

How can smart technologies be applied by smallholder farmers for increased productivity and sustained livelihoods?



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Department of Information Systems
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In fulfilment of the requirements for the
Bachelor of Commerce (Full-time Masters) degree in Information Systems

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Dedication

I dedicate this thesis to my late grandfather Bangiso Booi and my father Victor Mziwamawele Booi. My grandfather was a farm worker, my father became a farm owner, today I aspire to solve agricultural problems using technology. And tomorrow, I will hand over what was given to me to future generations. I thank the Lord for all the blessings I have received and pray in abundance for a future that is yet to come.

“My grandfather used to say that once in your life you need a doctor, a lawyer, a policeman and a preacher, but every day, three times a day, you need a farmer” – Brenda Schoepp

Abstract

Problem Statement: The world population is expected to rapidly increase, raising food security concerns across the world. This will impact Africa most severely. The use of innovative farming techniques and technology has proven to accelerate the production yields and improve resilience to vulnerabilities which impact agricultural productivity. The use of smart technologies in farming is mainly present among largescale commercial farms, with minimal representation in the smallholder farming sector. On the other hand, a substantial amount of food in developing countries is produced by small scale farmers.

Research Objective: The purpose of the study is to investigate the usage of smart technologies by smallholder farmers in South Africa, and to establish how smart technology could support smallholder farmers in increasing productivity through a three-dimensional view that takes into consideration capital, labour, and land utilization. To this end, an interpretive research philosophy was adopted.

Research Design: The study collected the data using semi-structured interviews. The sample for the study constituted of 10 smallholder farmers and 12 subject matter experts within the agriculture and technology domain. To strengthen rigour within the study, the interviews were supported by documents containing viewpoints about how technology is applied in the African context and how it may be introduced and ultimately applied in the South African context. The study employed a deductive approach to theory, applying the Sustainable Livelihoods Approach (SLA) as theoretical underpinning for the study. SLA consists of a pentagon of livelihood assets: physical, social, human, natural, and financial assets. The framework was extended to include technology as an asset due to its potential to contribute to improving the livelihoods of smallholder farmers.

Findings: The study found minimal to no use of smart technologies by smallholder farmers in South Africa. The factors which limited the use of technology include PEST (Political, Environmental, Social and Technological) factors. To achieve successful usage of smart technologies, collaboration is required from government, the private sector, smallholder farmers, and communities.

Research Contribution: The study aimed to expand on the limited literature on the use of smart farming in the context of smallholder farmers in a developing country context. In addition, it contributed to extending the pentagon of livelihoods to include smart technologies with respect to smallholder farmer livelihoods. Therefore, the findings of this study contributed to the broader body of knowledge. In addition, insights from this study may be gained by the Department of Agriculture, Forestry and Fisheries, smallholder farmers, agricultural entrepreneurs and technologists in formulate developmental strategies and policies to improve the productivity of smallholder farmers as well as their livelihoods as a strategy to increase their contribution to food security in Africa while alleviating household poverty.

Keywords: smart farming, smallholder farmers, small-scale farmers. precision farming, sustainable livelihoods approach

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List of acronyms

AFASA	African Farmers Association of South Africa
AGRITECH	Agriculture Technologies
AI	Artificial Intelligence
Co-ops	Co-operatives
COVID-19	Coronavirus disease 2019
DAFF	Department of Agriculture, Forestry and Fisheries
HA	Hectare
ICT	Information and Communication Technologies
IoT	Internet of Things
NYDA	National Youth Development Association
PEST	Political, Environmental, Social, Technological
RESP	Respondents
RFID	Radio Frequency Identification
SAOSA	South African Organic Sector Association
SLA	Sustainable Livelihoods Approach
SUBEXPERT	Subject Matter Expert

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Chapter 1: Introduction

The study explored the use of smart technologies by smallholder farmers in South Africa. The study analysed smallholder farmer smart technology usage. Further, the study sought expert views to understand the potential impact of smart technologies on smallholder farmer productivity. This chapter presents the background of the study, setting of the study, the research problem, research purpose, and research questions, followed by the overview of ensuing chapters.

This chapter is organised as follows: Section 1.1 presents the background of the study and Section 1.2 discusses the setting of the study. Section 1.3 explains the problem statement, Section 1.4 describes the research purpose and Section 1.5 covers the research questions for the study. Section 1.6 outlines the research approach and Section 1.7 describes the study rationale and significance of the study. The chapter concludes with a summary of overview of the rest of the thesis chapters in Section 1.8.

1.1. Background of the study

The world population is expected to surpass 9 billion people by 2050, raising food security concerns globally (Clover, 2003; Sundmaeker, Verdouw, Wolfert, & Freire, 2016; FOA, 2018; Rusere, Mkuhlani, Crespo, & Dicks, 2019). The African continent is the most severely impacted by food insecurity in comparison to other developing countries (Sibhatu & Qaim, 2017). In this context food security is defined as “when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life “ (FOA, 2006, p. 1). Sustainable food security is a function of several physical, social, economic, and political factors (Chang & Zepeda, 2001). On the demand side factors are population growth, demographic shifts, increased urbanisation, and income growth. On the supply side, technological development and agricultural productivity have a significant impact on sustainable food security.

The use of smart technology in agriculture is commonly referred to as “Smart Farming”. Smart farming represents the use of technologies such as, Information and Communication Technologies (ICT’s), Cloud Computing, Robotics, Internet of Things (IoT) devices and Artificial Intelligence (AI) in agricultural activities (Jayaraman, Yavar, Georgakopoulos, Morshed, & Zaslavsky, 2016; Sundmaeker, Verdouw, Wolfert, & Freire, 2016; Wolfert, Ge, Verdouw, & Bogaardt, 2017). The farming sector is undergoing a 4th industrial revolution (4IR), where IoT devices are used by farmers to track animal welfare, provide digital alerts about operational activities, and accurately predict weather conditions, to increase the efficiency of the agricultural value chain and improve overall food quality and nutrition (Gathorne-Hardy, 2016; Wolfert et al., 2017). Using smart technology, farmers can increase their aggregate production, quality, and output with limited risks, effort, and within the parameters of limited resources (Doss, 2017). The growth in the use of technology-based farming solutions in many parts of Africa has resulted in observed growth in agricultural productivity per hectare, higher yield output in several crops (including maize and cotton), and reduction in market information asymmetry (Schneider & Gugerty, 2011).

As smallholder farmers produce 70-80% of the world's food (Ricciardi, Ramankutty, Mehrabi, & Jarvis, 2018), effective use of smart technologies by this segment of the agricultural sector is one of the key strategies to achieving food security and enhance productivity (Mwangi & Kariuk, 2015; Jere & Maharaj, 2017). Productivity is measured by analysing the relationship between the inputs and outputs of goods produced (Doss, 2017). Agricultural productivity emphasises the efficient use of the factors of production, which include technology and other physical factors, to produce greater outputs (Dharmasiri, 2009). The overall productivity of smallholder farmers is low.

1.2. Setting of the study

Agricultural productivity is generally lower for smallholder farmers in sub-Saharan African countries (Gebre, Isoda, Rahut, Amekawa, & Nomura, 2019). The primary focus of this study, therefore, is the productivity of South African smallholder farmers within the broader agricultural sector. The infrastructure of South Africa's agricultural sector is one characterised by a dual, parallel system of capital-intensive commercial farmers alongside resource-poor small-scale (smallholder and subsistence) farmers (Kirsten & van Zyl, 1998; Pienaar & Traub, 2015; Rusere, Mkuhlani, Crespo, & Dicks, 2019). Commercial farmers dominate the agricultural sector and contribute immensely to agricultural production, while smallholder and subsistence farmers remain excluded in the modern agricultural value chains (Loeper, Musango, Brent, & Drimie, 2016). Commercial farmers effectively use smart technologies in their agricultural activities, which enables large production yields and increased productivity (Rose & Chilvers, 2018). In contrast, smallholder farmers still use traditional methods of production (Mwangi & Kariuk, 2015). The South African government seeks to ameliorate the lack of smart technology use by smallholder farmers; the government is promoting "smart" technology used in agriculture for future solutions to individual farmers (Elsenburg, 2016). In addition, a cardinal aim of the National Development Plan for 2030 is to invest in new agricultural technologies for commercial farmers and develop smallholder and subsistence farmer adoption and support strategies for these technologies (National Planning Commission, 2019).

1.3. Problem statement

Smallholder farmers play an important role in eradicating poverty, economic growth, and increasing food security (Pienaar & Traub, 2015; Awotide, Karimov, & Diagne, 2016). However, smallholder farmers are characteristically poor and lack social, political, and technical resources (DAFF, 2012; FOA, 2018). The lack of resources results in the exclusion of smallholder farmers from mainstream agricultural value chains and increases their exposure to vulnerabilities, which adversely impact their productivity levels.

Smart technologies have the potential to enable exponential increase in productivity of smallholder farmers by reducing the impact of vulnerabilities and environmental shocks (Rose & Chilvers, 2018). The benefits of using smart farming technologies include accurate and prompt response to decisions, reduction of production costs, and increased efficiency of yields in the primary stage of the agricultural supply chain, and their contribution to productivity is documented in literature (Jayaraman et al., 2016, Bach & Mauser, 2018; Zambon, Cecchini, Egidi, Saporito, & Colantoni, 2019). However,

most studies emphasise land productivity. However, there is a dearth of literature focusing on a three-dimensional view of agricultural productivity at the primary level, which includes land, capital, and labour productivity (Dharmasiri, 2009; Shiferaw et al., 2014; Thierfelder, Chivenge, Mupangwa, Rosenstock, Lamanna, & Eyre, 2017; Muktar, Man, Saleh, & Daneji, 2018; Yang, Liu, Lun, Min, Zhang, & Li, 2018).

1.4. Research purpose

The purpose of this study is to understand the use of smart technologies by smallholder farmers in South Africa, and how smart technology could support smallholder farmers in increasing productivity through a three-dimensional view. The study aims to contribute to the body of knowledge on the outcomes of smart technologies (Smart Farming) usage on the livelihoods of smallholder farmers. The insights on the application of the Sustainable Livelihoods Approach (SLA) in the context of Smart Farming for smallholders will provide insights on its influence on productivity. The study could assist policymakers and implementers in how to design and implement smart technologies strategies for the effective use of smallholder farmers as a strategy to improve their productivity. The Department of Agriculture, smallholder farmers, agri-entrepreneurs, and technologists may gain insight into producing strategies and policies to improve smallholder livelihoods and their contribution to achieving food security in South Africa.

1.5. Research questions

This study is guided by the research question:

- How can smart technologies be applied by smallholder farmers for increased productivity and sustained livelihoods?

Sub Questions:

- What factors influence South African smallholder farmers' usage of smart technologies to increase productivity?
- How can smallholder farmers in South Africa use Smart Farming technologies to build resilience against vulnerabilities?

1.6. Research approach

The study was conducted using an interpretivist approach and was guided by the Sustainable Livelihoods Approach to assess patterns of vulnerability contexts. These include a view on the pentagon of livelihood assets, transforming structures, livelihood strategies, and outcomes in relation to smallholder farmer perspectives. The study was qualitative and collected data using telephonic mediated semi-structured interviews. Purposive sampling and snowball techniques were applied to identify a sample. The sample for the study constituted of 10 smallholder farmers and 12 subject matter experts within the agriculture and technology domain. Traditional intents for qualitative research studies are to provide

in depth findings to a subject matter for a contextual setting rather than generalizing findings for an entire population (Carminati, 2018). Although it is possible to generalise findings in qualitative studies, this paper seeks to provide insight on the researchers understanding of the sample and collection of data in the given context.

1.7. Rationale and significance of the study

There is a plethora of studies (Tambo & Abdoulaye, 2013; Singh, Urquhart, & Kituyi, 2016; Jha, Pinsonneault, & Dubé, 2016) in the Information Systems (IS) discipline on smallholder farmer usage of technology. However, many of these studies focus on the socioeconomic and information access benefits of ICTs. There are also studies that look at the application of smart technologies about increasing productivity and increasing livelihood resilience, with heavy focus on land productivity with respect to external factors, such as climate changes (Sullivan, Mumba, Hachigonta, Connolly, & Sibanda, 2013; Thierfelder et al., 2017).

However, this study diverted from this approach and proposed an assessment of the influence of smart farming technologies on the productivity of smallholder farmers in South Africa. This included assessing a three-dimensional measurement of productivity, which includes land, labour, and capital productivity (Dharmasiri, 2009).

The pentagon of livelihood assets to visually represent the information on an individual's assets is well documented in literature (UNDP, 2017; Makoza & Chigona, 2010; Norton & Foster, 2001). However, there is a lack of representation of smart technologies opportunities and uses in improving individual livelihoods (Dorward, Poole, Morrison, Kydd, & Urey, 2003). The research attempted to conceptualise the livelihoods approach and to include smart technology as an asset to enhance smallholder farmers' productivity, thus leading to improved resilience to vulnerabilities and enhanced living standards. This study contributed to extending the pentagon of livelihoods to include smart technologies in respect of smallholder farmer livelihoods.

1.8 Overview of chapters

This section outlines the structure of the ensuing chapters of the dissertation.

Chapter 2: Literature review explores the literature review, which encapsulates an overview of the agricultural sector in South Africa, describes smallholder farmers in the global and South African contexts, explains some of the challenges smallholder farmers are confronted by, covers the three-dimensional definition of agricultural productivity, and finally, discusses the fourth industrial revolution in agriculture, smart technologies, and smart farming.

Chapter 3: Theoretical framework presents the theoretical framework, assesses the suitability of framework of the study, explains the Sustainable Livelihoods Approach, and illustrates the application of the Sustainable Livelihoods Approach for smallholder farmers to enable increased productivity using Smart Farming.

Chapter 4: Research methodology represents the research methodology used in this study. The chapter describes the research philosophy, approach to theory, sampling technique, data collection, research instruments, data analysis, research timeframe, ethics and confidentiality, research limitations, recording device, data collection process, and observations.

Chapter 5: Findings and analysis collates the findings and analysis by interpreting expert opinions on technology trends in agriculture and possible technology use by smallholder farmers. The chapter also describes the technologies which are available on the market as well as perceived influence of technology on productivity and factors which farmers should consider when adopting smart technology. The chapter also looked into the rate of technology usage in South Africa, factors impacting current rates of adoption, and recommendations for introducing smart technologies to farmers. The chapter applied the Sustainable Livelihoods Approach in the context of smallholder farmers in South Africa.

Chapter 6: Discussion, conclusion, and recommendations covers the discussion, conclusion, and recommendations of the study. The chapter explains the factors that influence smallholder farmers in the usage of smart technologies to increase productivity; how smallholder farmers can use Smart Farming technologies to identify, mitigate and prevent vulnerabilities; how smallholder farmers define productivity; and recommendations for further actions to execute smart technologies for smallholders.

Chapter 2: Literature review

This chapter presents the literature review which is intended to provide the background and justification of the research undertaken (Arshed & Danson, 2015). This chapter is organised as follows: Section 2.1 The South African apartheid history and land distribution. Section 2.2 discusses agriculture in South Africa, Section 2.3 presents the universal challenges smallholder farmers face. Section 2.4 discusses agricultural productivity while 2.5 outlines 4IR and smart technologies. The chapter concludes with a summary of the literature review in Section 2.6

2.1 The South African apartheid history and land distribution

The apartheid system was an institutional racial system orchestrated by a white colonial government that aimed to segregate white and non-white South Africans through geographic, systematic, and judicial policies and laws (Coombes, 2003; Rospabé & Selod, 2006). The system coordinated the disempowerment and enforcement of socio-economic injustice predominantly onto the indigenous African ethnic groups in South Africa (Modise & Mtshiselwa, 2013). Two of the most significant examples used to orchestrate this segregation were the Land Act of 1913 and the Glen Gray Act of 1894 which led to mass land dispossession, the weakening of the traditional leaders' governance structures, and an increased cheap black labour force (Thornton, 2009; Simelane, 2018). When these policies were enacted, blacks were forcibly moved to what are now called "former homelands" or "communal land areas", which are situated mainly in the Eastern Cape and KwaZulu-Natal (World Bank, 2018). Communal land may be owned by extended families, clans or communities that may be ancestrally related and may be administered by a leader who may demarcate portions of land to committee and non-committee members to be used for a given period (Gyasi, 1994). In South Africa, communal land was consolidated by the apartheid law which implemented the Black Authorities Act that embedded control in traditional leaders and customary law (Orleyn & Krause, 2017).

The apartheid regime ended in the early 1990's and marked the doorway to the first democratic elections which resulted in an induction of a majority black government led by the African National Congress (ANC) in 1994. However, the impact of apartheid policies has left a trail of inequality in the South African landscape in education, health, agriculture, and basic services (Akinyemi, 2019). South Africa is classified as one of the most unequal countries worldwide, with land being one of the key components in discussions of wealth (Stats SA, 2019). Inequality in agricultural land distribution in the country is still one of the heated conversations in the political landscape, with the bulk of land being owned by the minority white population of South Africa (Akinyemi, 2019).

Issues of food security and poverty are still prevalent in South Africa, and the former homelands were identified to suffer from high poverty and unemployment levels (Thornton, 2009). In 2017 black-headed households had the highest percentage of households with inadequate access to food at 17.9%, followed by coloured households with 13.5% (Stats SA, 2017). There were 8.3% coloured households that were reported to have the severely inadequate access to food. White and Indian headed households reported to have the largest proportion of adequate access to food sitting at 96.6%

and 93.2% respectively (Stats SA, 2017). The distribution of households by population group of the household head and level of adequacy in accessing food is summarised in Figure 2.1.

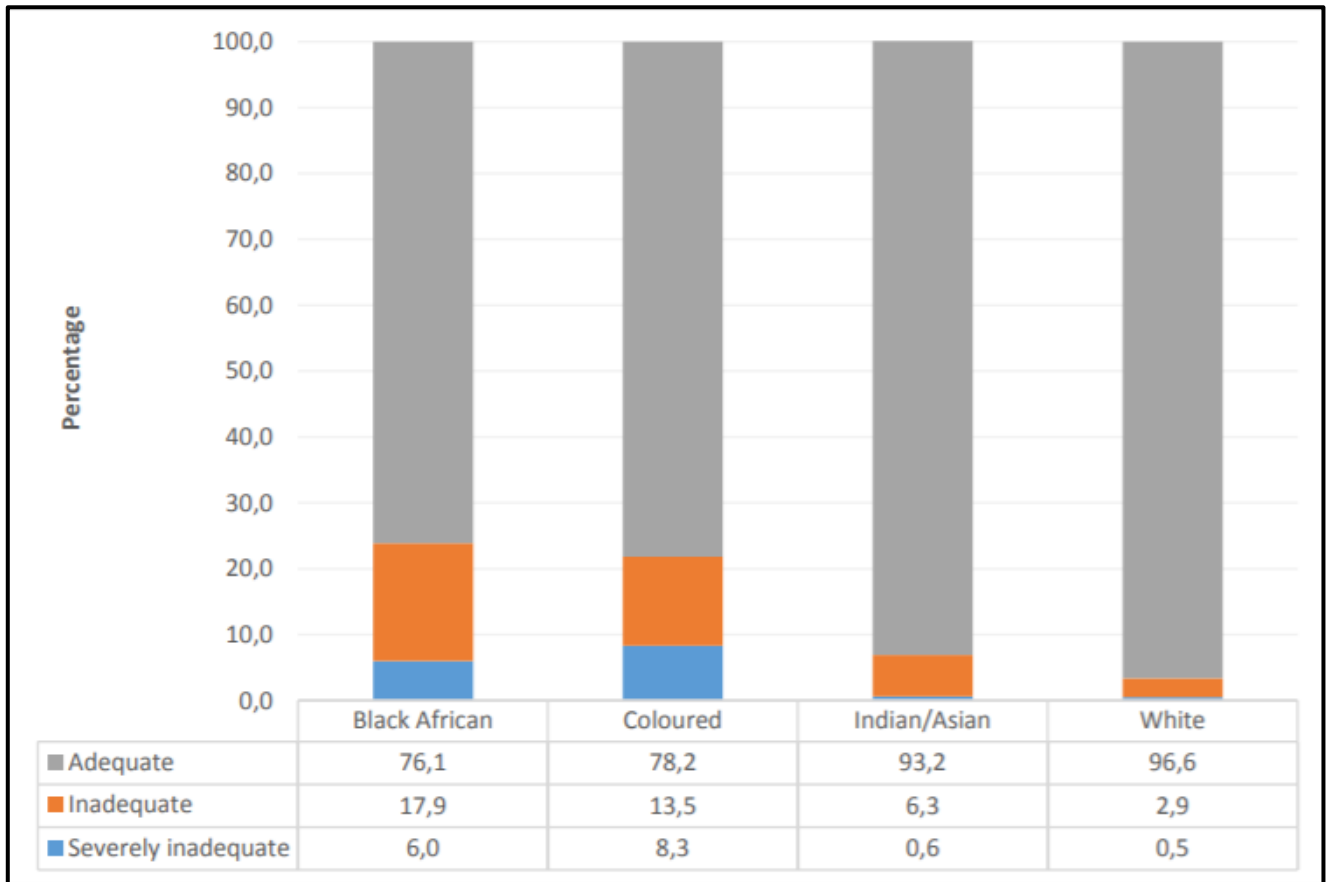


Figure 2.1: Distribution of households by population group of the household head and level of adequacy in accessing food (Stats SA, 2017)

2.2 Agriculture in South Africa

The South African agricultural sector can be broadly categorised into two primary sectors: commercial farming, which is highly capital intensive, and small-scale subsistence farming dominated mostly by rural households in the former homelands (Karaan & Vink, 2014; Zantsi, Greyling, & Vink, 2018). South Africa’s large-scale commercial sector is comprised of approximately 30 000 commercial farmers distributed across the nine provinces. The smallholder sector comprises more than 2 million farmers, primarily concentrated in the provinces of KwaZulu-Natal, Eastern Cape, and Limpopo (Wolfgang, Musango, Brent, & Drimie, 2016). The South African dual economy is mainly dominated by commercial farmers, with smallholder farmers contributing very little to the overall production of commodities (Pienaar & Traub, 2015).

