University of Cape Town

Department of Information Systems

The Readiness of the Agricultural Sector to adopt the Internet of Things: A Case of Western Cape, South Africa

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Master of Commerce in Information Systems

By

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26 July 2024

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In the name of God, the Most Beneficent, the Most Merciful.

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Abstract

Background: Food scarcity arising from climate change has garnered widespread recognition as a critical global concern, necessitating serious attention. Far-reaching impacts of climate change extend across dimensions such as the environment, technology, policy, and societal progress. Among these dimensions, the implications for food production within the agricultural sector is significant. With the expanding global population, the demand for agricultural output intensifies, exerting unprecedented pressure on the industry to meet this growing need. As a result, the agricultural sector is confronted with the imperative to transition towards sustainable farming practices to enhance overall productivity. Amid this imperative, the integration of technology, particularly the Internet of Things (IoT), emerges as an indispensable solution. Extensive research demonstrates that IoT implementation in agriculture yields manifold benefits, including enhanced food production, increased productivity, and bolstered sustainability. Moreover, IoT equips farmers with tools to navigate the complex challenges posed by climate change and food scarcity, ensuring their competitiveness and profitability. However, a pivotal consideration is the readiness of the agricultural sector to implement IoT.

Purpose of the Research: Despite the considerable potential gains, the readiness of the South African agricultural sector to adopt IoT remains a less-explored area. This study aims to address this gap by examining the landscape of IoT adoption readiness within the context of the South African agricultural sector.

Design/Methodology/Approach: To evaluate readiness to adopt IoT, a qualitative research method was adopted in this research and an analysis was methodically employed. This multifaceted analysis approach encompassed distinct dimensions—political, environmental, social, and technological (PEST). Each dimension was assessed to ascertain its strengths, weaknesses, opportunities, and threats (SWOT), in the context of IoT integration within the agricultural sector. This systematic PEST-SWOT analysis culminated in positioning the readiness of the agricultural sector in South Africa.

Findings: The findings of this study unveil a notable duality in South Africa's developmental landscape. This dichotomy becomes apparent through the coexistence of both developed and developing facets. This division manifests in distinct states. On the one hand, the developed portion of the agricultural sector exhibit a tangible readiness for IoT adoption. On the other hand, the developing portion encounter barriers that necessitate comprehensive mitigation of inherent weaknesses and threats resulting in its unpreparedness for adopting IoT. This division closely mirrors the distinction between the commercial and SME sectors, embodying the readiness of the developed state and lack of readiness in the developing state, respectively. This inherent dichotomy, rooted in historical challenges, underscores the urgency for holistic resolutions. Overall, the findings suggest that the South African agricultural sector is not ready for IoT adoption.

Practical Implications: The practical implication of this research underscores the vital need for tailored strategies that bridge the readiness gap between the developed and developing portion of the agricultural sector. Addressing the distinctive challenges faced by each portion, particularly considering their historical contexts, will be instrumental in fostering a cohesive and synchronised path towards embracing IoT.

Originality/Contribution: The contribution of this study lies in its comprehensive examination of readiness to adopt IoT within the South African agricultural sector. By employing a multi-dimensional PEST-SWOT analysis, this research not only sheds light on the nuanced landscape of IoT adoption but also positions the readiness of the Western Cape's agricultural sector in a holistic context. This approach offers a unique lens through which to understand the intricate challenges and opportunities that IoT adoption presents in this critical sector.

Keywords: IoT, technology, agriculture, South Africa, PEST, SWOT, readiness, adoption

Table of Contents

List of Figures

List of Tables

List of Acronyms

Acronym	**Definition**
3G	**Third Generation**
5G	**Fifth Generation**
ADSL	**Asymmetric Digital Subscriber Line**
AI	**Artificial Intelligence**
GCI	**Global Competitiveness Index**
GDP	**Gross Domestic Product**
ICT	**Information and Communication Technology**
IDI	**ICT Development Index**
IDT	**Innovation Diffusion Theory**
IoT	**Internet of Things**
LoRaWAN	**Long Range Wide Area Networks**
LPWA	**Low Power Wide Area**
NRI	**Networked Readiness Index**
PEST	**Political, Environment, Social, Technology**
R&D	**Research and Development**
SME	**Small and Medium Sized Enterprise**
SWOT	**Strengths, Weaknesses, Opportunities, Threats**
TOE	**Technology-Organisation-Environment Framework**
TR	**Technology Readiness**
TTF	**Task Technology Fit Theory**
UAV	**Unmanned Aerial Vehicles**
UN	**United Nations**
Wi-Fi	**Wireless network technology**
WSN	**Wireless Sensor Network**

Chapter 1

1 Introduction

1.1 Background

Climate change is fast becoming a major challenge of the 21st century. Of all the developing countries particularly vulnerable to climate change, African countries are the most affected (Malhi, Kaur, & Kaushik, 2021; Montmasson-Clair, Mudombi, & Patel, 2019). Climate change not only causes negative effects on the environment, but it is also affecting the economy, policy, and societal development. One of the main concerns of climate change is that it is causing food insecurity (Bedasa & Bedemo, 2023; Montmasson-Clair et al., 2019). Climate change causes weather variability and less rainfall, thereby, decreasing the amount of food produced. In a time where food demands are rising, a decrease in food production becomes a serious concern (Ayaz, Ammad-uddin, Sharif, Mansour, & Aggoune, 2019; Bedasa & Bedemo, 2023). The United Nations Organisation (UN) reports that there has been a food crisis that will continue to the year 2050 if it is not addressed (Arora & Mishra, 2022). To address these concerns, adaption plans to overcome climate change need to be developed and adopted in countries particularly vulnerable to food insecurity (Montmasson-Clair et al., 2019).

1.2 Context of Study

Research has found that of all the arable land in the world, in the future, about 50% of it will be usable for agriculture. The UN states that Africa and other developing countries will be the most vulnerable to food scarcity due to the variable weather patterns and climatic changes causing frequent droughts and flooding (Arora, & Mishra, 2022). Countries below the poverty line, like those of Southern Africa, are already under threat of reduced food outputs due to the inefficiencies in traditional farming such as inadequate irrigation, fertiliser misuse, and soil degradation (Malhi, Kaur, & Kaushik, 2021).

South Africa's population continues to grow at a rate of 2% per year. The population growth is expected to result in about 70 million people by the year 2035 (StatsSA, 2022). The increasing population inevitably requires the production of more food. However, South Africa is unable to meet this demand (Von Bormann, 2019). This is due to only 13.7% of South Africa's land being arable and largely dependent on unpredictable rainfall related to climate change (Kuschke, 2020; Montmasson-Clair et al., 2019;). In addition, as one of the driest countries globally, South Africa continues to experience water shortages, and this is expected to become more severe in the future. Furthermore, socio-economic conditions, political instability, biosecurity risks, infrastructure issues, and crime exacerbate these challenges, contributing to the major food and water scarcity issues in South Africa (Arora & Mishra, 2022; Bedasa & Bedemo, 2023; Malhi et al., 2021).. Thus, South Africa needs to implement adaption techniques to overcome food scarcity and climate change issues (Bedasa & Bedemo, 2023; Montmasson-Clair et al., 2019; Von Bormann, 2019).

Currently, farmland in South Africa accounts for less than two-thirds of what it used to be in the 1990's (Kuschke, 2020). Food consumption in South Africa has also been changing since the 1970's due to post-apartheid reforms and increased wealth in the middle classes. The result was a shift from staple diets based on bread and maize to an increase in the consumption of red meat, chicken, and poultry (Kuschke, 2020). As such, the South African agriculture sector will not be able to keep up with the increasing food demands together with the increased demand for high-quality products (Kuschke, 2020). These shifts have created a need to modernise, improve and increase productivity of the current agricultural practices (Kuschke, 2020; Montmasson-Clair et al., 2019). The focus of this research is the Western Cape as it is an ideal region due to its diverse agricultural landscape, varying climate conditions, and significant contribution to South Africa's food production, making it a valuable case study for understanding the practical application of IoT in addressing food security and climate change challenges.

The Internet of Things (IoT) has not only revolutionised the lives of human beings and entities alike, it has also created a paradigm from how things were done to how things can be done. Previously, agricultural decisions were largely subjective as decisions-making was based on data collected from the visual assessment of crops by the farmer (Goedde, Katz, Ménard, & Revellat, 2020). Currently, with the implementation of IoT technologies, farmers can make objective decisions based on quantitative data collected by IoT devices through sensors and actuators. These devices allow for large amounts of on-field data collection and has become a precursor in agricultural big data technology (Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019).

The Internet of Things (IoT) technologies improve performances and reduces inefficiencies for its stakeholders. Various industries have embarked on the adoption of IoT technologies to achieve just that, including the agricultural industry. The adoption of IoT within the agricultural sector increases food production and addresses climate change concerns through its vast capabilities, real-time monitoring and optimisation of resources like water, fertilisers, and energy, leading to higher crop yields to tackle food security while reducing waste and emissions to mitigate climate change. (Ayaz et al., 2019; Saiz-Rubio & Rovira-Más, 2020).

1.3 Problem Statement

Current farming methods are inefficient in that it requires famers to manually monitor crop nutrient levels as well as its use of relatively inefficient agricultural farming methods (Ayaz et al., 2019; Goedde et al., 2020; Malhi et al., 2021)). In addition, South Africa experiences frequent food and water scarcity. Due to these concerns, it is becoming increasingly important to focus on sustainable food production techniques in South African agriculture (Arora & Mishra, 2022; Malhi et al., 2021)). Redirecting the standard agricultural practices to more transformative technological facilitated practices, has the potential to address current food scarcity and climate concerns as well as achieving sustainability within South Africa (Ayaz et al., 2019; Bedasa & Bedemo, 2023). IoT technology transforms the agricultural industry through its application of non-human intervention in agricultural processes (Goedde et al., 2020). The use of technology has long been recognised as one of the approaches to improve productivity and achieve food security. When IoT is adopted in agricultural practices, it enables food security and improves productivity in the sector (Saiz-Rubio & Rovira-Más, 2020). However, to adopt IoT in South African agriculture, it becomes imperative to assess the IoT readiness of the South African agricultural sector before IoT adoption can take place (Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019).

Readiness, in this study, aimed to assess the factors of disposition that contribute to the Western Cape's agricultural sector to adopt and use new technology. Furthermore, readiness sought to understand what factors influences and limits the adoption of technology. The intent was to assess the agricultural sector regarding specific dimensions (political, environmental, social, and technological), and to determine the strengths, weaknesses, opportunities, and threats (SWOT) of those dimensions to determine readiness in the Western Cape, South Africa. Thus, a PEST-SWOT framework was employed. The SWOT framework which consists of strengths, weaknesses, opportunities, and threats seeks to understand what enables and limits the adoption of IoT by looking at the agricultural sector objectively and critically. This gives deeper meaning to the internal and external environment of the agricultural sector and that which may lead to the agricultural sector adopting IoT in its practices. Technology readiness understood in the context of a SWOT framework is given deeper meaning when employed using a PEST framework. The PEST framework consisting of political, environmental, social, and technological factors that seeks to further define the internal and external environment of the agricultural sector. This understanding allows decision makers to assess the agricultural sector's readiness to adopt IoT through its enabling and motivating factors of IoT adoption.

1.4 Research Questions

The main research question is: "***What factors influence the readiness of the South African agricultural sector to adopt IoT? "***

This is supported by the following sub-questions:

- What factors support agricultural sector readiness to adopt IoT?
- What factors limit agricultural sector readiness to adopt IoT?

1.5 Research Objective

The core objective of this research is: *To assess the factors influencing the readiness of South Africa's agricultural sector to adopt IoT*.

Followed by the specific objectives:

- To assess enabling factors that determine IoT readiness.
- To assess limitations that inhibit IoT readiness.

1.6 Significance of the study

In the realm of technological advancements, gauging technology readiness assumes important significance as it delves into users' inclinations to embrace and integrate novel technologies into their operations. Specifically, technology readiness endeavours to unravel the motivations and impediments that shape the adoption landscape of emerging technologies (Parasuraman, 2000; Zaidi & Faizal, 2017).

The outcomes of this study hold far-reaching implications, extending their influence on government bodies, technology experts, and the farming community. By assessing the agricultural sector's stance regarding the adoption of IoT in farming, the study presents an invaluable scope for relevant stakeholders. For governmental authorities and technology experts, this study highlights a spotlight on the sector's intricacies, exposing gaps through the identification of threats and weaknesses. This sets the stage for concerted efforts to bridge these gaps, steering the agricultural industry toward an IoT-empowered future.

Moreover, the insights gleaned from this study extend an open invitation to other researchers working within the expansive domain of IoT studies in South African agriculture. By integrating select findings into their own research, these scholars can assist their own endeavours. The research contributions go beyond its immediate context, enhancing the collective comprehension of the political, environmental, societal, and technological dimensions that underpin the adoption of IoT within agriculture.

At its core, the research serves as a pivotal steppingstone, elevating the discourse surrounding IoT research within the realm of South African agriculture. Through its nuanced exploration, the study seeks to catalyse progressive change and enhancing the prevailing landscape. This research stands as a point of innovation and a catalyst for future advancements.

1.7 Research Method

Research methodologies can be quantitative, qualitative or a mixture of the two (Creswell, 2009; Myers, 2009). The research methodology chosen by a researcher is based on its ability to address the research questions and objectives, problem statement, and methods of data collection and analysis (Neuman, 2006). A qualitative research method was adopted in this research as it allows for knowledge building that is based on multiple subjective realities, thus there is a need to understand individuals and their traditional and societal backgrounds to derive meaning (Hesse-Biber, 2010). The use of a qualitative research method supports this study in that farmers' have multiple subjective realities which are based on their variable backgrounds. Thus, influencing how they perceive the adoption of IoT in their agricultural practices. These differences in perceptions and backgrounds determine whether they adopt IoT or not, therefore, it requires a better understanding which was achieved through a qualitative research method.

1.8 Approach to Theory

There are two contrasting approaches to the theory adopted in research, namely, deductive and inductive analysis (Saunders & Thornhill, 2016). The deductive approach is concerned with developing a theory that consists of hypotheses or propositions that are subjected to the data (Saunders & Thornhill, 2016; Thomas, 2006). The deductive approach was adopted in this research due to the research goals and data analysis guided by a theoretical framework (Saunders & Thornhill, 2016; Thomas, 2006). The theoretical framework informs the data collection process because the questions are based on the theoretical model that aims to answer the research questions. The theoretical framework guided the data analysis process in that the findings were viewed and showcased through the lens of the framework.

1.9 Structure of the Dissertation

The following is the dissertation outline: the literature review defines key terms: climate change and food scarcity context, South African context, Agriculture, technology as a solution, and technology readiness. Following that is the conceptual framework which covers an IoT readiness assessment and the PEST-SWOT model. Following that are the research methodology, the findings, and the discussion are presented. Finally, the conclusion, recommendations, limitations, and future research areas are presented.

Chapter 2

2 Literature Review

2.1 Introduction

The literature review for this research was on the readiness of the agricultural sector to implement the Internet of Things (IoT) within the context of South Africa. The literature review focused on the Western Cape due to the dearth of literature relating to readiness of the South African agriculture in terms of IoT adoption. The capabilities of IoT are precursors towards creating a smarter, precise and more data-centric production within the agricultural sector (Ayaz et al., 2019). The literature assessed IoT's potential to mitigate key issues such as climate change, food scarcity, production inefficiencies, and supply chain issues amongst other things (Arora & Mishra, 2022; Goedde et al., 2020; Kuschke, 2020; Malhi et al., 2021; Von Bormann, 2019). A discussion is presented around important factors regarding agriculture and the current environmental effects on food scarcity. The technological solutions were discussed and presented as well as their various utilisations. The literature review highlights significant gaps in knowledge that have been identified.

2.2 Climate change and food security

Climate change is rapidly becoming the most urgent problem confronting the agricultural sector in the 21st century. Climate change would have several adverse impacts on economic growth, social advancement, environmental sustainability, and food security over the coming years (Montmasson-Clair et al., 2019).

2.2.1 Impact of climate change on Agriculture

Since the 1970s, researchers have been establishing a clear association between the cause-and-effect relationship of a decrease in rainfall (climatic event) and a decrease in crop production (agricultural responsiveness) (Arora & Mishra, 2022; Bedasa & Bedemo, 2023; Malhi, Kaur, & Kaushik, 2021; Montmasson-Clair et al., 2019; Parry, 2019). It has been shown that climatic change affects crops water use, crop growth rate, yield production, soil moisture and livestock which adversely impacts the amount of production and the profit and losses experienced by farmers. Climate change has been limiting agricultural production in many regions of the world, especially that of developing countries (Parry, 2019). Furthermore, increasing temperatures and unpredictable weather patterns are reshaping agricultural practices, making the adoption of innovative technologies and techniques in the sector an essential requirement for the future (Von Bormann, 2019).

2.2.2 Effect of climate change on South Africa

Climate change is a particularly pressing challenge in South Africa due to it being an arid country. South Africa is vulnerable to climate related issues and has already been experiencing water-shortages in certain parts of the country and is expected to continue to face serious water insecurity (Montmasson-Clair et al., 2019). The agricultural sector of South Africa is the biggest water-user and coupled with its inefficient irrigation schemes makes it more susceptible to climate change. Furthermore, this puts crop production under pressure due to unreliable rainfall (Arora & Mishra, 2022; Bedasa & Bedemo, 2023; Malhi et al., 2021). Farooq, Riaz, Abid, Umer, & Zikria (2020) corroborates the finding and adds that weather variability directly impacts agricultural productivity by causing unpredictable crop yields and costs which also affects the price (Ayaz et al., 2019; Parry 2019). Such constraints are putting tension on food production and food security (Arora & Mishra, 2022; Bedasa & Bedemo, 2023).

2.2.3 Significance of food production in South Africa

Many studies claim that climate change directly affects food security. It causes less rainfall, thereby decreasing the amount of food produced which causes food scarcity (Malhi et al., 2021). In addition to climate change, the increased use of food crops for bio-fuel production, bioenergy, and other usages has also put food security at risk. The high demands for food are resulting in an increased pressure on an already resource limited agricultural sector (Ayaz et al., 2019).

Food production in South Africa is under threat as rainfall and weather conditions becomes more variable and unreliable due to climate change. In addition, the rapid growth of the South African population requires food production to increase by 60% to mitigate food scarcity by 2050 (Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019).

The South African agricultural sector has not expanded as quickly as other sectors within the last decade; however, it remains a vital sector among the rural poor as it ensures food security and job preservation (AgriSETA, 2019; Von Bormann, 2019). AgriSETA (2019) claims that only 45.6% of South Africans are food secure and that climatic changes may cause further damage to the already fragile food scarcity situation. Ensuring national food security depends largely on the capital intensiveness and economies of scale of the agricultural industry and, therefore, small-scale subsistence farmers are more vulnerable to climatic changes. However, both small-scale and commercial agricultural productions are at risk of food scarcity due to climate changes (AgriSETA, 2019; Von Bormann, 2019).

2.2.4 Opportunity for transformation of food scarcity concerns

It has been shown that incorporating technology into agricultural practices will overcome issues and outweigh the detrimental consequences of climate change (Parry, 2019; Parry & Sinha, 2019; Crosson, 1989). Therefore, boosting production and efficiency, and the effective use of available resources through the adoption of technology within the agricultural sector provides an opportunity to combat food scarcity issues in South Africa (Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019). Furthermore, farmers need to be supported by government incentives regarding agricultural technologies and innovations that protects the agricultural sector from climatic volatilities, enhances efficiency and attracts a labour force that are technological inclined to ensure food security changes (Arora & Mishra, 2022; Bedasa, & Bedemo, 2023; Malhi et al., 2021). In addition, it was reported in the Gazette (2024) that by creating a technologically innovative agricultural sector, it becomes a lucrative choice as a career path for younger people.

2.3 Agriculture

Historically, agriculture started at least 22,000 years ago when wild grains were collected. The cultivation of crops has existed as early as 9500 BC in Levant, and since then farmers have been implementing significant innovations to increase production and reduce costs

(Hillman, 1996; Walsh, 2009). In the past few decades, agriculture has changed from predominantly small to medium sized farming to a more highly commercialised and industrialised farming (Ayaz et al., 2019).

2.3.1 Production complications

As Figure 1 illustrates, agricultural production needs to increase to at least 60% of what it is to feed the world population (Ayaz et al., 2019). Meanwhile, only a limited area of the earth's surface is suitable for agricultural usage. This is due to various constraints, including climate, topography, soil conditions, and technology. Furthermore, political, and economic factors also shape how agricultural land is used, such as environmental regulations, tenure patterns, and population density (Giua**,** Materia, & Camanzi, 2022; Ruzzante, Labarta, & Bilton 2021; Smidt, & Jokonya, 2022). While Ayaz et al. (2019) confirmed that political and economic factors like climate patterns, land, population density, and rapid urbanisation affect agricultural land availability.

