily accessible	28.6	24.3	38.6	5.7	2.9
Time effective	36.8	18.9	44.6	-	-
Reliable	31.5	19.2	49.3	-	-
Up-to-date information	36.6	21.1	40.8	1.4	-
Information is helpful	32.4	24.3	41.9	1.9	
Better than traditional sources	20.3	9.5	50.0	13.5	6.8
Easy to use	37.7	19.5	37.7	5.2	

Source: field survey (2023)

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The results in Table 5.1 show that the most common and persistent perception rated by the farmers is "Neutral", which could indicate that these farmers have limited knowledge of these technologies or have not yet adopted them. Consistent with this finding, Kernecker *et al.* (2020) state that farmers' perceptions of technologies are mainly informed by their lived experiences of using those technologies. Very few, 15.1%, of the farmers strongly agreed that digital technologies are complicated to use, 32.9% were neutral, while 27.4% strongly disagreed. Regarding the economic aspect, 23.9% of the farmers stated that digital technologies are costly, while 16.9% disagreed. This result is consistent with the findings of Hoang and Tran (2023), which indicates that many smallholder farmers in their study perceived the acquisition and utilisation of digital technologies as costly. Similarly, a study in the Eastern Cape by Bontsa (2023) reported that most of their studied population perceived the adoption of digital technologies to be expensive compared to other technologies.

Table 5.1 shows that 28.6% of the farmers strongly agreed that digital technologies are easily accessible while 36.8% also strongly agreed that these technologies are time adequate. Pishnyak and Khalina (2021) show that farmers' perceived effectiveness of digital technologies puts them in a better position to adopt these technologies. Digital technologies are considered easy to use by 31.5% of those who strongly agreed and reliable sources of information by 37.7% of farmers. Caffaro *et al.* (2020) highlight that farmers who perceive digital technologies as helpful, reliable and easy to use are more likely to adopt them. The information acquired from digital technologies was perceived to be up to date by 36.6% and helpful by 32.4% of smallholder farmers who strongly agreed. When comparing digital technologies as information sources to traditional ones, 20.3% of the farmers strongly agreed that digital technologies are better, while the majority (50%) were neutral, and only 6.8% strongly disagreed. 37.7% farmers strongly agreed that digital technologies are easy to use, with an additional 19.5% also agreeing with this sentiment. Hoang and Tran (2023) found that the majority of smallholder farmers in their study perceive digital technologies as challenging to use, a view attributed to the perceived lack of training on how to use these digital technologies. These farmers' perceptions were generally positive, which indicates a potential openness and willingness to adopt digital technologies as information sources. This finding contradicts that of Banga *et al.* (2020) who state that smallholder farmers in Africa perceive digital

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technologies as risky, leading to hesitation and unwillingness to adopt them. Therefore, exploring farmers' perceptions in order to establish their impact on adoption patterns is crucial.

5.2.1 Focus group discussion

In a quest to gain a deeper understanding of smallholder farmers' perceptions, a focus group discussion was arranged, to allow farmers can share their views and opinions on digital technologies explicitly in their own words. The findings are reported and presented in this section using a thematic analysis format.

Theme 1: Change in information needs

Is there a change in the need for agricultural information now when compared to the olden days?

The farmers responded affirmatively to the change in the need for agricultural information without elaborating further until FGD, farmer 3 commented:

"There is an increased need, meaning we need more information about what happens in agriculture because new things are happening, new ways of planting, and new machines that big farmers use, so we have to know all about these things now."

In line with these findings, Gido *et al*. (2015) state an increased demand for agricultural information so that farmers can stay up-to-date and informed about new technologies, farming techniques, market trends, and new pests and diseases.

Theme 2: Importance of keeping up to date with industry trends

How is keeping up to date with what is happening in the agricultural industry important?

When this question was asked, farmers expressed that it is extremely important to keep up to date with everything in the agricultural industry as they believe that access to current agricultural information can positively impact their development as farmers and, in turn, their farms. In their own words, the farmers said:

FGD, Farmer 1:

"When you are updated with information, you can make informed decisions that yield good benefits."

FGD, Farmer 2:

"To ensure successful production as a vegetable farmer."

Farmer 3:

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"It is important to stay up to date because when you know, you will do better as a farmer, and that ensures food security."

An empirical study by Wale and Mkuna (2023) concurs with the views expressed by these farmers, highlighting that now more than ever, smallholder farmers need access to information to enhance their ability to commercialise their farming operations and generally improve their livelihoods.

Theme 3: Smallholder farmers' ways of acquiring information

Besides radio, TV, and newspapers, in what other ways do smallholder farmers acquire information?

When this question was asked, various sources of information, mainly digital, were mentioned, including:

FDG, Farmer 3: *"The internet."*

FGD, Farmer 3: *"Google."*

FGD, Farmer 4: *"YouTube."*

FGD, Farmer 1: *"Extension officers."*

FGD, Farmer 4: *"Facebook farming groups."*

FGD, Farmer 2: *"WhatsApp group for farmers."*

FGD, Farmer 2: *"Other farmers."*

Mavhunduse and Holmner (2019) state that agricultural information is disseminated in various ways, including face-to-face interactions, mass media such as radio, and social media, which are accessed via ICT tools. Mgbenka et al. (2015) reported that smallholder farmers acquired farming information from sources such as the radio, other farmers, television, farmer field days, and agricultural development projects.