“This agrarian structure reflects South Africa’s colonial and Apartheid legacy of generous state support for white farmers, alongside the historical dispossession of black producers” (Neves, 2020, p. 1)

In addition, unlike smallholder farmers, commercial farmers extend their agricultural activities beyond primary production (i.e., agro-processing), which may be deemed more profitable (Neves, 2020). While the number and structure of commercial farming are clear, the same cannot be said about smallholder farming, which is complex, and where one can find sub-classes within the umbrella of small-scale farmers (Pienaar & Traub, 2015; Aliber & Hall, 2012). These groups include:

- **subsistence farmers:** who farm mainly for household consumption.
- **commercial smallholders:** whose operations are driven by profit margins, on privately owned land

Between these two types of smallholding/small-scale farming is the emerging farmers class which aims to attain an additional source of income, and mostly on communal land (Zambon, et al., 2019). However, the semi-commercial smallholders still farming on communal land can be referred to as potential emerging farmers, as the term “emerging farmers” is mostly used to describe beneficiaries of land reform (Gwiriri, Bennett, Mapiye, & Burbi, 2019).

2.2.1 Farmer support systems in South Africa

Post-apartheid the South African government has made strides in redistributing land through legislation to address poverty and inequality in former homelands (Thornton, 2009; Sekatane & Sekhampu, 2014; Kepe & Hall, 2016). In addition to legislative policies, government also provides extension services and administers programmes that facilitate infrastructure development and support, land acquisition and post-transfer support to farmers, as summarised in Table 2.1.

Table 2.1: Smallholder farmer programme and support systems provided by DAFF (Satgé, 2020)

Support system	Method of support	Examples of support systems
Programmes in former communal areas	<ul style="list-style-type: none"> • Infrastructure development and support for communal farmers 	<ul style="list-style-type: none"> • Letsema-Ilima (investment in infrastructure) • Tractor services and the “mechanisation programme” • Fetsa Tlala (food production programme)
Post transfer support for beneficiaries of land reform	<ul style="list-style-type: none"> • Post-transfer support for land reform beneficiaries • Land acquisition • Advisory services and facilitation of information access through extension services 	<ul style="list-style-type: none"> • Comprehensive Agriculture Support Programme (CASP) • Land and Agrarian Reform Project (LARP) • Linking producers to markets

DAFF, moreover, has strategic partnerships with parastatals, the private sector farmer associations, co-operatives, and financial institutions to provide support to small- and large-scale farmers (Satgé, 2020). In South Africa the Land Bank also plays a major role in the agricultural development of farmers (Mmbengwa, Ramukumba, Groenewald, & Van Schalkwyk, 2011). The Land Bank was developed in 1912 as one of the key lenders within the South African agricultural domain (Qwabe & Machethe, 2014).

2.2.2 Farmer associations and co ops

The term 'association' is defined as a group of individuals who are joined for a common objective. A cooperative or commonly referred to as 'co-op' can be defined as a type of voluntary association, with a primary objective of meeting economic, social, or cultural needs of the individuals who are part of it. Similarly, 'farmer associations' or 'farmer cooperatives' are entities formed by farmers to meet social, economic, or political objectives and goals (Igirisa, 2014; Otunomeruke, Dongs, Iweluegim, & Sunday, 2017; Lu, Wu, & Yang, 2018). Farmers join into collaborative units and use associations or cooperatives as an intermediary between farmers and government departments (Lu, Wu, & Yang, 2018).

There are distinct functions of farmer cooperatives, which include.

- Assist farmers by organising resources that contribute to agricultural development and reliant food security measures (Ngegba & Mansaray, 2016).
- A means to obtain and improve market bargaining power for farmers in respect of customer demands and farmer supply capacity; collectively farmers can ensure reliable supply of goods in relation to demand from customer's (Gardner & Lerman, 2006).

In South Africa, co-ops initially emerged in the agriculture sector with the primary focus of supporting white commercial farmers following the enactment of the Cooperatives Societies Acts of 1922 and 1939 (Nkonki-Mandleni & Anim, 2014). Today this has extended beyond focusing on commercial farmers and is leveraged in rural areas which allows for limited impact on the deterioration of rural areas and the possible exodus of individuals to urban cities in search for better livelihoods (Ngegba & Mansaray, 2016).

2.2.3 Smallholder farmers in South Africa

The definition of what constitutes smallholder farming is multivariate and characterised by a high degree of ambiguity (Aliber & Hall, 2012). Literature often uses the term "smallholder" interchangeably with terms, such as small scale, peasant, emerging, and resource-poor farmer (DAFF, 2012; Qwabe & Machethe, 2014; Pienaar & Traub, 2015). There is no unique or unambiguous way to define the term, smallholder; however, there is abundant agreement in the literature that defines smallholders based on the farm size (less than two hectares[ha] of land) and resource limitation (i.e., social, political, and technical resources) (DAFF, 2012; Lowder, Scoet, & Raney, 2016; FOA, 2018).

In the context of South Africa, the terms “farmer” and “producer” are used synonymously when referring to farmers. The *Executive Summary for the National Policy on Comprehensive Producer Development Support* report published by the Department of Agriculture Forestry and Fisheries (DAFF) and the Department of Rural Development and Land Reform (DRDLR) clearly categorises farmers into six categories, shown in Table 2.2:

Table 2.2: Farmer/Producer classification summary (DAFF, 2019)

Producers (farmers) category	Characteristics	Turnover (per annum)
Household producer (vulnerable)	<ul style="list-style-type: none"> Limited skills Vulnerability Registered as indigents 	N/A
Household producer (subsistence)	<ul style="list-style-type: none"> Household consumption Not indigents 	> R50 000
Smallholder producer	<ul style="list-style-type: none"> Income-driven venture Limited household consumption 	R50 000 – R1 000 000
Medium-scale commercial producer	<ul style="list-style-type: none"> Income-driven venture 	R1 000 001 – R10 million
Large-scale commercial producer	<ul style="list-style-type: none"> Income-driven venture 	R10 000 001 – R50 million
Mega/corporate producer	<ul style="list-style-type: none"> Income-driven venture 	> R50 million

Against this background, the focus of this study are farmers who are classified as “Smallholder Producers” who are income- and household-driven farmers with annualised turnover of R50 000 - R1 million per annum. The study also considers “Household Producers” who have income driven farming operations and turnover of < R50 000 per annum. These two categories, together with their grouping criteria, are considered as the smallholder definition for this study.

2.3 Universal challenges smallholder farmers face

Many smallholder farmers are still struggling to commercialise their farming operations, as most of their produce is still utilised as a household food source (Muricho, Manda, & Sule, 2015). Smallholder farmers globally face many challenges that hinder their ability to become commercial farmers. These are summarised in Table 2.3:

Table 2.3: Challenges faced by Smallholder Farmers

Challenges	References
High input costs	Khapayi & Celliers (2016); Dawson & Anand (2020)
Limited credit and insurance access (Financial Capital)	Chisasa & Makina,(2015); Aliber & Hall (2012); Qwabe & Machethe (2014); Loeper et al. (2016); Wolfgang, Musango, Brent, & Drimie (2016)

Limited access to markets	DAFF (2012); Qwabe & Machethe (2014); Loeper et al. (2016); Wolfgang et al. (2016)
Low efficiency and productivity	Dawson & Anand (2020)
Lack of involvement in the modern value chain	Wolfgang et al. (2016)
Many unregistered farmers, impacting their visibility to support services	Aliber & Hall (2012)
Government focus on existing relationships rather than identifying new farmers to support	Aliber & Hall (2012)
Environmental shocks (i.e., droughts and climate changes)	Rusere, Mkuhlani, Crespo, & Dicks (2019)
Poor access to market information leading to the exploitation of farmers (pricing and trading)	Mango, Zamasiya, Makate, & Kefasi (2014)
Supply of inputs (i.e., feed, electricity, water)	DAFF (2012); Rusere et al. (2019)
Inadequate access to land	Qwabe & Machethe (2014); Byela & Visser (2016)
Lack of skills	Khapayi & Celliers (2016)

Access to land (size and ownership) is, in large part, one of the major challenges faced by smallholder farmers in South Africa (Qwabe & Machethe, 2014). Land ownership is one of the drivers of inequality in South Africa, and, despite land policy efforts post 1994, a notable number of black South African farmers remain landless (Ramaila, Mahlangu, & du Toit, 2011). The lack of land ownership may also restrict farmers from gaining access to credit, which is essential for improving agricultural practices (Koirala, Mishra, & Mohany, 2016).

2.4 Agricultural productivity

Agricultural productivity emphasises the efficient use of the factors of production, which include technology, and other physical factors to produce greater outputs (Dharmasiri, 2009). The overall productivity of smallholder farmers is low, and its improvement is important to increasing farmer income potential, and meeting population demands for food (Jayaraman et al., 2016). Measuring labour productivity remains a complex process due to the out-of-date nature of labour input record-keeping processes for smallholders (Gaddis, Oseni, Palacios-Lopez, & Pieters, 2019). Dharmasiri (2009) highlighted three-dimensional measurement for agricultural productivity, which includes land, labour, and capital productivity (Doss, 2017).

- **Land productivity**, the physical output in yield per unit of land (Doss, 2017)
- **Labour productivity**, the output per unit of labour (Doss, 2017)
- **Capital productivity**, monetary investment of working capital and physical assets for output produced (Misztal, 2020)

Table 2.4 summarises the factors which limit productivity in relation to the three-faceted view.

Table 2.4: Summary of the factors limiting agricultural productivity

Productivity classification	Limiting factor
Labour productivity	<ul style="list-style-type: none"> • Environmental factors (land quality, water availability and infrastructure) • Insufficient investment in human capital (skills, literacy, and support) • Labour intensive tasks • Labour workforce demographics (ageing workforce, gender, health status) • Shortage of skilled labour and quality of inputs • Lack of technology innovation
Land productivity	<ul style="list-style-type: none"> • Weather shocks (drought, heavy rains, extreme cold etc.) • Land deterioration and soil erosion • Low quality inputs • Insufficient access to water resources (i.e., irrigation)
Capital productivity	<ul style="list-style-type: none"> • Wear and tear of inventory, machinery, and structures • Lack of financial capital and access to credit • Shocks (weather, fires, disease outbreak etc.)

2.4.1 Factors limiting labour productivity

Low levels of labour productivity remain one of the prominent barriers to achieving high yields of overall agricultural production (Shimeles, Verdier-Chouchane, & Boly, 2018). The difference in commodity type, land type availability of machinery and capital input can determine how much labour effort is required to operate a farm per hectare (Bechar & Vigneault, 2016). Land quality and ruggedness impact labour productivity because the more effort is required to work the impacted areas (Martín-Retortillo & Pinilla, 2012). This can pose a challenge for farmers who are ageing as they may be more susceptible to injury and health risks (Szabo, Apipoonanon, Pramanik, Leeson, & Singh, 2021). Older workers are more likely to be find difficulties to working long hours and would often be less productive than their younger counterparts (de Wind, van der Pas, Blatter, & van der Beek, 2016). Prolonged exposure to labour intensive conditions in farming can have long chronical health issues for employees, yielding lower productivity levels (Pérez-Ruíz, Slaughter, Fathallah, Gliever, & Miller, 2014).

In some instances, gender of farmers is also discussed to be a limitation in agricultural productivity (Zidouemba, 2020). The argument is that women face more severe constraints than men with regards to accessing resources and are more impacted by labour productivity shocks than men (Zidouemba, 2020). The shortage of labour with suitable skills in agriculture impacts productivity yields when recruiters struggle to attract and retain enough labour to operate their farms adequately (i.e., construction) (Millar & Roots, 2012). In some countries where wage compensation is low for farm workers, employee morale, productivity levels and retention rates can have an impact on the overall agricultural production quality and yield (Bechar & Vigneault, 2016). Family labour in the context of smallholder farms plays a role in alleviating the burden off farmers financially and in terms of effort required to run the basically operational needs of the farm (Reddy, Prakash, & Reddy, 2021). Farmers with limited access to funding for paying labour and limited access to family support systems may find it difficult to yield efficient productivity yields due to labour shortages (Reddy, Prakash, & Reddy, 2021). Labour productivity is also negatively impacted in areas where there is a lack of technology innovation (i.e., mechanisation technologies, soil additives) that accelerate yield growth and reduce input required results intensive labour required for minimal yield output (Ohwofasa, Adama, & Ajagono, 2020).

2.4.2 Factors limiting land productivity

There is limited evidence that a gradual change in weather conditions has major impacts on the overall agricultural productivity, however it is severely impacted by weather shocks (Ortiz-Bobea, Ault, Carrillo, Chambers, & David, 2021). The deviation of climate behaviour from historical patterns can negatively impact the natural vegetation and for certain countries (Martín-Retortillo & Pinilla, 2012). The effects of these shocks are argued to severely impact the livelihoods of impoverished households more than wealthier households (Amare, Jensen, Shiferaw, & Cisse, 2018).

Land deterioration and soil erosion are factors that negatively impact agricultural productivity (Wiebe, 2003; Reuben, et al., 2017; Giannakis & Bruggeman, 2018). Soil erosion impacts the organic matter and essential biological components of the soil, leading to decline of crop growth (Panagos, et al., 2018). Soil erosion also has a reciprocal effect on the increased global food security vulnerabilities for crop and animal producers (Webb, et al., 2017). The impact of land deterioration or soil erosion results in the need for producers to apply costly measures (i.e., fertilizer and soil additives) on affected areas to adequately produce on impacted land (Panagos, et al., 2018).

The use of the type of fertilizer applied on a crop can determine how much yield is produced on land. Organic fertilizers are favoured more than the conventional inorganic fertilizers because they are believed to produce greater yields (Jayne, Snapp, Place, & Sitko, 2019). The lack of access to adequate water systems also has major impact on land productivity for many farmers (Adama, Ohwofasa, & Ogunjobi, 2016;). Access to water resources can also determine the fertilizer consumption required, which is one of the inputs that influence agricultural land productivity for farmers (Panagos, et al., 2018). Depending on availability of water resources too much or too little fertilizer applied on a crop could lead to low quality yields. Previous studies have argued that there is an inverse relationship between fertilizer inputs and water access (Argwings-Kodhek, Jayne, Nyambane, Awuor, & Yamano, 1999).

- Where water resources are in abundance are more likely to respond to using larger amounts of fertilizer for the variety of crops accessible to the farmers.
- Where water resources are scarce the usage of fertilizers may not be favoured as they would have the potential to harm the crops by burning.

2.4.3 Factors limiting capital productivity

Agricultural finance is required by farmers to assist them in being able to build adequate infrastructures to operate their farms and harness the benefits of implementing new technologies (Mwihaki, 2015). Long-lived inputs (i.e., structures, machinery, trees, and livestock) can be used for longer than a year and are critical components to farmer production cycles (Fuglie, 2018). Capital can be less productive due to “wear and tear”, structures and machinery can depreciate or get damaged over a longitudinal period (Fuglie, 2018).

Financial institutions, government, and external investor’s ability to provide credit to farmers, results major boosts farmer productivity for smallholder farmers (Loeper, et al., 2016; Wolfert, et al., 2017). The access to credit and provisional initiatives to support farmers yields to increased efficiency in agricultural productivity of farmers (Wirakusuma & Irham, 2021). Smallholder farmers struggle accessing adequate credit aid them in acquiring financial capital required to run their farms successfully (Purbayu, Wiludjeng, Tri, Darwanto, & Hendarto, 2021). Resource constrained smallholder farmers lack collateral required by financial institutions to access capital (Purbayu, Wiludjeng, Tri, Darwanto, & Hendarto, 2021).

Shocks such as disease outbreaks, climate change and theft on livestock and fruit tree produce can have negative impacts on capital productivity yields of farmers (Delabougliise, et al., 2017; Lacetera, 2019). Livestock farmers have targets for specific animal traits and herd sizes to plan long term continuity of their production line. The impact of shocks leads to negative consequences on capital productivity yields for farmers (Lamy, van Harten, Sales-Baptista, Guerra, & de Almeida, 2012). The increased mortality rates of animals due to environmental conditions and delayed prevention mechanisms has dire consequences for farmers in general (Lacetera, 2019).

2.5 4IR and Smart Technologies

The increase in digitisation across industries has given rise to the emergence of Smart Technologies. The concept of “Smart” is mainly associated with Internet of Things (IoT) sensor technologies, which are the incorporation of various devices (i.e., cameras, sensors, smartphones, and wearables) (Georgakopoulos & Jayaraman, 2016, p. 1041). Smart IoT applications have also gained traction cross-industry by enabling intelligent services using smart farming, smart grids, smart cities, and smart manufacturing (Georgakopoulos & Jayaraman, 2016). This technology convergence is mainly referred to as the fourth industrial revolution (4IR). Every revolution brought about its own innovation within varied

sectors and contributed to the socio-economic statuses of countries. McPhee (2017) and Xu, David, and Kim (2018) define the different revolutions as follows:

- **The first revolution** consisted of manual labour, commonly known as the “handicraft economy” with a skilled labour force.
- **The second revolution** is associated with the introduction of electricity in machinery.
- **The third revolution:** Information technology was mainly used for automation.
- **The fourth industrial revolution** encompasses an age where technologies, such as, AI, cloud computing, 3D printing and augmented reality, are a part of life.

4IR is a development of the third revolution and is centred around the possibilities formulating a physical and digitally integrated system (Xu, David, & Kim, 2018).

2.6 4IR in agriculture

The agricultural sector has undergone several revolutions between 1774 and 1997, which have led to many changes in the supply of food to meet the needs of the human population. Table 2.5 summarises agricultural revolutions.

Table 2.5: Agricultural revolutions summary extracted from Lombardo et al. (2017) and Zambon et al. (2019)

Agricultural revolution	Year	Revolution innovations
First (Neolithic revolution)	1774	Theory on reversing plough; mechanical plants powered by water
Second (British agricultural revolution)	1890	First gasoline tractor engine; first mechanical line powered by electricity
Third (Green revolution)	1915	First Fordson tractor; programmable logic controller
Fourth (Fourth industrial revolution)	1997	ICT and digital systems in agriculture management; computerisation; and intelligent networks

2.7 Smart technologies usage in the farming sector

The “digital revolution” or fourth industrial revolution has seen an introduction in the usage of advanced technologies like sensors, artificial intelligence, and robotics in attempt to increase food production and reduce process inefficiencies (Rotz, et al., 2019). The integration of smart technologies in farming enables farmers to increase yields, limit impacts on vulnerabilities and optimise resource usage (Yahya, 2018). The use of smart technologies is also identified as an important element in ensuring sustainable change in the agricultural sector, food value chains, and increased food security (Sanyang ibiri, Kuiseu, Coulibaly, & Konaté, 2016). From an end consumer perspective, the integration smart technologies could

result in the overall decline in commodity prices and increased quality of food (Yahya, 2018). Table 2.6 summarises the common uses of smart farming technologies.