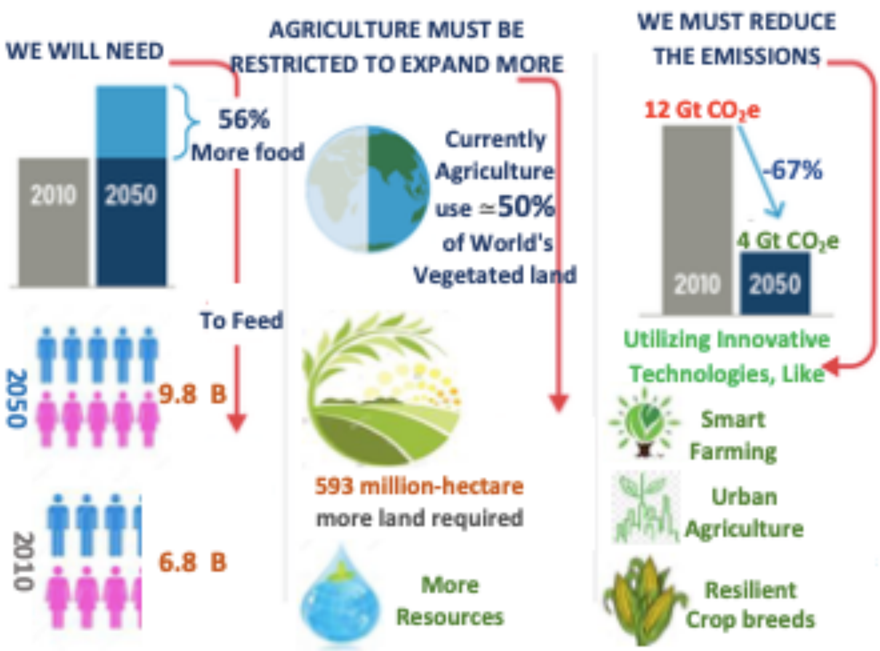


Figure 1 - A sustainable future in agriculture (Ayaz et al., 2019)

2.3.2 Traditional Agricultural Practices

During the 20th century, farmers continued to follow traditional agricultural methods to meet food demands by increasing the use of pesticides and fertilisers (Ayaz et al., 2019). The result was more food production, up to a certain extent. However, the effect was irreversible environmental implications. Ayaz et al. (2019) also argues that the utilisation of resources such as water, pesticides, fertilisers, and seeds cannot be uniformly applied to an entire field as a solution to increasing food demands. Furthermore, the inadequacy and inefficient irrigation systems results in wastage of water and power resources which negatively impacts the environment. Subsequently, farmers are required to frequently and physically monitor crop conditions, this leaves room for human error and could result in less output for the farmer (Ayaz et al., 2019). Unnecessary human intervention in agriculture leads to crop monitoring difficulties, water wastage, higher energy consumption, and higher labour costs (Montmasson-Clair et al., 2019). Traditional methods tend to be inefficient and unsustainable due to farmers' visual based crop inspection and decision-making resulting from accumulated experience which may lead to human error in projected agricultural production (Saiz-Rubio & Rovira-Más, 2020).

2.4 Technology in Agriculture

The agricultural future is headed towards a combination of both the virtual and physical worlds due to the use of Fourth Industrial Revolution innovations such as drones, Internet of Things (IoT), Artificial Intelligence (AI), big data, and wireless sensors (Ayaz et al., 2019; Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019). The systematic interconnection of technologies is an inescapable phenomenon that has infringed upon homes, cities, industries, and agricultural sectors, deriving various benefits and improving society (Kuschke, 2020; Zambon, Cecchini, Egidi, Saporito, & Colantoni, 2019). The big advancements anticipated from the Industrial Revolution include the interaction between equipment, IoT, and humans, and is predicted to push agricultural production to a higher standard of efficiency and precision (Zambon et al., 2019).

2.4.1 Potential for technological penetration

Montmasson-Clair et al. (2019) confirmed that traditional methods of farming are inadequate and recommended the adoption of sustainable agricultural practices that incorporates diverse technologies to meet increasing food demands. In addition, Giua et al. (2022) proposed the implementation of innovative agricultural techniques that improve and increase farming productivity are ways to ensure food security.

The solution to these issues lay in the adoption of technology within the agricultural sector (Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019). Regardless of the technological agricultural perceptions of people, presently, the agricultural sector has become smarter than ever, more data centric and precise (Ayaz et al., 2019). Technology aims to improve and maximise food production in agriculture, mitigate environmental impact, and increase profitability (Ayaz et al., 2019; Goedde et al., 2020; Kuschke, 2020). In addition, to ensure agricultural integrity, proper maintenance of soil fertility, soil structure and water usage which can be achieved through adopting technological innovations within agricultural practices (Kuschke, 2020). Furthermore, adopting technology in agriculture increases the productivity of agricultural process, which in turn, improves yields and cost-effectiveness (Montmasson-Clair et al., 2019).

2.4.2 Benefits of technology

The integration of technology contributes to the farming sector because of its potential to optimise crop yield and productivity, improve working standards and, the quality and efficiency of production (Goedde et al., 2020). Furthermore, technological innovation in agriculture is ideal for sustainable growth. Moreover, cross-analysis of climatic, environmental, and cultural aspects found that technology establishes and adheres to the nutritive and irrigation needs of the crops, thereby increasing productivity and production (Arora & Mishra, 2022; Bedasa & Bedemo, 2023; Malhi et al., 2021; Zambon et al., 2019). For instance, self-driving farm equipment utilised by farmers has been said to increase productivity, while reducing costs (Zambon et al., 2019). Through mechanisation and automation, agricultural practices will become more efficient, while producing higher yields, better product quality and achieving sustainable growth.

2.4.3 Current Advancements in Agriculture

Technology in agriculture has become a trendy topic within academia (Singh, Berkvens, & Weyn, 2021) and increasingly common among farmers. Various technologically based farming techniques already include the use of imagery and sensors, robotics and automation, big data, IoT and cloud computing (Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019).

In developing countries, mobile technology and Wi-Fi are of the technologies that are highest in demand in the agricultural sector (Tom, 2023; Ugwuanyi, Paul, & Irvine, 2021). These technologies are used as a tool to monitor water, crops, and land resources. Third generation (3G) connectivity is an accessible option for farmers because is available across most of South Africa (Ayaz et al., 2019; Tom, 2023; Ugwuanyi et al., 2021). Data collected from monitoring crops can be transmitted via SMS's, over the slowest networks, therefore, existing ICT infrastructure can be used. However, Madushanki et al. (2019) and Tom (2023) argues that due to cost, limited internet speed, low-powered, short-range networks, or low-rate wireless PAN (LoRaWAN) can be used as an alternative to Wi-Fi and 3G, especially regarding the utilisation of IoT.

The move towards technology adoption in agriculture are categorised by socio-economic and technological dimensions (see Figure 2) (Von Bormann, 2019).

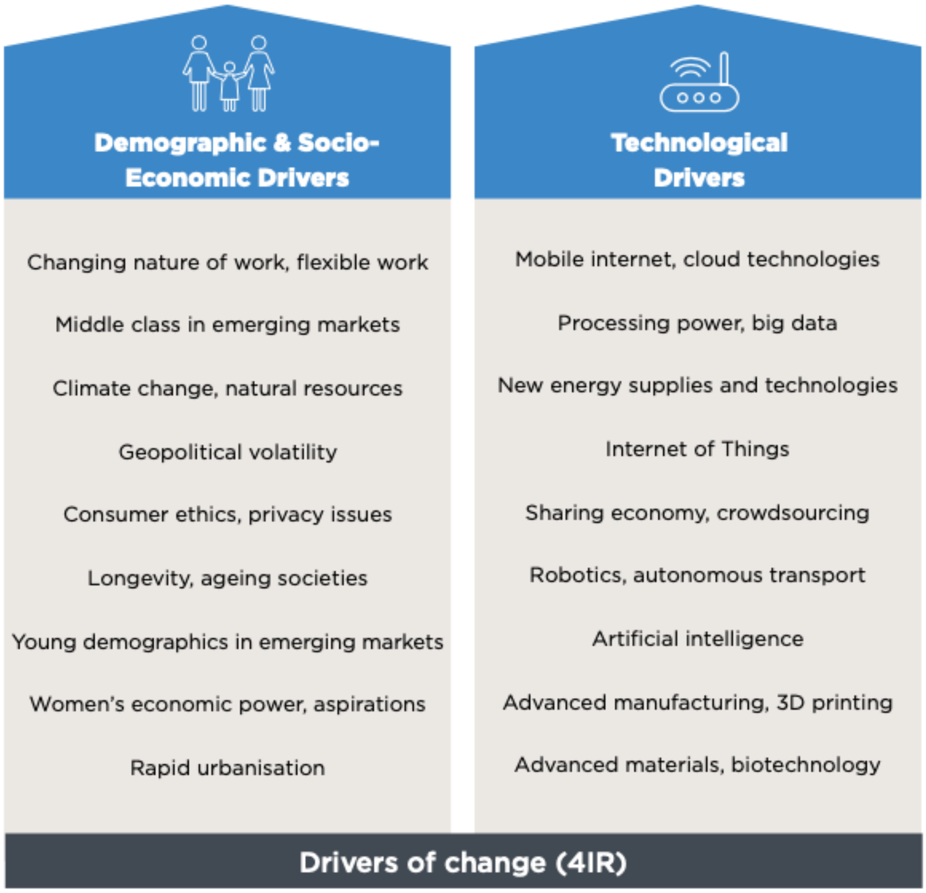


Figure 2 - Key drivers of change into the 4th Industrial Revolution (Ungerer et al., 2018)

2.5 The Internet of Things (IoT)

Kevin Ashton first coined the term Internet of Things (IoT) in 1999 and defined it as a uniform way for the internet to connect and understand the physical world (Schoenberger, 2002). IoT is an ecosystem comprised of intelligent devices and machines, objects, people, or animals that are interconnected without human-to-computer or human-to-human interaction. The internet is the channel that enables the communication and the exchange of data and information between IoT, and its players (see Figure 4) (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020; Liang & Shah, 2023; Pillai, & Sivathanu, 2020).

2.5.1 Benefits of IoT

IoT has created a paradigm from how things were done to how things can be done. Previously, agricultural decisions were largely subjective due to the visual assessment and memory-dependent data collection of crops by the farmer which, typically, informed their decisions-making (Farooq et al., 2020). Currently, with the implementation of IoT technologies, farmers can make objective decisions based on quantitative data collected by IoT devices through sensors and actuators. These devices allow for large amounts of on-field data collection and has become a precursor in agricultural big data technology (Farooq et al., 2020; Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019). Previously, only computers and smartphones, would have been imagined to be connected via the internet. However, currently, there are a plethora of devices and sensors connected to each other, from cars, wristwatches, and lights amongst others. The connection of things or objects to the internet eliminates the need for human intervention and is creating a wide range of networks and communication that is directly relevant to the agricultural sector. Figure 3 shows the key elements of IoT.

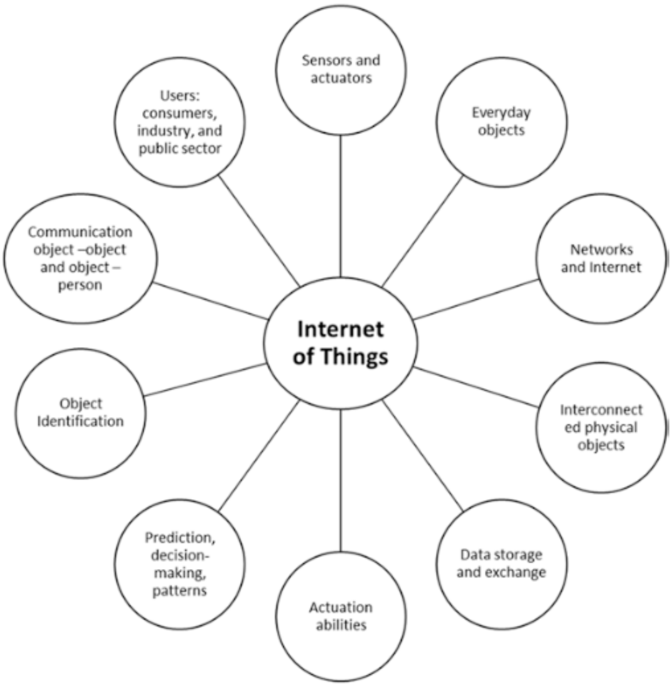


Figure 3 - Key elements of IoT (Gil-Garcia et al., 2020)

IoT generally refers to a mixture of technological functionality that intends to generate benefit based on functionality. For this reason, IoT devices range in complexity and are custom-made to achieve specific purposes (Ayaz et al., 2019; Georgios, Kerstin & Theofylaktos, 2019). The flexibility of IoT ranges from a minimum requirement of possible communication and cooperation with other devices in the system to vastly complex connectivity (Ayaz et al., 2019). At a minimum, communication and cooperation can occur via Bluetooth, Wi-Fi, or UMTS (Ayaz et al., 2019; Madushanki et al., 2019). To remotely control the smart devices, the devices are required to be addressable. The sensor technology enables the collection and transmission of information. While the processors and repository capacity allow the processing of collected data via the smart devices (Farooq et al., 2020; Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019). The local usability of IoT extends to user interfaces such as smartphones (Makate, Makate, Mango, & Siziba, 2019). IoT is responsible for the increase capacity, miniaturisation, low energy consumption of different components such as sensors, microcontrollers, and communication modules (e.g. Wi-Fi, Bluetooth, Zigbee, LoRaWAN), and the decreased prices of these technologies (Sanislav, Mois, Zeadally, & Folea, 2021). However, IoT is in its nascent stage and requires further improvement to become more accessible and less expensive to all. The benefits of IoT focuses on the ability of the network to gather and analyse data and, as a result, support organisations, communities, and individuals (Ayaz et al., 2019).

2.5.2 Potential to achieve sustainability in Agriculture

IoT's focus on agriculture is to automate all facets of agricultural practices to achieve a more sustainable, effective, and efficient process with minimal human intervention (Madushanki et al., 2019). Ayaz et al. (2019) argues that ensuring sustainability within the agricultural sector necessitates the use of IoT as the centre and driver of agricultural operations. This encompasses, machinery operation, water and power usage, market changes, crop transportation, and maintenance alerts. Examples of IoT applications in agriculture include precision irrigation systems that monitor soil moisture levels and deliver water only where and when needed, reducing water waste. Smart greenhouses equipped with IoT sensors regulate temperature and humidity for optimal crop growth, minimising energy consumption. In addition, automated pest monitoring systems use IoT-enabled traps to detect pest populations and alert farmers, reducing the need for blanket pesticide applications (García, Parra, Jimenez, Lloret, & Lorenz, 2020). IoT streamlines agricultural operations and crop production at each stage by recognising and predicting crop and farming needs, thereby, increasing production. Furthermore, IoT continues to be streamlined by developments in Wireless Sensor Networks (WSN) and mobile technology communications such as fifth generation (5G) connectivity which provides ubiquitous communication to farmers to engage with real-time data about their farms whenever and wherever they are. However, other low powered connectivity is available where internet speed is limited (Ayaz et al., 2019; Madushanki et al., 2019).

2.5.3 An opportunity for IoT to change Agriculture

IoT is a technological innovation that enables the agricultural sector to overcome food scarcity and climate concerns (Arora & Mishra, 2022; Bedasa & Bedemo, 2023; Malhi et al., 2021). This can be achieved through IoT devices, such as, automated drip irrigation, weather forecasting, water level detectors, and soil level detectors that use software intelligence, sensors, and ubiquitous connectivity (Madushanki et al., 2019). These IoT devices link to sensors which produce and collect data for analysis through open software. Thus, assisting farmers in managing and protecting crops by providing valuable information such as real-time data on soil moisture levels, temperature, and humidity levels to inform precision irrigation practices wirelessly or through low-powered networks (Farooq et al., 2020; Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019). In addition, it enables farmers to receive this information directly on their smart phones allowing for efficient and effective agricultural farm management and productivity (Kuschke, 2020). Furthermore, the benefits extend to the agricultural supply chain in that it facilitates transactions and monitoring of products from supplier to purchaser (Kuschke, 2020; Makate et al., 2019). Consequently, it reduces agricultural degradation and crop loss through its efficient crop and water management capabilities (Farooq et al., 2020; Goedde et al., 2020; Liang & Shah, 2023;). IoT adoption in the agricultural sector provides valuable insights and enables strategic decision making on crop and water level projections (Von Bormann, 2019). Currently, IoT has proven itself to be a breakthrough technology that will further transform the perceptions and the reality of agricultural practices by providing farmers with unparalleled power over their assets and land, thereby optimising their productivity and effectiveness.

2.5.4 Challenges of implementing IoT

Various challenges impede the advancement of IoT and its readiness, adoption, and utilisation within the agricultural sector. These challenges encompass a wide range of perspectives and applications. Some of the challenges faced are connectivity and coverage, trust, cost and infrastructure, digital literacy, and standard infancy. The challenges are elaborated as follows:

- **Connectivity and Coverage:** In more rural areas of South Africa, network coverage and connectivity remain limited (Ayaz et al., 2019; Trendov, Varas, & Zeng, 2019). To fully optimise IoT within the agricultural sector, provision of higher quality networks should exist. However, the use of low powered networks for IoT continue to be a viable option (Ayaz et al., 2019; Farooq et al., 2020; Trendov et al., 2019).
- **Lack of trust:** Agriculture in South Africa, particularly in the Western Cape, are heavily reliant on labour, infrastructure, and agricultural equipment, however, not every farmer trusts IoT to achieve what they can do themselves or even possesses the know-how on using the technology (Adli, Remli, Wan Salihin Wong, Ismail, González-Briones, Corchado, & Mohamad, 2023; Colizzi, Caivano, Ardito, Desolda, Castrignanò, Matera, 2020; Partridge, Morokong, & Sibulali, 2020). However, government programmes accommodate for training workers to use IoT effectively, thereby, creating trust in the technology.
- **Costly investments and lack of infrastructure: Various** parts of South Africa and rural areas lack the infrastructure and resources to invest in IoT. Farmers do not have the initial capital to implement IoT coupled with the lack of infrastructure causes a huge deterrence to the digitalisation of agriculture (Ayaz et al., 2019; Trendov et al., 2019; Sutherland, 2020; Von Bormann, 2019).
- **Lack of digital literacy:** The use of IoT requires a level of digital literacy that many developing countries lack. Cultivating digital skills in education and constant exposure aids the proper use of technology in agriculture which are challenging in countries such as South Africa (Ayaz et al., 2019; Liang & Shah, 2023; Shang, Heckelei, Gerullis, Börner, & Rasch, 2021; Trendov et al., 2019; Xu, Gu, & Tian, 2022).
- **Standard Infancy:** There is a lack of government policy, licensing, and frameworks regarding the digitisation of agriculture. In addition, standardising digitisation requires an increased administration capacity and management that countries like South Africa may not have (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020; Liang & Shah, 2023; Xu et al., 2022).

Figure 4 depicts the various challenges faced in the pursuit of implementing IoT:

Figure 4- Major hurdles in technology implementation for smart agriculture (Ayaz et al., 2019)

2.5.5 IoT as a disrupter

The increased use of IoT technologies is projected to be the most disruptive of the emerging technologies (AgriSETA, 2019; Farooq et al., 2020; Von Bormann, 2019). It has a direct impact on the employment demand and requirement for labour skills and expertise. Thus, IoT and other related technologies are predicted to increase the demand for jobs at all skill levels, for instance those with lower skill levels will be required to do more advanced jobs such as tagging, monitoring machines, etc. This allows South Africa to upskill workers through training labourers to handle these technologies, instead of diminishing the demand for lower end skilled labourers (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020; Liang & Shah, 2023; Xu et al., 2022).

2.5.6 Factors affecting the adoption of IoT

Various factors such as political, environmental, social, and technology affect the willingness of farmers to adopt IoT (Kuschke, 2020; Von Bormann, 2019). The effect of each factor is elaborated as follows:

2.5.6.1 Political

Economic viability and profit are a strong incentive for farmers to adopt new technologies. The probability of farmers adopting new technology depends on how well the system is suited to local conditions and the potential to create value (Antony, Leith, Jolley, & Sweeney, 2020; Pillai & Sivathanu, 2020). The adoption of technology is determined by a farmer's economy of scale and the costs saved using the technology (Goedde et al., 2020). Farmers, policy makers and technology providers believe that the adoption of technology maintains sustainability while improving agricultural activity and economic performance, thus positively influencing its adoption (Antony et al., 2020; Pillai & Sivathanu, 2020).

Government level or agricultural department polices will play a major role in the adoption of IoT in agriculture (Goedde et al., 2020; Pillai, & Sivathanu, 2020; Von Bormann, 2019). Governmental involvement, regulation, enforcement, and standardisation of IoT policies will need to be ensured from region to region (Pillai, & Sivathanu, 2020; Von Bormann, 2019). In addition, the recommendation that technology experts and policymakers raise awareness of IoT technologies through actively promoting it in the early stages influences the willingness to adopt (Saiz-Rubio & Rovira-Más, 2020). Furthermore, financial and tax incentives, increasing government support for farmers, growing populations, environment sustainability policy, and competitiveness were found to be factors that influence the adoption of IoT (Ayaz et al., 2019; Goedde et al., 2020; Pillai, & Sivathanu, 2020; Von Bormann, 2019).