Theme 4: Farming activities that require timeous information

Which farming activity requires you to stay up to date with agricultural news and information?

The farmers mentioned various activities that require them to stay up to date with agricultural news and information. The responses show that livestock farmers require information related to diseases and their control, while crop farmers are mainly concerned about soil preparation, planting techniques, and pest control.

FGD, Farmer 1 said:

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"Soil preparation and planting techniques because they are the important part of the whole crop production; if the soil is not good and healthy, then your crops will not be good and healthy."

FGD, Farmer 2 said:

"Diseases and pest control because there is always new disease and pests we don't know about."

Another farmer said:

"How do I increase my agricultural income? It is my only source of income."

Sharafi *et al*. (2015) posited that drought management requires farmers to receive timely information on climatic conditions. The Nigerian strategy support programme states that product planning information is crucial for farmers to access markets effectively.

Theme 5: Factors influencing adoption and non-adoption of digital technologies

What influences smallholder farmers' decision to adopt or not adopt digital technologies as information sources?

The farmers expressed that factors such as affordability, access to digital devices such as smartphones and network connectivity were the major factors that influence their adoption decisions.

FGD, farmers 2 said:

"I cannot use digital technologies because I cannot access a smartphone, and data is expensive. A person like me cannot afford such; I don't know about the others."

Another farmer expressed that:

"As a poultry farmer, it is important to stay up to date with disease outbreaks, so I have adopted digital technologies because they are accessible all the time except when there is no load shedding and network."

FGD, Farmer 3:

"To market my produce to a larger group of people, I use Facebook."

Similarly, various papers show that smallholder farmers' adoption of digital technologies is hindered by the lack of digital technology infrastructure, electrical infrastructure and low income levels (Munyua, 2007; Musa *et al.*, 2013; Nmadu *et al.*, 2013). Hoang and Tran (2023) state that the need for knowledge regarding which technology to adopt and training on how to use the technologies are significant challenges that hinder smallholder farmers' adoption of digital technologies. Sidibé *et al.* (2021) report that the expenses associated with digital technologies include inputs costs such as mobile data.

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Theme 6: Perceptions of access to information

Do you think you can farm successfully without accessing farming information?

The unanimous answer from the farmers was 'No," indicating that they perceive access to information as a critical factor for successful farming operations. In their own words the farmers said:

FGD, Farmer 1:

"No, I cannot farm successfully without accessing any farming information because I did not grow up in a farm so I have no farming knowledge, experience and background so I need as much information as I can get."

FGD, Farmer 3:

"No, you need to have access to information because you need to know what you are doing and if you are doing it right."

Mgbenka *et al.* (2015) state that farmers get information on cassava production which enables them to know when to plant, how to weed, which varieties to plant, how to determine planting space and which harvesting techniques to adopt.

Theme 7: The Challenge of accessing markets

What do you think is the biggest challenge when it comes to accessing markets as a smallholder farmer?

In this regard, the farmers identified various challenges such as transportation, distance and inconsistent production. However, the one challenge most pertinent to this study is their lack of sufficient knowledge on how to access markets.

FGD, Farmer 1:

"Transport to the markets which are in the city is costly so sometimes we do not have transportation which hinders growth."

FGD, Framer 2:

"Distance to markets is far since I live in the plots and sometimes I come back without having made any sales."

FGD, Farmer 3:

"We lack the skills and knowledge on how to access markets, I am clueless so I can't rely on farming income."

Farmer 4:

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"We cannot produce consistently due to the inconsistent supply of water, load shedding, inputs which make it hard to be a serious business."

The Food and Agriculture Organization (2003) states that smallholder farmers operate under a deficit of relevant knowledge, which amplifies their inability to access markets and results in higher costs of inputs for production. Furthermore, this paper notes that the inability to access markets has a detrimental effect on farm production. The Nigerian Strategy Support Program observed that transportation expenses to markets was a consistent issue for farmers in the regions.

5.3. Adoption of digital technologies and the effect of smallholder farmer characteristics on adoption

This section reports on findings from the assessment of farmers' adoption of digital technologies as information sources. A chi-square test was conducted to determine the significance of the relationship between the independent and dependent variables.

5.3.1 Adoption of digital technologies as information sources by farmers

This section reports on farmers' adoption of digital technologies as information sources. A chi-square test was conducted to determine the significance of the relationship between the independent and dependent variables.