Table 2.6: Smart farming opportunities

Smart technology	Use in market	References
IoT devices and sensor technologies	<ul style="list-style-type: none"> • Remote monitoring of crops (soil, fertilizer, and irrigation). • Climate control • Water conservation • Pest management • Recycling • Animal control • Traceability 	Jayaraman et al. (2016); Bruinsma (2017); Rehman, Jingdong, Khatoon, Hussain, & Iqbal (2017); Walter et al. (2017); Wolfert et al. (2017); Ray (2017)
ICTs	<ul style="list-style-type: none"> • Communication and market access 	Ogbeide & Ele (2015)
Robotics	<ul style="list-style-type: none"> • Crop management • Dairy farming 	Walter et al. (2017); Skvortsov (2020)
Drones and satellite technologies	<ul style="list-style-type: none"> • Crop status and input to insights 	Walter et al. (2017)

There are practical examples of where smart farming technologies were collaboratively used and successfully adopted in different parts of the world, especially African continents. Table 2.7 summarises practical examples of how smart farming technologies are used in different parts of the world.

Table 2.7 Smart farming practical examples

Country	Case Study/Example	Smart technology	Challenge	Initiative impact	References
South Africa	Agritechnica, an annual German based agricultural trade fair had selected a South African farmer as one of their participants to illustrate the success that smart farming can achieve. The farmer owned a family business in the Western Cape. As part	Robotics	<ul style="list-style-type: none"> • Lack of adequate water resources 	<ul style="list-style-type: none"> • Saved 8% - 10% water consumption • Reduced chemical and fuel costs • 8% - 10% quicker field spraying time 	Farmer's Weekly (2018)

How can smart technologies be applied by smallholder farmers for increased productivity and sustained livelihoods?

	of their initiative in 2017, the farmer used the “ <i>John Deere’s Greenstar system</i> ” which is a platform that enabled efficient field coverage using precision GPS tools to control the machines on the farm.				
Kenya	UjuziKilimo, a Kenyan based Agri-tech company supports farmers with optimizing crop growth and yields through sensor technology. Advises farmers based on data insights generated.	IoT	<ul style="list-style-type: none"> • Lack of access to information • Traditional farming mechanisms 	<ul style="list-style-type: none"> • Assisted over 200 farmers to achieve • Impacted direct and indirect livelihoods of rural farmers 	Dawson & Anand (2020)
Canada	Cuckoo Search Algorithm developed to allow the allocation of water (controlling irrigation) using IoT.	IoT	<ul style="list-style-type: none"> • Lack of adequate water resources 	<ul style="list-style-type: none"> • Prevented water wastage • Saved costs and labour effort 	Pathak et al. (2019)
Nigeria	Hello Tractor, a platform developed to mediate interactions between tractor owners and smallholder farmers. The platform allows farmers to request via SMS and mobile money to and pay for using tractors at a point in time.	Platform	<ul style="list-style-type: none"> • Inadequate access to capital 	<ul style="list-style-type: none"> • Assisted farmers in being able to access capital • Has contributed to the rise in crop yields by 200% 	Dawson & Anand (2020)

The successful implementation of smart technologies means that strategies aiming to introduce smart technologies need to be farmer centric to ensure that proposed solutions are solving actual problems and will empower farmers to deal with the challenges themselves (Makuvaro, Walker, Masere, & Dimes, 2018). Government has the responsibility to intervene and improve rural infrastructure, encourage technology usage for all, enable upskilling programmes for technology usage and facilitate the procurement or subsidy for such services for farmers (Amare, Jensen, Shiferaw, & Cisse, 2018; Baležentis, Tianxiang, & Xueli, 2021). There is also a need to introduce specific policies that will align to objectives. The private sector has a strong influence and role to continue developing of agricultural technologies that will influence the increased productivity in farming (Fugile, 2016).

2.8 Smart technologies influence in agricultural productivity and livelihoods

The growth of the overall agricultural productivity in Africa has been one of the key focus areas for the African Union (AU) who have initiated the Comprehensive Africa Agriculture Development Programme (CAADP) in 2003 (AU) (Diao, McMillan, & Wangwe, 2017). In line with CAADP’s objective, Sub-Saharan African countries have increasingly promoted the use of technology to combat low agricultural productivity (Vandercasteelen, Dereje, Minten, & Taffesse, 2018). The increased improvement in technology is one of the major contributors to increased global food production (Wiebe, 2003). CAADP’s development strategy aimed to directly impact the generation of wealth, enablement of food security and food nutrition in African countries through the strategic focus on smallholder farmers (Diao, McMillan, & Wangwe, 2017). Table 2.8 summarises smart farming in relation to the three-dimensional view of productivity.

Table 2.8 Potential that smart technologies hold and the three-dimensional view of productivity

Productivity classification	Limiting factor	Smart farming technology use in market
Labour productivity	<ul style="list-style-type: none"> • Environmental factors (land quality, water availability and infrastructure) • Insufficient investment in human capital (skills, literacy, and support) • Labour intensive tasks • Labour workforce demographics (ageing workforce, gender, health status) • Shortage of skilled labour and quality of inputs • Lack of technology innovation 	<ul style="list-style-type: none"> • The use of smart technologies can assist farmers in being able to better predict required inputs (i.e., water resources, fertilizer, pesticides, and seeds) and better understanding environmental factors that may impact farmers productivity (Rotz, et al., 2019) • Autonomous robots are examples of smart technologies that can be used to automate labour intensive tasks, resulting in increased work efficiency and decreased production and manual labour costs (Sparrow & Howard, 2021). Practical examples could be leveraging robots to render weeding, picking, and packing tasks which can allow for farmers to realise tremendous productivity gains (Vasconez, Kantor, & Cheein, 2019).

Land productivity	<ul style="list-style-type: none"> • Weather shocks (drought, heavy rains, extreme cold etc.) • Land deterioration and soil erosion • Low quality inputs • Insufficient access to water resources (i.e., irrigation) 	<ul style="list-style-type: none"> • Smart technologies are identified to be critical in combating server climate changes and achieving agricultural productivity in Africa (Amare, Jensen, Shiferaw, & Cisse, 2018; Shimeles, Verdier-Chouchane, & Boly, 2018). • Farmers can leverage remote sensing technologies to monitor and compare variations in crop yields crops, identify potential issues, and react promptly to alerts (Du, Zhang, & Xiaobin, 2018).
Capital productivity	<ul style="list-style-type: none"> • Wear and tear of inventory, machinery, and structures • Lack of financial capital and access to credit • Shocks (weather, fires, disease outbreak etc.) 	<ul style="list-style-type: none"> • Farmers may leverage cloud-based platforms that are embedded with IoT based solutions to identify potential plant diseases (Kim, Lee, & Shin, 2018). • The use of platforms and mobile phones can allow the infrastructure to track commodity sources and facilitate financial transactions between farmers and buyers (McIntosh & Mansini, 2018). • IoT devices can be used in for asset management of farm assets and machinery against theft, routine maintenance, and replacements (Elijah, Rahman, Orikumhi, & Hindia, 2018).

Although these studies refer to the positive impacts of technology usage to increase productivity (Sparrow & Howard, 2021), some studies have also acknowledged that the introduction of technology in agricultural activities does not necessarily equate to increased levels of productivity growth (Vandercasteelen, Dereje, Minten, & Taffesse, 2018; Acemoglu & Restrepo, 2020). Technology advancements in agriculture can be negatively perceived to be competing with farm worker on manual and repetitive tasks, which may lead to farm owners in having to decide between whether to adopt the technologies or not (Rotz, et al., 2019). There is a narrative that smart technologies replace manual labour demand, meaning smart technologies are more productive than traditional manual methods (Acemoglu & Restrepo, 2020 ; Skvortsov, 2020). A decline in the demand for labour in the agriculture sector due to the advancement of technologies also means an expansion of more job opportunities in other sectors (Acemoglu & Restrepo, 2020). Agriculture digitisation

also allows for the costs of production to be reduced due to increased levels of labour productivity growth, which therefore decreases commodity prices and better's smallholder livelihoods (Skvortsov, 2020).

2.9 Summary of chapter

Smallholder farmers have the potential to contribute immensely to the production in the mainstream value chain. However, the farmers face many challenges. Many of these challenges have the potential to be alleviated using smart technology. The impact of using smart technologies in farming must be fully utilised by smallholders to reduce some of these challenges. This chapter covered the South African apartheid history; the country's agricultural landscape, farmer support systems, and smallholder farmers; universal challenges smallholder farmers face; agricultural productivity; 4IR and smart technologies; 4IR in agriculture and smart technologies usage in the farming sector; smart technologies influence in agricultural productivity and livelihoods.

Chapter 3: Theoretical framework

A theoretical framework is one of the key elements in research and is often misunderstood by many writers in academia (Osanloo & Grant, 2016). Commonly referred to as the “blueprint”, it provides a skeleton for researchers to guide their study and logically frame ideas to fit a phenomenon (Heale & Noble, 2019). To understand how smallholder farmers can use smart technologies to improve productivity, three main frameworks were considered: (i) Alsop and Heinsohn’s Empowerment Framework (Alsop, Bertelsen, & Holland, 2006), (ii) the Sustainability Livelihoods Approach (SLA) (Serrat, 2017; Yang et al., 2018) and (iii) Choice Framework (Kleine, 2010; 2013). The study used the Sustainable Livelihoods Approach as a lens in understanding the livelihoods of smallholder farmers. This chapter is organised as follows: Section 3.1 argues the suitability of the framework of the study, Section 3.2 expands on what SLA entails while Section 3.3 discusses how the SLA will be applied for this study. Lastly the chapter concludes by summarising the theoretical framework in Section 3.4

3.1 Suitability of the framework of the study

The Empowerment Framework emerged from in-depth discussions on power dynamics in a social context, and is primarily influenced by individual agency, opportunity structure and degree of empowerment, which determine development outcomes (Alsop, Bertelsen, & Holland, 2006). The livelihoods approach is centred around understanding poverty in a multi-dimensional manner and organising opportunities and constraints that impact individual livelihoods (Serrat, 2017). The Choice Framework aims to systematically view and understand the various development process elements (Kleine, 2013). The Choice Framework is a combination of Alsop and Heinsohn’s Empowerment Framework and the Sustainable Livelihoods Approach, linking components of empowerment, choice and individual capital portfolios that define an individual’s life choices (Kleine, 2010; Hatakka, Thapa, & Sæbø, 2016). The combination of these framework elements allows the choice framework to expand on the real freedoms enjoyed by people, leading to living lives that they have reason to value (Kleine, 2010; 2013; Alsop, Bertelsen, & Holland, 2006; Serrat, 2017; Yang et al., 2018). Table 3.1 summarises the frameworks considered for the study and their suitability in relation to the research objectives.

Table 3.1: Summary of potential frameworks for assessing productivity of smallholder farmers in relation to smart technology use

Framework	Focus	Outcomes	Comment
Alsop & Heinsohn's Empowerment Framework	Micro and macro	Development outcomes at various levels. <ul style="list-style-type: none"> • Macro level • Intermediary level • Local level 	Places choice at the centre of the framework and articulates it in relation to individual agencies. The framework consists of opportunity structures which refer to policies, norms, and regulations, however, does not elaborate on intervening programmes that assist in building resilience.
Sustainable Livelihoods Approach	Micro and Macro	Livelihood outcomes include: <ul style="list-style-type: none"> • More income • Increased well-being • Reduced vulnerability • Improved food security • More sustainable use of natural resources 	The sustainable livelihoods approach provides a systematic framework that details the link between centre structures and agency elements.
Choice Framework	Macro	Development outcomes included principal and secondary outcomes, namely: <p>Principal: choice (which is inclusive of choice of ICTs)</p> <p>Secondary: depends on what the individuals value</p>	Focus is more aligned to how people's choices influence development outcomes. There is limited focus on strategies/policies driven by transforming structures to build resilience to vulnerability contexts impacting individuals.

3.2 Sustainable Livelihoods Approach

The study used SLA as a guide to frame the study. SLA was first established in 1987; however, it has evolved, and been utilised in diverse domains, including, commerce, social, political, environmental and development studies (Makoza & Chigona, 2010; Scoones, 2015; Slater & Yeudall, 2015). Although there are several sustainable livelihood approaches, the

Department for International Development's (DFID) SLA Framework is the most used in literature (Liu, Chen, & Xie, 2018). The DFID framework was developed in the early 1990s and aimed to form policies that focused on assistance to the poor (De Haan, 2012).

The Sustainable Livelihoods Approach is defined as:

- “An analytical structure for coming to grips with the complexity of livelihoods, understanding influences on poverty and identifying where interventions can best be” (De Haan , 2017, p. 349).
- “A holistic approach that tries to capture, and provide a means of understanding, the fundamental causes and dimensions of poverty without collapsing the focus onto just a few factors” (Majale, 2002, p. 3).

The livelihoods approach describes poverty beyond ordinary classifications that are narrowed to the levels of income (Farrington, Carney, Ashley, & Turton, 1999; Krantz, 2001). Livelihoods are made up of activities and assets that people require to make a means of living (Elasha, Elhassan, & Ahmed, 2005). An individual's livelihood is considered sustainable if it can withstand vulnerabilities and if it can be strengthened without deterioration of natural assets (Thang, Dung, Hulse, Sharma, & Shivakoti, 2017; Liu, Chen, & Xie, 2018). SLA has five main constructs: pentagon of capital assets, vulnerability context transforming structures and process, livelihood strategies, and livelihood outcomes. These constructs will be discussed in the sub-sequent sections.

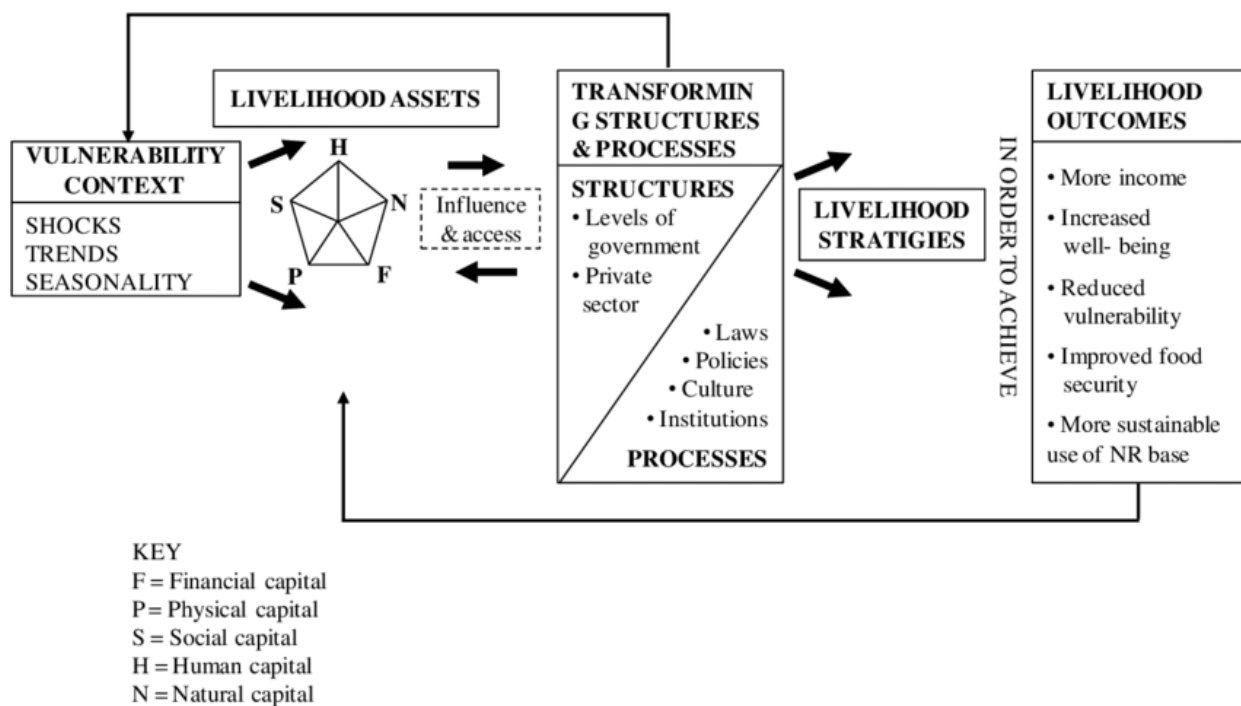


Figure 3.1: Sustainable livelihoods approach (De Haan, 2012, Liu, Chen, & Xie, 2018)

3.2.1 Livelihood assets

Livelihood assets refer to key resources required by an individual to survive. These are transferable and can be stored by individuals to create an income and other benefits (Yang, et al., 2018). Traditionally, the livelihood approach comprises

of five individual livelihood assets: natural, physical, human, social, and financial assets (Serrat, 2017; Pour, Barati, Azadi, & Scheffran, 2018). Table 3.2 summarises the pentagon of assets.

Table 3.2: individual livelihood assets and examples of their impact on smallholder farmers (Serrat, 2017; Pour, Barati, Azadi, & Scheffran, 2018)

Assets	Definitions	Example of impact on smallholder farmers
Natural assets	These are natural resources (e.g., land and water)	<ul style="list-style-type: none"> • Land use • Water availability
Physical assets	Tangible assets that are critical to production purposes (i.e., livestock, production equipment and vehicles)	<ul style="list-style-type: none"> • Equipment and agricultural tools • Roads • Storage facilities • Physically owned assets
Human assets	Knowledge, skills, and health of individuals, and how they leverage these to achieve livelihoods (i.e., experience and age)	<ul style="list-style-type: none"> • Quantity of labour • Health • Education and technical capacity
Social assets	Resources that are available to individuals through networks and social circles (i.e., NGOs, communities, and families)	<ul style="list-style-type: none"> • Networks • Support groups and community • Associations • Affiliations • Relatives and family support
Financial assets	A basic and fundamental asset that refers to savings and access to credit in formal and informal places (i.e., loans, savings, and funds)	<ul style="list-style-type: none"> • Credit and savings • Grants and funds • Income generation

3.2.2 Vulnerability context

Vulnerability context refers to an individual's livelihood being highly influenced by social, economic, and environmental factors (Slater & Yeudall, 2015). The ability to predict, prevent and recover from natural disasters is measured by an individual's vulnerability capacity (Madhuri, 2014). Vulnerabilities are associated with external forces that impact an individual's livelihood (Makoza & Chigona, 2010). Table 3.3 summarises the vulnerability context.

Table 3.3: Vulnerability context and examples on the impact of smallholder farmers

Vulnerability context	Definitions	Example of impact on smallholders
Trends	Long term occurrences that may impact individual livelihoods (i.e., population, or economic or employment-related trends)	<ul style="list-style-type: none"> • Poor government support structures • Limited market access • Lack of finance and resources • Lack of skills
Shock	Unplanned events, including natural disasters and hazards (i.e., floods, diseases, fires, droughts, and pests)	<ul style="list-style-type: none"> • Stock theft • Breed polarization • Disease outbreak
Seasonality	Cycle changes that occur over a given period (i.e., climate changes)	<ul style="list-style-type: none"> • Animal breeding patterns • Climate changes

3.2.3 Livelihood strategies

Livelihood strategies refer to all the methods and choices utilised to achieve livelihood goals (Liu, Chen, & Xie, 2018). These livelihood strategies of all farming households are heavily reliant on an individual’s asset status, (Liu, Chen, & Xie, 2018). There are different types of livelihood strategies that may be employed by individuals trying to obtain a livelihood, these include general livelihood strategies, adaptive strategies, and coping strategies (Krantz, 2001). Farmer’s livelihood strategies are not only limited to agricultural-related activities and may extend to include non-farm activities that may aid farmers in being able to diversify their revenue streams (Van Breda, Dufresne, & McNevin, 2010).

Table 3.4: Livelihood strategy types and examples applied by smallholder farmers (Krantz, 2001)

Livelihood strategy	Definitions	Example of strategies that smallholders may adopt
Adaptive strategy	Strategy that deliberately includes a process of change to respond to long term trends	<ul style="list-style-type: none"> • Policy formulation • Skills development programmes • Government extension services
Coping strategy	Functions on a short-term basis in response to urgent shocks and trends	<ul style="list-style-type: none"> • Disaster funds • Community involvement

		<ul style="list-style-type: none"> • Farmer support groups and schemes • Additional streams of employment
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3.2.4 Transforming structures and process

Livelihood strategies and outcomes are dependent on “transforming structures and processes” to achieve individual livelihoods (Serrat, 2017). “Transforming structures and processes” and “policies and, institutions and processes” are synonymously used terms to classify bodies or institutions that enable livelihood strategies in aid of achieving individual outcomes and strengthening livelihood assets (Lowe & Schilderman , 2001). Transforming structures and processes are key pathways to accessing assets, livelihood strategies and decision-making bodies (GLOPP, 2008).