2.5.6.2 Environmental

The increased agricultural production, weather predictability, cost reduction and sustainability were found to be of the most influential factors affecting the adoption of a new technology (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020; Liang & Shah, 2023; Pillai & Sivathanu, 2020; Saiz-Rubio & Rovira-Más, 2020; Xu et al., 2022).

Due to South Africa's drought prone climate, climate change is driving the agricultural sector to adopt resilient technologies within its farming practices to improve production and conserve water (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020). Furthermore, the rising input costs for pesticides, fertilisers, and electricity, as well as limited arable land and water wastage as a result of inefficient farming practices are some of the factors that affect the adoption of IoT (Farooq et al., 2020). Ayaz et al. (2019) and Kuschke (2020) suggests that IoT addresses these factors by reducing of the costs of fertilizers, and pesticides as well as water wastage due to its precision application of resources. Thus, weather variability, environmental degradation, and climate change can be better managed through IoT. Furthermore, factors that make it economically feasible to adopt technology in agriculture were found to be the decrease in cost of new technologies and an increase in demand for sustainable products by consumers (Ayaz et al., 2019; Goedde et al., 2020; Meyer, Kirsten, Davids, Delport, Vermeulen, Sihlobo, & Anelich, 2022; Pillai, & Sivathanu, 2020; Von Bormann, 2019).

2.5.6.3 Social

Saiz-Rubio and Rovira-Más (2020) stated that the social factors that facilitate adoption of technology are willingness to adopt, farmer training, information sharing, accessibility to financial resources, and an increasing demand for food. In addition, the perceptions associated with the social factors of technological innovation affect the adoption of a new technology (Giua et al., 2022; Ruzzante et al., 2021; Smidt & Jokonya, 2022). Furthermore, Saiz-Rubio and Rovira-Más (2020) argues that the age and education of the farmer does not affect adoption. However, Shang et al. (2021) found that age negatively influences the adoption of more complex technologies. Moreover, education and social class had a positive influence on adoption, while younger farmers that were better educated were more likely to adopt technology (Giua et al., 2022; Shang et al., 2021).

Social factors affecting adoption of IoT in developing countries, like South Africa, were found to be farm size, education, age, partnerships, deployment costs and farmer awareness (Giua et al., 2022; Goedde et al., 2020; Ruzzante et al., 2021; Shang et al., 2021; Smidt & Jokonya, 2022). Older farmers, without tertiary qualifications, smaller farm sizes, lack of awareness or those in partnerships were found to be less likely to adopt new technologies, such as IoT (Goedde et al., 2020). Whereas Kuschke (2020) also found that those most likely to adopt IoT are younger farmers, with tertiary qualifications, larger farm sizes or those who are not in partnerships. In addition, IoT enables farming communities that share data and information as well as promote interaction between agricultural experts and farmers (Ayaz et al., 2019; Goedde et al., 2020; Pillai & Sivathanu, 2020; Von Bormann, 2019).

2.5.6.4 Technological

The accessibility of information regarding technologies influences the adoption of technology, even though it is found to improve farming practices (Farooq et al., 2020). Farmers who are aware of the benefits of technologies to their agricultural production are more likely to adopt. This has been corroborated by Pillai and Sivathanu (2020), who found that accessibility to information and markets was a positive influential factor on adoption. Furthermore, communication is a major desirable prerequisite for farmers to adopt technology, implying that if more farmers know about the technology, then more would adopt. When choosing to adopt technology within agricultural practices, farmers will base their decision on the net benefits derived from the technological investment.

Low Power Wide Area (LPWA) technology is likely to dominate the agricultural sector and entice farmers to adopt IoT due to its low power and long-range communications capabilities (Goedde et al., 2020; Pillai & Sivathanu, 2020; Von Bormann, 2019). The development of a universal IoT platform will allow easy modification, monitoring and managing of crops and livestock and, therefore, act as an enabler to the adoption of IoT by farmers. Low cost IoT deployments offer opportunities for more adoption of IoT as well as its ability to optimise power consumption of the IoT devices themselves (Pillai & Sivathanu, 2020). The development of a universal IoT platform provides support for a variety of software and enables the connection of different applications without heterogeneity issues and, thus, influencing the adoption of IoT (Liang & Shah, 2023; Pillai & Sivathanu, 2020; Xu et al., 2022). Moreover, the technological factors that farmers need to consider before adopting IoT are the roaming supportability, geographic location suitability, technology suitability to farm size and type, soil type, and climatic conditions.

2.5.7 Limitations of IoT adoption

Some of the limitations to the adoption of new technologies are restricted access to knowledge, risk aversion, lack of credit, farm size, lack of incentives associated with farm tenures, lack of human capital and equipment, and inadequate transport infrastructure (Pillai & Sivathanu, 2020; Ruzzante et al., 2021; Smidt & Jokonya, 2022). The lack of adequate knowledge of IoT and its use by farmers, especially those in rural developing countries, where farmers are more likely to be uneducated (Goedde et al., 2020; Pillai, & Sivathanu, 2020; Von Bormann, 2019). Saiz-Rubio and Rovira-Más (2020) recommends that these limitations be addressed and solutions that mitigate the effects should be proposed.

Research has outlined the limitations to the adoption of IoT in South Africa as a lack of awareness of IoT, lack of information accessibility, the weak currency rate and low return on investment makes importing technologies too costly for farmers (Kuschke, 2020). Furthermore, regulation hurdles such as assessment of new technologies, and lack of research and development (R&D) funding has been found to impede adoption of IoT. South Africa has been experiencing frequent electricity shortages and power outages which limits the uptake of technology in farming practices. However, is has also become a driver of solar energy use in the agricultural sector (Kuschke, 2020).

Other limitations include the large data sets constantly being generated by IoT devices, which require maintenance and the ability to understand and derive insights from the data (Goedde et al., 2020; Peng, Pal, & Huang, 2020). In addition, it becomes challenging to cope with heterogeneity and interoperability, data management and security and privacy issues. The widespread utilization of IoT agricultural industries, has caused severe apprehension regarding existing data, security and heterogeneity management strategies and necessitates the re-evaluation of it. Over the years, IoT technologies has become extremely complex because of its ability to autonomously exchange data between billions of embedded devices. Due to its impact on the various aspects of life as well agriculture, it becomes imperative to focus on managing the key issues and challenges that IoT has on the agricultural sector (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020; Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019).

2.6 South Africa

2.6.1 A Global Context

In California, strawberry production within the Oxnard region, is experiencing water shortages and water salinity concerns related to continuous droughts and depletion of water reserves. To overcome these issues and maximise production efficiency, El Rio Farms, set up a network of sensors to track soil conditions and incorporate precision farming. The El Rio farm manager reported that water usage was decreased by 27% as a result of smart drip irrigation and soil monitoring. The devices were also able to manipulate the temperature of the crops when conditions became unfavourable and could potentially cause damage to production (Ungerer et al., 2018).

Nigerian Minister of Agriculture, Dr. Akinwunmi Adesina (2011-2015), introduced IoT-based innovations into the agricultural sector. These IoT innovations included an Android application that connected various agricultural subsectors with the Bank of Industry (BOI) and the Ministry of Agriculture. This innovation significantly reduced fertiliser corruption and enhanced the value chain of agricultural products. In addition, farmers were better equipped to determine the appropriate crops to plant based on prevailing conditions (Chinwe, 2023).

2.6.2 A South African Context

South Africa is a rich and diverse country with an agricultural sector that is characterised by its dual agricultural economy (AgriSETA, 2019; Botha, 2021; Sutherland, 2020; Von Bormann, 2019). The diversity of the South African agricultural sector is depicted by various types of farming, such as, crop and animal production, horticulture, dairy, fish, and game farming (Kuschke, 2020). The agricultural economy of South Africa is categorised into subsistence, or small-scale, farming (SME) and well-developed commercial farming. However, among these categories there are a lot of complexity and fluidity (AgriSETA, 2019; Kuschke, 2020; Sutherland, 2020). South African commercial farming is highly developed, and export driven and is still a significant exporter of agricultural products. Whereas the small-scale subsistence farming is less developed and subject to various production constraints (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020).

Only 13.7% of South Africa's total surface area is arable and used for crop production, while only 3% of the arable land is considered as truly fertile land (Goedde et al., 2020). Since the early 1990's, South Africa was left with less than two-thirds of the number of farms it had due to climate change, water scarcity and declining farming profitability (Arora & Mishra, 2022; Bedasa, & Bedemo, 2023; Malhi et al., 2021). The lost farms have been used for other uses, while the remaining farms have increased its productivity to achieve sustainability through technology adoption within their farming practices (Kuschke, 2020; Sutherland, 2020).

2.6.3 National Situation of agriculture

South Africa has experienced immense economic and social reform in the past 15 years. Following the end of the Apartheid-era, economic reform and policy changes proposed to eliminate the previous Nationalist Governments' socialist control of agriculture by improving the agricultural environment and redressing land inequalities (Botha, 2021; Ngam, 2021). The result was both negative and positive in that government dismantled support to farmers leaving them incapable of competing with farmers of developed countries, while also increasing initiatives that enabled the growth of high-valued exportable crops (Botha, 2021; Ngam, 2021).

2.6.3.1 Political

Political factors encompass government interventions, policies, and behaviours. In addition, it examines government regulations in laws and legislation and its influence on operations and strategic decisions on the sector making it essential for organisations to consider their impact while developing plans and policies (Mihailova, 2020; Odey, 2021).

The Department of Agriculture, Farming and Fisheries (DAFF, 2019) has stated that they have increased and continues to facilitate access to technology within the agricultural sector despite the cost reflective electricity pricing. There has been an increase in mechanisation of agricultural practices over the years. The use of drones/unmanned aerial vehicles (UAV)'s, satellites, and aircrafts within the agricultural sector results in higher electricity use and, thus, DAFF (2019) states that a move to solar or renewable energy sources will become imperative, due to the possibility of rolling blackouts as a risk in South Africa.

Technologies such as drones equipped with multispectral cameras enable farmers to monitor crop health, detect stress, and optimise input applications. Satellite imagery provides real-time weather data and maps of soil moisture, helping farmers adapt their strategies to changing conditions. Precision farming systems, which integrate remote sensing tools, enhance decision-making by providing actionable insights, such as identifying specific areas that require irrigation, fertiliser, or pest control (Fuentes-Peñailillo, Gutter, Vega, & Silva, 2024). These technologies enable the remote sensing of agricultural production while enhancing farmer decision making and increasing productivity. This highlights the need to invest more in technology and technological research and development initiatives which will assist in finding innovative solutions to high agricultural costs and, the climatic effects of food scarcity (DAFF, 2019). In addition, the Gazette (2024) has stated that the move to a more technologically driven agricultural sector will be supported by available infrastructure and universal access to ICT services for all. The main political factors that affect the agricultural sector are ICT policies, land reforms, agrarian reform, food sustainability, economic development, environment strategic goals, and food security (AgriSETA, 2019; Von Bormann, 2019). The lack of ICT Research and Development investments can be seen in Figure 5.

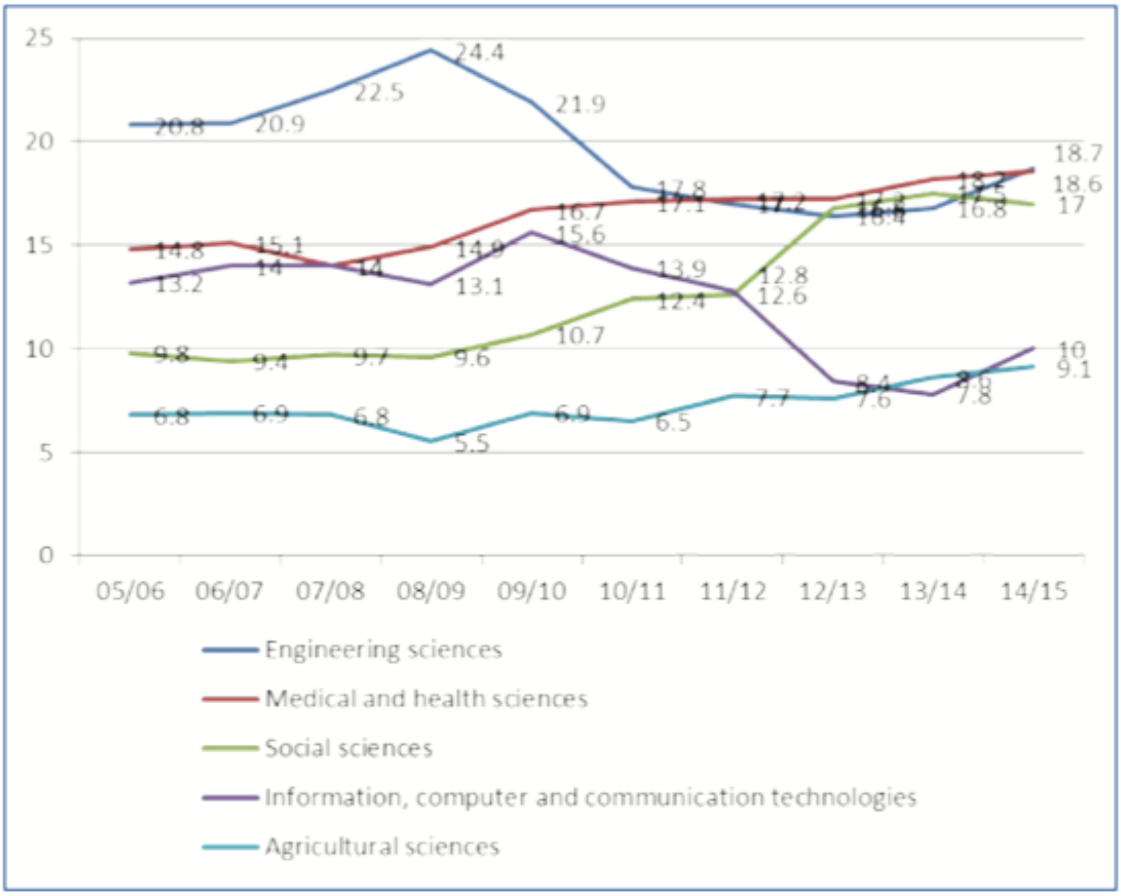


Figure 5- Investment distribution per research field in SA (DAFF, 2019)

The South African forecasted gross domestic product (GDP) showed a reduction of 2% in GDP from 2019 – 2020 due to the COVID-19 outbreak, causing additional economic challenges to SA's increasing debts, large fiscal deficits, depressed growth, and high social vulnerabilities (OECD, 2019). However, the agricultural sector has had a good quarter with a rise of 27,8% in production activity due to an increase in the production of field crops, animal, and horticultural products (StatsSA, 2020a). Moreover, the fundamental economic factors that affect the agricultural sector are agricultural production expansion due to increasing food demands, unemployment, weakening South African currency impacts imports and exports, state support for agriculture sub-sectors, and increased food prices due to rising input costs such as electricity (AgriSETA, 2019; Von Bormann, 2019).

2.6.3.2 Environment

Environmental factors are defined by aspects linked to the implementation of technological solutions aimed at conserving agricultural ecological resources. Ensuring the sustainability of economic systems hinges on safeguarding the potential of the environment, making it a crucial consideration for long-term viability and prosperity of the agricultural sector (Mihailova, 2020).

Water is an important resource for sustaining life; thus, the protection of water becomes critical without a viable substitute. Ensuring water security enables economic growth as well as food security (Von Bormann, 2019). Food security is reliant on the supply and availability of water and any added pressure influences the volatility of food supply. South Africa is a water scarce country because of its erratic climatic conditions, low annual rainfall and high rainfall runoff (Arora & Mishra, 2022; Goedde et al., 2020; Von Bormann, 2019). In addition, South Africa's water infrastructure is in poor condition and continues to deteriorate due to poor maintenance (Millington & Scheba, 2021). Agriculture is the largest consumer of water in South Africa and, therefore, a focus on sustainability using alternative solutions such as adopting technology in agricultural practices provides a valuable solution because it allows for the efficient use of water (Millington & Scheba, 2021; Veriava, 2020). Figure 6 depicts the consumption and withdrawal of water per sector per year.

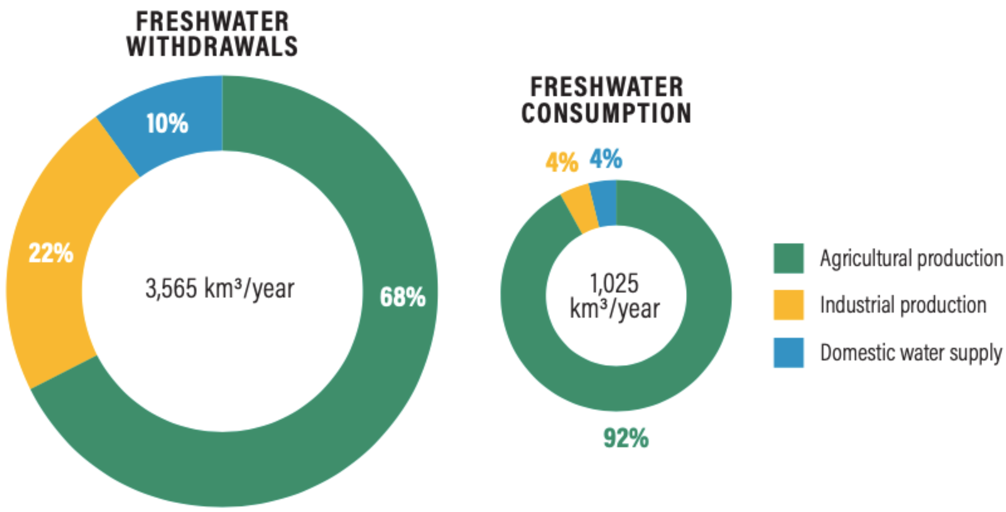


Figure 6 - Distribution of water per sector in SA (AgriSETA, 2019)

2.6.3.3 Social

Social factors comprise the demographic trends, education, cultural beliefs, publics aversion to change, and social acceptance. Understanding these social dimensions are crucial in assessing the viability and acceptance of technological solutions for the sustainable developments of agricultural ecosystems (Mihailova, 2020; Odey, 2021; Shang et al., 2021).

Broader social factors such as crime and farm attacks pose significant threats to IoT readiness in agriculture. High rates of crime discourage investment in new technologies, while farm attacks directly affect the livelihoods and safety of farmers, reducing the incentive to adopt innovative solutions. In addition, the quality and accessibility of education in rural areas impact the capacity of farmers to understand and implement IoT-based technologies. Limited technical skills and education further exacerbate the slow adoption of IoT, particularly in small-scale farming operations. Demographic factors such as age also play a role, as younger farmers are generally more willing to adopt new technologies, while older farmers may resist change (Akinola, 2020; Botha, 2021; Ceccato, Lundqvist, Abraham, Göransson, & Alwall Svennefelt, 2021; Shang et al., 2021).

The lack of economic growth in South Africa has negatively impacted the employment rate in the agricultural sector, as a result, there was a 0.6% decrease in employment due to the increased mechanisation of farming processes (StatsSA, 2020b). Table 1 presents AgriSETA (2019)'s data showcasing the decline in employment within the agricultural sector:

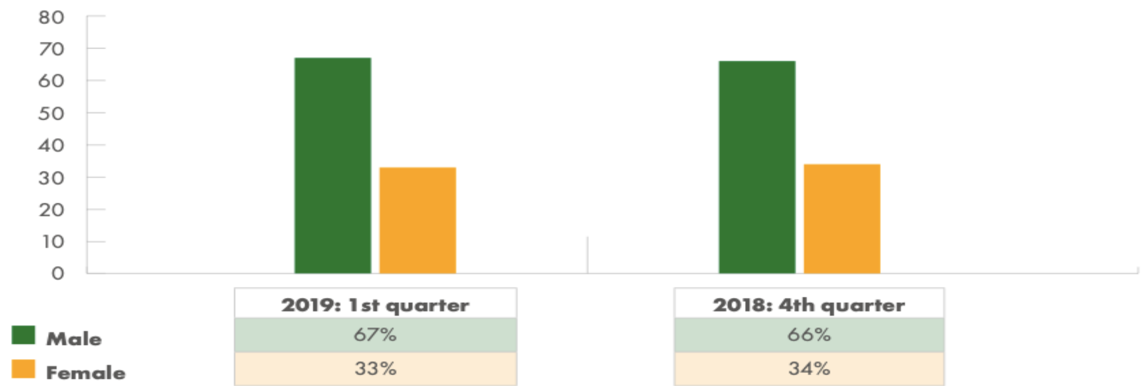
Table 1 - Employment distribution by sector in SA (AgriSETA, 2019)

Industry	Jan-Mar 2018	Oct- Dec 2018	Jan-Mar 2019	Quarter to Quarter change	Year on Year change	Quarter to Quarter change %	Year on Year change %
Total	16 378	16 529	16 291	-237	-86	-1.4	-0.5
	Thousands						
Agriculture	847	849	837	-12	-9	-1.4	-1.1
Mining	397	438	417	-20	20	-4.6	5.2
Manufacturing	1 849	1 766	1 780	14	-69	0.8	-3.7
Utilities	143	134	150	16	7	12.1	4.7
Construction	1 431	1 481	1 339	-142	-92	-9.6	-6.4
Trade	3 276	3 320	3 345	25	69	0.8	2.1
Transport	960	965	1 025	59	64	6.1	6.7
Finance	2 402	2 611	2 516	-94	114	-3.6	4.7
Community and social services	3 785	3 624	3 574	-50	-211	-1.4	-5.6
Private households	1 275	1 332	1 301	-31	26	-2.3	2

Source: Quarterly Labour Force Survey, Quarter 1:2019

There is the concern that technology will increase the already high unemployment rate as semi-skilled and unskilled workers are replaced by technological innovations. However, it is reported that, technology is enabling job creation with the possibility of retaining and upskilling the agricultural labour force (Goedde et al., 2020; Kitenge, 2020; Kuschke, 2020; Pillai & Sivathanu, 2020; Sutherland, 2020; Von Bormann, 2019).