Table 5.2: Adoption of digital technologies as information sources by farmers in Tshwane

Digital technologies adopted as information sources	% adopted
Any other digital technology	26
Internet (web pages)	38
YouTube	24
Farming solutions App	6
Farmers weekly website	16
GPS	4

Source: Field survey (2023)

When the adoption of digital technologies as information sources was assessed, only 26% of smallholder farmers stated that they have adopted some type of digital technology, such as social media as a source of information. This finding corroborates reporting by Abdulai *et al*. (2023) that

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adoption of digital technologies by smallholder farmers in developing countries is exponentially low. Engås, Raja and Neufang (2023) assert that the low adoption levels of digital technologies are propelled by the digital divide. When the technologies were analysed independently, the most commonly adopted digital technology as an information source is the internet, at 38%. A similar study in Vietnam by Hoang (2023) found that the internet and wireless connectivity accounted for the majority of the adoptions, with 80.9% of cases. In Rwanda, McCampbell *et al.* (2023) reported that this type of digital technology was only adopted by 10% of the banana farmers which contradicts the findings of this study. Nie, Ma and Sousa-Poza (2021) highlighted a positive effect of using the internet on the general wellbeing of the farmers and their households.

YouTube was the second most commonly adopted technology, at 24%, followed by 16% of Farmer's Weekly adoption. YouTube is reported to be among the social platforms that can be used to disseminate agricultural information and propagate extension services and activities to a broader audience (Kipkurgat, Onyiego and Chemwaina, 2016; Saravanan and Suchiradipta, 2017; Barau and Afrad, 2017). Farming solutions apps and GPS were the least adopted technologies among the farmers, at 6% and 4% adoption rates respectively. Hoang and Tran (2023) corroborates this finding by revealing that mobile applications and digital technologies rank as the second and third most commonly adopted digital technologies by farmers. However, an American study by Schimmelpfennig and Lowenberg-DeBoer (2020) found GPS to be the most commonly adopted technology among farmers in their region, which is inconsistent with the results of this study.

5.3.2 Effect of socio-economic factors on the adoption of digital technologies

To examine the influence of socioeconomic factors modelled as independent variables, on the adoption of digital technologies presented as dependent variables, a regression was conducted, and a chi-square test was used to model the significance of the relationship between the independent and dependent variables. Table 5.3 depicts that only two of the five outcomes had a significantly statistical variable that are relative to the choice of adopting digital technologies as information sources, which are access to extension services and age. Variables such as farming experience, type of farm, government support, gender and educational level had no statistical significance relative to the adoption of digital technologies. The binary regression results are presented in Table 5.3.

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Table 5.3: Factors influencing digital technology adoption

Variables	Coefficient.	Odds ratio	Marginal effects.
Internet			
Farming years	0.018	0.962	
Type of farm	0.594	.962	0.060
Government support	0.444	3.139	0.080
Access to extension	1.967***	5.927	0.202*
Age group	1.231	10.973	-0.003
Gender	0.412	0.649	0.001
Own farming land	-0.263	0.688	0.050
Level of education	6.361	210.817	-0.237
YouTube			
Farming years	0.055	1.018	
Type of farm	-0.138	0.437	0.016
Government support	0.666	1.559	0.063
Access to extension	2.154***	7.151	0.283**
Age group	1.255	3.423	-0.007
Gender	0.396	1.510	0.052
Own farming land	-0.090	0.769	-0.071
Level of education	0.233	578.750	-0.221
Farmers weekly			
Farming years	-0.089	0.915	
Type of farm	2.335	1.271	0.068
Government support	-0.395	0.674	-0.007
Access to extension	2.348**	10.461	0.164**
Age group	0.481	1.617	0.014
Gender	1.317	3.732	0.069
Own farming land	0.955	2.599	0.076
Level of education	-1.458	0.233	-0.199
Farming App			
Farming years	0.141	1.056	
Type of farm	-0.732	0.354	-0.008
Government support	0.217	1.947	0.063
Access to extension	1.353	8.618	0.249
Age group	3.274	3.507	-0.034
Gender	2.038	1.486	0.045
Own landing land	1.732	0.914	-0.014
Level of education	1.565	295.655	-0.197
GPS			

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Farming years	-1.252		1.152		
Type of farms	-79.958		0.348		-0.006
Government support	-76.655		1.242		0.025
Access to extension	105.177		3.870		0.038
Age group	117.581		26.426		0.066
Gender	-174.694		7.678		0.065
Own farming land	33.771		5.560		0.051
Level of education	-110.736		4.781		0.016
Constant	2.808	2.990	9.085	14.712	282.389
	(357.064)	(366.164)	(1,171.970)	(2,993.595)	(151,015.600)
Observations	116	116	116	116	116
Log likelihood	-45.501	-36.379	-29.728	-16.579	-0.000
Akaike Inf. Crit	121.002	102.757	89.457	63.158	30.000

Notes: ***, **, * means significant at level 1%, 5% and 10% , respectively

Source: Field survey (2023)

Table 5.3 shows that only one of the eight independent variables included in the binary model demonstrated statistical significance in relation to the choice of adopting digital technologies as information sources, which is access to extension services. This variable was significant for adopting the internet, YouTube and the Farmer's Weekly website. In contrast, variables such as farming experience, type of farm, government support, gender and educational level had no statistical significance relative to the adoption of digital technologies.