Table 3.5: Transforming structures and processes and examples applied by smallholder farmers

Transforming structures and process	Definitions	Example of transforming structures and process affecting smallholders
Structures	“Structures, organisations, customs, laws are all words used to define ‘institutions’; these are the mechanisms by which processes function, without them legislation does not exist” (Lowe & Schilderman, 2001, p. 8). Institutions are defined as the hardware which forms governance structures (Lowe & Schilderman, 2001)	<ul style="list-style-type: none"> • Government • Private institutions • Farmers’ associations • Co operatives • NGO and NPO’s • Institutions
Processes	Mediators that are embedded in formal institutions and organisations to render strategies that may yield to livelihood outcomes (Scoones, 1998)	<ul style="list-style-type: none"> • Policy • Programmes • Projects • Legislation

3.2.5 Livelihood outcomes

Livelihood outcomes are determined by the nature of livelihood strategies adopted by individuals (Yang, et al., 2018). These outcomes may include increased income, improved food security, better future for generations to come and sustainable usage of natural resources (GLOPP, 2008).

3.3 Application of the SLA for this study

The SLA is mainly used for planning and implementing effective interventions to alleviate poverty and promote sustainability. Although this is the main purpose of the SLA approach, it has also been used to deal with challenges that affect natural resources and agricultural productivity (Murambadoro, 2009). Based on the ecological concept, sustainability is defined as a system’s ability to maintain productivity even when faced with a variety of vulnerabilities (Yaro, 2004). Therefore, the concepts of productivity and sustainability are interlinked and require an understanding of approaches to secure resilience to vulnerabilities, considering the economic, environmental, institutional, and social dimensions of livelihoods (Norton & Foster, 2001).

Taking this into perspective, the study uses the SLA to evaluate smallholder farmers’ use of smart technologies to increase productivity. Smallholder farmers are usually poor and marginalised and rely heavily on farming practices to improve their livelihoods (Asfaw, Shiferaw, Simtowe, & Lipper, 2012; FOA, 2018). The use of technology by farmers is linked to the capital assets to which different farmers have access to (Wei, Osman, Idrus, Sabudin, & Shiang-Yen, 2012). Productivity growth can be achieved by leveraging smart technologies (Asfaw, Shiferaw, Simtowe, & Lipper, 2012), and it would be interesting to understand the influence smart technologies have on the productivity of smallholder farmers in the context of South Africa.

Table 3.6 Information technological assets and examples of their impact on smallholder farmers

Asset	Definitions	Example of impact on smallholder farmers
Information technological assets	The presence and use of smart technologies (i.e., drones and IoT devices) contributing to livelihoods and improving resilience	<ul style="list-style-type: none"> • Data insights and trends • Forecasting • Alerts

SLA is applicable to all agriculture sectors. This approach is applied to a mix of sectors, which include livestock farming and crop farming. The justification for this approach in the study is that mixed livestock-crop strategies positively impact livelihoods of smallholders (Rudel et al., 2016).

There has been debate in literature that SLA lacks an ICT component, despite the role of ICTs in an individual’s livelihood and related assets (Yang et al., 2018). In some studies, the livelihoods approach has been applied to assess the impact of ICTs in weather and flood communication, towards livelihood resilience for farmers (Muktar, Man, Saleh, & Daneji, 2018). The study adopted a similar approach (i.e., to add information technological assets as the sixth asset) and assessed the impact of Smart Farming on the productivity of smallholder farmers in South Africa. The livelihoods approach is centred around smallholder farmers and articulates the increased food security and productivity of smallholder farmers using Smart Farming technologies. The framework may be applied to:

- identify gaps, vulnerability contexts and process (i.e., it can be used to identify factors leading to the failure of the usage of smart technologies by marginalised farmers)
- identify the limitations and benefits of implementations enabled by transforming structures and process
- assess smart farming policies, i.e., assessment of smart technology implementation strategies for smallholder farmers in disadvantaged areas
- explain poverty-eradicating areas, such as, the farming sector, and summarise strategies to derive transformation processes and structures to improve the livelihoods of individuals (i.e., smallholder farmers) (Nazari, Rad, Sedighi, & Azad, 2015; Hidayat, Glasbergen, & Offermans, & 2015; Yang et al., 2018).

3.4 Summary of chapter

A theoretical framework serves as a guide to, or blueprint for, analysing a phenomenon. SLA was selected as the preferred framework to analyse how smallholder farmers can use smart technologies to increase their productivity. SLA provides a systematic framework that details the link between centre structures and agency elements. It was essential to apply the framework to define poverty levels of farmers beyond the definitions based solely on income. In this study, smallholder farmer livelihoods were assessed based on natural, physical, social, financial, human and information technological assets. The study extended SLA to include technology as an asset to strengthen smallholder livelihoods. In addition, it is important to acknowledge the ability of the integration of technology in daily lives to mitigate vulnerabilities. The SLA is extended to include an information technological asset which is not included in the pentagon of assets.

Chapter 4: Research methodology

This study aimed to explore how smallholder farmers can use smart technologies in their agricultural activities to increase their productivity. It is important to understand the realities faced by farmers. I used a research approach and instrument that are in line with achieving this objective. This chapter is organised as follows: Section 4.1 outlines out the research paradigm applied in the study, Section 4.2 discusses the research strategy and Section 4.3 explains the approach to theory. Section 4.4 outlines the sampling technique, Section 4.5 explains the data collection process, and Section 4.6 explains the data analysis process. Section 4.7 explains the research timeframe, Section 4.8 discusses the ethics and confidentiality methods applied, while Section 4.9 outlines the research limitations. The chapter concludes with a summary of the research methodology in Section 4.10.

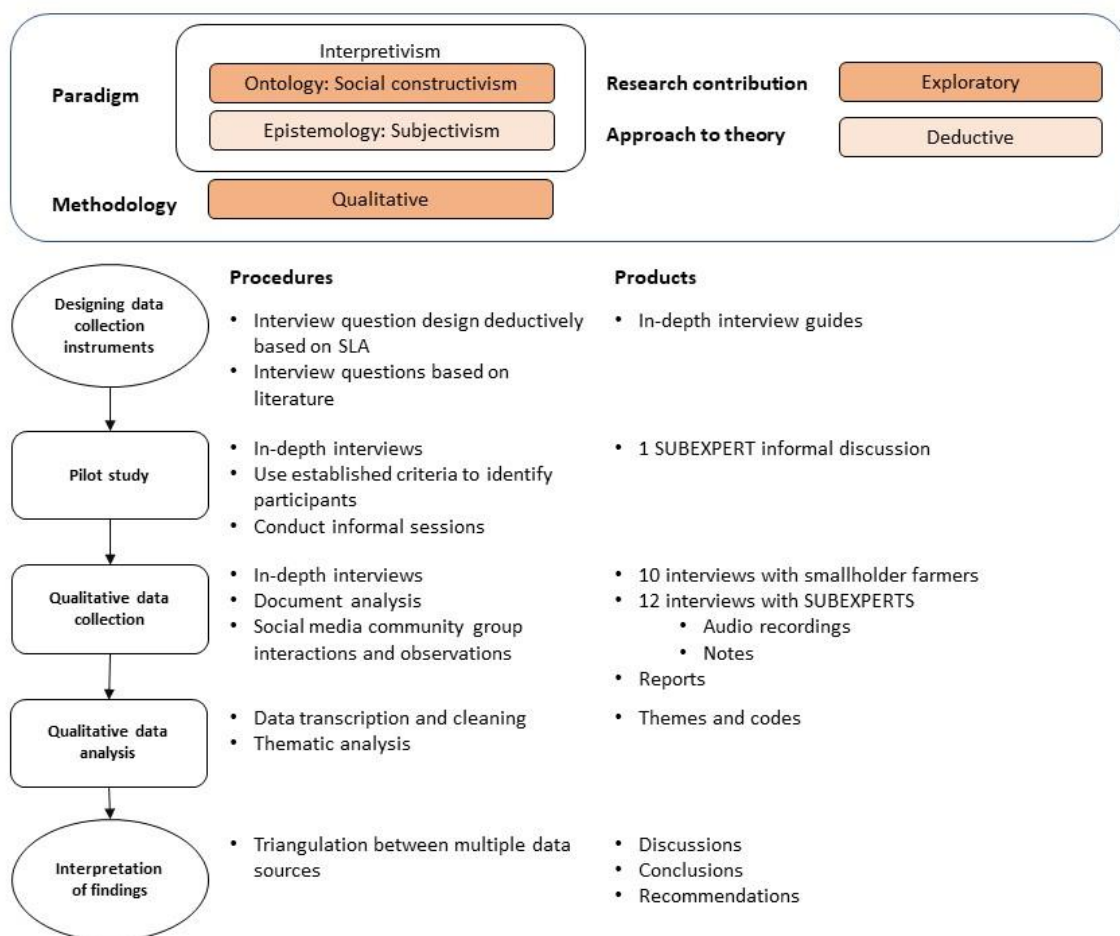


Figure 4.1: Summary of the research design

4.1 Research paradigm

Researchers need to articulate and comprehend their opinions on reality: what can be known, and how that knowledge can be obtained (Rehman & Alharthi, 2016). For these to be achieved, a research paradigm needs to be applied. A paradigm is a belief system and theoretical framework that comprises of four main elements which include the ontology, epistemology, methodology and methods (Rehman & Alharthi, 2016). This study employed an interpretivist paradigm, which allowed me to view the world through the eyes of the respondents (Thanh & Thanh, 2015).

Ontology “concerns our beliefs about the kind and nature of reality and the social world” (Al-Saadi, 2014, p. 1). The study adopted a constructivist perspective to reality, which entails that reality is socially constructed and multifaceted (Saunders, Lewis, & Thornhill, 2016; Harrison, Birks, Franklin, & Mills, 2017). In addition, the approach infers that the world has diversified meanings, realities, and interpretations (Saunders et. al., 2016). Table 4.1 summarises constructivist assumptions that are applied when considering a constructivist perspective.

Table 4.1: Extract from (Al-Saadi, 2014) on the constructionism ontology and its underlying assumptions

Ontology	Assumption
Constructionism	<ul style="list-style-type: none"> External reality exists but is only known through the human mind and socially constructed meanings
	<ul style="list-style-type: none"> There is no shared social reality, only a series of different individual constructions of it
	<ul style="list-style-type: none"> Reality is subjective
	<ul style="list-style-type: none"> There exists only estimated or approximate observations or views of reality.
	<ul style="list-style-type: none"> Social phenomena and their meanings are continually being accomplished by social actors
	<ul style="list-style-type: none"> Social phenomena and their meanings are produced through social interaction and are in a constant state of revision
	<ul style="list-style-type: none"> Life is defined in “estimated” terms based on inner experiences of humans where choice, freedom and individual responsibility are appreciated.

Epistemology refers to the acquisition of knowledge, and how this knowledge may be validated (Kivunja & Kuyin, 2017; Rehman & Alharthi, 2016). The study assumed that knowledge is socially constructed and can change, depending on conditions (Golafshani, 2003). This entails that, to acquire knowledge, I was required to be interactive and may have been subjective to a point in time. In addition, the belief that knowledge is socially constructed entails me needing to become involved with participants to understand the phenomena in context (Rehman & Alharthi, 2016).

Considering the interpretivist paradigm, and ontological and epistemological stance, the study leveraged the use of a qualitative approach, which used a naturalistic approach to analyse a phenomenon in the context of specified settings (Golafshani, 2003). Qualitative research is classified into three dimensions (Maxwell, 2012), namely:

1. understanding the world from the perspectives of people in your study,
2. the ability to comprehend how different perspectives are informed by social, physical, and cultural contexts and,
3. understanding explicit relationships and processes that influence a phenomenon.

All individuals have varied perceptions of realities that may be understood through social constructions (Klein & Myers, 1999). It was important for me to understand and interpret the meaning of smallholder farmer behaviours in relation to the usage of smart technologies in their agricultural activities. The qualitative approach also allowed me to be able to compare varied responses from participants and outline explicit relationships that may influence the usage of smart technologies to achieve productivity.

4.2 Research strategy and approach to theory

The study employed an exploratory approach which allowed me to probe answers where further clarity was required from the respondents (Saunders et al., 2016). I sought to understand how smallholder farmers can use smart technologies to increase productivity. The study used a deductive approach to theory, where the research starts with a theory based on research which was tested by the design strategy (Saunders, et.al., 2016). In this regard, the study used the Sustainable Livelihoods Approach (SLA). The theory articulates the holistic view of poverty beyond ordinary definitions that are limited to income (De Haan , 2017). The timeframe is cross-sectional as the research looks to describe how smallholder farmers can make use of smart technology to achieve productivity (Saunders et al., 2016).

4.3 Sampling technique

The target population for the study is smallholder farmers who reside and operate their farms in South Africa. The research used non-probability sampling which is based on non-random selection of sample participants (Wallian, 2011). Snowball sampling is used when participants refer researchers to their peers (Emerson, 2015). I applied the snowball technique sampling method to expand the number of participants in the study. Upon the completion of the interviews with the participants, I asked for referrals to suitable candidates who might be interested in participating in the study.

Purposive sampling was used to identify subject matter experts and smallholder farmers within the agriculture and technology domain. I approached participants via three social media platforms: Facebook, WhatsApp, and LinkedIn. I searched for farmer support groups on Facebook and WhatsApp and joined the groups to further engage with farmers on the intent of the study. I also used LinkedIn to identify subject matter experts. I viewed the profile of the participants and purposely engaged with them based on their profiles. Many authors could argue that this approach could lack rigour and could not be easily adopted in other studies; however, I have included the detailed data collection process conducted (Saunders, Lewis, & Thornhill, 2016).

4.3.1 Criteria for the selection of participants

The purpose of this study was to explore how smallholder farmers may leverage modern technologies to increase their productivity. Although smallholder farmers share many homogenous qualities, they are not a monolith. There are inherent variations in conditions that distinguish them. Table 4.2 summarises the criteria used to select the sample.

Table 4.2: Criteria used for the selection of smallholder farmers for the study

Factor	Criteria
Age	Participants aged between 14-60+ years were selected to participate in the study.
Education	Primary, secondary, diploma and above were considered.
Gender	Male and female were considered.
Marital status	All considered
Type of land ownership	All land ownership forms
Hector size category	1-20 ha
Type of commodity	All commodities
Farming experience	Farming experience between 0-15+ years was considered
Annual turnover from operations	R0-R500 000 per annum
Geographic location	Within all 9 provinces of South Africa
Area	Considered farmers in both rural and urban areas

The age of participants was widened to gain a broad perspective on older and younger, emerging farmers. Including diversified age groups could either verify or disprove the hypothesis that youth are more likely to use technology than older generations (Levickaitè, 2010).

I considered all educational groups to allow the comparison of the various educational groups. The educational status has a direct link to the intent of technology usage by participants (Abu-Shanab, 2011; Maga, Kamdjoug, Wamba, & Tcheuffa, 2019). The educational level of an individual is also considered one of the key elements that influence human capital (Olawuyi & Hardman, 2019). It is, therefore, important to explore the various levels of education.

I aimed to have a balanced sample of gender groups. There are dominant arguments in literature relating to the productive potential of women in relation to men and the neglect of poor women farmers by support groups in comparison to men (Doss, 2017). Many farmers in Oceania, Southern Asia and sub-Saharan Africa are women, yet are their characteristics are categorised as more economically vulnerable, resource-deprived, and less productive (Huyer,

2016). This diversified approach assisted me in mapping similarities or deviations from this narrative. Participants of all marital statuses were considered for the study. Marital status is one of the factors that may influence a farmer's production output (Olawuyi & Hardman, 2019). Olawuyi and Hardman (2019) suggest an inverse relationship between marital status and production output, which may be influenced by the migration of children or youth from rural areas to cities to find employment.

The study considered a variety of land ownership types which included communal land, leased land, owned land, and other tenures. As indicated in literature, the type of land smallholder farmers have access to, serves as a barrier to credit access (Section 2.3). It was, therefore, important for me to collate these varieties and identify their relationship to productivity.

The study considered sizes between 1 and 20 hectares. The farm size and its relationship to agricultural productivity has been a major debate within development economics (Rada & Fugile, 2019; Sheng, Ding, & Huang, 2019). A plethora of studies mention the opposite relationship between agricultural productivity and land size, however this relationship is not applicable for all countries (Yao & Hamori, 2019).

All agriculture commodities were considered for this study. The approach taken is in line with the paradigm that most smallholder farmers consider mixed crop-livestock as a strategy to safeguard livelihoods and sustainability within poor communities (Rudel et al., 2016). Commodities that were considered for this study include aquaculture, crop/grain, horticulture, livestock, poultry, and mixed commodities. The lack of skills and experience are among some of the factors that lead to smallholder farmers to fail to meet necessary market requirements. Human capital also consists of experience as an element that contributes to individual livelihoods (Serrat, 2017; Pour, Barati, Azadi, & Scheffran, 2018). The researcher considered a wide range of farmer experience.

I considered only participants who earn an annual turnover of R0-R500 000 per annum. The consideration is in line with the definition of smallholder farmers in the context of South Africa (see Section 2.2.1). I considered smallholder farmers from different provinces South Africa (recall Section 1.2) with most farmers residing in Western Cape and Eastern Cape. I also considered views from subject matter experts within the agriculture, corporate, government and technology domains. These views were collected from directors, extension officers, social innovators, technology enthusiasts, entrepreneurs, and corporate employees.

4.4 Data collection

The study applied multiple methods in data collection to ensure reliable and validated constructions of reality (Golafshani, 2003). The main question on smart technologies can be applied by smallholder farmers for increased productivity and sustained livelihoods was answered using semi-structured interviews, social media observations, document reviews and email conversations. Although the data collections varied, the research instruments remained consistent and formed the structure of the questions applicable to the study. Table 4.3 elaborates on the data collection techniques employed in the study.

Table 4.3: Data collection methods employed to answer research questions in the study.

Research question/objectives	Applicable data collection method	Number	Respondents
What factors influence South African smallholder farmers' usage of smart technologies to increase productivity?	Semi structured interviews (video conference)	10	Smallholder farmers
	Social media observations	N/A	Personal
How can smallholder farmers in South Africa use Smart Farming technologies to build resilience against vulnerabilities?	Document review	2	Accenture and World Economic Forum
	Email conversations (Google form)	7	Subject matter experts
	Semi structured interviews (telephonic)	5	Subject matter experts

- **Semi-structured Interviews**

I conducted primary data collection via semi-structured interviews. Interviews are one of the dominant data collection methods in qualitative, interpretive studies (Golafshani, 2003). Semi-structured interviews allowed me the flexibility to ask questions depending on the organisational context (Saunders, Lewis, & Thornhill, 2016). The value of semi-structured interviews is that it allows researchers to explore complex concepts, such as productivity. The respondents were asked open-ended questions which allowed me to validate and expand on some areas in a relaxed dialogue. I conducted telephonic, video conferencing and email mediated interviews as an alternative since government restrictions during the COVID-19 pandemic did not allow the respondent to visit farmers and subject matter experts for face-to-face interviews. The study considered subject matter expert points of views and collected data via telephonic and email mediated methods from experts within various occupations, which included government officials, corporate employees, entrepreneurs, and consultants. The experts interviewed had expertise in data analysis and data science, entrepreneurship, agricultural economics, business development, agriculture development and extension, animal nutrition, drone technology, irrigation, sustainable development, and environmental management.

- **Social media observations**

I joined farmer support groups and observed communication among the farmers. This enabled me to view and understand challenges and opportunities farmers faced. It also allowed me to understand smallholder farmer sentiment around smart technology usage.

- **Document review**

To strengthen rigour within the study, the interviews were supported by limited documents on point of views on how technology is applied in the African context and how it may be introduced in the South African context. A summation of both reports considered both a broader African and local South African perspective on developments on smart technologies. The reports were also used to provide context on how farmers may be using smart technologies. Table 4.4 details the documents consulted when considering smart technology usage by smallholder farmers.