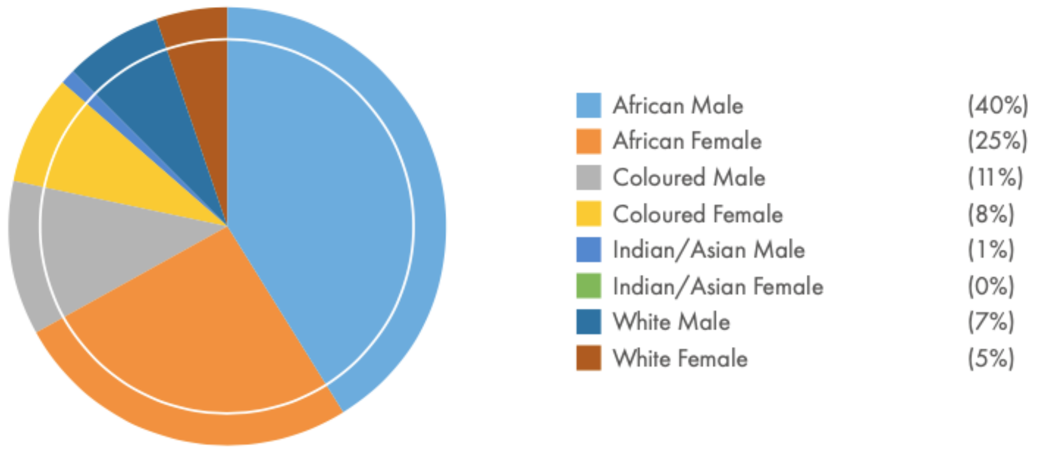
Gender in the agricultural sector was dominated by males and increased in the last quarter standing at a 67% male to 33% female ratio (see Figure 7) (StasSA, 2020b). These observations were supported by the Workplace Skills Surveys in 2019.



Source: StatsSA, Quarterly Labour Force Survey, Q1:2019

Figure 7 – Gender-based distribution of labour in SA's agricultural industry (AgriSETA, 2019).

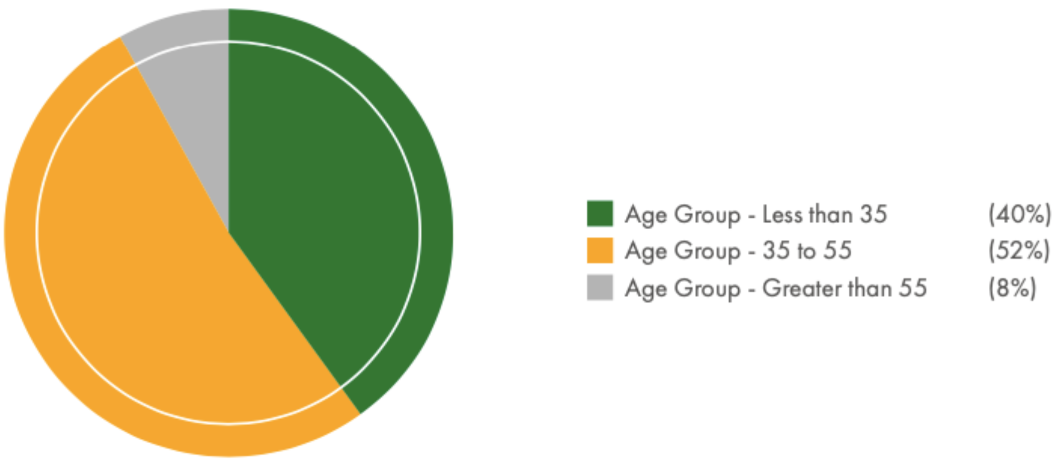
Moreover, most of the employees in the agricultural sector were predominantly black (65%), followed by coloured (19%), white (12%) and few Asians (1%) (see Figure 8) (AgriSETA, 2019).



Source: AgriSETA WSP Submissions, 2019/20WSP

Figure 8– Race distribution for labour in SA agriculture (AgriSETA, 2019)

The age of employees in the agricultural sector was reported to be between 15 and 65 years, while 40% were under the age of 35, 52% were between the ages of 35 to 55 and 8% were greater than 55 years old (see Figure 9) (AgriSETA, 2019).



Source: AgriSETA WSP Submissions, 2019/20

Figure 9 – Age distribution in the agricultural sector in SA (AgriSETA, 2019)

The lack of farmer support is causing the number of farms to decrease. According to The African Farmer's Association of South Africa (AFASA), of its total members, only one third of them farm for income, and of that one third only 2% of those farming commercially, are successful (Botha, 2021). Thus, regardless of the type of farming, many farms in South Africa are operating hand-to-mouth and require support to become sustainable. Over the years, the number of commercial farms has substantially decreased. However, this decrease in numbers has been accompanied by increases in farm sizes as well as a mixture of technology adoption on the farms. The key social factors that affect the agricultural sector are crime and farm attacks, ethics and privacy issues, mobility technology, perceptions of agriculture, age, gender, education, race, lack of technical skills, lack of farmer support, employment rates, and the transformation of small-scale subsistence farms into profitable operations to ensure food security (AgriSETA, 2019; Shang et al., 2021; Sutherland, 2020; Von Bormann, 2019).

2.6.3.4 Technology

Technological factors involve the presence or absence of necessary technological elements that facilitate the achievement of the organisation's goals. These factors include various aspects such as the availability of expertise, connectivity, trust and reliability of technology, the efficiency of the technological supply chain, and the adherence to industry standards (Mihailova, 2020; Odey, 2021).

DAFF (2019) intends to use technology to promote sustainable agricultural production. The department proposes the transformation of the agricultural sector through integrating, aligning and efficiently using technological resources. The aim of DAFF (2019) is to improve the Department of Information and Communication Technology (ICT)'s, focus on technological development and dissemination through agricultural innovation. The primary technological factors that affect the agricultural sector are mobile technology growth, internet penetration growth, the increasing number of smart devices, adoption of technological advancements for less labour usage, and sustainable farming production (AgriSETA ,2019; Gazette, 2024; Sutherland, 2020; Von Bormann, 2019).

South Africa is a major importer of technology, however, the deficit in budget is impinging on South Africa's' ICT innovativeness as less money can be spent on improving the sector. Although agriculture is not a primary contributor to the GDP of the ICT sector, given the technological boom, this could potentially change (Gazette, 2024). Some key technological factors that influence technological adoption are potential benefits, cost, initial investment, economies of scale, awareness of technology, and the theft and security of technology further define technological factors (Goedde et al., 2020; Kuschke, 2020; Pillai & Sivathanu, 2020; Von Bormann, 2019).

2.6.4 A Western Cape context

Agriculture plays a significant role in the Western Province economy. In the Western Capes agricultural sector, the most important sub-sectors, based on their rand value output, are wine, fruit and wheat as they contribute up to 90.5% of South Africa's total agricultural exports (Meyer et al., 2022; Partridge et al., 2020). While the Western Capes' trade of agricultural exports contributed more than 50% of the South African total agricultural exports (see Figure 10) (Weser, 2019).

Refined petroleum oil	Botswana **R2.76bn**	Namibia **R1.36bn**	Lesotho **R846.11m**	Togo **R629.25m**	Mauritius **R603.33m**
Citrus fruit	Netherlands **R1.99bn**	United Kingdom **R1.31bn**	Russia **R963.23m**	UAE **R877.66m**	China **R752.01m**
Wine	United Kingdom **R1.56bn**	Germany **R1.11bn**	Netherlands **R761.00m**	United States **R602.19m**	Canada **R467.10m**
Grapes	Netherlands **R2.40bn**	United Kingdom **R1.54bn**	Hong Kong **R383.89m**	Germany **R283.46m**	Canada **R281.19m**
Apples, pears and quinces	United Kingdom **R1.10bn**	Netherlands **R708.71m**	Malaysia **R622.68m**	UAE **R442.85m**	Russia **R407.02m**

Figure 10 - Top five markets for the top exported products in the Western Cape (Wesgro, 2019)

As illustrated in Figure 11, the Western Cape is the largest producer of deciduous fruit (pears, grapes, apples, peaches, wine grapes and watermelons) (Wesgro, 2019).

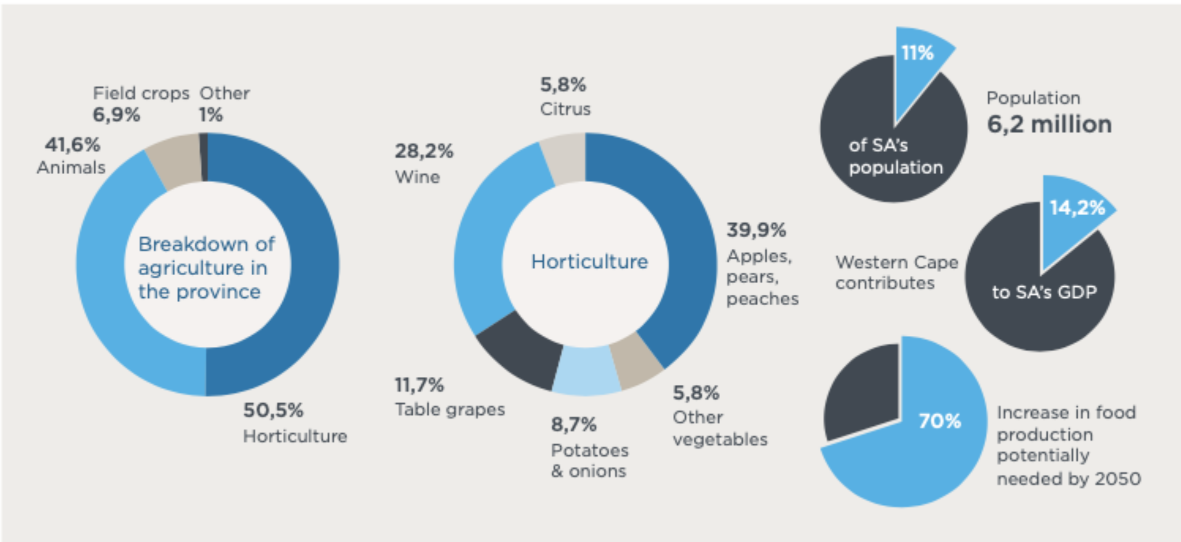


Figure 11- Breakdown of Agriculture in the Western Cape (Ungerer et al., 2018)

Furthermore, the Western Cape agricultural sector is a fundamental area for targeted intervention due the high number of agricultural farmers. Figure 12 shows that majority of farmers registered at AgriSETA (2019) are in the Western Cape. DAFF (2019) and AgriSETA (2019) states that although the different provinces have specific-focus development strategies for their agricultural sectors, the shared aim is the provisioning of food security through investing in technologies that enhance the efficiency of agricultural processes (DAFF, 2019; AgriSETA, 2019).

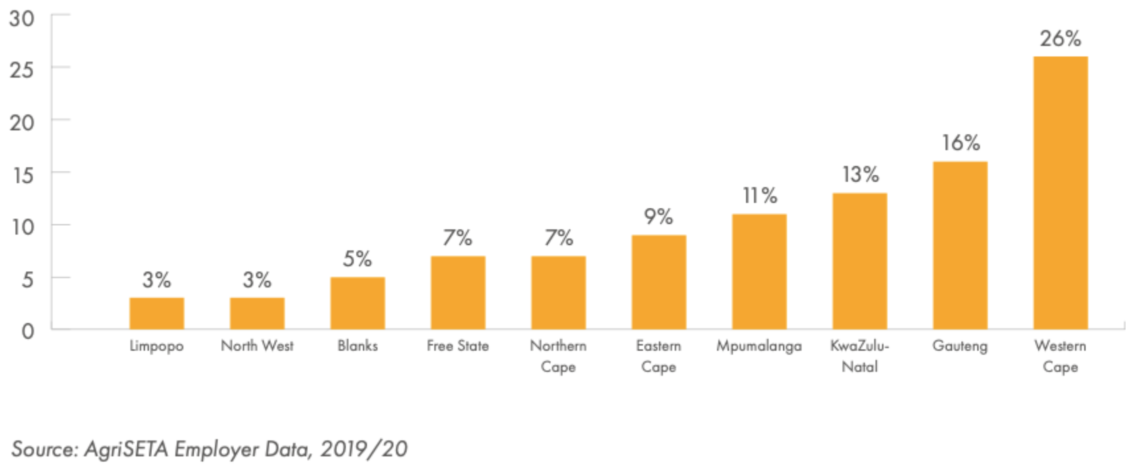


Figure 12- Provincial distribution of employers registered with AgriSETA in SA (AgriSETA, 2019)

In addition, the adoption of IoT within the agricultural sector will enable strategic alignment of the Western Capes' Department of Agriculture to the National Development Plan (NDP). This will be achieved through maintaining exports within the agricultural sector for job security, supporting agricultural land reform to contribute towards food security, optimising sustainable water usage techniques for a climate-smart agricultural sector, and providing youth development opportunities and skills for a technologically advanced farming (Kuschke, 2020; Sutherland, 2020; Von Bormann, 2019).

2.7 Chapter Summary

Food scarcity, climate change, an increasing population and greater demand for food are putting pressure on agricultural sectors to use IoT tools to meet the demand for food. IoT utilises sensor devices connected through high or low powered networks to enable farmers to increase production. The challenges of the agricultural sector and subsequent opportunities for IoT were presented. The South African agricultural sector experiences complications adopting IoT due to its high investment costs, lack of infrastructure, lack of trust and digital literacy, and standard infancy.

IoT devices connects via a network and requires wireless/ mobile technology to provide its services. Other farming equipment can be integrated with IoT to deliver its services to farmers on their mobile technologies. IoT opportunities and challenges were outlined.

AgriSETA (2019) reported that more than 50% of South Africans are food insecure and that climatic changes may cause further damage to the already fragile food scarcity situation. Therefore, it becomes imperative to assess the Western Capes readiness to adopt IoT to combat the ongoing concerns surrounding food.

Chapter 3

3 Conceptual Framework

3.1 Introduction

The conceptual framework assists researchers in structuring their thoughts, expounding, and clarifying their research questions, and guides the design and implementation of their research (Creswell & Creswell, 2018). In this research, the conceptual framework was used as the tool to define, describe and, select the key elements in this study (Creswell, 2009; Creswell & Poth, 2018; Creswell & Creswell, 2018).

The conceptual model for this research incorporates the concepts of Political, Environmental, Social, and Technological (PEST) factors that determine readiness within a context. It uses the Strengthens, Weaknesses, Opportunities, and Threats (SWOT) to evaluate the situation to further understand readiness. The combination of the two conceptual models, PEST and SWOT, aims to inform, guide, and assess the interplay between the various dimensions and their influence on IoT readiness within the South African agricultural sector.

3.2 Readiness: A prerequisite to adoption

Loevinsohn, Sumberg, Diagne, and Whitfield (2013) defines adoption as integrating and adapting new technologies into existing methods. Whereas adoption is defined by Feder, Just, and Zilberman (1985) as the mental process that an individual experiences once they have heard about an innovation, up to their final utilisation of the innovation. When looking at adoption on an individual (farm-level) adoption and aggregate (national) adoption, the latter is commonly referred to as diffusion (Rogers, 2003). Historically, adoption was understood as a behavioural change. This implied that the adoption process occurs over time once the innovation has been accepted by the user.

The adoption of technological innovation within the agricultural sector has drawn considerable interest among economists, especially among those in developing countries. This is due to developing countries deriving a huge portion of their livelihood from agricultural production, thus, needing new ways to improve and maintain production. The adoption of new technologies, thus, creates the opportunity for farmers to increase their profitability and productivity (Feder et al., 1985). The accelerated adoption of technology in the agricultural sector provides modern, productive, and sustainable farming methods. This leads to increased competition between farmers economically, as well as from a technological perspective (Kuschke, 2020; Sutherland, 2020; Von Bormann, 2019).

Technology readiness is the assessment of a user's disposition to adopt and use new technology. More specifically, technology readiness seeks to understand what motivates and inhibits the adoption of new technologies (Parasuraman, 2000; Zaidi & Faizal, 2017). Technology readiness can be determined by various frameworks and are commonly used to assess the organisational readiness to adopt emerging technologies. While technology innovation frameworks are used to assess the level of acceptance and adoption of technological innovations (Compeau & Higgins, 1995; Davis, Bagozzi & Warshaw, 1989; Leonard-Barton & Deschamps, 1988).

3.3 Assessment of conceptual frameworks

Many areas of adoption, acceptance, and readiness studies have been conducted using various frameworks to determine the users readiness, acceptance, and adoption to make use of new technologies. These frameworks assess and focus on users readiness to adopt and accept technology innovation.

Task Technology Fit (TTF) Theory: The TTF framework refers to the degree to which the functionality of technology aligns with task requirements and the abilities of individuals (Sinha et al., 2019).

Technology-Organisation-Environment (TOE) framework: The TOE framework was developed to showcase the organisational factors that impact an organisations ability to accept technology (Tornatzky & Fleisher, 1990).

Innovation Diffusion Theory (IDT): The IDT framework: examines the transmission of technological innovations within a particular context where the adoption of technology is being considered (Rogers, 2003).

Technology Readiness (TR) framework: The TR framework is defined as the individuals inclination to achieve goals through the acceptance and utilisation of new technologies (Parasuraman, 2000).

Each model touches on various components of IoT readiness for agriculture and assessed readiness for a particular purpose, however, those aspects were too broad and neither measured readiness holistically by considering external factors which is in line with the intent of this research. Through careful analysis, the following factors were considered for the proposed conceptual framework as best suited to IoT readiness: political readiness, environmental readiness, social readiness, and technological readiness. Each factor was further broken down into an assessment of their respective strengths, weakness, opportunities, and threats.

3.4 Proposed Conceptual Framework

The study intended to assess the agricultural sector's readiness to adopt IoT and not to measure the adoption or acceptance of IoT. However, some studies mentioned above, emphasise that the user's behaviour is the primary determinant for technology adoption. It is important to understand the impact of a new technology, such as IoT, on the whole agricultural sector before its adoption. More so, it is imperative to determine whether the agricultural sector, holistically, is prepared to adopt IoT in their current practices. This suggests that various other factors, outside of users should be considered when determining IoT readiness. Therefore, the PEST and SWOT frameworks were employed to assess the technological readiness of the agricultural sector. The PEST and SWOT frameworks determines where the South African agricultural sector currently is, and whether it is ready to adopt technology.

3.5 Political, Environmental, Social, Technological (PEST) Model

A PEST analysis is a valuable tool used to assess strategic risk by examining the four sources of change: "political, economic, social, and technological" (Sammut-Bonnici & Galea, 2015). It determines an organisations competitive position through understanding the impact and changes of the external macro environment. The external environment comprises of factors outside of an organisations control which make them susceptible to major impacts to its competitive position. Thus, necessitating understanding and analysis to align its strategy with changing environments. A PEST analysis provides fundamental insights that can be applied to the entire organisation (Sammut-Bonnici & Galea, 2015). The PEST analysis is commonly used in market analysis in various sectors such as education, health, finance, government, and retail (David, David, & David, 2017; Helms & Nixon, 2010).

To assess the readiness of adopting technology in the South African agriculture sector, the sector should be examined through four directives, namely, political, environmental, social, and technological (PEST) factors to determine alignment and synchronicity (Law, 2006). It allows the assessment of the current and prospective state of the agricultural sectors' readiness. PEST analysis is a tool used to analyse the macro-factors (political, environmental, social, and technological) of the external environment to enable strategic management. In addition, it allows organisations to take advantage of opportunities and mitigates threats (Nganga & Maruyama, 2015). The results of the PEST analysis will illustrate the environment within the agricultural sector, identify the aspects that may strengthen, impede, or create opportunities for technological growth, and enables the development of strategic action (see Figure 13).