5.3.2.1 Internet

Accessing extension services had a 10% statistical significance and positive coefficients, which means this variable positively affected the likelihood of adopting the Internet as an information source. This finding also shows that the probability of $y = 1$ related to access to extension services increases by 85% while all the other factors remain constant. While this finding agrees with that of Oyetunde-Usman *et al*. (2021), who noted that farmers with access to extension services are more likely to adopt digital technologies due to the awareness of these services, it contrasts with Miine *et al.* (2023), who reported a negative correlation between accessing extension services and adoption of digital solutions. Farming years, type of farm, government support, age, gender and level of education had positive coefficients, implying that the average marginal effects of probability $y = 1$ increase by 49%, 49%, 76%, 92%, 39%, and 99% respectively, while all the

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other factors remain constant. This finding corroborates that of Bese *et al.* (2021) that greater farming experience increases the probability of adopting new technologies in the agricultural industry. The ownership of farming land variable had a negative coefficient, which implies a negative effect on the likelihood of adopting the Internet as an information source. This depicts that this variable does not affect the likelihood of adopting the Internet as an information source.

5.3.2.2 YouTube

Access to extension services was statistically significant at the 10% level and had a positive coefficient in relation to the adoption of YouTube as an information source. The anticipated difference in probability of $y = 1$ related to access to extension services increases by 87.7%. Farming years, government support, age, gender and level of education also had positive coefficients which means the anticipated difference in probability of $y = 1$ related to farming skills increases by 50.4%, 60.9%, 77.3%, 60.1%, 99.8% respectively. At the same time, all the other factors remain constant. Schwering, Bergmann and Sonntag (2022) state that a farmer's educational level influences their openness to adopt digital technologies, which is consistent with the findings of this study. However, the type of farm and ownership of farming land had negative coefficients, indicating no correlation with the adoption of YouTube as an information source. Kernecker *et al.* (2020) posited that the type of commodity farmed influences adoption, reporting that crop farmers, compared to livestock farmers, are more likely to adopt digital technologies.

5.3.2.3 Farmers weekly website

Access to extension services has a 5% statistical significance and a positive coefficient, implying that this variable has a positive correlation to the dependent variable. This is an indication that the average marginal effect on the probability of $y = 1$ associated with this variable increases by 91.2% while all the other factors remain constant. In line with this, Hoang and Tran (2023) report that access to extension services had a statistical significance to adopting digital technologies and conclude that farmers who have access and contact with extension personnel are more likely to adopt digital technologies. The type of farm, age, gender and ownership of farming land variables have positive coefficients. This indicates that the average marginal effect on the probability of $y = 1$ associated with these variables increases by 55.9%, 61.7%, 78.8% and 73%, respectively. This means there is a positive correlation between the age of the farmer, gender of the farmer, type of

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farm, farmers' ownership of farming land and adoption of the Farmer's Weekly website as a source of information for farming activities. Farming years, government support and level of education have negative coefficients, which means that these variables have a negative correlation with adopting this digital technology as an information source. This finding contradicts mainstream literature, which outlines that farmers' demographics and farm/household characteristics, such as educational level and farming experience, influence farmers' adoption of digital technologies (Barnes *et al*., 2019; Pfeiffer *et al*., 2021; Marescotti *et al*., 2021; Ammann, Walter, and El Benni, 2022; Gyawali, Paudel and Jean, 2023)

5.3.2.4 Farming solutions app

The independent variables farming years, government support, access to extension, age, gender, ownership of farming land and level of education have positive coefficients. However, none of these independent variables are not statistically significant to the dependent variable. This result contradicts that of Sikwela (2013), who states that the more educated the farmer is, the more likely they are to adopt advancements that improve their farming activities. Furthermore, it contradicts Ammann *et al.* (2022) report stating that the gender of the farmers influences technology adoption by further noting that male farmers in Switzerland were more commonly adopters of digital technologies. In line with this study, Ammann *et al.'s* (2022) study revealed that age as an independent variable did not affect the adoption of digital technologies, which contrasts with this study. The independent variable, the type of farm, has a negative coefficient, which indicates no correlation with the dependent variable.

5.3.2.5 GPS

None of the independent variables had a statistical significance relative to the dependent variable. The gender of the farmer, farming years, type of farm, government support, and level of education had negative coefficients, which indicates that these variables do not correlate with the adoption of GPS. Access to extension services has a positive coefficient, which suggests that the average marginal effect on the probability of $y = 1$ relating to the farmer's level of education increases by 79.4%. This result is in line with that of Sikwela (2013) that the more educated the farmer is, the more likely they are to adopt advancements that improve their farming activities. The age variable had a positive coefficient which means a positive correlation with the adoption of GPS and an average marginal effect on the probability of $y = 1$ relative to the farmer's age increasing by

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96.3%. Ownership of farming land had positive coefficients and correlation to the dependent variable, with an average marginal effect on the probability of $y = 1$ increasing by 84.7% while all the other factors remain constant.