Table 4.4: Documents consulted when considering smart technology usage by smallholder farmers

Content	Description	Source
South African point of view on smart technology usage	Report: <i>Digital agri-technologies can create value for South Africa</i>	Accenture and the World Economic Forum (WEF)
African point of view on smart technology usage	Report: <i>The Digitalisation of African Agriculture Report, 2018-2019 - Executive summary</i>	The Technical Centre for Agricultural and Rural Cooperation (CTA)

- **Email conversations/Form distribution**

I conducted preliminary email mediated interviews with subject matter experts on their thoughts on the status quo of smallholder farmer usage of smart technologies. In the email a Google link form was shared for them to share their point of views on the subject matter. The preliminary conversations influenced refining the approach to conducting data collection.

4.4.1 Research instruments

A research instrument is a method used to collect data to achieve research objectives (Onwuegbuzie & Frels, 2016). I used different research instruments for smallholder farmers and subject matter experts. The research questions in the instruments were used as a guide for the interviews and were not conducted in any specific order. The respondents were not limited in the way they answered questions, allowing them to express themselves in accordance with their realities.

- The research instrument for smallholders was based on constructs of SLA. This allowed a set structure for conducting interviews. The questions were separated into five main sections, namely: vulnerability context, capital assets, policies and institutions, livelihood strategies, and livelihood outcomes (Appendix A — Research Instrument Overview: Smallholder Farmers).
- The research instrument used to collect data from subject matter experts (Appendix B — Research Instrument Overview: Subject Matter Experts)

This dual approach allowed the study to gain a two-dimensional view of how technology may be used to achieve productivity for smallholder farmers. Both instruments included questions on demographic information (Section 4.3.1) that assisted the study in selection criteria and making comparisons between respondents.

4.5 Data analysis

Data were analysed using a thematic analysis approach. NVivo software was used as an instrument for analysis. Figure 4.2 summarises the method for collecting and analysing data for the study.

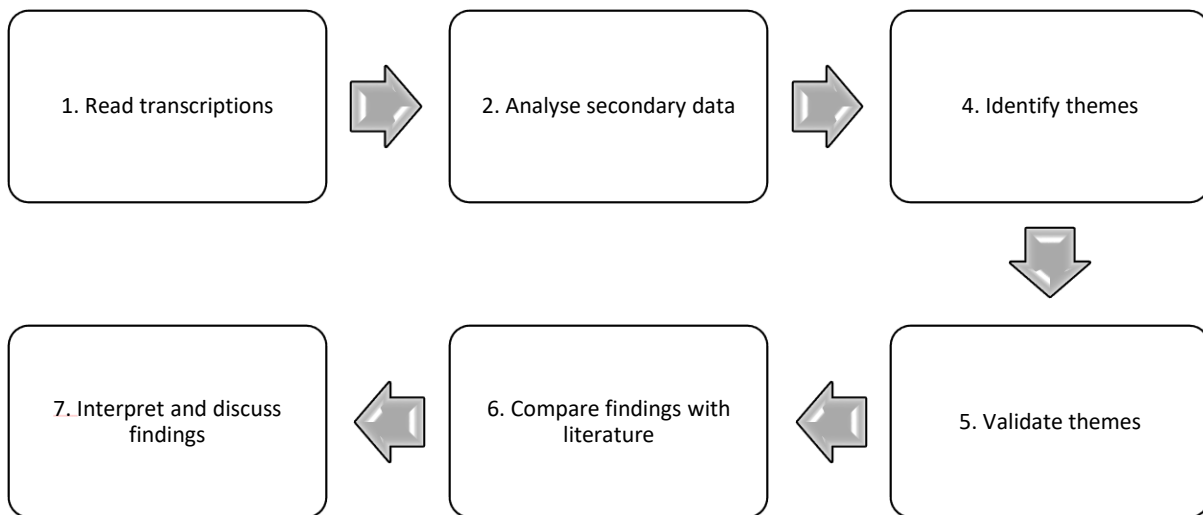


Figure 4.2: Data analysis process

4.6 Ethics and confidentiality

I obtained ethics clearance from the University of Cape Town's Ethics Committee. I also obtained approval from relevant organisations/associations to interact with stakeholders and smallholder farmers involved. Written consent forms or verbal consent requests were presented to all interviewees to explain the intent of the research to the participants and request permission to record the interview. Transcriptions and recordings of the interview were submitted to the university to ensure traceability and transparency of the study. The transcriptions of recordings did not contain any participant names. Confidentiality and privacy were ensured by anonymising the identities of participants, subject matter experts were referred to as **SUBEXPETxx** and farmers as **RESPxx**, Results of the research were submitted with the final dissertation. The interview data were stored on OneDrive administered by the University of Cape Town, for which I used my student account.

4.7 Research limitations

The study had several limitations that may have impacted the outcome of the study. These include detail on the recording device used, data collection process and observations.

Recording device: I used a laptop and cell phone to record telephonic interviews. Due to this approach, the quality of recordings was not consistent and had slowed down the time I took to transcribe the interviews. The author had to listen attentively and recite recordings made with interviewees. The author also made additional notes to reinforce learnings from interviewees and compared with recordings during the transcription process.

Data collection process: The process was greatly delayed because of multiple factors, which included the Coronavirus Disease 2019 (COVID-19) outbreak and the minimal adoption rate of smart technologies by smallholders in South Africa. I relied on social media platforms and organised interviews with relevant stakeholders. I also considered repositioning the study to accommodate circumstances.

Sample size: The study considered a sample of 10 smallholder farmers which can create arguments on the lack of generalization of the subject area. To reinforce the arguments, the author considered viewpoints from other sources and recognises that there may be a need to expand the sample of farmers in future studies.

Observations: I had intended to use observations as an additional means to collect data from respondents identified for the study. Observations would have allowed me to immerse himself in the setting of the smallholder farmers, while taking notes and recording. Because of COVID-19, I opted for using telephonic and email mediated interviews.

4.8 Summary of chapter

This chapter discussed the research methodology approach applied in the study. The research adopted an interpretive research philosophy with the purpose of describing the influence of Smart Farming on smallholder farmers' productivity. The study applied a deductive approach to theory, leveraging the SLA as a guide in understanding smallholder livelihoods. The study also leveraged literature to formulate questions for subject matter experts. Data were collected via semi-structured interviews and data were summarised into themes.

Table 4.5: Summary of the research design of the study

Research domain	Use of smart technologies by smallholder farmers in South Africa
Research contribution	Exploratory
Approach to theory	Deductive
Ontology	Realism and constructivism
Epistemology	Interpretive
Frameworks	The sustainable livelihoods approach
Unit of observation	Smallholder farmers

How can smart technologies be applied by smallholder farmers for increased productivity and sustained livelihoods?

Unit of analysis	Smallholder farmers in South Africa with an interest in using modern technologies
Methodology	Qualitative
Data collection methods	Semi-structured interviews, documents, informal conversations, observation of participants and informal conversations
Data analysis methods	Thematic analysis
Generalisation	This approach is reusable and testable in a new context

Chapter 5: Findings and analysis

The objective of the study was to gain an understanding of the usage of smart technologies by smallholder farmers in South Africa, and how smart technology could support smallholder farmers in increasing productivity in a three-dimensional view, considering capital, labour and land utilization. The study considered the views of smallholder farmers, subject experts, and supportive documentation to understand smallholder farmer usage of smart technologies (modern technologies). This chapter is organised as follows: Section 5.1 outlines demographic profile of the respondents of the study. Section 5.2 discusses how do smallholder farmers define productivity. Sections 5.3 through 5.7 applies the constructs of SLA on the data. The chapter also describes technology trends in agriculture and usage by smallholders in Section 5.8 and concludes with a summary of the findings and analysis covered in Section 5.9.

5.1 Demographic profile of participants in the study

This section provides the demographic profiles of the respondents of this study: smallholder farmers and subject matter experts.

5.1.1 Demographic profile of smallholder farmer sample

A sample of 10 respondents participated in the study. Table 5.1 summarises the first section of the smallholder demographics. Nine were male and only one was a woman. Our intention was to have a balanced representation of women and men. However, most respondents, who agreed to participate, were male. In terms of age, there was a higher rate of younger participants in the study, which may be due to the channels used for data collection. In terms of education, seven respondents had diploma and above levels, and a minority had secondary and primary education. As covered in Section 4.3.1, most of the respondents may be considered more productive than the minority. The majority – seven respondents – had 1-13 years' experience in farming. This may be because the bulk of respondents interviewed were youth.

Table 5.1: Summary of smallholder farmer personal demographics(n=10)

Age category		Education		Gender		Marital status		Experience	
14-34	5	Primary	1	Male	9	Single	7	1-13	7
35-59	2	Secondary	2	Female	1	Married	3	14-28	2

60+	3	Diploma and above	7					29-43	1
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Four of the respondents were using leased land, 2 communal land, 2 owned land, and other tenures. Four respondents were operating on land between 16 and 20 ha in size mainly used for grazing area for livestock. Respondents distinguished between arable land and grazing land; this was fundamental to understanding the intended use for the land. Sixty percent of respondents were farming with mixed commodities. Eight respondents had an annual turnover below R50 000 and 20% between R100 000 – R500 000. The research instrument aimed to gather respondents who earned more than R500 000 however were not available in the sample data collected. This finding correlates with the parameters of smallholder annual turnover as reported by (DAFF, 2019). Table 5.2 summarises the demographics.

Table 5.2 Summary of smallholder farm portfolios(n=10)

Land ownership		Size (hectares)		Commodity		Annual turnover		Province		Area	
Communal land	2	0-1	1	Crop/Grain	3	<R50 000	8	Western Cape	1	Urban	2
Leased land	4	2-5	3	Poultry	1	R100 000 – R500 000	2	Eastern Cape	5	Rural	8
Own land	2	6-10	1	Mixed commodities (Livestock and Crop/Grain)	6			Gauteng	2		
Other tenure	2	16-20	4					Limpopo	2		

5.1.2 Subject matter expert sample demographics

The study had a sample of 12 subject matter experts. Table 5.3 summarises the demographics of subject matter experts. A large proportion of the sample were male; 10 males two females. Six experts were youth, falling between the ages of 18-34, three between 34-59 and three over the age of 60. In terms of education, all 12 experts had diploma and above levels. The majority – 4 respondents – over 15 year’s experience in farming. One respondent had 10 -15 year’s experience and two were had experience of 2-5 and 0-3 years respectively. Participant’s experience was mainly in livestock and other

areas – 4 experts, respectively. Followed by grain and lastly aquaculture – an expert. The sample of participants also consisted of cross industry experts, with the majority being entrepreneurs (five). The sample consisted of three government officials and 2 consultant and corporate employees, respectively.

Table 5.3: Summary of demographics of sample of the subject matter experts (n=12)

Age category		Occupation		Experience		Sector experience		Gender	
18-34	6	Government official	3	0-2	3	Aquaculture	1	Male	10
35-59	3	Corporate employee	2	2-5	2	Crop/Grain	3	Female	2
60+	3	Entrepreneur	5	5-7	2	Livestock	4		
		Consultant	2	10-15	1	Other	4		
				15+	4				

5.2 How smallholder farmers define productivity

In respect to the three-dimensional view of productivity, farmers were mainly interested in achieving the following outcomes.

- **Labour Productivity**

In respect to labour productivity, smallholder farmers were more interested in the reduction of labour costs, prompt alerts that allow for faster decision making and the reduction of manual effort complete tasks. Farmers believed that technology could allow them to complete tasks at a faster rate, with reduced number of labour and less effort.

- **Land Productivity**

Building resilience to vulnerabilities and increasing capacity yields on the land smallholders currently used seemed to be key variables that were important to them. They needed to know what to plant on their land in accordance with the climate, soil condition and season. Farmers required to know the ideal conditions to plant crops to ensure healthy outputs. Farmers also acknowledged the ability of technology to identify the areas that require crop checks, allowing them to apply pesticides accurately allowing greater yields.

- **Capital Productivity**

The main benefits the farmers noted were resource optimization and enabled trust and transparency. Farmers are more likely to reduce the operational costs when could respond quickly to shocks and vulnerabilities. The farmers also indicated that technologies had the ability of enhancing trust between them and the market, which could link to their ability to supply more produce.

5.3 Livelihood assets

This section discusses the assets available to smallholder farmers. Table 5.4 summarises the assets.

Table 5.4: Summary of livelihood assets available to smallholder farmers

Livelihood assets	Application in relation to smallholder farmers
Natural assets	<ul style="list-style-type: none"> • Large grazing communal land • Wetlands that are ideal for crop farming
Physical assets	<ul style="list-style-type: none"> • Inadequate water infrastructure • Lack of reliable electricity supply • Inadequate fencing leading to theft and increased spread of diseases • Access to tractors and expensive equipment via extension services
Human assets	<ul style="list-style-type: none"> • Many farmers had tertiary qualifications • Many farmers had experience in farming • Farmers had access to mentors which included their parents, businessmen and commercial farmers
Social assets	<ul style="list-style-type: none"> • Family involvement on access to labour, skills development and mentorship, moral support, financial support, market access, product purchase and improvement, land access and access to seedlings
Financial assets	<ul style="list-style-type: none"> • Personal finance • Supplementary income • Government financing • Family financial aid
Information technological assets	<ul style="list-style-type: none"> • Access to basic ICT's • Limited to no access to smart technologies

5.3.1 Natural assets

Many smallholder farmers in the study were operating on communal or leased land. The land size ranged between 2 to 20 hectares. The farmers used the land for a variety of purposes including livestock farming, crop cultivation and residential housing. The communal land was beneficial to some farmers: *“the farming sector has many opportunities, for instance in our area, our graze land (idlelo) is so beautiful”* [RESP2]. The grazing land they had access to provided more than enough food for their cattle, that could sustain them in tough seasons, and because in their area there are *“about 10-15 farmers, so there are enough resources”* [RESP2]. Also, for some areas are *“...full of wetland.”* [RESP5]. This allowed the community to plant crops in larger areas. RESP4 highlighted a similar context and foresaw greater yields due to water supply that passes through the farm: *“that stream is forever there”*.

5.3.2 Physical assets

The study identified two main categories of physical assets available to smallholder farmers. These included access to public infrastructure (i.e., water and electricity services) and a personal (i.e., water tanks and fencing) physical assets procured by farmers. Basic services of water and electricity supply posed a major challenge for some farmers. In 2018, an estimate of 46.3% of households had access to piped water in their dwellings, 28,5% accessed water via sites, 12,3% on communal taps and 1.9% had access water through neighbours taps (SA, 2019). Despite significant improvements by government in ensuring adequate provision of water to citizens, access to improved water sources increased by less than 5% between 2002 and 2018 (SA, 2019). For most farmers, the lack of access to appropriate water infrastructure limited their ability to plant their crops in an effective manner.

Farmers who had limited access to water, installed irrigation systems and fitted in tanks to curb the impact of lack of water supply. Other farmers implemented *“rainwater harvesting, and conservation practices”* coupled with tanks in their infrastructure.

“...we pull water from the river then we store that water into tanks, then we again push the water using diesel” [RESP2].

“...but there are tanks, there are two tanks. I thought they would sustain me while the infrastructure issue is handled” [RESP3].

There has been an increase in household electricity connectivity from 76.7% in 2002 to 84.7% in 2018 (Stats SA, 2019). In contrast to the increase in connectivity of electricity, there has been a decline of 1.8% in the overall customer satisfaction rating of electricity services (Stats SA, 2019). The shortage of reliable supply of electricity has seen to be one of the critical challenges faced in South Africa (Goldberg, 2015). The lack of reliable and consistent electricity had a negative impact on other physical assets of farmers. Power outages were also a major issue for chicken farming. Chickens require consistent and warm temperatures in their crops. *“When there is load shedding [power outages], chickens need heat. So, when there*

is load shedding it becomes a problem" [RESP9]. The lack of electricity had a direct impact on other assets. RESP4 could not use their borehole *"due to lack of electrify"*.

Some farmers faced challenges pertaining to fencing. This led to further challenges including theft and disease control.

"Oh fencing. That is a concern [now], finance for fencing because the fence that is there has holes" [RESP3].

Although several farmers did not own tractors, they had access to these through extension services and schemes. RESP2 and RESP3 mainly used leased tractors for land preparation and ploughing on arable land. Among other assets, farmers also used vehicles to transport inputs and in aiding of their farming operations. This is prevalent in the case of RESP3, who used vehicles to *"collect the grass from time to time to re-mulch and cover the soil"*.

"I would say mechanically we use tractors to plant and cultivate" [RESP2].

"...the technology that we have exposure and access to is tractors" [RESP3].

5.3.3 Human assets

Farmers had varied levels of experience, education, and training exposure in farming. Many farmers did not formally study agriculture at tertiary learning institutions. Most farmers learnt their farming skills through hands-on training and learning that was passed on by either family or commercial farmers in neighbouring areas. People who grew up in a farming setting were likely to pursue farming careers, with skills being passed on:

"The skills, I got them from my father" [RESP10].

"I have grown up on a farm with cattle back home; we also have a place to grow crops" [RESP8].

In some instances, commercial farmers played a vital role in guiding new and emerging farmers through mentorship and advice. Smallholder farmers would approach commercial farmers and observe how they operate their successful enterprises and learn best practices that will ensure great results.

"I would watch these big farmers and ask them [...] what is going on. I would ask them now and again on what they do to grow crops that are better" [RESP6].

"I got coached by a gentleman called Christopher from the poultry association.... For business growth on how to manage money [wisely], financial management, I got that from my uncle who is a taxi owner and an Engen garage owner" [RESP9].

Some farmers learnt mainly through trial and error. Subsequently, some farmers enrolled in agricultural courses, and read books that equipped them with relevant expertise to be able to operate more effectively.

"I did not formally do agriculture in university. I did other degrees, now I am learning from trial and error" [RESP2].

"I did not study agriculture. I studied environmental education. and I took a permaculture course" [RESP3].

"I got more encouraged once I attended a few more courses around piggery, I got information about the support from Department of Agriculture" [RESP5].

Some of the skills that farmers highlighted included record keeping skills, planning, business management, agricultural technical skills, and people management skills.

A large proportion of farmers had a limited understanding of smart technologies. However, they all had access to cell phones as a median for communication. The majority did "... not know much about [smart technology]" [RESP1] and were "...not so well versed around it" [RESP5]. Some farmers had knowledge about smart technologies but did not understand of its usage from an agricultural perspective. Farmers articulated the potential value that technology could bring into their farming operations, indicating its ability of "making life easy" [RESP6]. Although they had limited knowledge, technology would be "something that [would] be able to boost" [RESP5] them further. RESP7 argues that "[today] there is no life without" technology because it is heavily integrated in our lives. Juxtaposed to most farmers, RESP7 had in-depth understanding of smart technologies, however, cautioned its usage in all agricultural activities: "we have to be conscious of how much we use technology in our spaces". The farmer felt that heavy reliance and centralisation on technology could lead to challenges should there be a failure in technology. In addition, RESP7 argued that nature should not be tampered with as things are operating effectively without major human interference.

Human capital for some farmers was not a major challenge and as high demand for labour was mainly required seasonally. Major labour demands for crop farmers were required at harvest times, "...when there is high demand for labour, like at time for harvesting, I employ them" [RESP2]. To minimize costs some farmers used family members for mitigating labour demands. "When I want to harvest, I do not employ anyone, I would call my relatives and call my family and we would harvest" [RESP6]. Farmers who owned livestock on the other hand had to incur costs of employing herdsmen to guard their livestock to prevent theft and mitigate the spread of animal diseases.

5.3.4 Social assets

Many respondents, who went into farmer support associations, were encouraged by extension officers to form or join associations to increase their chances of getting support. The farmers explained that government support services were more likely to be issued when government issues goods to a collection of farmers rather than individuals.

"Extension officers would advise [smallholder farmers] to [form part] of primary Co-Ops [Farmer committee groups] to be able to benefit from Government initiatives" [RESP1].