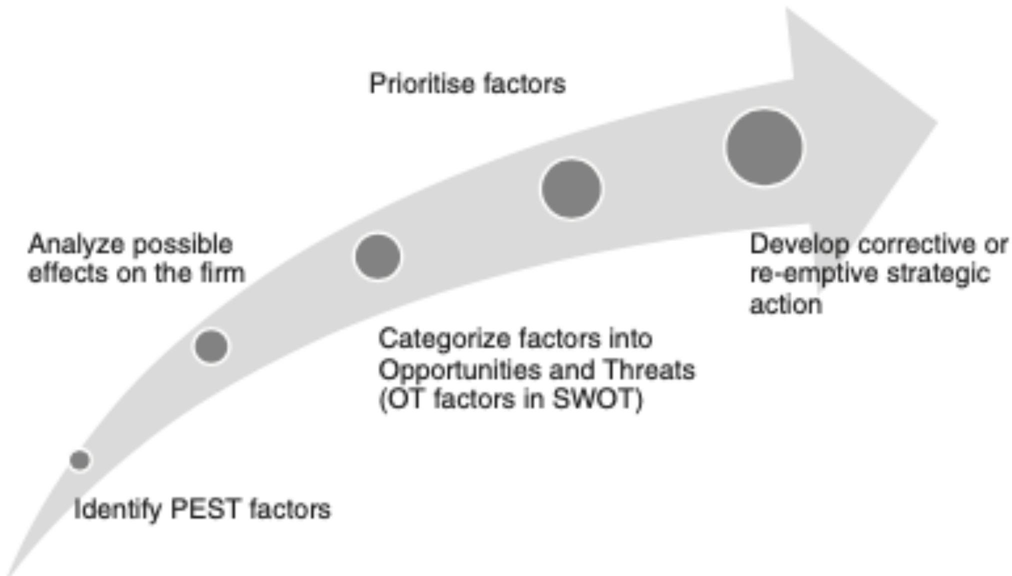


Figure 13 - Process and stages of PEST (Sammut-Bonnici & Galea, 2015)

3.5.1 Limitations of the PEST Model

While the framework provides valuable insights into the external macro environment, it also has certain limitations. Understanding these limitations are essential to ensure a thorough analysis and prevent potential pitfalls (Burt, Wright, Bradfield, Cairns, & Van Der Heijden, 2006; Sammut-Bonnici & Galea, 2015).

- **Static Nature:** The PEST analysis is a static evaluation and does not account for an external environment's dynamic nature, rapid changes, and evolving trends (Burt, et al., 2006; Ortega et al., 2019).
- **High-level perspective:** It provides a broad overview of macro environmental factors which lacks the specificity and depth on issues and trends, thereby, hindering the ability derive valuable insights required for informed decisions (Burt, et al., 2006; Sammut-Bonnici & Galea, 2015).
- **Lack of standardisation:** PEST analysis lacks an established set of criteria/universally standardised framework which may create inconsistencies when applying or interpreting various contexts (Song, Sun, & Jin, 2017).
- **Limited predictive capability:** The nature of the PEST analysis is to look at past and current factors that influence an organisation, thus, hindering its predictive power regarding future trends and changes (Burt, et al., 2006; Sammut-Bonnici & Galea, 2015; Song et al., 2017).

While the literature acknowledges the limitations of a PEST model, it still serves as a valuable starting point for assessing the various factors of readiness when combined with other frameworks.

3.6 Strengths, Weaknesses, Opportunities and Threats (SWOT) Matrix

A SWOT analysis is a widely used tool for gathering and presenting information on the internal and external factors that currently or potentially affect an organisation (Pickton & Wright, 1998). It is praised for its simplicity and effectiveness in directing attention towards critical issues that impact organisational growth and development. Furthermore, it holds the potential to be a valuable tool in identifying key factors that shape an organisation's strategy and determine its success. The SWOT matrix is commonly used in analysis and textbooks, and by consultants, managers, organisations, and business schools who advocate the adoption of the SWOT framework (Pickton & Wright, 1998).

The readiness of an organisation is determined by an organisations ability to recognise its internal and external environments, and future objectives. In addition, it enables an organisation to enumerate the aspects that influence a strategy, both internally and externally, so that it can be thematically and visually brought together (Helms & Nixon, 2010; Houben, Lenie, & Vanhoof, 1999).

Each organisation functions within a complex environment of political, environmental, social, and technological factors. This complexity shapes the organisational and operational structure of each organisation, thereby, defining its strategic and business strategy. An organisation has, both, an internal and external environment (Helms & Nixon, 2010; Houben et al., 1999). The SWOT analysis is widely used in the marketing sector (Helms & Nixon, 2010).

The external environment consists of opportunities and threats, which are beyond the organisation and, frequently, beyond its control. It is divided into three distinct parts, namely, the natural, societal and task environment. The natural environment includes climate, physical resources, and the ecological system. The societal environment are those factors that influence long-term organisational strategic decisions but does not directly affect its short-term operations. The societal environment can further be divided into political (policy and regulation), environmental (weather, energy, materials, and resources), social (ethics and customs), and technological factors. The task environment are all the factors that directly impact the organisation, such as government, stakeholders, local community, labour unions, employees, and competitors (Helms & Nixon, 2010; Houben et al., 1999; Machuki, 2011). Figure 14 shows the SWOT Matrix.

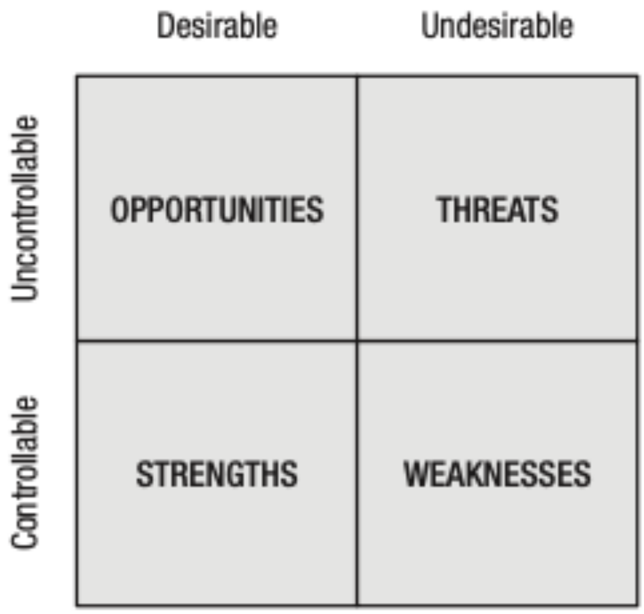


Figure 14 - SWOT Matrix (Ghazinoory, Abdi & Azadegan- Mehr, 2011)

In addition to the external environment, there is an internal environment of the organisation which comprises of strengths and weaknesses, that are usually within its control. The internal environment is made up of three parts, structure (organisational structure), culture (shared beliefs, values, and expectations), and resources (tangible and intangible assets) (Helms & Nixon, 2010; Houben et al., 1999; Claudiu, Andrei & Gabriela, 2011).

Through assessing the dynamic and multifaceted internal and external environments of an organisation, important strategic considerations will become apparent and facilitate the best strategic choices and influence formulation, execution, and assessment of the strategy. This is achieved through a SWOT analysis (Gürel & Tat, 2017; Zhao, Liu & Xue, 2019). It is an effective tool when thinking about nascent ideas on a topic. Thus, the use of a PEST and SWOT analysis on the agricultural industry, is a practical method that sets an inroad to the analysis and development of an initial set of issues which informs the adoption of technology within the sector (Zhao et al., 2019).

A SWOT analysis of IoT adoption in South African agriculture highlights its potential to improve productivity and sustainability. Strengths include the potential of advanced technologies such as drones and precision irrigation, climate monitoring capabilities, government support, and improved water efficiency and productivity. However, weaknesses such as the likelihood for high initial costs, limited technical skills, infrastructure gaps, and social barriers like poverty and resistance to change remain challenges. Opportunities lie in the prospect for renewable energy integration, job creation through upskilling, enhanced climate resilience, and export potential, while threats include the possibility of crime, economic instability, extreme weather events, and data privacy concerns. Addressing these weaknesses and threats while leveraging the strengths and opportunities can transform South Africa's agricultural sector into a more sustainable and productive system.

By clearly articulating these interconnections, such as the cascading effects of political decisions on political opportunities or how technological advancements mitigate weaknesses in environmental practices, this study could demonstrate a cohesive relationship between the PEST-SWOT constructs and the research objectives. For example, illustrating how government funding for IoT-enabled water management systems addresses environmental challenges like water scarcity while simultaneously reducing operational costs for farmers would directly link the framework to the primary research question. This approach would not only strengthen this study's conceptual framework but also provide a more comprehensive and theoretically grounded analysis of IoT readiness in agriculture. Thus, a SWOT analysis enables IoT adoption in South African agriculture by providing a structured framework to evaluate key factors influencing its implementation and success.

3.6.1 Limitations of the SWOT Matrix

The SWOT matrix, a widely employed strategic tool, assesses an organisation's internal strengths and weaknesses, along with its external opportunities and threats. While it provides a structured framework for assessing critical factors, it is not without limitations. Understanding these limitations are essential in facilitating a well informed and comprehensive decision-making process (Namugenyia, Nimmagaddab, & Reinersc, 2019; Pickton & Wright, 1998).

- **Simplistic categorisations**: Pickton and Wright (1998) argues that the oversimplification of complex strategic issues into four distinct categorisations may result in a lack of depth and nuance in the analysis and does not sufficiently account for the interconnectedness of its internal and external factors.
- **Lack of prioritisation**: The SWOT matrix does not provide a clear way to rank the importance of identified factors which can make it a challenge when determining critical factors for strategic decision making (Namugenyia, et al., 2019).
- **Subjectivity and bias**: The analysis of a SWOT matrix relies heavily on the judgements and perspectives of the researcher, thereby introducing potential biases and subjectivity into the process (Namugenyia, et al., 2019; Pickton & Wright, 1998)

Although these limitations of a SWOT matrix have been identified in literature, it serves as a valuable point of departure for strategic analysis when used in conjunction with other frameworks.

3.7 A combined approach: PEST-SWOT Framework

The combination of a PEST analysis with a SWOT analysis allows for the identification and classification of both internal and external parameters affecting an organisation or sector. The advantage of using this combined approach lies in its ability to assess factors that may impact an organisation, especially those beyond the organisations control and harder to identify individually. By examining the organisations strengths, weaknesses, opportunities, and threats, along with external political, environmental, social, and technological factors, organisations can gain a comprehensive understanding of the projects context and make more informed decisions (Christodoulou & Cullinane, 2019).

Technology readiness understood in the context of a SWOT framework is given deeper meaning when employed using a PEST framework. The PEST framework evaluates the political, environmental, social, and technology factors and seeks to further define the internal and external environments of the agricultural sector (Sammut-Bonnici, & Galea, 2015). This understanding allows decision makers to determine whether the agricultural sector is ready to adopt IoT by assessing the political, environmental, social, and technological enabling factors of IoT adoption. A deeper understanding of readiness to adopt IoT is sought because the PEST-SWOT framework enables the positioning of the agricultural sector in terms of the political, environmental, social, and technological strengths, weaknesses, opportunities and threats to adopting IoT.

Through understanding these factors, the PEST and SWOT frameworks (see Figure 15) assesses the current state of the South African agricultural sector, before adopting technology, which then gives meaning to readiness.

Political	**Environmental**
Strengths Weaknesses Opportunities Threats	Strengths Weaknesses Opportunities Threats
Social	**Technological**
Strengths Weaknesses Opportunities Threats	Strengths Weaknesses Opportunities Threats

Figure 15 - Adapted PEST-SWOT analysis from Zhao, Liu, and Xue (2019)

The following definitions are ascribed to the PEST factors: (Adapted PEST-SWOT analysis from Zhao, Liu, & Xue, 2019).

Political: Political factors encompass government interventions, policies, and behaviours. In addition, they examine government regulations in laws and legislation and its influence on operations and strategic decisions on the sector making it essential for organisations to consider their impact while developing plans and policies (Mihailova, 2020; Odey, 2021).

Environmental: Environmental factors are defined by aspects linked to the implementation of technological solutions aimed at addressing environmental issues. Ensuring the sustainability of economic systems hinges on safeguarding the potential of the environment, making it a crucial consideration for long-term viability and prosperity of the agricultural sector (Mihailova, 2020).

Social: Social factors comprise the demographic trends, education, farm size, impact on labour, and security. Understanding these social dimensions are crucial in assessing the viability and acceptance of technological solutions for the sustainable development of agricultural ecosystems (AgriSETA, 2019; Mihailova, 2020; Odey, 2021; Shang et al., 2021; Smidt, & Jokonya, 2022).

Technological: Technological factors involve the presence or absence of necessary technological elements that facilitate the achievement of the organisation's goals. These factors include various aspects such as the availability of expertise, connectivity, trust and reliability of technology, the efficiency of the technological supply chain, and connectivity (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020; Liang & Shah, 2023; Mihailova, 2020; Odey, 2021; Pillai, & Sivathanu, 2020; Torky & Hassanein, 2020; Xu et al., 2022).

The results of the PEST analysis aim to inform the SWOT analysis (see Figure 17) to reach a detailed understanding of the readiness of the agricultural sector regarding actual adoption of technology (Law, 2006). The SWOT analysis will identify the technology potential of the agricultural sector with a particular focus on the contributing factors that determine the readiness to adopt IoT in South African agriculture. How to strategies based on the PEST-SWOT matrix (Zhao et al., 2019)

External Environment		Interior Environment			
		Weaknesses	WP	Strengths	SP
			WE		SE
			WS		SS
			WT		ST
Opportunities	OP	WO Combination strategy		SO Combination strategy	
	OE				
	OS				
	OT				
Threats	TP	WT Combination strategy		ST Combination strategy	
	TE				
	TS				
	TT				

Figure 16 - How to strategize based on the PEST-SWOT matrix (Zhao, Liu, & Xue, 2019)

The PEST-SWOT analysis conceptual framework is an integrated tool that allows researchers to examine external environmental factors (PEST) and internal strategic elements (SWOT) within a specific context, such as IoT readiness in agriculture. To enhance understanding, it is critical to explain the relationships and interactions between these concepts and how they connect to the research question.

Political Factors and SWOT: Political factors in the PEST analysis, such as government policies, subsidies, and regulations, often serve as external drivers influencing the strengths, weaknesses, opportunities, and threats in SWOT. For example, government support through subsidies for IoT adoption can be categorised as a strength in SWOT, while regulatory challenges or corruption may appear as threats. The interaction between these factors helps shape the environment for IoT adoption by either enabling or inhibiting implementation, directly impacting readiness.

Environmental Factors and SWOT: Environmental factors, such as climate change, soil degradation, water scarcity, and biodiversity, directly link to strengths, weaknesses, opportunities, and threats in SWOT. For instance, favourable climatic conditions that support year-round farming can be a strength, while soil degradation and water pollution may act as weaknesses or threats. Conversely, the need to address environmental challenges can drive the adoption of IoT solutions, such as precision farming tools for sustainable resource management, thereby creating opportunities for agricultural innovation and improved efficiency.

Social Factors and SWOT: Social factors, such as education, community influence, and cultural attitudes, influence farmers' willingness to adopt IoT and relate to both weaknesses and threats in SWOT. For example, a lack of technical skills among farmers could be a weakness, while resistance to change due to cultural norms could be a threat. Conversely, community-driven training programs can transform these barriers into opportunities by improving readiness and creating a more technology-friendly environment.

Technological Factors and SWOT: Technological factors, such as precision farming tools, remote sensing, and connectivity solutions, directly shape the strengths and opportunities in SWOT. For instance, the availability of affordable IoT solutions like LoRaWAN can be a strength, while limited infrastructure or unreliable electricity in rural areas may present weaknesses or threats. These factors interact by enabling the use of innovative tools while highlighting the need to address infrastructural gaps.

Interconnection Between PEST and SWOT Elements: The PEST-SWOT framework emphasises how external and internal factors interact within the research context. For example, political incentives (P) can drive technological advancements (T), transforming a weakness like limited farmer awareness into a strength through targeted training programs. Similarly, environmental challenges (E) like water scarcity can drive the development of IoT-enabled water management solutions, converting a threat into an opportunity. Social barriers (S), like resistance to technology, can shift to opportunities when combined with technological advancements, such as accessible mobile-based IoT tools. By explicitly linking these interactions to the research question, the framework illustrates how IoT readiness is shaped by the dynamic interplay between political, environmental, social, and technological factors, providing a holistic understanding of the adoption landscape.

3.8 Chapter Summary

IoT readiness within the agricultural sector of the Western Cape, South Africa requires the understanding of various factors. These factors considered viewing readiness through the lens of the strengths, weaknesses, opportunities, and threats within the political, environmental, social, and political dimensions.

Various readiness and adoption frameworks assess the readiness and adoption of technology. Each framework serves its purpose to determine readiness in a particular way. However, none of the predictors fit the trajectory of this study. Therefore, the SWOT and PEST frameworks were found to be the best-suited framework to guide this study and were combined to achieve the research objectives.

Chapter 4

4 Research Methodology

4.1 Introduction

This study aims to assess the readiness of the agricultural sector in adopting IoT. The research focused on the agricultural sector in South Africa, specifically those in the Western Cape. It aims to address the main research question regarding IoT readiness in agriculture: *What are the factors that influence the readiness of agricultural farmers to adopt IoT?*

This chapter presents the research questions, methods, paradigms, and approach to theory. It highlights the importance of using the qualitative method, the research instrument and data collection and analysis techniques employed in this research. Thereafter, the research ethics are presented as well as the summary.

The research paradigm is pivotal to the process in that it details the ontological and epistemological paradigms that is built on worldviews and socially construct knowledge (Orlikowski & Baroudi, 1991). The study uses the following investigative lenses:

- Qualitative method used to collect and analyse data (Myers, 2009).
- Interpretivist epistemology which assumes that multiple subjective realities are derived through socially constructed means (Hesse-Biber, 2010).
- An exploratory approach which derives insights and an in-depth understanding of the phenomena (Saunders & Thornhill, 2016).
- A deductive approach informed by the conceptual framework and research questions and objectives (Saunders & Thornhill, 2016; Thomas, 2006).
- A phenomenology approach which thematically analyses data obtained through semi-structured interviews to derive important meanings of the participants' (Miles, Huberman, & Saldana, 2014).

4.2 Research Paradigm

Ontology is the lens which forms the way the researcher views and studies research objects. Ontology refers to the study of what phenomena or entities exist in the world and their interconnectedness (Creswell, 2009). Ontology is important because it creates the foundation for how a researcher perceives and interprets their point of study. Different ontological stances exist and were carefully considered regarding their relevance for this research (Creswell, 2009; Creswell, 2018; Saunders & Thornhill, 2016).

Positivism: Positivism is an ontological stance that observes phenomena and establishes causal relationships using empirical evidence or quantitative methods. It assumes that the social and natural world operates similarly, and therefore, can be objectively studied (Creswell, 2009). However, the readiness of IoT in the agricultural sector involves complex human behaviours, perceptions, and attitudes which are not easily quantifiable or understood in a simple cause-effect relationship. The positivist approach may oversimplify the complex nature of IoT readiness and overlook subjective experiences and meanings that farmers attribute to this technology .

Post-Positivism: Post-positivism acknowledges the role of subjectivity, albeit a modified version of positivism, it tends to prioritise objective knowledge and generalisability. (Creswell, 2018). In the context of this study, focusing solely on generalisable findings may disregard the contextual nuances and diverse perspectives of farmers regarding the readiness for IoT adoption. The post-positivist approach might also not fully capture the dynamic interactions between the political, environmental, social, and technological dimensions that influence readiness for IoT.

Critical Realism: Critical realism acknowledges the existence of both the objective reality and subjective perceptions; however, it highlights the need to uncover underlying mechanisms and structures that form social phenomena (Saunders & Thornhill, 2016). While it provides a more comprehensive understanding of a social reality than positivism, its focus on hidden structures and mechanism may not fully align with the interpretive nature of this study. The study aims to explore farmers perceptions and experiences of IoT readiness, rather than identifying causal mechanisms or hidden structures.

Pragmatism: Pragmatism is a stance that allows for the integration of multiple research methods and approaches and finds practical solutions to problems (Creswell, 2018; Saunders & Thornhill, 2016). However, while pragmatism can be adaptive, it may not fully suit the interpretive nature of this study, which prioritises understanding the deeper meanings and experiences of farmers. Pragmatism may potentially overlook the richness of qualitative data and depth of insight it can offer due to its prioritisation of the most effective approach.

Constructivism: Constructivism is an ontological stance that delves into the nature of reality and the way knowledge is constructed. It states that reality is not an objective, fixed entity that is independent of human perception; rather, it is actively constructed by individuals and communities through their interpretations, interaction, and experiences (Creswell, 2009; Creswell, 2018; Saunders & Thornhill, 2016).