5.4 Differences in agricultural incomes between adopting and non-adopting farmers

This section assesses the difference between agricultural incomes of adopting and non-adopting farmers using an independent t-test. The results of this test are presented in Table 5.4 and Table 5.5.

Table 5.4.1: Means of adopting and non-adopting groups in relation to agricultural income

	N	Mean	Std. deviation	Std. error mean
Agricultural income (R/A)				
Yes	25	1.16	.473	.095
No	59	1.22	.559	.073

Source: Field survey (2023)

Table 5.4 displays agricultural income distribution between adopting and non-adopting farmers. The mean income for the group that adopted digital technologies is 1.16, while for the non-adopting group, it is slightly higher at 1.22. The difference in the means is considerably small, with the number of adopting groups being considered average compared to the non-adopting group. Despite the low adoption rates reported in the literature (Nyaga *et al.* 2021; Abdulai, *et al.*, 2023), this finding indicates that more and more smallholder farmers are adopting digital technologies as information sources. Baumüller and Kah (2019) and Ndhlovu (2020) attribute this acceleration to the COVID-19 pandemic, which restricted physical interactions and climate change.

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Table 5.4.2: Independent samples test

	Levene's test for equality of variances				t-test for equality of means		
	f	**sig.**	**t**	**df**	**sig.**	**Mean dif**	**Std. error dif**
Agricultural income (R/A)							
Equal variances assumed	.753	.388	-.472	82	.638	-.060	.128
Equal variances not assumed			-.506	53.178	.615	-.060	.119

Source: Field survey (2023)

The difference in the means indicates a variance between the adopting and non-adopting groups. Levene's test for equality of variances indicated that equal variances are assumed, with a *P* value of 0,388 which is greater than the significance level of 0.05. Therefore, the null hypothesis that the means of adopters and non-adopters are equal is accepted as there is no statistical difference between the means of the two groups.

Table 5.4.2 shows that non-adopters have a higher mean relative to the distribution of agricultural income. The null hypothesis suggests that this variance was by chance and not a reflection of the analysed sample size. This finding addresses the fourth objective, which shows no difference on agricultural incomes of smallholder farmers that have adopted digital technologies as information sources and those who did not. This finding aligns with Hoang and Tran (2023), who reported that smallholder farmers perceived a lack of real-life depiction of economic benefits from digital technologies, which would be reflected in increase in agricultural income/productivity. Essentially, this states that smallholder farmers are still determining the economic benefits derived from the incorporation of digital technologies into their farming activities, which could make the adoption of these technologies a financial liability.

This study contradicts the findings of a study in the Eastern Cape by Mdoda *et al.* (2023), where the adoption of information sources from digital devices such as mobile phones increased agricultural productivity measured by income. In line with this, Evangelista *et al*. (2014) state that the utilisation of ICT tools and digitisation is associated with enormous economic impacts such as increased productivity, generation of employment and market participation.

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5.5 Chapter Summary

This chapter presented empirical findings to address the following key objectives: assess smallholder perceptions of digital technologies as sources of information for farming activities, determine the adoption of digital technologies and the effect of smallholder farmer characteristics on adoption, and assess agricultural income of adopting and non-adopting farmers. In summary, the empirical results presented in this chapter illustrate a nuanced view of smallholder farmers' engagement with digital technologies as information sources. While there is a general awareness and recognition of the potential benefits of these technologies, factors such as complexity, cost, and access barriers significantly hinder widespread adoption.

The focus group discussions underscored the importance of staying informed through various channels, emphasising the need for timely and accessible agricultural information. Despite the limited adoption rates and the non-significant impact on agricultural income, the findings suggest a latent openness and potential for future adoption, provided the challenges identified can be effectively addressed. Understanding these dynamics is crucial for designing interventions that can enhance the adoption and effective use of digital technologies among smallholder farmers, with the aim of improving their productivity and livelihoods.

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CHAPTER 6: SUMMARY AND CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

6.1 Introduction

This section provides a comprehensive summary of all the chapters of this thesis presents deduced conclusions, states limitations and offers recommendations. The study, employing a mixed-method research approach, aimed to provide empirical evidence on the adoption of digital technologies and their impact on agricultural income, as well as insights into farmers' perceptions of these technologies.

6.2 Summary of key findings

The data collected was analysed using descriptive statistics—frequencies, means, percentages and standard deviations—to deduce farmer characteristics and address the study's first objective. Smallholder farming in these regions is predominantly female (56%), with middle-aged (35-45) farmers, primarily crop farmers and a significant proportion with no income (60.9%). Assessment of farmers' perceptions of digital technology was successfully implemented using Likert-scale questionnaires and focus group discussions to gather the relevant data. The scale ranged from 1 being "Strongly agree", 2, "agree", 3, "Neutral" 4 ", Disagree", to 5 beings "Strongly disagree". The results showed that 27% of farmers disagreed, and a further 20.5% strongly disagreed that digital technologies are complicated to use. On the economic aspect, smallholder farmers perceived digital technologies as costly (37.7% strongly agreed, 19.5% agreed). However, these technologies were perceived as easy to use, accessible, and reliable and time-efficient.