A minority of farmers were not part of any support group. However, for most farmers their families and communities played important roles in running their farms. This is in relation to labour, marketing, and financial and moral support, which are essential in keeping farmers motivated to continue. Their social assets allowed farmers to strengthen other assets, which assists them in reducing vulnerabilities they are exposed to. Access to social assets could lead to

strengthened human, financial, and natural assets. Table 5.5 summarises the support provided through the availability of social assets

Table 5.5: Access to support provided through the availability of social assets

Support	Quotations to support the theme	Type of asset
Skills development and mentorship	<ul style="list-style-type: none"> • <i>“I encourage them on different practices, and I help them in their gardens”</i> [RESP7]. • <i>“they support by being mirrors and consultants”</i> [RESP3] • <i>“It is supportive of youth, who would like to venture into these things”</i> [RESP8.] 	Human asset
Moral support	<ul style="list-style-type: none"> • <i>“...community yes, where I am in De Novo, people are supportive”</i> [RESP5] • <i>“...my family is supporting me [...] Morally”</i> [RESP5] 	Social asset
Finance support	<ul style="list-style-type: none"> • <i>“My wife was supporting me and also financially”</i> [RESP5]. • <i>“They are also willing to financially support me”</i> [RESP3]. 	Financial asset
Market access	<ul style="list-style-type: none"> • <i>“The community and family assist with regards to labour and the local market. They would buy and recommend some of our products to families”</i> [RESP1]. 	Financial asset
Product purchase and improvement	<ul style="list-style-type: none"> • <i>“They only do support in terms of buying the product and whenever they are unsatisfied, they will let me know”</i> [RESP9]. 	Financial asset
Land access	<ul style="list-style-type: none"> • <i>“...the land other than the 3 hectares I have. I asked for it and the community granted it for me”</i> [RESP2]. • <i>“I’m the one who engaged and spoke with my parents to give people of the community a portion of land”</i> [RESP4]. 	Natural asset
Farming materials	<ul style="list-style-type: none"> • <i>“I share seedlings when I have seedlings”</i> [RESP7]. 	Natural asset

5.3.5 Financial assets

Financial assets posed a major concern for most farmers, as the access to finance allowed farmers to sustain and expand their operational activities. The farmers noted that inadequate access to finance was stressful and frustrating for farmers as it limited their ability to operate their farms effectively.

"...personal finance, out of my own pocket, I will be honest, have been very taxing and very stressful" [RESP5].

Many farmers used their personal finances to start and maintain their farming operations. Personal finances comprised of mainly family assistance, savings, and secondary income streams from their daily jobs. Farmers would contribute their personal finances for initial capital investments required and ongoing operational expenses.

"I did not receive any grants, I just invested using my personal finances and I would borrow money here and there" [RESP2].

Many grants and loans were also accessible to some farmers via government support services. In some instances, these funds would be received by farmers after proving evidence of their initial investment. Farmers who had ongoing farming operations received government support services and loans; for instance, RESP5 received the funding after making an initial investment in the earlier stages of the farming practice.

"I did qualify for an amount of about R120 000 from the department [Department of Agriculture, Elsenburg]" [RESP5].

"We got finance from a loan [as well] as the owner's contribution" [RESP9].

Government grants included farmers' budgets for allocated amounts, which were not accessible in cash. Farmers would be allowed to buy certain goods from vendors recommended by the respective government departments. Some farmers felt this system sometimes worked to their disadvantage. RESP1 contended that the grants would be allocated to many farmers at the same time. This would result in farmers having high supplies of similar commodities within close proximity which forced the farmers to sell their commodities at low prices.

Other farmers had secondary means of income generated from other businesses or jobs to assist in sustaining their operations. This was more prevalent for younger farmers.

"I am part time farmer and part time researcher" [RESP3].

"I am currently doing an internship so have that money to finance" [RESP10].

"Because I started off with a bottle store, I would use profits made from my bottle store for start-up capital. That is how I would survive" [RESP8].

The stringent regulations on access to loans applied by land banks limited the farmers access to finances. The banks require farmers to have collateral and land in exchange for this access. Limited resources and the fact that many smallholders operate on communal land, caused major difficulties “...issues of finance which is very difficult because we personally do not have anything particular to lease because the land is not ours” [RESP2]. Further, COVID-19 regulations had a negative impact: “it was better when I had the bottle store; now that there is the lockdown, there is no way forward.” [RESP8]

5.3.6 Information technological assets

The farmers were mainly performing their operations in a conventional manner and had minimal to no use of smart technologies for their agricultural activities. Smallholder farmers in the study relied mainly on manual labour to execute tasks on their operations. The farmers articulated the potential benefits that smart technologies have for farmer livelihoods. The benefits included:

- Simplifying daily operations by reducing manual effort
- Enables easy communication between peers and customers
- Marketing to broader audience
- Calculating area of land

The usage of smart technologies by smallholder farmers was limited. The main form of ICTs used by smallholder farmers were smart “...Android and iPhone {IOS}” supported devices [RESP2] and feature phones [RESP8]. These were mainly used for networking with peers in support groups, communicating with employees and marketing their products. Some farmers who did not own phones used “neighbour’s smartphone[s]” [RESP3] to access communication, data access and marketing needs. RESP1 used GPS technologies to assist in calculating the average hectareage of the crop size.

5.4 Vulnerability context

Vulnerability contexts include the trends, shocks and seasonalities that have a negative impact on smallholder farmer livelihoods. Table 5.6 summarises the vulnerability context impacting smallholder farmer livelihoods.

Table 5.6: Summary of vulnerability contexts impacting smallholder farmer livelihoods

Vulnerability context	Application in relation to smallholder farmers
Trends	<ul style="list-style-type: none"> • Limited access to the market • Stringent regulations and laws • Lack of access to finance due to type of land tenure • Low quality government and extension services

Shocks	<ul style="list-style-type: none"> • Animal exposure to diseases when encountering animals in a communal setting • Crop pests • Stock Theft and predation • Livestock breeding polarisation
Seasonalities	<ul style="list-style-type: none"> • Lack of control on animal breeding seasons

5.4.1 Trends

Smallholder farmers in this study experienced several trends that had a negative impact on their farming business. The trends these included:

- Limited market access
- Stringent laws, regulations, and standards
- Poor government support and extension services
- Lack of access to finance
- Low quality services in farmer support associations

Farmers indicated that they had limited *“access to the market”* [RESP1] within their respective regions. Some of the farmers lived in rural settings which were far from the urban areas where most customers resided. Farmers living in rural areas were forced to sell to travel to further locations due to low demand of commodities in their respective rural areas.

“My sheep can only be sold on further locations because I am in Mount Fletcher, and I sell them to the informal market. But sometimes I am unable to sell everything locally and I end up have a surplus of sheep” [RESP2]

The farmers *“struggle to get into the formal the formal value chain”* [RESP2] mainly due factors such as distance, stringent market competitive pricing mechanisms and standards.

The farmers were also impacted by various laws, regulations, and standards, which limited their ability to achieve higher income. Due to the stringent market requirements, the probability of their livestock being rejected ions were high. This posed challenges for farmers.

“...it becomes so difficult and there [are] so many reasons that can attribute to them not being able to take my stock” [RESP2].

Farmers indicated that in addition to limited resources they experience poor government support and extension services within their regions. The service rendered by extension officers was inconsistent across different regions, with some farmers admiring the high-quality service and others questioning what was delivered. Extension service quality was, however, not consistent across all regions; in *“...remote areas you would find that government extension services in especially here in the Eastern Cape are so weak”* [RESP2].

Other challenges for farmers were low quality services in farmer support associations. When dissatisfied with perceived benefits, some farmers would easily leave these associations to find avenues that would be more appealing for their pressing needs.

“NERPO... But I was not satisfied with the service, and it did not make sense for me to pay for being part of such an organisation without benefit” [RESP9].

“...sometimes when there is something of benefit that comes into the organisation, some of the leadership would want to benefit themselves” [RESP2].

5.4.2 Shocks

Smallholder farmers in this study experienced the following shocks:

- Disease and virus outbreaks
- Stock theft
- Breed polarisation

Due to lack of fencing, the farmers were susceptible to undesired circumstances that negatively impacted their herd immunity and crop yields. Animals roamed in communal grazing lands and farmers had limited control over how and where they go. Disease control posed a major challenge for some farmers. Livestock farmers, who were vulnerable, mentioned that using vaccines on the livestock was not good enough. Measures taken to curb this effect were not completely sustainable, as livestock from neighbouring villages continue to carry and spread the viruses to their livestock. The farmers incurred costs of employing herdsmen to guard their livestock to mitigate some of these issues.

“...one of our issues is diseases control. As an individual farmer you would be able to purchase vaccines, but they would not be effective” [RESP2].

Farm owners managed the livestock theft and predation through the employment of herdsmen. The situations relating to stock theft was worse if farmers were produced high value commodities that were in demand in communities.

“...we have many herders to help protect our livestock from predators like jackals and others” [RESP2].

“...one of the people’s challenges is theft, like growing stuff that other people want is like scary and could result in loss in your farming practice” [RESP3].

The farmers could also face the challenge of breed quality if livestock is not managed effectively. Lower quality breeds could possibly breed with superior breeds of livestock, leading to the decreasing of value of farmer’s breeds.

“...if, for example you do not have a shepherd, it would be easy for your high-quality breed livestock to mix with those within the village. This would be a similar case for cattle and other high-quality livestock. Your high-quality breed would mix with others, which could cause even more problems” [RESP2].

Crop growers were also heavily impacted by pests which if not treated correctly, could damage their crops. *“...we lose up to 30-400 cabbages and you find that it is a certain type of pest that resulted in this damage”* [RESP8].

5.4.3 Seasonalities

Farmers had limited control over breeding seasons for their livestock. If the cattle bred naturally and out of season, this posed challenges as there could be instances where calves are born in dry seasons which could eventually increase their mortality rates.

“What you would find out breeding is not controlled, it is natural. We know cattle will breed in November and will give birth in August the following year, at a time where there is not enough grass and that time a lot of calves die” [RESP2].

5.5 Transforming structures and processes

This section discusses the transforming structures and processes that assisted smallholder farmers in alleviating the impact of vulnerabilities on their livelihood assets. The section specifically details the various structures and later lays out the processes applied to alleviate these impacts. Table 5.7 summarises the transforming structures applied in context of smallholder farmers

Table 5.7: Transforming structures applied in context of smallholder farmers

Transforming structures and process	Application in relation to smallholder farmers
Structures	<ul style="list-style-type: none"> • Had access to the Department of Agriculture • Encouraged to formulate and join co-ops and associations by extension services
Process	<ul style="list-style-type: none"> • Extension Services • University research programmes

5.5.1 Structures

Farmers in the study had access to various levels of government services and structures that assisted them in wide-ranging areas of their agricultural operations. The Department of Agriculture played a critical role in assisting farmers with all areas related to agricultural support. In the Western Cape, Elsenburg provided support *“...involved with farming and agriculture in general”* [RESP5].

Farmer associations, co-ops and schemes also contributed to farmers' access to resources, allowing them to operate their farms better. Benefits of partaking in support associations was an element that was directly linked to aiding farmers in reducing the impact of some of the challenges faced.

"...there is a scheme called the Zanyokwe Irrigation Scheme, and Phuhlale Co-Op. As a farmer, I can form part of those groups, and I can consult those officials" [RESP3].

"We are part of a co-op; the government assists people who work together rather than individual farmers" [RESP1].

Farmers also understood the need to partner with existing support structures to increase their chances of better achieving their growth objectives. These include *"engagement with the commercial sector"* [RESP2], other government departments, research institutions, and associations. Institutions of higher learning can contribute to making their expertise, knowledge, and networks available to farmers.

"Kokstad research station, it is attached to the University of KwaZulu Natal (UKZN). I should think that there should be a link with them, as they have some agricultural insights" [RESP2].

"Also, the University of Stellenbosch to an extent, although I have not been in touch with them. But the door is open" [RESP5].

RESP3 learnt water-harvesting techniques through an initiative run by Rhodes University. These skills are being applied by the respondent and minimized the impact of water shortages endured during climate change. At *"Rhodes there is an Amanzi for Food Project the project is commissioned by the Water Research Commission to share rainwater harvesting conversations, use and knowledge"* [RESP3].

5.5.2 Processes

The role of extension services was dominant amongst many smallholder farmers in the study. Extension services are provided by the Department of Agriculture to assist farmers with a range of needs and form the *"primary assistance"* [RESP1] for many farmers. Extension officers do *"not always [form] part of Co-Ops but are provided as a service by government"* [RESP1]. Nevertheless, government extension offices were central to guiding and linking farmers to resources that will allow better functioning in their enterprises. Extension services also encouraged farmers to form or join co-ops to facilitate access to government services and resources; since *"it is easier for the Department of Agriculture to work for a co-op rather than [individual] people"* [RESP5].

5.6 Livelihood strategies

The Department of Agriculture and other government structures are the main contributors that provide aid to the development officers. Their assistance is mainly in relation to access to information through extension services, resources, and access to finance and infrastructure. In conjunction, some farmers also use co-ops and associations to access solutions to their problems through sharing with other farmers and to support, resources, finances, and services provided. Table 5.8 summarises the strategies implemented by these structures.

Table 5.8: Livelihood strategies applied by transforming structures

Transforming structure and process	Livelihood strategy	Quotations to support the theme
Government - The Department of Agriculture	Commodity price benchmarking	<ul style="list-style-type: none"> “I think extension officers, would inform us on the market prices of stock in different geographic regions, like in East London [and] King Williams town, and check the prices of stock from street vendors” [RESP1].
	Medical advice and supplies	<ul style="list-style-type: none"> “In as far as the treatment of pigs, their health and in terms of the structure, I work closely with the farmer support group” [RESP5].
	Infrastructure development	<ul style="list-style-type: none"> “...if we could get support from government to maybe assist us with a borehole or maybe a pipe or generator to pull the water” [RESP8]
	Access to finance	<ul style="list-style-type: none"> “NYDA [National Youth Development Agency]” [RESP8]
Associations	Inputs and access to finance	<ul style="list-style-type: none"> “...for example, Umthiza, because they really help with medication and feed” [RESP8] “We are still in the process of getting registered so that we can qualify for supports financially and otherwise” [RESP4].

How can smart technologies be applied by smallholder farmers for increased productivity and sustained livelihoods?

	Information	<ul style="list-style-type: none"> • <i>“Information is best retrievable through being part of such institutions” [RESP3]</i> • <i>“AFASA! Yes, so there is AFASA and BOFASA, I think” [RESP3].</i>
Government – other government departments	Market access	<ul style="list-style-type: none"> • <i>“The Department of Health [and] Department of Correctional Services. They need to be supplied with food; they can assist us in delivering to the demand needed” [RESP1].</i>
Academic institutions	Market research	<ul style="list-style-type: none"> • <i>“Kokstad research station, it is attached to the University of KwaZulu Natal (UKZN), I should think that there should be a link with them as they have some agricultural insights” [RESP2].</i> • <i>“[At] Rhodes there is an Amanzi for Food Project; the project is commissioned by the Water Research Commission to share rainwater-harvesting conversations, use and knowledge” [RESP3].</i> • <i>“Also, the University of Stellenbosch to an extent, although I have not been in touch with them. But the door is open” [RESP5].</i>
NGOs	Regulatory compliance	<ul style="list-style-type: none"> • <i>“SAOSA is a [...] are permaculture or organic or agroecology organisations” [RESP3].</i>
	Environmental management	<ul style="list-style-type: none"> • <i>“Conservation Planning Specialist Group, which is wildlife... there is an issue of wild pigs and monkeys in my farming community” [RESP3].</i>
Private institutions	Market access	<ul style="list-style-type: none"> • <i>“I think if we can get into the retail sector or maybe if we can get [into] organisations, such as your Shisa</i>

		<i>Nyama, for braais, hotels and restaurants” [RESP9]</i>
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5.7 Livelihood outcomes

Smallholder farmer assets and interventions produced by transforming structures enabled farmers to have positive livelihood outcomes, which included.

- Increased revenues
- Increased wellbeing
- Community development
- Increased food security
- Increased productivity

For smallholder farmers to achieve these outcomes, a wave of vulnerabilities, which may be unexpected at given times, also needed to be considered.

RESP1, and RESP8 outlined the importance of achieving food security as their fundamental contribution to the community and their wellbeing. Food security is multifaceted and can be achieved on individual, household, and community food security levels. RESP3 mainly propounds on the intent to sustain individual food security, indicating, *“I would like to produce everything that I consume.”* RESP1 achieved household food security: *“We are able to provide for our family.”* In addition, RESP1 and RESP8 contributed towards achieved community security.

“We are able to feed the demand around us” [RESP1].

“From the farm I would say to supply the local community” [RESP8].

RESP8 also indicated the importance of youth development, which is driven by the agricultural activities on the farm, illustrating that in the farming operations, one should *“be able to assist the youth where we can”*. commercial viability and sustainability were some of the most critical outcomes required by smallholder farmers. Profitability is essential to the livelihoods of smallholder farmers, as it not only assists them in being able to provide for themselves, but also allows them to access other limited resources

“...my financial goal is to make this establishment three times better, then I will be happy” [RESP2]. “I am a smallholder farmer for food production but the main goal I would like to achieve is back to the commercial level and be able to supply as a commercial farmer” [RESP5].

“I would like to get funds to be able to extend the farm because the demand is higher than the supplier” [RESP9].

“I need to one day be able to plant all my hectares without many challenges” [RESP6].

Smallholder farmers aspire to expand and diversify their operations through extended land use and increased productions scale.

While other farmers aspired to being integrated into the existing value chain, others aspired a parallel system; RESP8 wanted to his *“own supermarket locally and to be able to supply local stores”*.

The quality of the products produced is one of the key considerations applied by farmers, with crop growers emphasising the quality of the soil, which has a direct link to the produce. RESP7 and RESP10 emphasised the importance of good quality and healthy products.

“...whatever it is, it must be good quality, it must be healthy” [RESP7].

“Like the soil is so rich. It is influencing fresh products” [RESP10].

Table 5.9 summarises smallholder farmer productivity outcomes derived from smart technology usage.

Table 5.9: Smallholder farmer productivity outcomes derived from smart technology usage

Productivity Classification	Outcome	Quotations to support the theme
Labour productivity	<ul style="list-style-type: none"> • Reduction of labour costs • Prompt alerts that allow for faster decision making • Reduced manual effort 	<ul style="list-style-type: none"> • <i>“...the more I know, the quicker I can make decisions. The better decision[s] I can make”</i> [RESP3]. • <i>“I will do many things because I know that I will not put much effort”</i> [RESP6]. • <i>“...reduce the cost of employing people to do certain things”</i> [RESP8] • <i>“I think new technology will help with sharing the knowledge faster”</i> [RESP3].
Land productivity	<ul style="list-style-type: none"> • Strengthened resilience to vulnerabilities • Increased capacity of yields 	<ul style="list-style-type: none"> • <i>“Some places we do not plant because we do not understand what we can plant there”</i> [RESP1]. • <i>“...the technology will be able to tell us what kind of pests we have and where. This will allow us to quickly act by placing pesticides”</i> [RESP8]. • <i>“We could be able to plant more rapidly. Some things are wasted because they are planted out of season... sometime technology can predict the most suitable time to plant crops”</i> [RESP1].

Capital productivity	<ul style="list-style-type: none"> • Optimisation of resources • Enabling trust and transparency 	<ul style="list-style-type: none"> • “...would definitely cut down the current running costs, for instance, if I need anything, I need to drive to and from. Whereas if I had technology, I could use technology to place an order” [RESP5]. • “...technology would also create some trust between myself and the market, myself and suppliers as well” [RESP5].
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5.8 Technology trends in agriculture and usage by smallholder farmers

This section discusses the technologies in the South African landscape, perceived impact of technology on productivity, key considerations for smart technology adoption, technology usage rate in South Africa, factors impacting current rates of adoption, and recommendations for introducing smart technologies to farmers.

5.8.1 Technologies in agriculture used in the South African landscape

Many experts posited that smart technologies have been widely adopted in the agriculture sector in South Africa. However, in most cases the technologies are relevant to a specific commodity. The views of the expert and smallholder farmer are in line with the literature (Section 2.5) and secondary data reports on the current smart technologies in agriculture. The views included the use of ICTs, Cloud Computing, Robotics, IoT devices and AI in farming activities. In addition, experts also suggested that platforms, biotechnologies, blockchain, satellite, and modern methods of farming were also widespread across the agriculture spectrum. Table 5.10 provides a summation of smart technologies in the market.