Constructivism is the most appropriate ontological stance for this study due to its alignment with the subjective nature of IoT readiness in the South African agricultural sector. Farmers perceptions and attitudes toward IoT adoption are shaped by their social interactions and experiences. The context of the agricultural sector in South Africa influences farmers readiness, and constructivism allows researchers to explore these contextual factors. As a qualitative approach, constructivism enables in-depth exploration of farmers thoughts and feelings through interviews and focus groups. It emphasises interpretation and meaning-derivation in human experiences, acknowledging the role of subjective interpretations in IoT readiness. Researchers actively co-construct knowledge with participants, promoting reflexivity and awareness of biases.

The ontological assumption that is considered suitable for this study is constructivism as it reflects the notion that no single reality is the same for everyone. Therefore, reality is determined by the perceptions and actions of the researcher and the social actors involved (Saunders & Thornhill, 2016). Research has found that no single reality exists for determining readiness. Readiness will mean different things to different farmers, thus, there is a need to better understand the farmers realities and perceptions of readiness as a prelude to the adoption of IoT. This is consistent with the aim of the study because each farmer's reality and perception of readiness is subjective, therefore, a deeper understanding of what readiness means to each farmer would create a holistic understanding of farmer readiness in adopting IoT.

Epistemology deals with assumptions about knowledge, such as what makes knowledge valid, legitimate, and accepted, and how this knowledge can be communicated to others (Saunders & Thornhill, 2016). A positivist epistemological perspective posits that reality exists independently and can be objectively verified. According to this stance, properties of reality are measurable and remain uninfluenced by the instruments or perspectives of the researchers. The primary aim of positivist research is to validate theories to deepen the understanding of a given phenomenon (Myers, 2009; Myers, 1997). A critical epistemological perspective, on the other hand, views reality as historically and socially constructed, allowing for its reproduction as necessary. The critical paradigm examines assumptions underpinning societal conditions that inhibit emancipation, freedom, enlightenment, and justice (Myers, 2009). In contrast, interpretive epistemology suggests that reality is subjective and is constructed through social processes, such as shared agreements, realisations, tools, and language. In interpretive inquiry, researchers interpret and derive understanding through these socially constructed means (Myers, 2009).

Interpretivism assigns meanings to phenomena and context based, on individual interpretation (Hesse-Biber, 2010). An interpretivist approach will be adopted in this study because the data collected from individual participants will determine their perception of the world. In this case, it will guide the research in understanding the subjective perceptions of the farmers and the factors that influence their readiness to adopt IoT. This will then formulate a meaningful assumption about their readiness to adopt IoT. The assumptions will then aid in the creation of a holistic understanding of the factors that determine readiness to adopt IoT in agriculture.

4.3 Research Method

Research methodologies, such as quantitative, qualitative, or a mixture, are chosen based on their suitability for addressing research questions, objectives, problem statements, and data collection, and analysis methods (Creswell, 2009; Myers, 2009; Neuman, 2006). Quantitative research methods focus on studying natural phenomena, often through controlled experiments conducted in laboratory settings (Myers, 2009). In contrast, qualitative research involves the use of qualitative data, such as interviews, organisational records, documents, and participant observations, to understand and explain social phenomena (Neuman, 2006; Myers, 2009). This study employs qualitative research to understand diverse subjective realities influenced by individual and societal backgrounds, important for deriving meaning (Hesse-Biber, 2010). The qualitative approach is particularly suitable for exploring farmers' varied perceptions shaped by their backgrounds, crucial for assessing IoT adoption in agriculture, as these perceptions determine adoption and readiness decisions (Hesse-Biber, 2010).

4.4 Research Purpose

The purpose of the research is to examine agricultural farmers' readiness for IoT adoption, which is exploratory in nature. An exploratory approach aims to derive insights and better understand the phenomena being studied by asking open-ended questions (Saunders & Thornhill, 2016). Thus, an exploratory approach is considered suitable for this study as it explores and seeks to understand how factors influence the readiness to adopt IoT by agricultural farmers. This is facilitated by asking questions to farmers and understanding their answers in a context that provides the most representable insights of their readiness to adopt IoT.

4.5 Approach to Theory

Research employs two contrasting theoretical approaches: deductive and inductive analysis. (Saunders & Thornhill, 2016). The deductive analysis is concerned with developing a theory that consists of hypotheses or propositions that are subjected to the data. While the Inductive analysis involves interpreting raw data to develop themes, concepts, or theories based on an in-depth understanding and the researchers insights (Saunders & Thornhill, 2016; Thomas, 2006). The deductive approach was adopted in this research because the research objectives and data analysis were guided by a theoretical framework (Saunders & Thornhill, 2016; Thomas, 2006). The theoretical framework informed the data collection process as the questions were based on the theoretical model that aims to answer the research questions. The theoretical framework guided the data analysis process in that the findings were viewed and showcased through the lens of the framework.

4.6 Research Strategy

Qualitative researchers can adopt research methods such as phenomenology, ethnography, grounded theory, and case study. The action research method seeks to address real-world problems while simultaneously contributing to academic knowledge. The ethnography method involves immersing oneself in the field to observe and understand people's social situations and contexts. Grounded theory focuses on developing a theory derived from systematically collected and analysed data. The case study method aims to investigate or explain contemporary real-life situations, particularly when the boundaries between the context and the phenomenon are ambiguous (Creswell, 2009; Saunders & Thornhill, 2016). The strategy employed in this study is phenomenology. Phenomenology inclines to thematically analyse data to obtain the important meanings of participants' interpretations. This was considered suitable for this study because the data collected will derive meaning and seek to understand the readiness to adopt IoT in agriculture (Miles et al., 2014).

The research strategy for the qualitative data collected will be done through semi-structured interviews. It is considered suitable for this study because it enables data to be collected from natural settings, in a rich holistic way, and reveals the complexity of the data collected (Miles et al., 2014). It is an appropriate choice due to its nature of emphasising individuals lived experiences by associating meanings to it and connecting it to the society around them (Miles et al., 2014). The theoretical framework will guide the development of the interview questions. The lived experiences and society of the farmers becomes an indication of what factors influences their readiness to adopt IoT in their practices.

4.7 Time Horizon

Time horizon chosen for this study is a cross-sectional approach due to time constraints. Furthermore, the approach enables the understanding of the factors of readiness for the agricultural sector adopting IoT at a point in time which still derives meaning.

4.8 Research Sample and Population

The targeted research sample consisted of the following participants within the Western Cape:

- Agricultural crop farmers
- IoT experts/ specialists
- Government employees in the Department of Agriculture relating to Smart Agriculture and Agriculture.

Agricultural IoT users and non-users were interviewed to avoid bias. Experts were identified through online sources, such as Google and social media search engines. For example, LinkedIn was used to find crop farmers in the Western Cape and emails were sent asking for participation in an ethical manner. Crop farmers and government employee details were found online. Contact with participants was done ethically by informing them of my student status at the University of Cape Town, and that I have contacted them for research purposes and not invasively. Finally, consent letters was sent for signature before engagement occurred and read to them before the interview began.

The intended nonprobability sampling technique used was purposive sampling as it allowed the researcher to judge which participants would be best suited to answer the research questions and meet research objectives (Saunders & Thornhill, 2016). In this study, it was important to select participants who possessed the relevant information or knowledge and met the criteria of the study.

The sample size was based on saturation which meant that the interview process ended once the participants, being interviewed, were not giving any new information or were pointing out similar sentiments (Saunders & Thornhill, 2016).

4.8.1 Sampling Criteria

Purposive sampling informed the agricultural employees eligibility. The selection criteria developed by Miles and Huberman (1994) was adopted in this study to identify participants. The research studies three types of participants: agricultural farmers, IoT experts, and government employees (see Table 2). The selection criteria for agricultural crop farmers, included those with varying levels of technology knowledge. A total of five interviews were conducted with individual farmers to gather insights into their practices and perspectives. In addition, three interviews were held with experts in the field, one of which involved a group session where three experts participated in a single interview. Furthermore, two interviews were conducted with government officials to gain an understanding of policy implications and governmental perspectives.

Table 2 - The research population and number of interviews

Category	Participant	No. of Interviews
Farm	Farmer	5
	Farmer/ Farmer Manager	
	Farmer Technology Researcher	
	Farmer	
	Farmer	
Experts	IoT Expert	3
	IoT Expert	
	IoT Expert	
	IoT Expert	
	IoT Expert	
Government	Government Official	2
	Government Official	

4.8.2 Pilot Study
A pilot interview tested the procedure for conducting the interviews. The pilot study was distributed to participants like those who would be completing the questionnaire (Saunders & Thornhill, 2016).

4.9 Data Collection
4.9.1 Data Collection Sources
The data was sourced qualitatively from semi-structured interviews. Existing policies regarding South African agriculture and Information and Communications Technology (ICT) was sourced through the interviews with government officials and through online sources.

4.9.2 Data Collection Technique
The data collection technique employed in this research was semi-structured interviews. The semi-structured approach allowed the researcher to gather, explore and understand data obtained from the participants lived experiences (Saunders & Thornhill, 2016). This approach enabled the researcher to collect data from the participants practical experiences and allowed the participants to freely respond in a relaxed atmosphere. Thereafter, the interviews were transcribed.

4.9.3 Actual Data Collection
Data collection consisted of three methods: (a) face-to-face interviews (b) online/remote interviews and (c) collection of documentation. The primary data collection method was semi-structured interviews which used predesigned questions to guide the session (see Appendix 1). However, the researcher was not limited to the questions. Due to COVID-19, some interviews were conducted remotely through online interviews. Face-to-face interviews were conducted in a safe way by wearing masks and using social distancing protocols.

4.10 Data Analysis

Data analysis was conducted through the qualitative method of thematic analysis. Thematic analysis is used to identify, analyse, and report themes found in the data collected (Braun & Clarke, 2006). The theoretical framework, namely the PEST-SWOT framework, guided code development to align the political, environmental, social, and technological themes to their corresponding strengths, weaknesses, opportunities, and threats.

For the thematic analysis, the tool used was Nvivo (Smit & Pilifosova, 2003).

The unit of analysis employed in this study was individuals/roles.

4.11 Research Validity

The proposed interview questions were sent to the researcher's supervisor for a quality and validity check, which was then approved by the Ethics Committee before it was used. Internal validity is ensured through the theoretical relationships being established in a rich collection of data. While the external validity allows for generalisations where research settings are similar (Saunders & Thornhill, 2016).

Interview questions were validated through the researchers' supervisor and Ethics Committee before research commenced. Trustworthiness of qualitative research is derived by assessing credibility, dependability, transferability, and confirmability of the data collection and data analysis processes.
The data collection was validated through subject variability, size of population, characteristics of population, interaction of population selection and research, and through the data collection methodology. Data analysis was validated by the researcher's supervisor checking the process of code development steps, use of codes and coded data.

4.12 Ethical Issues

Ethical considerations are a moral responsibility to protect and adhere to the rights of those participants involved in the research study (Payne & Payne, 2004). The main ethical considerations that pertain to this research are sensitive information shared by farm owners that would not be shared with competitors, and government information would not be shared so that it may cause damage to the department.

Confidentiality was ensured by assuring anonymity of the participants information being shared. Data and information obtained during the interviews was password protected and kept in a secure location on a computer. The researcher took full responsibility to ensure the information obtained from participants remained confidential, protected, and anonymous. No information was shared with unauthorised people. Participants were notified of the above information prior to the interview.

Ethical principles that were adhered to were truthfulness, which ensures no deceit and elements of lying; thoroughness by avoiding shortcuts and following appropriate methodological approaches; objectivity that prevents the inclusion of the researchers own biases and beliefs; and relevance that ensures the inclusion of anything of relevance to the research problem (McNabb, 2002). Various ethical aspects were considered, such as seeking informed consent from participants, informing participants of the aim of the study and the data use, that participation was voluntary and that data will be protected (Myers, 2009). Ethical approval was received from the Faculty of Commerce Research Ethics Committee of the University of Cape Town in November 2020 to proceed with research. The researcher got permission from the Department of Agriculture, to interview the selected participants in different government ministries and departments. Participation in the research for each participant is voluntary.

4.13 Chapter Summary

This chapter addressed and explained the technique the researcher used to achieve the objective of this study. The study used the interpretive research philosophy and elaborated on why it is best suited to this research. It demonstrated the research method and paradigm used, the importance of utilising a qualitative method and employing a phenomenology approach through semi-structured interviews to elicit rich data from the participants was stated. This was followed by stating the method of data analysis which gave meaning to the data collected. Finally, the ethical considerations were addressed.

Chapter 5

5 Findings and Discussion

This chapter presents an analysis and discussion of the data derived from this study. Each dimension will be discussed, in conjunction with its most significant themes. The SWOT analysis will be applied to determine the readiness of the Western Cape's agricultural sector to adopt IoT. The overlaying factors that determine IoT readiness are introduced, and the criteria that are important for the readiness of IoT adoption are presented.

Table 3 provides the theme codes, descriptions, and explanations of the main themes found in this study.

Table 3 – A description/explanation of each PEST theme code

Theme Codes	Descriptive themes	Definition/Explanation
Pol01	Government Support	Support provided by government through programmes or funding
Pol02	Corruption	Misuse of given power for personal gain
Pol03	Government Technology Incentives	Provision of funding, using farmers as test cases to showcase IoT, and programmes to educate
Pol04	Employment Strategies	Restructuring of jobs or the creation of new jobs
Envi01	Resource Availability	Availability of good rain and fertile soil
Envi02	Environmental Impact	Soil becoming infertile and water being polluted
Envi03	Sustainability	Conserving natural resources and protecting ecosystems
Envi04	Climate change	Unpredictable weather
Soc01	New Farmer	Those who are first generation farmers who are starting to farm (not inherited)
Soc02	Farmer Support and Influence	Support and the influence of the farming community onto other farmers
Soc03	Age	Categorisation of humans based on age
Soc04	Race	Categorisation of humans based on shared physical or social qualities into groups
Soc05	Education and Upskilling	Transmitting knowledge or fostering skills through an established institution
Soc06	Labour Impact	The effect on the labour workforce
Soc07	Security	How secure each individual feels and the security of their devices
Soc08	Farm Size	The size of the farm
Tech01	Awareness of IoT	The level of awareness of IoT technology
Tech02	Cost	The cost of technology implementation
Tech03	Connectivity	The ability to connect devices to the internet
Tech04	Lack of Electricity	The insufficient supply of electricity
Tech05	Full IoT Solution	Provision of an IoT solution that is a customised product to the farmer needs
Tech06	Reliability	Measurement of performance and trust of the product

The results, based on the analysis of the participants responses, showcased the four fundamental themes of the research, political, environmental, social, and technological. Furthermore, the emerging sub-themes were grouped into their respective strengths, weaknesses, opportunities, and threats. All themes were in-line with the research objectives.

5.1 Political Dimension

5.1.1 Strengths

Government Support

This theme falls under the political dimension as it directly relates government actions, policies, and interventions. This influences the agricultural sector's readiness to adopt IoT technologies and shape the environment in which farmers operate (AgriSETA, 2019; Pillai & Sivathanu, 2020).

> *You can only apply if you already have land or enough land to farm on and then they will fund you.* – Farmer_1

During the 2021/22 fiscal year, the national government funded R29,6 billion to support scientific and technological activities (STAs) in South Africa (DST, 2022) of which R9.1 billion was allocated to the Department of Science and Innovation (DSI) for R&D, technological advancements such as IoT, and socioeconomic innovation (CSIR, 2023).

Government investment in the agricultural sector is imperative. Participants in this study expressed willingness to adopt IoT since it was receiving adequate resources and funding from government. This aligns with Antony et al. (2020) and AgriSETA (2019), highlighting that government funding encourages technological readiness and adoption in agriculture. However, SME farmers tend to prioritise spending the government funding they receive on traditional inputs like seeds and fertilisers, instead of using it for technology on their farms. Targeted funding for technology, particularly for commercial farmers, could spur IoT adoption. Nonetheless, there was limited awareness and access to government programs and subsidies. Consequently, IoT implementation might primarily be observed among commercial farmers, limiting generalisability to non-commercial farmers.

Research and Development (R&D) within government exist for the purpose of advancing technology and innovation in the agricultural sector, promoting farmer education, and creating awareness of technology in agriculture (CSIR, 2023). Participants highlight the drive from government in R&D and other initiatives to promote careers and educate the youth within the agricultural sector. This suggests that there is a political interest to encourage the youth to pursue agricultural careers by showcasing the potential of agriculture in the context of technological advancements. However, one government participant reported that there are challenges in raising technological awareness, since majority of farmers lack basic literacy skills or education.

> *We try to promote the Internet of Things on farms… We have career days, where we showcase the different programs …* – Government_2

The study identifies government-led initiatives that test various agricultural technologies to enhance sector sustainability and efficiency. However, most SME farmers are excluded from these benefits due to the focus on expensive technologies favoured by larger commercial farmers. High costs further marginalise SME farmers, who are also unaware of cheaper alternatives. Government awareness campaigns targeting affordable IoT solutions for SMEs could bridge this gap, aligning with literature advocating for government-supported IoT adoption (AgriSETA, 2019; Antony et al., 2020; Ayaz et al., 2019; Goedde et al., 2020; Pillai & Sivathanu, 2020).

It was reported that in some instances of agricultural development, environmental legislation may impede the technological advancements of agriculture. This implies that implementing any new IoT technology may become an expensive and time-consuming process due to environmental legislation and management plans. The findings raise the issue of licensing procedures and environmental regulations that may create barriers and additional costs for farmers intending to adopt IoT. This may hinder IoT readiness within the farming sector.

> *Licensing…Sometimes environmental legislation hampers development in farming...* - Government_2

Government or agricultural department legislation plays a role in the implementation of IoT in agriculture, due to its ability to influence the introduction of new technologies (Goedde et al., 2020; Pillai & Sivathanu, 2020; Von Bormann, 2019).

Participants emphasised knowledge gaps in agricultural communities, suggesting the need to address basic education before introducing technology. This is particularly crucial for SME farmers in developing areas, indicating their current unpreparedness for IoT adoption. Literature emphasises education's role in fostering technological awareness and adoption among farmers, highlighting the positive impact of ICT skills and education (Antony et al., 2020; Pillai & Sivathanu, 2020). Overall, the literature emphasises education and literacy as pivotal in fostering technological readiness and adoption among farmers (Farooq et al., 2020; Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019).

These findings highlight specific initiatives related to farmer affluency levels, government support and funding, technological awareness, and agricultural career promotion. This shows the existence and availability of government support from a political perspective; however, most farmers are unaware and/or lack access to it. Due to the current availability of government support in the industry, it can be said that the Western Cape commercial farmer is ready to adopt IoT, whereas the non-commercial farmer is not.

5.1.2 Weaknesses

Corruption

Corruption is an integral part of the political dimension because it directly relates to the behaviour and actions of government and political institutions (Botha, 2021; Ngam, 2021). In South Africa, corruption undermines intended government funding for agriculture, with concerns raised by participants regarding misallocation and misappropriation of funds. Funders take a portion of the funding, if not all, and use it for personal use or for unrelated purposes, as reported by one participant. In addition, participants share apprehensions about the unequal distribution of funding and the influence of politics on the allocation of resources and support. Participants express that large populations of farmers need funding, but do not receive it. This hinders IoT readiness in agriculture, as high start-up costs for IoT implementation often require funding that may be siphoned off or unevenly distributed due to corruption and political influences.

> *So yes, maybe we could have this technology but who is it going to benefit… many farmers like me, we are not rich…*
> *...certain things cause these things not to happen, because we also have corruption.* - Farmer_4

Participants emphasised the direct impact of politics on the agricultural sector, citing barriers to progress and unequal resource distribution as a hinderance to IoT adoption. Mistrust and frustration are evident, signalling a need for systemic changes to address corruption. Corruption is a major issue in South Africa and has implications for the agricultural sector (Ganda, 2020; Salahuddin, Vink, Ralph, & Gow, 2020). Government funding intended for farmers is often diverted, limiting their ability to fully implement projects (Cook, 2020; Klaaren, 2020). Corrupt practices in government fund allocation result in inadequate financial support for farmers, impeding their adoption of IoT solutions. This lack of funding means farmers are unable to afford necessary IoT devices and infrastructure (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020).

Corruption impedes South Africa's readiness for IoT implementation in agriculture (Ganda, 2020; Salahuddin et al., 2020). Fund diversions and incomplete funding allocation hinder the potential benefits of IoT systems (Cook, 2020; Klaaren, 2020), limiting farmers ability to fully utilise the advantages of IoT technologies. Addressing corruption and ensuring transparent fund allocation are crucial for successful IoT implementation (Cook, 2020; Ganda, 2020; Klaaren, 2020). The Western Capes lack of adequate funding due to corruption at a national level render it unprepared for IoT implementation.

5.1.3 Opportunity

Government Technology Incentives

Technological incentives, funding, test cases, and educational programmes are indicative of the political dimension as they are influenced by government policies, initiatives, and interventions supporting technological advancement and readiness within the agricultural sector (Goedde et al., 2020; Pillai & Sivathanu, 2020; Von Bormann, 2019). The political dimension encompasses the role of government in shaping the political environment for technology readiness and adoption, including governmental funding, testing, and educating.