The third objective determined the effect of farmer characteristics on the adoption of digital technologies. The data was gathered using questionnaires and analysed using percentages and binary logistic regression initiated by a chi-square test to determine the statistical significance between the two variables. The adoption of digital technology was generally low among the farmers. The most adopted technology was the internet, followed by YouTube. The GPS had the lowest adoption rate at only 4%. Among the farmer characteristics modelled as independent variables, only age, access to extension services and educational level had a statistical significance on the adoption of the digital technologies, with a higher likelihood of adoption associated with these variables.

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Finally, the impact of digital technology on agricultural income was assessed using an independent t-test. The two groups used on this analysis were the adopters and non-adopters. There was a difference in the means of the two groups, however, equal variances were assumed and the analysis revealed that digital technologies have no impact on agricultural income.

6.3 Conclusions

This section presents the conclusions drawn from the quantitative and qualitative analysis methods used in this study. The descriptive statistics reveal that the farmers in the regions of the City of Tshwane municipality were predominantly female, considered to be middle aged and had some sort of formal education. The most common activity was crop farming, with household members being the primary source of labour. This study explored access to extension services and technology use, which were factors used to further assess the adoption trends for digital technologies. Only 38% of famers had access to extension services, with the majority (49.1%) citing difficulties in reaching extension officers and their offices as a primary reason for limited access. These farmers own and have access smartphones which positions them well for the adoption of digital technologies. Furthermore, 48.9% of the farmers are aware that the digital technology YouTube can be used to acquire farming information. A large proportion of the farmers stated that other farmers, extension officers and digital technologies were their preferred source of information, which, despite the low adoption levels, depicts that more and more farmers are not only open to adopting these technologies, but those who have adopted them prefer using them to acquire farming information

The empirical results show that adoption of the various technologies is still considerably low with the most commonly adopted technology being the internet (web pages) at 38%, followed by YouTube at 24%. The overall difference in the mean value of farmers that have adopted digital technologies and non-adopters is considerably small with the number of the adopting group being considered average when compared to the non-adopting group. This means that despite the low adoption rates, more and more smallholder farmers are adopting digital technologies as information sources. The binary regression depicted that access to extension services was the only socio-economic factor that was statistically significant to the adoption of the internet (web pages), YouTube and Farmer's Weekly website. This thesis concludes that there is no significant

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difference in the agricultural income of farmers that have adopted digital technologies and farmers that have not adopted any digital technology as information sources.

6.4 Limitations

The sample size of 117 smallholder farmers used in this research study is relatively small compared to the total population of smallholder farmers in the regions. Consequently, the findings of this study do not represent the broader smallholder farming population. Additionally, this research received no funding which constrained the study, affecting the sample size and the completion timeline.

6.5 Recommendations and policy implications

This study offers several recommendations and policy implications based on its explanatory and empirical findings. The following suggestions aim to enhance adoption of digital technologies and potentially improve agricultural productivity for smallholder farmers.

6.5.1 Recommendations for smallholder farmers and agricultural stakeholders

- Partnership with tech companies and incentives/subsidiaries should be prioritised to foster reduced costs, ensure affordability, and increase accessibility of these technologies.
- "Other farmers" were a prominent information source among the farmers. Because of this, peer-to-peer learning should be encouraged so that farmers that are proficient in utilising digital technologies to acquire and disseminate farming information can share their knowledge with other farmers.
- Access to extension services was statistically significant in the adoption of digital technologies; this study recommends that extension officers servicing areas in the City of Tshwane should promote the use of digital technologies to farmers, both those who are aware and those who are unaware of these technologies in a way that is accessible and easy to understand, in order to bridge the gap in information asymmetries.

6.5.2 Policy implications for government and agricultural stakeholders

- Supportive Policy Framework: Policies that support and promote the integration of digital technology into smallholder agriculture should be implemented to prioritise the improvement of digital technology infrastructure, promote digital literacy and provide

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financial support for technology adoption through subsidies, grants and fostering smallholder farmer's access to credit facilities.

- Impact monitoring and evaluation: Evaluation of digital technology adoption on agricultural productivity and income should be promoted. Data should be gathered from these technologies by government research agencies and be used to inform policy decisions that address challenges encountered specifically by smallholder farmers.
- Public-Private sector partnerships and community engagement: Collaborative initiatives between the public and private sectors can ensure the advancement and deployment of digital technologies into smallholder agriculture. Formation of farmer groups and cooperatives that can collectively invest in digital technologies and share resources and knowledge should be encouraged.

By implementing these recommendations and policy implications, stakeholders in the agricultural sector can create an enabling environment that fosters the adoption of digital technologies among smallholder farmers. This, in turn, can enhance their productivity, improve access to markets, and ultimately improve their agricultural income and livelihoods.