Table 5.10: Subject matter expert and smallholder farmer views on smart technologies in the market

Category	Technology	Use in the market	Quotations to support the theme
Smart Technologies	Drones and satellite technologies	<ul style="list-style-type: none"> • Crop monitoring 	<ul style="list-style-type: none"> • “Grapes – AI, Soil Monitoring, Satellite Information”. [SUBEXPERT1]
		<ul style="list-style-type: none"> • Transportation 	<ul style="list-style-type: none"> • “I do not know if technology can help with[it], because it is difficult because you have to transport things and it is difficult moving” [RESP6] • “...if you need to move cows around” [RESP6]

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			<ul style="list-style-type: none"> “...for livestock I think tracking, cameras like right now, those thieves are taking sheep in the kraals” [RESP10]
Sensor and IoT devices	<ul style="list-style-type: none"> Monitoring quantity, quality and of inputs and outputs 	<ul style="list-style-type: none"> “Monitoring quantities (input-feed, water, etc./output) and qualities (input/output) during production process for maximum efficiency and market compliance together with traceability”. [SUBEXPERT7] 	
	<ul style="list-style-type: none"> Animal tracking 	<ul style="list-style-type: none"> “Anti-theft technologies for livestock in rangeland situations”. [SUBEXPERT7] “RFiD and ear tags is the only beef technology in play, GSM is coming into the market “. [SUBEXPERT10] “But I did hear that it is going to help us as farmers as well, for instance animals need to be tagged” [RESP5]. 	
	<ul style="list-style-type: none"> Sensor-based soil testing 	<ul style="list-style-type: none"> “I would like these technologies to be able to test my soil and tell me the kind of fertilizers that can be used for this land” [RESP8]. “Soil testing as these processes are time consuming” [RESP1]. 	
Robotics process automation	<ul style="list-style-type: none"> Mechanization of farming 	<ul style="list-style-type: none"> “Mechanized planting... mechanized harvesting”. [SUBEXPERT8] “We will no longer be physical, there will be automated machines” [RESP10]. 	
Artificial intelligence	<ul style="list-style-type: none"> Animal weighing 	<ul style="list-style-type: none"> “...an app you can use to weigh; you can take a photo and weigh it” [RESP2]. 	
	<ul style="list-style-type: none"> Medical diagnosis 	<ul style="list-style-type: none"> “...identify what kind of sickness your pig has. So technically you will be able to see, hey here is this sickness. Then ... 	

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			<i>you can go straight to the pharmacy and buy that medication” [RESP8].</i>
	Blockchain	<ul style="list-style-type: none"> • Traceability 	<ul style="list-style-type: none"> • “...blockchain technology in farming”. [SUBEXPERT8]
	Big data and data analytics	<ul style="list-style-type: none"> • Forecasting and predications 	<ul style="list-style-type: none"> • “...data science and data engineering within the sector of agriculture”. [SUBEXPERT2]
ICT’s	Smartphones	<ul style="list-style-type: none"> • Resource optimization 	<ul style="list-style-type: none"> • “Resource-optimizing cell phone/computer applications”. [SUBEXPERT6]

Platforms for market connection, advisory and data capturing were technologies identified by subject matter experts and smallholder farmers in South Africa. Table 5.11 provides a summation of platforms in the market.

Table 5.11: Subject matter expert and smallholder farmer views on platforms in the market

Category	Technology	Use in the market	Quotations to support the theme
Platforms	Connection Platforms	<ul style="list-style-type: none"> • Market connection 	<ul style="list-style-type: none"> • “Market connection platforms (e.g., live prices, online sales)”. [SUBEXPERT8] • “They can help us gain new markets and enable us to grow varieties” [RESP1] • “...sort of online auction where I can sell my livestock” [RESP2] • “I think new technology will make me more known to the market” [RESP5]
	Advisory Platforms	<ul style="list-style-type: none"> • Advisory services 	<ul style="list-style-type: none"> • “Technical advisory platforms (e.g., live weather, chat with an expert)”. [SUBEXPERT8] • “...if there is any way to virtually show vets on the status of the sick livestock and perform a diagnosis” [RESP2]. • “...you can seek specialist advise using technology” [RESP6].

	Data capturing	<ul style="list-style-type: none"> Record keeping 	<ul style="list-style-type: none"> <i>"...recording system, the other areas. That those are the kinds of things that can be helpful in assisting me in better managing my livestock" [RESP2].</i> <i>"...what farmers are not good at is bookkeeping. So, technology, especially with handheld devices, now that you are there on the field you can capture data" [RESP6].</i>
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Although not directly used by smallholder farmers, modern farming practices such as artificial breeding mechanisms, seed modification, hydroponics and aquaponics were technologies available in the South African landscape. Table 5.12 provides a summation of modern farming practices in the market.

Table 5.12: Subject matter expert views on modern farming practices in the market

Category	Technology	Use in the market	Quotations to support the theme
Modern farming practices	Genetic modification	<ul style="list-style-type: none"> Artificial breeding Seed modification 	<ul style="list-style-type: none"> <i>"Using genetic material from superior global and local sources with artificial breeding methodologies". [SUBEXPERT7]</i> <i>"...the main technology that has been widely adopted is more in the seed and the varieties of the crops being used in small scale farmer sector". [SUBEXPERT3]</i>
	Hydroponics and Aquaponics	<ul style="list-style-type: none"> Soil-less farming 	<ul style="list-style-type: none"> <i>"Currently I think it is soil-less ways of farming using hydroponics and the likes of aquaponics, I think that is the most modern way of farming". [SUBEXPERT4]</i>

5.8.2 Perceived impact of technology on agriculture productivity

Subject matter experts believed that technology had a positive link to productivity and believed that technology could unlock potential within agriculture. Experts thought the potential benefits of smart technologies were *"very high"* [SUBEXPERT7]. The main productivity outcomes driven by smart technologies which the experts articulated include the

decreased time to investigate issues, increased quality of inputs, enabled resilience on vulnerabilities, resource optimization, increased traceability, strategic decision making and the resolution of production issues which could result in the reduction of costs. Table 5.13 summarises subject matter expert views on the effects of technology on productivity.

Table 5.13: Subject matter experts’ views on effect of technology on productivity

Productivity classification	Outcomes	Quotations to support the theme
Labour productivity	<ul style="list-style-type: none"> • Decreases time to investigate issues • Increases quality of inputs 	<ul style="list-style-type: none"> • <i>“IoT - helps us do what we could not do back in the day ... we can now use technology to determine what we should be feeding cattle when and where”</i> [SUBEXPERT9]. • <i>“Through precision farming — by increasing the efficiency of resource (water, fertilizer, pesticide, etc) application [...] to maximize total yield per hectare”</i> [SUBEXPERT6].
Land productivity	<ul style="list-style-type: none"> • Builds resilience leading to vulnerabilities 	<ul style="list-style-type: none"> • <i>“...it assists them by getting better yields and I think maybe crops and pest resistance”</i>. [SUBEXPERT3] • <i>“I can take data from weather services, and I can safely assume or predict that in the next five years we will have a drought, or we will have rainfalls”</i> [SUBEXPERT2].
Capital productivity	<ul style="list-style-type: none"> • Resource Optimization • Increased value of produce through traceability • Enables strategic decisions on areas to commit effort, limiting costs. • Enables the resolution of production problems 	<ul style="list-style-type: none"> • <i>“Use of resources more effectively, saving money”</i> [SUBEXPERT1]. • <i>“They can see beforehand non-productive planting areas and decide if they want to plant [there] or not”</i> [SUBEXPERT1]. • <i>“Detection of underperformance, redress. Unlocking full genetic potential of animals. Sellable produce to lucrative markets because systems can provide proof of compliance”</i> [SUBEXPERT7].

5.8.3 Key considerations for smart technology adoption

The key areas that smallholder farmers need to consider when adopting technology included assessing the cost-benefit of technology investment in the long run, the variants of costs involved with technology in the long term, where technology can add value in their operations. Farmers should also consider the contingency plans should technology fail and lastly, think around skills involved with operating the technology.

5.8.3.1 Cost-benefits and variants of costs involved with technology in the long term

According to the experts, the affordability of technology is one of the factors that farmers should consider when adopting technology. Some indicated that it was essential to consider the cost-benefit ratio for these propositions. In other words, the value of technology in relation to addressing their challenges. Experts mentioned that there are many technology solutions in the market, but the farmer needs to consider the economic viability of these systems.

Bearing in mind the costs involved, some experts noted that it is beneficial for farmers to consider technology as long-term investment rather than a short-term benefit to problems. It is essential to understand the value that the technology may bring to a farmer in the long run.

“Another big challenge is the cost of technology. An initial investment in technology can be costly. When you do take that leap, you need to remind yourself that it is a long-term investment” [SUBEXPERT1].

Experts also mentioned that when contemplating whether to adopt technology, farmers would need to realise that technology incurs different dimensions of costs. These include operational and maintenance costs, scaling of the solution, and skills required to manage the solution.

“Does the technology require regular maintenance?” [SUBEXPERT6].

“...together with maintenance, depreciation, scale of operation, capital/interest redemption and level of management that are required” [SUBEXPERT7].

In addition, experts emphasised that farmers should *“Start simple”* [SUBEXPERT1] and gradually uptake the usage of technology. *“You do not have to break your pocket to pick up a project in technology in the farming sector”* [SUBEXPERT4]. Experts encouraged farmers to approach educational institutions for assistance and guidance on how to apply these technologies in their operations.

5.8.3.2 Farmers need to assess where technology can add value

Farmers should not get caught in the hype that technology is the solution to all problems. An emphasis was that technologies *“are not the silver bullet”* [SUBEXPERT1]. There are many other integrated data collection and analysis processes that would need to be considered for the technologies to be of value to farmers. Experts argued that farmers would need to interrogate the need for specific technologies within their own context.

"Farmers need to bear in mind, technology is not a new thing. It is just how you apply it" [SUBEXPERT4].

Farmers should *"ask a person, what are you trying to do there? Because I have my needs. Are you solving my needs?" [SUBEXPERT1].*

5.8.3.3 Farmers need to consider contingency plans of operating the technology and skills required to operate technology tools

Taking into consideration the application of these technologies, SUBEXPERT9 also stressed the importance of having manual contingency plans in an event of technology failure at any point. The experts mentioned that the danger of centralising most processes on technology is the fear that this may cause issues for farmers who have become heavily reliant on them. Like many other processes, farmers would need a contingency plan in an event that technology fails to operate adequately.

"Sometimes tech fails. You should still have good manual processes that can serve as backups when things go wrong" [SUBEXPERT9].

Other points of consideration by SUBEXPERT6 related to the environmental impacts of proposed technologies and recommended that farmers should ask *"Does the technology contribute toward sustainable farming?"* and *"What is the carbon footprint of the technology?"*

5.8.4 The rate of technology usage in South Africa

The experts posited that smart technologies were not fully exploited in the country and Africa as a whole. They noted little to no evidence supporting the wide adoption of smart technologies farmers in South Africa.

"In [South Africa] I still feel like it's a bit slow especially in the Eastern Cape where I am" [SUBEXPERT9]

"It's very low...there's barely 10% adoption of agritech in Africa" [SUBEXPERT1].

Some experts believed that the current rate of adoption and usage of smart technologies is *"very low in South Africa"*. Others linked this to the country' dual economy; the adoption is specifically low for smallholder famers, relative to commercial farmers.

"The current state of adoption is very low in the smallholder" [SUBEXPERT3].

"In [the] South African context for small farmers it is of no use. It does not stop theft, or increase traceability, thus excluding these farmers from the formal food value chains" [SUBEXPERT10].

SUBEXPERT6 said that the main technologies adopted by smallholder farmers are of the mechanical technologies such as tractors, seed drills and milling machines which are mainly provided through extension services.

"The curve of innovation adoption by South Africa's smallholder farmers has flattened since the introduction of tractors, seed drills, and milling machines [at] the height of the 20th century" [SUBEXPERT6].

5.9 Summary of chapter

This chapter discussed the findings of the study in relation to subject matter expert point of views and the context of the SLA framework. Smallholder farmers are impacted by vulnerabilities which impact their livelihoods and are heavily reliant on transforming structures to manage some of these issues. Smart technology can decrease time to investigate issues, increase quality of inputs, build resilience on vulnerabilities, allow resource optimization, increased value of produce through traceability, enable strategic decision making, limit costs and enable the resolution of production problems.

Chapter 6: Discussion, conclusion, and recommendations

This chapter presents the discussion, conclusion, and recommendations of the analysis on empirical materials. This chapter is organised as follows: Section 6.1 uses the PEST (Political, Environmental, Social and Technological) factor analysis to explain the factors that influence and hinder smallholder farmers usage of smart technologies to increase productivity, Section 6.2 discusses how can smallholder farmers use Smart Farming technologies to identify, mitigate and prevent vulnerabilities. Section 6.3 discusses recommendations and Section 6.4 recommends future work that may be applied. The chapter concludes with a final word of the discussion, conclusion, and recommendations in Section 6.5.

6.1 Research approach and problem summary

The increase of smallholder farmer productivity is a core strategy to alleviating economic, institutional, and social constraints faced my farmers. The use of smart technologies by smallholder farmers could assist in pre-empting vulnerabilities that impact smallholder livelihoods and production returns. The use of data derived from IoT devices, drones, sensor, and other technologies could be leveraged for gathering actionable insights that could benefit smallholder farmers in making more effective decisions. The study applied SLA and extended the pentagon of assets to include modern technology as plan to strengthen smallholder farmer livelihoods. The study leveraged the views of subject matter experts and reports for a perspective on the usage of smart technologies in Africa and South Africa. A combination of smallholder, subject matter expert and reports influenced the studies recommendations on how smart technologies may be leveraged to increase the productivity of smallholder farmers.

6.2 Factors that influence smallholder farmers in the usage of smart technologies to increase productivity

PEST analysis is a tool or framework used to evaluate and identify the impact of political, economic, social and technological external factors of an entity (Rastogi & Trivedi, 2016). The study applies the PEST analysis framework to discuss the findings of smallholder farmer usage of smart technologies. Table 6.1 summarises PEST factor definitions.

Table 6.1: PEST factor definitions

Factors	Definition
Political factors	Determine the extent to which government may influence the economy or industries.
Economic factors	Determinants of economic performance and its impact on entity long term and short-term objectives
Social factors	All events that impact the community and market socially
Technological factors	Technological innovations that may impact the market

6.2.1 Political Factors

The study noted that there is limited to no support from government to provide access to smart technologies for smallholder farmers. There may be many reasons for the lack of support, which may include the high capital investments and lack of knowledge of smart technologies by smallholder farmers. The study also noted that there is lack of collaboration between government, the commercial sector, academic institutions, and the private sector also constitutes a major hindrance to technology adoption for smallholder farmers. Leadership power dynamics across multiple stakeholders leads to information asymmetry between industry experts and smallholder farmers. Workshops where Agri-tech innovations are created lack the involvement of smallholders which leads to the lack of smallholder problem-centric solutions.

6.2.2 Economic Factors

The study noted that high costs of technology and limited access to finances serve as a major hindrance for smallholder farmers. The implementation and maintenance of smart technologies requires high initial capital investment. In addition, the usage of skilled labour for operational activities could pose large strain on smallholder finances. Smallholder farmers already have low capital resources and would struggle to bear the costs involved with the implementation and maintenance of smart technologies.

6.2.3 Social Factors

Another aspect considered in the study is the importance of buy in from associations and co-ops. Farmers are more likely to use smart technologies if more farmers are reaping value from them. Social assets that farmers rely on for advice and access to other assets have not actively encouraged the use of smart technologies. Associations and groups with whom they interact in gatherings and on social media platforms. Currently smallholder farmers are heavily reliant on manual processes that lack data driven insight. The study noted that for most farmers, there was a lack of knowledge on smart technologies.

6.2.4 Technology Factors

There is an increased appetite for the usage of smart technologies in the agriculture sector, with more feasible use cases being developed around IoT and other connected technologies (Choudhary, et al., 2020; Velosa, Kutnick, Lheureux, & Williams, 2020). The true value of using smart technologies is to enable effective use cases that may encompass a combination of multiple technologies. The study noted that there was little to no evidence of the use of smart technologies by smallholder farmers. Reasons for the lack of usage included the lack of awareness of how smart

technologies may be used by smallholder farmers, inadequate infrastructure to accommodate the usage of smart technologies and the scarcity of smart technologies in smallholder communities.

In respect to IoT devices, there are challenges with the battery life, connectivity, scalability and heterogeneity of IoT options in the market (Velosa, et al., 2020). Applying the use of smart technologies in rural areas is still a major discussion across the technology domain, with experts recommending the use of Narrowband-IoT (NB-IoT) and Lora Wide Area Network (WAN) as cheaper alternatives to resolving these bandwidth and battery life issues (Vodacom, 2017). Drones also have stringent aviation regulations in South Africa (Jupp, 2018). Some farmers have realised the true potential of what drones can achieve for their establishments, however there are limitations of its abundant adoption due to its perceived use as a toy or tool for maliciousness (spying on neighbours) (Jupp, 2018).

6.3 Recommendations

This section recommends a smallholder problem-centric approach to designs, collaboration across multiple stakeholders, the introduction of digital extension services, farmer group buy in acquiring technologies, smallholder digital training to allow successful use of smart technologies by smallholder farmers and lastly encouraging active participation of youth in farming.

6.3.1 Smallholder problem-centric approach to designs

Smallholder farmers have specific challenges that can be overcome through relevant channels and cross collaboration between them and other key stakeholders. The minority of farmers who are knowledgeable on the true value that smart technology can bring to them, acknowledge that conferences and workshops held by innovators and stakeholders take place far from the actual farmers. There are several new innovations and technologies that may work for the context of smallholders in South Africa; however, these need to be tested and validated with the actual users. SUBEXPERT7 further added: that if *“the smallholder sector successfully adopts and demonstrate the benefits of these technologies [they would need to be] compatible with farmers' situations, perception, and acceptance of adequate relative advantages”*. A larger representation of smallholder farmers in conferences and workshops is fundamental to underpinning the crux of the challenges that smallholder farmers are facing. The technologies need to be smallholder problem-centric and need to be relevant to the smallholder's circumstances. Another facet is building robust and affordable solutions that are not only relevant to smallholder farmers, but which are also commercially viable.

6.3.2 Collaboration across multiple stakeholders

The successful introduction of smart technologies to smallholder requires a collaborative effort from a community of stakeholders. Government, private institutions, and farmers need to collaborate to deliver valuable and viable solutions to smallholder farmers. Government and private institutions have the responsibility of making an investment in building

infrastructure that will strengthen connectivity for farmers in remote areas and reduce data costs. Communities need to be enabled with infrastructure and internet connectivity to access and utilize resources that will upskill them and open more opportunities for them. The major challenge for government in granting access to subsidised smart technologies is identifying the commercial viability of smart technologies. SUBEXPERT7 argued that smart technology solutions would need to *“make economic sense (sustainable without recurrent government support)”*. The role of institutions of learning and the private sector is the development of smallholder problem-centric solutions that will benefit farmers and ensure commercial viability. In addition, the above forementioned need to be resolved through the collaboration of multiple stakeholders which include smallholder farmers, government officials, the communities, and the private sector experts to co-create solutions that will ensure rapid adoption of smart technologies in smallholder farmer operations.

6.3.3 Digital extension services

There is an opportunity for government extension officers to play a role in rapid technology uptake by smallholder farmers. Extensions services are dominant transforming structures that assist smallholder farmers with not only operational challenges, but also open doors to other assets. SUBEXPERT6 recommended that, since government extension officers are innovation channels to smallholder farmers, they have up to keep up to date on the latest technologies and key features that may be used by farmers. Most importantly, they should be more knowledgeable on the cost-benefit dynamics involved in investing in technology, to advise smallholders.

RESP3 mentioned that, if smart technologies were to be supplied, they would not need to learn how the technologies are used, but rather would be interested in the outcomes that the technologies may bring. *“I don't need to know how to operate government commissions or government access made technologies, because there are people hired to do that”* [RESP3]. It is therefore paramount to empower extension offers with technical skills to advise and apply high tech tools on behalf of farmers. Smallholder farmers trust extension services to advise provide tools that will assist them in operational efficiency and productivity. The cost of procuring and learning the complexities of smart technology should not be endured by farmers, but rather should be accessed through extension services to allow farmers to reap the benefits of using these technologies on a need's basis.

6.3.4 Farmer group buy in approach

A group buy-in approach can accelerate the adoption of smart technologies as farmers may collate and purchase smart technologies at scale, minimizing total costs. The cost of implementing technologies can be minimised if farmers could collaborate as a community or association in procuring and consuming smart technologies. This is a similar approach to how smallholder farmers are using mechanical technologies today can be applied: associations purchase high-value mechanical technologies, such as tractors and allow farmers to rent them for usage on a need's basis. It may not make sense for a smallholder farmer to buy a drone because it will take them longer to understand the benefit and process due

to its complexity. Smallholder farmers do not need to know the technical details on how to set up and configure technology, rather, they need to benefit from what the technology can do for them.