The study shows that significance of government-subsidised funding and community drives IoT readiness, particularly from a political perspective. Tailored government funding for technological implementations on farms emerges as a key driver, capable of expanding technology adoption across different farm types (Adli et al., 2023; AgriSETA, 2019; Farooq et al., 2020; Kuschke, 2020; Sutherland, 2020). While commercial farmers may derive greater benefit from technological funding, SME farmers prioritise necessities over technology investments when funded (AgriSETA, 2019; Farooq et al., 2020; Goedde et al., 2020; Kuschke, 2020; Von Bormann, 2019). Accessible and informative technology campaigns and programs are crucial for equipping the farming community with essential knowledge about current technologies, including IoT (Saiz-Rubio & Rovira-Más, 2020).

Participants stressed the need for resources and technical support alongside funding to facilitate IoT adoption and the use thereof, highlighting the pivotal role of financial and technical assistance in farmers readiness for IoT implementation. The study suggests that for SME farmers, an IoT solution would need to include technical support and user-friendly features to be adopted, while funding remains the primary concern for commercial farmers.

> *Also, if something breaks, I would like to know that it would not cost me R40,000 to fix it. If you want me to adopt that you would need to make it really easy for me. -* Farmer_1

The reluctance to embrace the unfamiliar highlights the necessity for community trust-building, warranting a trusted community member to pilot IoT (Fortino, Fotia, Messina, Rosaci, & Sarné, 2020; Mihailova, 2020; Odey, 2021). Participants emphasise the need for farmers within the community to endorse and promote the technology as a trusted solution. This indicates that community-driven approaches and word-of-mouth recommendations can positively impact the readiness to adopt IoT.

> *What would work is if someone who is involved in that farming community already, is coming to the rest of his neighbouring farmers and saying, this is a solution that we can all use as a community...* - Expert_5

The findings emphasised the importance of resources and support for IoT integration. DAFF (2019) reported that increased investments into technological developments facilitate more innovation in the sector. Here, the critical role of financial assistance, often backed by government initiatives, stands out as a key facilitator in driving farmers readiness for IoT implementation (Ayaz et al., 2019; Saiz-Rubio & Rovira-Más, 2020; Von Bormann, 2019). For SME farmers, the nature of IoT solutions, encompassing support and ease of use, emerges as a determinant of their readiness to adopt IoT. In addition, the findings highlighted the importance of community endorsement - government partnering with trusted farmers to showcase successful IoT implementation becomes instrumental in establishing trust among fellow farmers.

Government initiatives influence IoT adoption (Ayaz et al., 2019; Goedde et al., 2020; Saiz-Rubio & Rovira-Más, 2020). The study recommends a comprehensive approach, integrating governmental support, industry partnerships, and community-driven strategies to enhance IoT readiness. Collaborations with connectivity partners and IoT providers improve awareness, accessibility, and affordability (Ayaz et al., 2019; Sutherland, 2020; Von Bormann, 2019). Merely presenting IoT as a solution is insufficient; trusted community farmers endorsed by government support play a crucial role in technology adoption. Education and training programs tailored to elevate community members as technology advocates are an important step to IoT readiness (Ayaz et al., 2019; Sutherland, 2020; Trendov et al., 2019; Von Bormann, 2019). Examining technological funding, test cases, and educational programs within the political dimension highlights the importance of governmental support, community engagement, and industry collaboration in fostering IoT adoption readiness. This collaboration can enhance the agricultural sectors technological landscape by making it affordable and feasible within the farming community. Thereby positioning the Western Cape as ready to implement IoT.

5.1.4 Threats

Employment Strategies

Employment strategies can be considered as part of the political dimension due to relative government policies and regulations that impact labour practices and workforce development within the agricultural sector (Kuschke, 2020; Sutherland, 2020; Von Bormann, 2019). The political dimension encompasses how governments shape the labour environment and policies that influence employment practices, which in turn can affect the readiness of the sector to adopt new technologies like IoT.

Job loss due to IoT adoption has been a concern cited within literature. However, the findings in this study present contrasting results to Kitenge (2020) who suggested that IoT diminishes the employment gap. Farmers participating in this study noted that IoT may make some jobs redundant. In addition, the findings imply that job loss can lead to job restructuring, allowing farmworkers to engage in other tasks or roles on the farm.

> *It will take away some of the jobs from the guys…* - Farmer_2

> *… it allows for creativity and less time spent doing hard labour, it means that that time could be spent on other things…* - Farmer_4

The findings highlighted the impact on employment in the agricultural sector when IoT is introduced. A threat of introducing IoT into farming is its potential to restructure the agricultural workforce. In the short term, job loss may occur, but in the long run farms will start employing more people than before due to an increased efficiency and production on the farm. The lack of actualisation of benefits in the long run may act as a hinderance to IoT readiness.

Advanced technologies like IoT technology or robot pickers could positively impact the labour force in the South African agricultural sector. However, the high investment costs make them unaffordable for most farmers. IoT may ultimately improve efficiencies and productivity. Initial implementation requires extensive workforce training and support (Gazette, 2024; Sutherland, 2020; Von Bormann, 2019), that may not be readily available in South Africa. While IoT restructuring of the workforce is seen as positive for adoption readiness, smaller farmers, whose workforce often consists of family or friends, are more hesitant due to potential job losses. In contrast, commercial farmers are better equipped to manage workforce restructuring, making them more ready for IoT adoption than SME farmers who struggle with workforce decisions.

5.1.5 Summary

The analysis of IoT readiness of the Western Cape's agricultural sector through the political lens reveals themes that offer valuable insights into the complex interplay of political factors and their influence on IoT adoption and readiness in South Africa (see Figure 17).

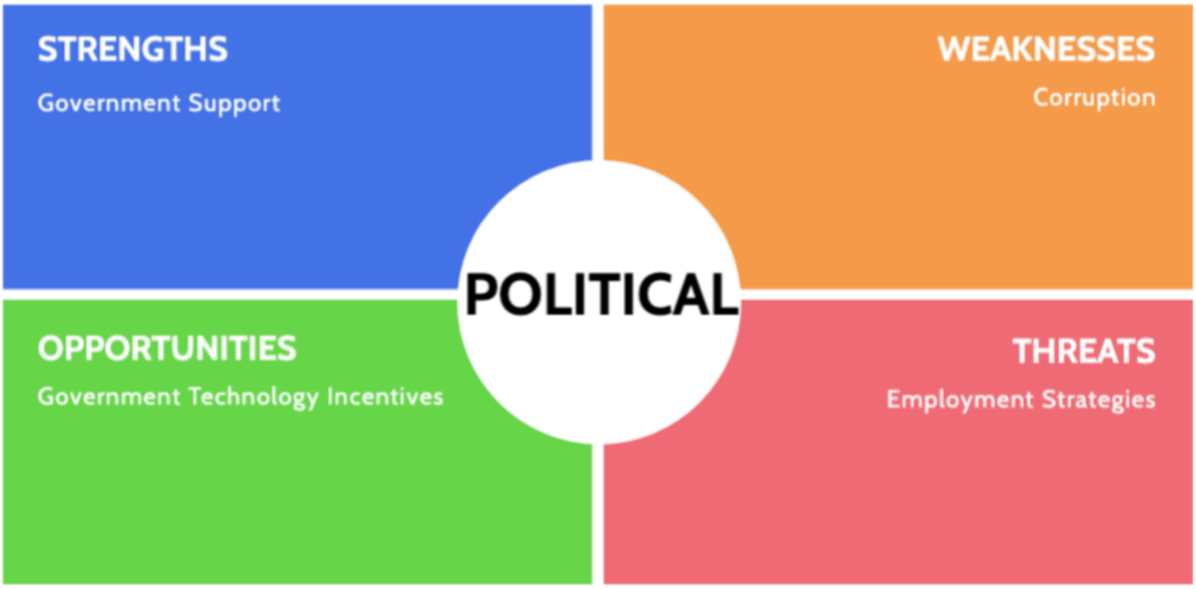


Figure 17 - Political factors influencing the readiness to adopt IoT

The political dimension necessitates a balance between governmental legislation and farmer support. Furthermore, collaboration with trusted farmer community members, investments in education, training programmes, and knowledge transfer initiatives can empower and equip farmers with the necessary skills to enable their readiness for IoT adoption, while addressing any weaknesses and threats. Acknowledging the need for a comprehensive approach that integrates political support, community engagement and involvement, and supportive programmes can foster readiness towards a technologically advanced agricultural sector and towards using IoT. Therefore, from a political dimension, commercial farmers within the Western Cape agricultural sector are ready to adopt IoT, while non-commercial farmers are not ready for IoT adoption.

5.2 Environmental Dimension

5.2.1 Strengths

Resource Availability

Resource availability is considered part of the environmental dimension as it relates to the natural resources and ecological conditions that play a role in agricultural activities and the adoption of IoT technologies. The environmental dimension encompasses factors that originate from the natural environment and impact agricultural practices and technological readiness.

Agricultural production is largely influenced by environmental soil and water conditions (Goedde et al., 2020; Montmasson-Clair et al., 2019; Sutherland, 2020; Von Bormann, 2019). While some participants, in this study, benefit from good rainfall, concerns arise regarding excessive environmental conditions leading to both positive and negative implications for agriculture. Excessive rain poses risks of waterlogging and flooding, while past drought experiences in South Africa highlight the importance of pre-emptive techniques to prevent crop loss (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020; Parry, 2019). IoT emerges as a viable solution to prepare for climate disasters by employing water conservation techniques proactively. This suggests that South Africa is ready for IoT adoption.

South Africa's favourable climatic conditions support year-round farming, with zero frost days allowing for continuous crop cultivation (Jack, 2022). It "*has zero frost days of the year so we can grow things basically forever or we can crop outside it does not matter*". This implies that farmers have longer growing seasons, allowing them to cultivate crops throughout the year, in different environments. Along the west coast, temperatures influenced by the cold Benguela current range from 6-8°C in July, with minimal to no frost occurrences (Jack, 2022; Lima, Soares, Semedo, Cardoso, Cabos, Sein, 2019). Given these conditions, farmers may question the necessity of implementing IoT.

> *…we do not have unfertile soil we have a good soil, and it is not like we must press for every single efficiency...* - Farmer_1

Some farmers perceive South African soil to be fertile so technologies to protect soil fertility is not necessary. However, soil fertility is more than just perception. Soil fertility plays a crucial role in crop production as it serves as a primary supplier of micronutrients. Insufficient presence of these nutrients in the soil results in plant deficiencies, while their excessive amounts can lead to toxicities, ultimately hampering crop yields (Liliane & Charles, 2020). Therefore, IoT may further improve the current fertility of soil and, thereby, improving crop yield. Although, farmers did not have issues with soil or water, they understood the benefit that IoT has on water and soil, therefore, making them ready for IoT.

5.2.2 Weaknesses

Environmental Impact

The environmental impact is included as an environmental dimension as it pertains to the effects and consequences of agricultural practices when adopting IoT technologies on the natural environment.

The findings indicated that current farming practices are degrading soil and polluting water, emphasising environmental implications and potential negative consequences. Excessive use of inorganic fertilisers results in runoff, causing water pollution. Farmers express concerns about the long-term sustainability of such practices and advocate for environmentally friendly soil management approaches. This emphasises the importance of sustainable farming practices and soil conservation methods, indicating readiness for IoT implementation to mitigate pollution caused by traditional farming methods.

> *…And the inorganic fertiliser, for example, can also run off a river water system and that can cause pollution.* - Farmer_3

The study found that farming degrades soil and causes major water pollution. This suggests that there is an opportunity for IoT to monitor the degradation of soil and improve soil health through the addition of proper nutrients. Moreover, it can limit the amount of chemicals that pollute the water by monitoring the number of pollutants, allowing farmers to redirect them to disposable bins. This is corroborated by the authors Sutherland (2020) and Von Bormann (2019) who stated that there is a reduction in agriculture degradation when IoT is utilised. Thus, implying that the agricultural sector is ready for IoT regarding soil degradation and water pollution.

5.2.3 Opportunity

Sustainability

Sustainability is a key factor in the environmental dimension as it directly addresses the long-term viability of agricultural practices, including the integration of IoT technologies, within the context of the natural environment.

Incorporating sustainable agricultural practices, which offer long-term benefits for both farmers and society, is a key advantage of technology adoption (DAFF, 2019). However, current unpredictable weather patterns hinder farmers ability to forecast optimal crop choices and monitor nutrient quantities accurately. This emphasises the need for tools to address these challenges and promote sustainability. IoT has been identified as a solution to assist farmers with precise nutrient management, weather predictability, and yield predictions, thereby enhancing production efficiency (Madushanki et al., 2019). Therefore, adopting IoT is crucial for the agricultural sector to achieve sustainability.

Consumer-demand on farmers to be more sustainable and minimise their carbon footprint is greater for the commercial farmer than on SME farmer.

> *I think we are sort of forced to look at more sustainable ways to produce a product.* - Farmer_3

Due to commercial farmers being a net exporter of food to multinational firms, international clients require agricultural practices to be as environmentally friendly as possible, prompting commercial farmers to include IoT into their farming operations.

In addition, the findings suggested that other alternative farming strategies are being considered by participants to ensure sustainability. These considerations include re-examining present farming practices, establishing sustainability, and studying alternative sustainable farming methods. When IoT becomes the centre and driver of agricultural operations, it ensures that all processes are sustainable (Ayaz et al., 2019). The focus on sustainability suggests that an opportunity for IoT exists within the agricultural sector of the Western Cape, ensuring readiness to adopt IoT.

5.2.4 Threats

Climate change

Climate change is a critical factor within the environmental dimension as it influences the conditions under which agriculture operates. Climate change refers to long-term shifts in weather patterns and temperature, which can have profound impacts on agricultural productivity, resource availability, and overall ecosystem dynamics (Ayaz et al., 2019; Goedde et al., 2020; Pillai & Sivathanu, 2020; Von Bormann, 2019). Considering climate change in the environmental dimension is essential due to its pervasive effects on the agricultural sector.

The study illustrated the challenges posed by climate change and shifting weather patterns, necessitating adaptation to these environmental shifts. However, piloting IoT across diverse climates may hinder its adoption, as perceived among farmers. One participant expressed concern about IoT compatibility across regions, stating, "*I would not trust it because of the* *different climate in that area...*" This apprehension about IoTs reliability may lead some farmers to be hesitant in adopting the technology due to doubts about its effectiveness in their specific climate. The reluctance to adopt technology from different regions is attributed to climate variations and concerns about IoT compatibility with specific environmental factors. Thus, there is a need for region-specific IoT technologies tailored to specific weather patterns.

This study found that changing weather patterns remain a threat to farmers. Previously, as found in this study, farmers were able to predict the length of a summer or winter season, and the temperature associated with that. However, weather patterns are so invariable that farmers are unable to determine the temperatures of a season. Literature by Ayaz et al. (2019) and Von Bormann (2019) suggest that weather variability can be better managed using IoT. Thus, IoT is the enabler that assists farmers to accurately predict weather patterns, enabling farmers to get a clearer understanding of the upcoming season's outlook. This makes farmers ready to adopt IoT, depending on their desire to better understand weather patterns.

5.2.5 Summary

The exploration of the environmental dimension in the context of IoT readiness in the South African agricultural sector has unveiled critical themes that provide insights into how environmental factors shape the sector's readiness to adopt IoT (see Figure 18).

Figure 18 - Environmental factors influencing the readiness to adopt IoT

The environmental dimension plays a pivotal role in shaping IoT readiness within the Western Cape's agricultural sector. Resource availability, environmental impact, sustainability, and climate change are interconnected themes that highlight the sector's need to embrace sustainable practices and IoT solutions as a means of addressing environmental challenges and promoting long-term resilience. The need for sustainable farming techniques presents an opportunity for IoT implementation within the agricultural sector due to its ability to monitor weather patterns and control soil degradation. Thus, making the Western Cape ready for IoT adoption.

5.3 Social Dimension

5.3.1 Strengths

New Farmer

This theme can be considered as part of the social dimension due to its connection with various social aspects within the agricultural sector, such as demographics, access to resources, social networks, social acceptance, and equity etc.

The study emphasises the social dynamics among younger and/or new farmers toward IoT technology adoption in the farming communities. Aspiring and/or new farmers, those who lack farming backgrounds or generational knowledge, may derive greater benefit from IoT adoption. Findings in this study suggest new farmers as a positive aspect to IoT readiness. New farmers are perceived as having less experiential knowledge than a long-term farmer (generational farmer). Therefore, new farmers would find benefit in implementing IoT in their agricultural practices to inform their decision making. Participants highlighted that new farmers might lack knowledge regarding soil health, and nutrient and water levels. Relying on IoT technology to provide farming information would therefore enable farmers to provide proper nutrients to attain healthy soil.

> *So, the guy that cannot pick with the eye that something is wrong, would get benefit more than a guy that is been doing it for years* - Farmer_1

The findings indicate that younger generations, with early exposure to technology, may be open to implementing IoT in their farming practices due to cultivated technological skills, knowledge, and education which enables an ease of use of IoT and it's deriving its full benefit. This is in line with the view in literature that farmers with higher level education are more open to using IoT technology on their farms (Ayaz et al., 2019; Goedde et al., 2020; Kuschke, 2020; Sutherland, 2020). However, it is important to acknowledge that some older farmers or generational farmers are willing to embrace new technology, particularly when it is made affordable and easy to use for them. Furthermore, not all younger farmers are comfortable with technology usage and express reservations about it, especially within the South African context where theft, reliability, support, and power outages are significant problems. New farmers that have inherited a farm presents an opportunity for IoT readiness as their predecessors may encourage the use of technology in their practices to keep the younger generation interested in the family business.

From a social perspective, the analysis highlights the importance of IoT adoption to ensure the future viability within generational farming, attraction of new farmers and younger generations as a means of increasing farming in the agricultural sector. Integrating technology in farming practices is known to modernise farms and enhance efficiency. However, the level of adoption varies among individuals based on their knowledge, level of comfort with technology, perceived benefits, and personal circumstances. Thus, new farmers present an opportunity for IoT readiness within the agricultural sector.

Farmer Support and Influence

Farmer support directly influences social interactions, relationships, and community dynamics within the agricultural sector. Farmers are a tight knit community, posing challenges for outsider penetration. IoT presents an opportunity to leverage trusted members of farming communities as test cases, fostering exposure to the technology. One participant reported a solution as, "*I will take this IoT product to the existing farming communities where I have the trust, and the relationships already built*". Successful adoption within a community can lead to widespread IoT usage, while failure may erode trust, hindering adoption. Therefore, IoT technology requires extensive piloting across communities over an extended period, demonstrating consistent effectiveness and showcasing benefits for widespread adoption.

In the SME farming community, presenting IoT to farmers as a solution is insufficient. The government should collaborate with a trustworthy farmer in the community to utilize the technology on their farm, demonstrate its success, and promote it to the community as a trusted technology. This would result in farmers trusting the reliability of IoT and implement the technology. However, government would need to play the role of funding, educating, supporting, and training farmers in the utilisation of IoT by farmers which is supported by Ayaz et al. (2019) and Von Bormann (2019).

Farming communities demonstrate a culture of collaboration and mutual support, fostering openness and knowledge sharing among farmers. This environment allows successful IoT practices to be shared and adopted, creating a ripple effect for widespread implementation (Ayaz et al., 2019; Goedde et al., 2020; Kuschke, 2020; Sutherland, 2020). Recognising the influence of social networks and existing relationships is crucial for introducing technological innovations in farming. However, farmers are hesitant to adopt IoT due to concerns about technological reliability and the risk it poses to crops (Ayaz et al., 2019; Goedde et al., 2020; Kuschke, 2020; Sutherland, 2020). Piloting IoT within farming communities to gain positive community influence could facilitate widespread adoption.

5.3.2 Weaknesses

Age

This theme is associated with the social dimension due to its connection to family dynamics, cultural heritage, and intergenerational interactions. The analysis showcases the social dynamics from the perspective of older, generational farmers.

Some older farmers resist adopting new technologies due to their extensive real-life experience and comfort with traditional farming practices. This indicates that generational and experienced farmers, having developed deep understanding through hands-on experience, may be sceptical about the reliability of computer-based recommendations, fearing potential compromises to crop quality or outcome. However, one generational farmer eagerly embraces the possibility of using IoT devices on their farm if it is free of charge. Thus, while many generational farmers may be hesitant to implement IoT despite being aware of the technologies, it is worth noting that not all older farmers are reluctant to adopt IoT.