6.6 Areas for further research

The empirical findings presented in this study should be used as a foundation to reassess and guide future research in similar disciplines and regions to help deepen understanding and address gaps in the existing literature. Potential areas for further research include:

- Comparative studies between regions reveal regional differences in adoption rates and barriers, which can help tailor interventions to specific contexts.
- Longitudinal studies track changes in technology adoption over time, providing insights into how perceptions and adoption rates evolve. This could be valuable for understanding the long-term effectiveness of digital interventions and the factors influencing sustained use.

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APPENDICES

This is a questionnaire designed for data collection for the research project: Farmers Perceptions and adoption of digital technologies as information sources for farming activities in Tshwane, South Africa.

By Mogashane Chantelle (083 583 1019, chantellemogashane2@gmail.com)
Under the supervision of Dr. O Loki

Take note of the following:

1. Participation is voluntary and that you can choose not to answer certain questions.
2. Only tick the box with an applicable answer

Interview no	
Region	
Date	

Section A: Demographic Characteristics of smallholder farmers

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1. Age group: 18-25 ☐ 26-35 ☐ 36-45 ☐ 46- 55 ☐ 56+ ☐
2. Ethnicity:______________
3. Gender: Male ☐ Female ☐
4. Marital status:__________
5. How long have you been farming for (Years)? ____________________
6. Are you a full time or part time farmer?______________
7. Household size___________________________
8. Do you have any external sources of income: Yes ☐ No ☐
9. Please indicate the highest level of education you have achieved:

No formal education ☐ Primary ☐ Secondary ☐ Tertiary ☐

Section B: Farm Characteristics

1. What is your Farm size/ production land?__________________
2. Do you own the land you farm on? Yes ☐ No ☐
3. If No to above question then how did you acquire the land?

Bought		Lease		Renting		Communal		Inherited		Other (Specify)……….

4. Type of farm? Crop farm ☐ Livestock farm ☐ mixed farm ☐
5. Do you farm annually or seasonally? _______________
6. What do you farm (Specific commodities)?____

____

7. What is your main reason for farming?

Selling		Household consumption		Both	

Other (Specify____

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8. What is your annual Agricultural Income (R)?

>50 000		50 000-100 000		100 000-150 000		150 000-200 000		200 000-250 000		<250 000

7. What challenges do you face?

Access to markets		Finances		Farming support and training	

Others (Specify) ____

____

Section C: Extension services

1. Do you receive any support from the government in your farming activities?

Yes ☐	No ☐

2. If the answer above is yes, what support do you get?

Finances		Advisory services		Training		Resources	

3. Are you aware that there are extension services for your farming information needs?

Yes ☐ No ☐

4. Do you have access to these extension services?

Yes ☐	No ☐

5. If the answer above is no, then why do you not have access to these services?

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Extension offices are far		I don't know how to reach extension officers		Extension officers are hard to reach	

6. How often do extension officers visit you?

Weekly		Bi-weekly		Monthly		Annually		Other (specify)	

7. Are you satisfied with the frequency of these visits?

Yes ☐	No ☐

8. Are the extension visits helpful in sharing information related to farming activities?

Yes ☐	No ☐

9. What kind of farming information do you get from extension officers?

____

____

____

____

10. Are you satisfied with the information you get from extension officers?

Yes ☐	No ☐

11. Is the information helpful in your farming activities?

Yes ☐

No ☐

12. Can you reach extension officers for questions related to your farming activities?

Yes ☐

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No ☐

Sometimes ☐

13. If no to the above question then why?

They take time to respond ☐

They never respond ☐

They promise to get back/visit with answers but never do ☐

14. Rate the quality of extension services in relation to information sharing

Very poor ☐ Poor ☐ Neutral ☐ Good ☐ Very good ☐

15. Do you think it's important to have access to reliable information for your farming activities? Please elaborate

____

____

____

16. How is the information you get from extension officers helpful?

____

____

Section D: Technology adoption and use

1. (Please choose any or all that apply)

I own a computer

I have access to a computer

I use the Internet regularly for information on farming activities

I know how to use the farmers' weekly website

I use farmers weekly to get the latest farming news

I own a smartphone

I have access to a smartphone

I know that the YouTube streaming platform can be used to acquire information on farming activities

I do not know of any digital technologies that are used as information sources for farming activities

I have a farm calculator app downloaded for crop farming information

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I use YouTube to acquire information on farming activities

I know of the farming solutions app developed by the farmer2market program

I use the farming solutions app for farming insights

I know that digital technologies provide information on farming activities

I use digital technologies as information sources for farming activities

I use GPS device to track my livestock

I do not use any digital technology for acquiring farming information

2. List all the other digital technologies you use as a source of information

____

____

____

____

3. What information about farming activities have you acquired from digital technologies?

____

____

____

4. Do you think the farming information from digital technologies is reliable?

____

5. Which information source do you prefer? Tick all that apply

Extension officers		Digital technologies		Other farmers	

6. Please explain why you prefer the above selected information source/sources

____

____

____

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7. Do you think it is important to have access to real-time farming information?