6.3.5 Extensive training of smallholder farmer digital and data literacy skills

Experts argued that technology in isolation cannot be effective in adding value to farmers, but rather the information the technology can provide. SUBEXPERT1 stressed that data derived from smart technologies cannot be effective if farmers do not understand or know how to use or interpret it. Farmers should be able to comprehend data to be able to offer meaningful insights that will be valuable to decision-making. Farmers should not be concerned about the actual technology provided to them, but rather the kind of information these technologies may provide to allow them to make better decisions. Experts mentioned that educating farmers on how to use these technologies will increase their adoption rate. Farmers will derive value of smart technologies when they understand what these technologies can do.

For this to be achieved, farmers need to be trained and skilled through focused training programmes that will allow them to read and understand data patterns that will be provided by technology tools. Associations and co-ops could also serve as a centre for training smallholder farmers on the benefits of smart technologies and data to drive decision making. Smallholder farms need to understand the value that technology may bring into their operations. To achieve this, their human capital should entail a level of data analysis skills. Through the mediation of associations and extension services, farmers need to be taught on the basics of reading data to be able to make decisions based on what the technology is telling them. Access to information and data is key to reaping benefits to technologies that may be made available to smallholder farmers.

A value outcome driven approach should allow smallholders to make decisions based on a collation of data sets and predictive models which could benefit farmers immensely. Technology should be the enabler and vessel for prompt and consistent actionable insights through notifications that will allow farmers to improve their operations. In instances where image processing is required to analyse crop performance, these may be requested on a need to know basis, and scheduled frequency to allow for patterns to be recognised by analysts and farmers.

6.3.6 Active involvement of youth in farming

There are great opportunities to leveraging youth to drive the usage of smart technologies within the agriculture sector. Today, there are growing opportunities to be involved in farming, even more so with youth who are born in the digital age. Experts claim that younger farmers are more open to using technology and are inclined to introduce to new ways of working that can lead to increased productivity. *“The age of farmers is seen as an important factor. Younger farmers might be more technologically and digitally inclined and willing to take more risks in comparison with the older generation”* [SUBEXPERT7]

6.4 Future research work

Future research may consider broadening its approach by benchmarking the use of smart technologies by smallholder farmers in other developing countries. In addition, the future work may consider looking at the factors that may have influenced successful or failed technology implementations in the respective countries. The sample of the present study was limited to 22 participants; future work could expand the sample of smallholder farmers and subject matter experts. The sample of participants was biased in terms of gender with mainly male participants contributing to the study; future work should address this by encouraging a more gender-balanced sample of farmers and experts. The study may also consider looking into commercial farmers' perspectives on the usage of smart technologies to increase productivity. The sample of smallholder farmers in the study did not include many examples of the successful usage of smart farming technologies and would need to be expanded as part of the future work.

6.5 The final word

Extension officers and associations are critical avenues to introduce smart technologies to smallholder farmers and could apply their usage through a similar approach to how mechanical technologies are applied today. To achieve these, there are numerous limiting factors that will need to be considered and dealt with through the collaboration of government, private sector corporations, communities, and smallholder farmers. Smallholder problem-centric technical solutions are key in assisting farmers to be able to achieve labour, capital, and land productivity.

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Appendix A - Research instrument overview: smallholder farmers

The Sustainable Livelihood Framework serves as a guide for the interview layout. The questions will be asked in for constructs provided in the framework. The constructs include the Vulnerability Context, Livelihood Assets, Structures Livelihood Strategies Livelihood Outcomes

SMALLHOLDER FARMER DEMOGRAPHICS

1. Age categories
 - a. 14-34
 - b. 35-59
 - c. 60+
2. Education
 - a. Primary
 - b. Secondary
 - c. Diploma and above
3. Gender
 - a. Male
 - b. Female
 - c. Rather not say
4. Marital status
 - a. Single
 - b. Married
 - c. Widowed
 - d. Divorced
5. Type of Land Ownership
 - a. Communal Land
 - b. Leased Land
 - c. Own Land
 - d. Other Tenure
6. Hector size category
 - a. 1
 - b. 2-5
 - c. 6-10
 - d. 11-15
 - e. 16-20
7. Type of Commodity
 - a. Aquaculture

- b. Crop/Grain
 - c. Horticulture
 - d. Livestock
 - e. Poultry
 - f. Mixed Commodities
8. Farming experience(years)
- a. 1-13
 - b. 14-28
 - c. 29-43
 - d. 44-58
9. Estimated annual turnover from operations
- a. <R50 000
 - b. R50 000 – R100 000
 - c. R100 000 – R500 000
 - d. >R500 000
10. Province in South Africa
- a. Western Cape
 - b. Eastern Cape
 - c. Northern Cape
 - d. North West
 - e. Free State
 - f. KwaZulu Natal
 - g. Gauteng
 - h. Limpopo
 - i. Mpumalanga

VULNERABILITY CONTEXT

1. Describe the major events/issues that affect your farming operations?
2. How do you manage the impact of these issues? How do you overcome them?
3. Who would assist you in managing these issues?

LIVELIHOOD ASSETS

1. What do you need to run the farm successfully?
2. What type of skills did you acquire to operate your farm?
3. Where does your farm get finance from? Financial loans/grants?
4. What impact did available access to financial services affect your farm?

5. Are you part of any farmer support associations? Why?
6. How did you get to know of these associations?
7. How do you communicate with members of these associations?
8. Other than these associations, who supports the running of the farm?
9. How is the community and family involved in the running of the farm?
10. Where do you access information to run your farm?

TECHNOLOGY ASSET

1. What do you know about the 4th Industrial Revolution and Smart Technologies?
2. What type of skills do you think you would require to be able to use modern technologies on your farm?
3. What kind of technologies do your employees use?
4. Did you receive any assistance in purchasing technology tools for your farm?
5. What technologies do you use to support daily operations on the farm?
6. What challenges have you faced when using technology?
7. What laws and regulations could affect your farm and its usage of Smart technologies?

TRANSFORMING STRUCTURES

1. What organisations/institutions can you work with to realise your desired goals?
2. How does your family/community support you to realise your desired goals?
3. What is the impact of these institutions/organisations in running the farm?

LIVELIHOOD OUTCOME

1. What goals would you like to achieve for the farm?
2. What outcomes do you find as most important on your farm?
3. How can using new technologies influence you achieving your desired goals?
4. How can Smart Farming technologies influence your productivity?

Appendix B - Research instrument overview: subject matter experts

Literature and the SLA serves as a guide for the interview questions.

SMART FARMING EXPERT DEMOGRAPHICS

1. Age categories
 - a. 18-34
 - b. 35-59
 - c. 60+
2. Education
 - a. Primary
 - b. Secondary
 - c. Diploma and above
3. Occupation
 - a. Government Official
 - b. Corporate Employee
 - c. Entrepreneur
 - d. Consultant
4. Year experience
 - a. 0-2
 - b. 2-5
 - c. 5-7
 - d. 7-10
 - e. 10-15
 - f. 15+
5. Agriculture sector experience
 - a. Aquaculture
 - b. Crop/Grain
 - c. Horticulture
 - d. Livestock
 - e. Poultry
 - f. Other
6. Gender
 - a. Male

How can smart technologies be applied by smallholder farmers for increased productivity and sustained livelihoods?

- b. Female
- c. Rather not say

1. What is your area of expertise?
2. What modern technologies are widely adopted in the agriculture sector?
3. How are these modern technologies influencing productivity of farmers using them?
4. What are the key considerations that farmers need to be aware of they think of adopting modern technologies?
5. What is the current state of adoption of these technologies?
6. What factors affecting the current rates of adoption?
7. What in your opinion would be required for smallholders to utilize more technology centred approaches for their agricultural activities?

Appendix C - Management consent form



Department of Information Systems

Leslie Commerce Building
Engineering Mall, Upper Campus

OR

Private Bag, Rondebosch 7701
Tel: +27 (0)21 - 650 2261
Internet: <http://www.commerce.uct.ac.za/informationssystemsf/>

12 September 2019

Request to conduct research and interview participation consent form

Dear Sir/Madam,

In terms of the requirements for completing a master's degree in Information Systems at the University of Cape Town a research study is required.

The study, in this case Samkelo Lutho Boo, has chosen to conduct a case study entitled "How can smart technologies be applied by smallholder farmers for increased productivity and sustained livelihoods?? ". The study would like to request permission to conduct this case study at your organization. The objective of the research is to:

- Evaluate the factors that influence smallholder farmers in the usage of modern technologies to increase productivity.
- To assess how smallholder farmers, use Smart Farming technologies to identify, mitigate and prevent vulnerabilities.

We would like to inform you that the ethical aspect of the research ensures the preservation of the identity of the participants, the data collected will be used purely for academic purposes. All personal details will be treated with the highest form of confidentiality. Please note that participation in this research is voluntary and participants can opt out of the study at any time.

The data collection method will be one-on-one interviews with a small group of the staff responsible for Smart Farming initiatives and selected smallholder farmers, based on your guidance. The interviews will be

How can smart technologies be applied by smallholder farmers for increased productivity and sustained livelihoods?

conducted at Western Cape Department of Agriculture and on smallholder farmer premises. The interviews will last 30-60 minutes. If you authorise this study to be undertaken at your organization, please kindly sign the attached form and return to me at your earliest convenience.

Should you have any questions regarding this research, please feel free to contact me on 0788880500 or email: bxxsam001@myuct.ac.za

Your organization's participation in this study would be greatly appreciated.

Sincerely,

Samkelo Lutho Boo

Signature Removed

Study \ MCOM Student, (UCT)

Department of Information Systems

University of Cape Town

Email: bxxsam001@myuct.ac.za

Wallace Chigona

[signature]

Research Supervisor

Department of Information Systems

University of Cape Town

Email: Wallace.Chigona@uct.ac.za

Management Consent

I, _____, give the study of this study consent to conduct their study in the following organization:

I am aware that participation is voluntary and that respondents may choose to withdraw from this study at any time, should they choose to do so.

Signature

Date

Appendix D – Interview consent form



Department of Information Systems

Leslie Commerce Building
Engineering Mall, Upper Campus

OR

Private Bag, Rondebosch 7701
Tel: +27 (0)21 - 650 2261
Internet: <http://www.commerce.uct.ac.za/informationssystemsf/>

12 September 2019

Dear Sir/Madam,

I am a student enrolled in the full-time master's programme of the Department of Information Systems at the University of Cape Town. In fulfilment of the course, I am required to conduct a research study relating to a topic in the field of Information Systems.

The objective of this study is to gain an understanding of the usage of modern technologies by smallholder farmers in South Africa and how modern technology could support smallholder farmers in increasing productivity.

The findings of this research will be compiled into a report and presented to the University of Cape Town for academic purposes. Ideally the outcomes of this study will benefit Government and private organizations by providing insight on modern technology could support smallholder farmers in increasing productivity.

The details of participating individuals and their organisations will remain strictly confidential throughout the research and will not be published in the final report. The information collected will only be used for the purposes of this report. This research has been approved by the Commerce Faculty Ethics in Research Committee.

Your participation in this study will be greatly appreciated. Participation is entirely voluntary. If you have any further queries, please do not hesitate to contact the study, Samkelo Lutho Boo.

If you are willing to participate in this study, please sign the attached consent form.

Thank you for your time.

How can smart technologies be applied by smallholder farmers for increased productivity and sustained livelihoods?

Sincerely

Samkelo Lutho Boo

Masters Student
Department of Information Systems
University of Cape Town
Email: bxsam001@myuct.ac.za

Professor Wallace Chigona

Research Supervisor
Department of Information Systems
University of Cape Town
Email: Wallace.Chigona@uct.ac.za

“Our Mission is to be an outstanding teaching and research university, educating for life and addressing the challenges facing our society.”

Participant Consent Form

I, _____, consent to participate and be interviewed for the purpose of this research study.

I am aware that participation is voluntary and that I may choose to withdraw from this study at any time if I so wish.

Signature

Date

Appendix E – Ethics form



UNIVERSITY OF CAPE TOWN
FACULTY OF COMMERCE
 Igniting Knowledge and Opportunity



Commerce Faculty Ethics in Research Application Form

Any person planning to undertake research in the Faculty of Commerce at the University of Cape Town is required to complete this form **before collecting or analysing data**. If any of the questions below have been answered YES, and the applicant is NOT an Honours student, the form it should be submitted to the supervisor (where applicable) and from there for approval by the Faculty EIR committee: Ms Samantha Alexander (samantha.alexander@uct.ac.za).

It is assumed that the study has read the [UCT Code for Research involving Human Subjects](http://web.uct.ac.za/depts/educate/download/uctcodeforresearchinvolvinghumansubjects.pdf) (Available at <http://web.uct.ac.za/depts/educate/download/uctcodeforresearchinvolvinghumansubjects.pdf>) in order to be able to answer the questions in this form.

Students must include a copy of the completed form with the dissertation/thesis when it is submitted for examination.

1. PROJECT DETAILS		
Project title: How smallholder farmers use modern technologies (Smart Farming) to increase productivity in South Africa?		
Principal Study/s: Samkelo Lutho Booï	Email address(es):	Bxxsam001@myuct.ac.za
Research Supervisor: Assoc. Prof Wallace Chigona	Email address(es):	Wallace.Chigona@uct.ac.za
Co-study(s):	Email address(es):	
Department: Information Systems		

Brief description of the project:

The objective of this study is to gain an understanding of the usage of modern technologies by smallholder farmers in South Africa and how modern technology could support smallholder farmers in increasing productivity in a three-dimensional view.

Data collection: (please select)

Interviews Questionnaire Experiment Secondary data Observation

Other (please specify) _____

Have you attached a research proposal OR a literature review with research methodology? (please select) Yes No

2. PARTICIPANTS

2.1 Does the research discriminate against participation by individuals, or differentiate between participants, on the grounds of gender, race or ethnic group, age range, religion, income, handicap, illness or any similar classification?	YES	NO
2.2 Does the research require the participation of socially or physically vulnerable people (children, aged, disabled, etc.) or legally restricted groups?	YES	NO
2.3 Will you be able to secure the informed consent of all participants in the research? (In the case of children, will you be able to obtain the consent of their guardians or parents?)	YES	NO
2.4 Will any confidential data be collected, or will identifiable records of individuals be kept?	YES	NO
2.5 In reporting on this research is there any possibility that you will not be able to keep the identities of the individuals involved anonymous?	YES	NO
2.6 Are there any foreseeable risks of physical, psychological or social harm to participants that might occur in the course of the research?	YES	NO
2.7 Does the research include making payments or giving gifts to any participants?	YES	NO

If you have answered **YES to any of these questions**, please describe how you plan to address these issues (append to form):

Affiliations of participants: (please select)



Company employees Hospital employees General public Military staff Farm workers Students

Other (please specify): _____

Race / Ethnicity:

Are you asking a question about race/ethnicity in your questionnaire?

Yes No

Which race categories have been used?

Have you included the option: "Prefer not to answer" as part of your race/ethnicity question?

3. PROVISION OF SERVICES

Does your research involve the participation of or provision of services to communities? No

If your answer is YES, please complete below:

3.1 Is the community expected to make decisions for, during or based on the research?	YES	NO
3.2 At the end of the research will any economic or social process be terminated or left unsupported, or equipment or facilities used in the research be recovered from the participants or community?	YES	NO
3.3 Will any service be provided at a level below the generally accepted standards?	YES	NO

If you answered YES to any of these questions, please describe below how you plan to address these issues.

3. ORGANISATIONAL PERMISSION

If your research is being conducted within a specific organisation, please state how organisational permission has been/will be obtained:

A letter for will be sent to ask permission from the organisation

Have you attached the letter from the organisation granting permission? (please select)

Yes No, but this **will be** obtained before commencing the research Not applicable

Are you making use of **UCT students** as respondents for your research? (please select)

Yes No

If yes, have you contacted Executive Director: Student Affairs for permission? (please select)

Yes No

Was approval granted? (please select)

Yes

No

Awaiting a response

Are you making use of **UCT staff** as respondents for your research? (please select)

Yes No

If yes, have you contacted Executive Director: Human Resources for permission? (please select)

Yes No

Was approval granted? (please select)

Yes

No

Awaiting a response

Contact Emails: Executive Director: Human Resources (Miriam.Hoosain@uct.ac.za)

Executive Director: Student Affairs (Moonira.Khan@uct.ac.za)

4. INFORMED CONSENT

What type of consent will be obtained from study participants?

- Oral Consent
- Written Consent
- ✓ Anonymous survey questionnaire (covering letter required, no consent form needed) Other (please specify)

How and where will consent/permission be recorded? N/A

Have you attached an informed consent form to your application? Yes No

5. SPONSORSHIP OF RESEARCH

If your research is sponsored, is there any potential for conflicts of interest? No

If your answer is YES, please complete below

4.1 Is there any existing or potential conflict of interest between a research sponsor, academic supervisor, other study's or participants?	YES	NO
4.2 Will information that reveals the identity of participants be supplied to a research sponsor, other than with the permission of the individuals?	YES	NO
4.3 Does the proposed research potentially conflict with the research of any other individual or group within the University?	YES	NO

If you have answered **YES** to any of these questions, please describe how you plan to address these issues (append to form)

6. RISK TO PARTICIPANTS

Does the proposed research pose any physical, psychological, social, legal, economic, or other risks to study participants you can foresee, both immediate and long range? (please select)

Yes No

If yes, answer the following questions:

1. Describe in detail the nature and extent of the risk and provide the rationale for the necessity of such risks
2. Outline any alternative approaches that were or will be considered and why alternatives may not be feasible in the study
3. Outline whether and why you feel that the value of information to be gained outweighs the risks

1.

2.

3.

I certify that I have read the Commerce Faculty Ethics in Research policy

(<http://www.commerce.uct.ac.za/Pages/ComFac-Downloads>)



I hereby undertake to carry out my research in such a way that

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

Signed by:


	Full name and signature	Date
Principal Study/Student:	Samkelo Lutho Booi Signature Removed	12/09/2019

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This application is approved by:

Supervisor		
HOD (or delegated nominee – for all Honours Projects):		
Chair: Faculty EIR Committee (only for postgraduate research at Master and PhD level)		

CHECKLIST	SELECT
A full copy of a research proposal or a literature review with methodology is attached in a separate file	<input checked="" type="checkbox"/>
Interview schedules / cover letters / questionnaires / forms and other materials used in the study are attached in separate files	<input type="checkbox"/>
Organisational consent letter / UCT student or staff approval letter	<input type="checkbox"/>

<p>On your cover letter to your questionnaire have you included the following?</p> <p>1. The following UCT Logo</p>  <p>2. A sentence explaining the aim of the research</p> <p>3. Sentences of a similar nature to below must be included in the cover letter or consent form:</p> <p>This research has been approved by the Commerce Faculty Ethics in Research Committee.</p> <p>Your participation in this research is voluntary. You can choose to withdraw from the research at any time.</p> <p>The questionnaire will take approximately X minutes to complete</p> <p>You will not be requested to supply any identifiable information, ensuring anonymity of your responses.</p> <p>Due to the nature of the study you will need to provide the study's with some form of identifiable information , however, all responses will be confidential and used for the purposes of this research only.</p> <p>Should you have any questions regarding the research please feel free to contact the study (insert contact details).</p>	<p><input type="checkbox"/></p> <p><input checked="" type="checkbox"/></p> <p><input checked="" type="checkbox"/></p> <p><input type="checkbox"/></p> <p><input checked="" type="checkbox"/></p> <p><input checked="" type="checkbox"/></p> <p><input checked="" type="checkbox"/></p> <p>OR</p> <p><input type="checkbox"/></p> <p><input checked="" type="checkbox"/></p> <p><input checked="" type="checkbox"/></p>
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4. Have you scanned in your signature for the last section of the form?

How can smart technologies be applied by smallholder farmers for increased productivity and sustained livelihoods?

4. INFORMED CONSENT

What type of consent will be obtained from study participants?

Oral Consent

Written Consent



How and where will consent/permission be recorded?

5. SPONSORSHIP OF RESEARCH

supervisor, other researchers or participants?		
4.2 Will information shared with the identity of participants be supplied to a research sponsor, other than with the permission of the individuals? If your answer is YES, please complete below	YES	NO
4.3 Does the proposed research potentially conflict with the research of any other individual or group within the University?	YES	NO

If you have answered YES to any of these questions, please describe how you plan to address these issues (append to form)