Yes ☐	No ☐

8. Please explain your answer to question 7

____

____

____

____

9. Would you say, having access to farming information helps in making informed farming decisions? Please elaborate

____

____

____

____

10. Do you ever have farming questions that you needed to consult information sources for answers? Please elaborate

____

____

____

____

____

11. On a scale of 1 to 10, Please rate the importance of accessing farming information that is delivered timeously

____

12. Do you think having easily accessible reliable and up-to date farming information improves any of your farming activities?

Yes ☐	No ☐

13. Digital technologies are better to use for record keeping than traditional methods

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Yes ☐	No ☐

Section E: Perceptions of digital technologies

Please complete the following questionnaire with specific regard to the above enquiry, by placing a CROSS in the appropriate box

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	strongly agree	agree	uncertain/ not applicable	Disagree	strongly disagree
1. Digital technologies are easy to use as information sources	☐	☐	☐	☐	☐
2. Digital technologies are easily accessible	☐	☐	☐	☐	☐
3. Using digital technologies as sources of information is time effective	☐	☐	☐	☐	☐
4. Information from digital technologies is timeous and reliable	☐	☐	☐	☐	☐
5. I think digital technologies are better sources of information than traditional sources	☐	☐	☐	☐	☐
6. I receive up-to date information from digital technologies	☐	☐	☐	☐	☐
7. The information from digital technologies is helpful	☐	☐	☐	☐	☐
8. Using digital technologies as sources of information is costly	☐	☐	☐	☐	☐
9. Information about farming activities from digital technologies is easily accessible	☐	☐	☐	☐	☐
10. Information from digital technologies help in facilitating production decisions	☐	☐	☐	☐	☐
11. Digital technologies as information sources are complicated to use	☐	☐	☐	☐	☐

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Focus group discussion guide

Thank you for agreeing to be a part of this discussion which intends to gather your opinions and views of digital technologies as information sources for varied farming activities.

1. Please note the following:

- Confidentiality is our number one priority therefore your name will not be associated to any information you give in this discussion
- Participation is voluntary and you will be allowed to withdraw from this discussion at any time
- You have to right to not answer any of the asked questions

2. Introduction

This study intends to explore smallholder farmers' perceptions and adoption of digital technologies as information sources for farming activities. The specific objectives are as follows:

1. Describe sociodemographic characteristics of smallholder farmers
2. Assess the determinants of smallholder perceptions of digital technologies as sources of information for farming activities
3. Determine smallholder farmers' adoption of digital technologies as sources of information for farming activities

3. Basic instructions for this discussion

- There is now wrong and right answer
- Every participant will be given to an opportunity to answer every question
- Participants can choose to not answer when asked a question and they can withdraw participation at any time
- Only the participants of this discussion are allowed to contribute
- Participants can have disagreeing opinions and views

4. Perception and technology adoption questions

4.1 Is there a change in the need for agricultural information now than when compared to the olden days?

4.2 How is keeping up to date with what is happening in the agricultural industry important?

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4.3 Besides radio, television and the newspapers, what other ways are smallholder farmers acquiring agricultural information?

4.4 Which farming activity requires you to stay-up to date with agricultural news and information? E.g. selling, disease and pest control, scheduling of planting and harvesting, irrigation techniques, marketing of produce, planting techniques, record keeping, soil preparation, fertiliser

4.5 What influences smallholder farmers decision of adopting or not adopting digital technologies as information sources?

4.6 Do you think you can farm successfully without accessing farming information?

4.7 What do you think is the biggest challenge when it comes to accessing markets as a smallholder farmer?

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Faculty of Natural and Agricultural Sciences
Ethics Committee
E-mail: ethics.nas@up.ac.za

17 October 2023

ETHICS SUBMISSION: LETTER OF APPROVAL

Dr O Loki
Department of Agricultural Economics Extension and Rural Development
Faculty of Natural and Agricultural Science
University of Pretoria

Reference number: NAS185/2023
Project title: Farmers perceptions and adoption of digital technologies as information sources in Tshwane

Dear Dr O Loki,

We are pleased to inform you that your submission conforms to the requirements of the Faculty of Natural and Agricultural Sciences Research Ethics Committee.

Please note the following about your ethics approval:

- Please use your reference number (NAS185/2023) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.
- Please note that ethical approval is granted for the duration of the research (e.g. Honours studies: 1 year, Masters studies: two years, and PhD studies: three years) and should be extended when the approval period lapses.
- The digital archiving of data is a requirement of the University of Pretoria. The data should be accessible in the event of an enquiry or further analysis of the data.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.
- **If Applications using GM permits:** If the GM permit expires before the end of the study, please make an amendment to the application with the new GM permit before the old one expires
- **If Applications using Animals:** NAS ethics recommendation does not imply that Animal Ethics Committee (AEC) approval is granted. The application has been pre-screened and recommended for review by the AEC. Research may not proceed until AEC approval is granted.

Post approval submissions including application for ethics extension and amendments to the approved application should be submitted online via the Ethics work centre.

We wish you the best with your research.

Yours sincerely,

Prof VJ Maharaj
Chairperson: NAS Ethics Committee

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