> *Generational or conservative farmers, they know that there are technological advancements, but they are not willing to adopt it.* - Farmer_3

The study found that age influences farmers readiness to adopt IoT technology. Most participants under 60 years old were likely to adopt IoT, while one participant over 60 years old was reluctant to use any technology on their farm. This contradicts the finding of Pillai and Sivathanu (2020) in that age does not affect adoption, rather, it supports the findings of Arogundade, Odeyinka, Mustapha, Abayomi-Alli, Adejuyigbe, Folorunso … (2024) and Pivoto, Laimer, Mores, Waquil, Talamini, Dalla Corte, & De Matos (2023) in that age negatively influences IoT adoption. Therefore, age impacts the readiness of a farmer to adopt IoT. The older the farmer is, the less likely they are to be ready to adopt IoT. Subsequently, the younger the farmer is, the more likely the farmer is to be ready to adopt.

While some older and generational farmers may resist change and prefer traditional methods, others may be open to embracing new technologies, recognising the potential benefits they can offer in terms of efficiency, productivity, and improved farming practices. Thus, older and/or generation farmers are not ready to adopt IoT.

Race

Race influences social interactions, disparities, and identity within societies, making it a crucial aspect of the social dimension. In South Africa, historical injustices continue to shape social issues and inequalities, particularly in the agricultural sector. Race remains a determinant of success on farms and access to funding, with one participant highlighting the potential impact of skin colour on grant applications. This suggests that resource allocation is influenced by race, potentially disadvantaging farmers outside certain racial categories. Moreover, racial inequality creates barriers between successful and unsuccessful farmers, with certain racially categorised farmers facing greater challenges in advancing projects and accessing financial support. In addition, inherited farms benefit from generational knowledge and wealth, making them more likely to succeed, while non-inherited farms face additional difficulties in establishing themselves and achieving success.

> *The only successful farm is the one that you inherited because that is already up and running and nobody is learning how to farm. There are very few to none, successful black farmers.* - Government _2

Race remains a determinant of success in the agricultural sector, with inherited farms, primarily owned by white farmers, perceived as more successful. This suggests that white farmers are more inclined to adopt IoT on their farms due to their farm’s success. In addition, race may influence funding decisions, as noted by one participant who suggested it could determine whether one receives funding or not. However, some participants believe that race does not always impact readiness for IoT adoption.

Overall, the analysis highlights the social inequalities in the agricultural sector in South Africa, particularly in relation to race and the advantages of inheriting established farms. The challenges faced by farmers who do not fit certain racial categories (i.e. non-white farmers) impact the farmers’ readiness to adopt IoT; these farmers are already on the backfoot. Emphasis is placed on the need for equal opportunities and support for all farmers, regardless of their race or generational background to provide resources for IoT implementation. Thus, the importance of addressing systemic biases and promoting a more inclusive and equitable agricultural system may enable a more IoT ready sector.

5.3.3 Opportunity

Education and Upskilling

Education is an essential element of the social dimension due to its profound influence on individual development, societal progress, and overall well-being. The findings highlight the importance of education and knowledge dissemination in the context of implementing technology in agriculture and IoT provides this opportunity for education.

> *It will work because it is a matter of education and showing people the benefits of these things.* - Farmer_4

Farmers and farm workers alike require education and training when using IoT as the tool to fulfil a job. This demonstrates the benefits of IoT adoption and assists with its success. Furthermore, the farmer requires an in-depth understanding of their needs, which IoT system best meets those needs, and how to interpret the data. This implies that all players need to comprehend the significance of the information, the value-added processes, and the implications provided by IoT technologies to ensure its effective utilisation. This further suggests that education plays a vital role in bridging the gap between the data collection phase and its analysis for decision-making in farming practices. However, not all farmworkers are educated or literate enough to comprehend the technology which may impact its effectiveness and hinder its success.

> *And those are your bread-and-butter items, like getting people educated. If you see the communities that we work with, technologies, they are far from that.* - Government _2

Smaller farming communities may find it challenging to use IoT when basic education is lacking. This observation points to a potential barrier to IoT readiness among certain communities where access to education and understanding of technology may be limited. It highlights the need to address fundamental educational gaps as a prerequisite for effective technology readiness, implementation, and acceptance.

Education remains a critical factor influencing IoT readiness in the agricultural sector of the Western Cape (DAFF, 2019). Commercial farmer participants, who all possess tertiary education in this study, are more knowledgeable about technology and better positioned to implement it. Conversely, although most SME farmers in the study have tertiary education and awareness of IoT, they lack resources for implementation. This suggests that education positively influences IoT readiness, but other factors hinder implementation. This finding aligns with Smidt and Jokonya (2022), indicating that education and social class increase IoT adoption likelihood, contrary to Shang et al. (2021), who contests educations significance. However, the study finds education crucial in fostering understanding and willingness to adopt IoT, with upskilling opportunities enhancing adoption readiness (Antony et al., 2020; Pillai & Sivathanu, 2020). Despite this, not all farm workers are receptive to learning new technology, reflecting challenges in its implementation. Overall, education and upskilling positively influence IoT adoption readiness in the sector.

5.3.4 Threats

Labour Impact

Labour impact is an essential aspect of the social dimension due to its influence on individuals, families, communities, and society at large. The analysis reveals the difficulty in justifying the cost of technology when there is an abundance of manual labour. Furthermore, farmers find it difficult to justify the initial cost of technology when labour comes at a cheaper cost. Particularly when technology has long term benefits that cannot be actualised immediately. Thus, farmers are reluctant to invest in IoT when tasks on the farm are already being completed.

> *…So, the thing is, we already have things. We are doing it manually; we are using labour for it.* - Farmer_2

Participants perceive technology as competing with and potentially replacing labour, which is currently cheaper and readily available in South Africa. This raises concerns about the potential negative impact on employment rates and the larger societal implications.

> *But then we cause a bigger, higher unemployment rate and all those things. So, I mean, for a country like ours, it is quite a complex thing to do and think about.* - Farmer_3

The participants acknowledge the complexity of implementing IoT in a country like South Africa where unemployment is a significant challenge. They believe that introducing IoT on a smaller scale within local communities may lead to the displacement of labourers who are often family members or individuals from the community. This creates a barrier to the adoption of IoT in these communities.

> *We get hundreds, if not thousands, of people in during the picking season, to come and pick the fruit so that impact would be catastrophic...* - Farmer_3

The participants raised concern that opting for technology over manual labour in a country like South Africa could result in job losses, which would have a catastrophic impact on the livelihoods of many people, and within the farming community, job losses for people they know. This indicates that the ethical considerations of job loss are a threat to the readiness to adopt IoT.

Overall, the analysis suggests that farmers are aware of the potential benefits of IoT technology, however, they are cautious about its impact on labour and the broader social and economic dynamics of their communities. The perceived risks and complexities associated with adopting IoT in agriculture contribute to their hesitation. This necessitates a careful and considerate approach to the implementation of IoT within smaller communities, that alleviates the labour concern. Thus, rendering them as unprepared for IoT adoption.

Safety

Safety is included in the social dimension as it reflects a societal issue that involves human interactions, threat to human security, and social dynamics. Participants emphasise safety and security issues. Farmers are at risk of violence, whether it is theft of land, crime, killing, torturing, or mutilation of farmers. The findings suggest that farmers live in constant fear of their lives and livelihoods. These threats result in farmers carrying firearms or weapons as a means of protection against danger.

> *The farmer will tell you that the government is trying to take their land. They have political parties singing, "kill the boer[1]"…*- Expert_4

Land reform policies, a result of apartheid legacies, involve government acquisition of land from farmers to redistribute to black farmers (AgriSETA, 2019; Botha, 2021; Ngam, 2021). This study identifies a troubling trend where individuals unjustly claim entitlement to land, leading to violence against farmers. Consequently, farmers face threats of eviction, harm, and theft, irrespective of any legal basis. However, these acts of violence are not racially motivated, as reported by one participant.

Security remains a constant threat to the South African agricultural sector. The participants highlight cases of theft and security issues experienced on their farms. Farmers express the need for security systems once IoT has been implemented.

> *We found that after two months or so of the project been live, the sensors were stolen.* - Expert_4

This suggests that cheaper more reliable ways to protect their assets and equipment are needed in the agricultural sector. Theft and security issues affect the entire agricultural sector which is causing both SME's and commercial farms to reconsider IoT implementation unless it is coupled with or incorporates ways to ensure security of IoT devices. There is potential for IoT companies to design devices that appear inexpensive and rugged to deter theft of devices. Security and safety concerns pose a barrier to IoT readiness in agriculture, with farmers wary of expensive devices being stolen. Farmers hesitate to invest in IoT if it makes them vulnerable to theft, harm, or loss of lives.

Farm Size

Farm size is categorised in the social dimension as it pertains to the scale and scope of technology implementation which can vary based on the size of the farm. This theme explores how the size of a farm affects the feasibility, practicality, and potential benefits of adopting IoT technologies. Larger farms may have more resources and capacity to implement advanced IoT solutions, while smaller farms might face limitations due to budget constraints and resource availability. The social dimension recognises that the appropriateness and customisation of IoT solutions may depend on the specific needs and capacities dictated by affluency and farm size, emphasising the need for tailored technological strategies that align with the farm's scale and operational requirements. Farm size affects IoT readiness, aligning with findings by Giua et al. (2022) and Shang et al. (2021) on IoT adoption in South Africa. Smaller farms may not perceive IoT as necessary due to their ability to manage farm needs effectively, although it still offers benefits such as

^1 The phrase "kill the boer" is a politically charged slogan associated with the South African context, often referring to the historical and ongoing conflicts between different racial and ethnic groups. It has elicited debates regarding its implications and potential for inciting violence. The usage of this phrase highlights the complexities of socio-political dynamics in South Africa.

efficiency and productivity improvement. Conversely, larger farms necessitate IoT adoption for automation, reduced labour costs, and data-driven decision-making (Madushanki et al., 2019). One participant reported "*If you are doing it commercially like doing big production, then you need sensors to do all the work for you*". This is because automation and sensor-based systems are more suitable for managing large acreages, making IoT more relevant and feasible for bigger farms. In addition, commercial farmers with financial resources and investors are more inclined to adopt IoT. Hence, commercial farms are ready to implement IoT, while smaller SME farms lag in adoption readiness.

5.3.5 Summary

The assessment of the social dimension concerning IoT readiness in the South African agricultural sector has uncovered a multifaceted landscape shaped by various themes, each contributing to the sector's preparedness for IoT adoption. The findings uncovered insights regarding the social strengths, weaknesses, opportunities, and threats (see Figure 19).

Figure 19 - Social factors influencing the readiness to adopt IoT

After considering the various social findings, farmers expressed a range of concerns and considerations that influence their readiness and willingness to embrace IoT on their farms. The challenges associated with high unemployment, ethical considerations thereof, lack of education, willingness to learn or invest, high costs, reliability and accessibility issues, and lack of awareness and trust may hinder farmers readiness to IoT and derive its benefits. Addressing these concerns may contribute to an IoT ready agricultural sector.

5.4 Technological Dimension

5.4.1 Strengths

Awareness of IoT

This theme falls under the technological dimension, focusing on farmers awareness and readiness to adopt IoT solutions in agriculture. It assesses their knowledge of IoT technologies and their potential benefits, emphasising the importance of education and training in facilitating successful adoption. A key aspect of the technological dimension

"*Awareness of IoT"* acknowledges the significance of educating and equipping farmers with the necessary information to make informed decisions about integrating IoT solutions into their practices.

Farmers show interest in IoT technologies for enhancing farming practices, desiring tools like sensors, drones, and applications for real-time monitoring. However, cost poses a major hindrance to implementation, as one participant hesitates to invest due to the high price and risk of theft. This underscores the importance of cost-effectiveness and tangible returns on investment in farmers' decision-making.

> *If I could have any tech, I wanted it would be a few cameras to watch my crops or sensors to watch that my water levels are correct.* - Farmer_1

Most participants in the study recognise the benefits of IoT technologies. Each farmer proposed ways to utilise IoT for enhancing farming practices, suggesting a desire for adoption if economically feasible. Perceptions were positive, with farmers anticipating cost reduction, increased yield, innovation, and improved efficiency. These findings align with Zambon et al. (2019), who assert that technological innovations increase yield production, working standards, and the efficiency of production (Ferehan, Haqiq, & Ahmad, 2022).

The analysis illustrates varying levels of awareness and accessibility to technology within the agricultural sector. While farmers acknowledge the existence of technological solutions, some farmers, particularly those with smaller operations, may lack knowledge about specific technologies or their names. The slim profit margins in the agricultural industry also deter farmers from making investments in technology.

> *I think they understand what it is, I think they just did not know it had a name….* - Farmer_1

Furthermore, there are big exhibitions that showcase the latest agricultural technologies and equipment. However, these events may be more accessible and beneficial for larger, commercial farmers, while SME farmers may not have the same opportunities to attend or have the funding to benefit from such exhibitions. This suggests that there is a gap between different types of farmers, with commercial farmers having more exposure and access to the latest advancements in agricultural technology compared to SME farmers. This implies that commercial farmers are ready to implement IoT, while SME farmers are not.

> *Big farmers would go to exhibitions like NAMPO… they are exposed to these new technologies at these places at these events. Smallholder farmers necessarily will not go there.* - Government_1

NAMPO, a prominent annual farming exhibition in South Africa, serves as a platform for farmers to access information on the latest agricultural trends and innovations, including IoT technologies. However, limited accessibility to such events may hinder awareness among smaller or less affluent farmers, relying instead on word of mouth for exposure. This discrepancy in exposure suggests that while some farmers are well-informed about IoT, others may lack awareness, impacting their readiness to adopt (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020; Shang et al., 2021). Therefore, commercial farmers with accessibility and awareness may be poised for IoT adoption, while SME farmers may not be ready due to limited awareness.

5.4.2 Weaknesses

Cost

Cost is positioned within the technological dimension as it gauges farmers openness to allocate resources, both financially and strategically, for the integration of IoT technologies. This theme explores farmers readiness to commit funds, time, and efforts to embrace IoT solutions in their agricultural operations. This dimension emphasises the financial commitment required for successful IoT adoption and highlights the need to align technological investments with the overall goals and benefits of IoT adoption in agriculture.

Participants consistently stress the cost implications of adopting IoT solutions in farming. Concerns revolve around initial purchase expenses, ongoing costs, and maintenance. Cost emerges as a major barrier, especially for SME farmers and those with limited budgets, creating inequality between large commercial and smaller-scale SME farms in technology adoption (Cook, 2020; Klaaren, 2020).

> *We will need about 20 to 30 sensors in field. At the moment I just asked four, and those were R60,000[2].* - Farmer_2

The study highlights that the cost of IoT technology presents a barrier to adoption among farmers. Initial device costs and ongoing subscriptions render adoption unfeasible for many. This aligns with prior research by Antony et al. (2020), Pillai and Sivathanu (2020), and Kasilingam and Krishna (2022), suggesting deployment costs affect IoT adoption. The substantial investment, coupled with theft concerns, implies reluctance among farmers to adopt IoT. Commercial farmers with greater financial resources or investment opportunities are more likely to adopt IoT, consistent with findings by Shang et al. (2021) on the role of economies of scale in IoT readiness.

One participant noted the emergence of smaller, more affordable IoT devices, aligning with research by Ayaz et al. (2019) indicating the increasing economic feasibility of IoT. However, concerns were raised about additional subscription fees, limiting accessibility to farmers with sufficient funds. While farmers acknowledge IoT benefits, it remains a luxury for many SME farms.

Overall, the cost factor emerges as a challenge and a key consideration in the readiness to adopt IoT technology in agriculture, particularly for SME farmers. However, IoT technologies remain unattainable by most farmers in the Western Cape due to its implementation cost, recurring expenses, and the threats to the IoT technologies once implemented. Once more low cost IoT technologies, that addresses all the weaknesses and threats into the solution, the South African agricultural sector will be ready to implement IoT.

Connectivity

Connectivity is a pivotal aspect of the technological dimension due to its fundamental role in enabling the successful deployment and functioning of IoT technologies in the agricultural sector. This theme encompasses internet access and network reliability, impacting real-time monitoring and decision-making. A stable connectivity environment is essential for maximizing the benefits of IoT solutions in the agricultural sector (Ayaz et al., 2019).

The study found varying network coverage in the Western Cape, with better options (3G, 4G, 5G, as well as Wi-Fi) closer to urban areas and limited connectivity in rural regions (Ayaz et al., 2019; Sutherland, 2020; Von Bormann, 2019). Most farms are situated outside of the city where there is more space to farm, thus, they have less connectivity. Research completed by Ayaz et al. (2019) and Farooq et al. (2020) supports the findings in this study that cellular connectivity is widespread through South Africa. However, the authors do not mention the limitation of cost associated with it as airtime and data is costly in South Africa and poses a challenge for farmers, especially in areas with limited coverage.

Participants noted the disparity in network availability and highlighted the high costs associated with cellular networks, hindering IoT adoption. One participant said "*Let us say this technology is introduced, who is it going to benefit more, the one that has internet? The one who has data? The one who has a network available?*". Various participants highlighted the limited availability and high cost of cellular networks, including airtime and data, which are crucial for IoT functionality.

> *So, we have a whole Wi Fi network on our farm to get the information back. Because it makes it easier for us, but we can afford it. And that does not mean the small holder farmer can afford that.* - Government_1

Commercial farmers may be more likely to set up Telkom ADSL lines or fibre to assist with IoT device uses, however, the issue of theft of those telephone lines remain a risk. Madushanki et al. (2019) suggests the use of low-powered, short-range networks or low-rate wireless PAN (LoRaWAN) as an alternative to Wi-Fi and cellular data. However, deploying such networks over large areas incurs costs. Collaboration among farmers could reduce deployment expenses, enabling wider IoT usage. Despite several options, connectivity remains a challenge and hinders IoT adoption readiness in the agricultural sector.

Lack of Electricity

This theme is an intrinsic component of the technological dimension as it directly influences the feasibility and functionality of IoT technologies within the agricultural sector. This theme highlights the challenge of inadequate or intermittent electricity supply, which hampers the consistent operation of IoT devices.

> *… Firstly, we need consistent power, I cannot trust the technology when the electricity does not work all the time.* - Farmer_1

A reliable power source is essential for powering IoT sensors, data transmission, and other technology components. In regions where electricity access is limited, IoT adoption faces barriers, as these devices require a stable power supply for uninterrupted functionality. Addressing the issue of electricity scarcity is crucial for ensuring the seamless operation of

IoT technologies, enhancing the sector's capacity to benefit from the data-driven insights and automation that IoT offers.

South Africa continues to experience intermittent bouts of electricity and frequent power outages (Erero, 2023). This crisis discourages farmers from adopting electricity-dependent technologies. While alternative energy sources like generators or solar power are viable options, they pose financial challenges for SME farmers (Erero, 2023). Commercial farmers, with better resources, are better suited for alternative energy adoption. Despite increasing electricity demand due to technological innovation (DAFF, 2019), the timing of alternative energy implementation remains uncertain. Therefore, South Africa's electricity crisis impedes IoT readiness and adoption.

5.4.3 Opportunity

Full IoT Solution

A full IoT solution is vital for integrating IoT technologies into agriculture, ensuring it meets farmer specific needs. It includes hardware, software, analytics tools, support, and training, addressing compatibility and operational challenges (Torky & Hassanein, 2020). This holistic approach empowers farmers to confidently adopt and benefit from IoT, enhancing the sectors readiness for technological adoption.

Farmers are more inclined to adopt IoT when presented with clear, integrated solutions (Kuschke, 2020; Torky & Hassanein, 2020; Von Bormann, 2019). However, current offerings lack centralised platforms tailored to agriculture's diverse needs (Abu et al., 2022). There is an opportunity for Agri-centric IoT platforms addressing farm complexities. While some companies offer custom solutions, they may not fully meet agricultural requirements (Abu et al., 2022; Torky & Hassanein, 2020). Introducing IoT through trusted partners and demonstrating its benefits to disadvantaged farmers could promote adoption (Tzounis et al., 2017). Thus, developing comprehensive, farm specific IoT solutions is crucial for widespread adoption.

The participants express the need for an IoT solution that is a fully packaged IoT system custom made for the farmer. Furthermore, a solution that is user-friendly, simple, easy to adopt and integrate into existing systems, and delivers tangible outcomes encourages IoT readiness within the agricultural sector.

> *I think a finished system that delivers an outcome. I think they will adopt faster than most, but it needs to be simple and easy to adopt.* - Expert _1

Simplification is a key factor in encouraging adoption, with the suggestion that trusted partners should present solutions tailored to specific needs, such as water, soil, or security management.

Farmers need assurances that the IoT technology they invest in will effectively address their concerns and deliver the expected results. However, the experts also highlight the financial constraints faced by IoT companies, which limit their ability to extensively research and develop solutions for individual farmers.

> *… as an IoT company, you do not have the funds to do R&D on just a sensor that costs R10,000 for the sake of selling it to one person ...* - Expert _4

Accuracy in IoT technology is an important factor to IoT readiness as farmers expect them to perform at least as well as their own abilities. These perspectives highlight the significance of designing IoT solutions that are intuitive, reliable, and tailored to address specific agricultural challenges, while also considering the financial viability and trustworthiness of the technology for farmers. Once an agriculturally tailored IoT device is created, the agricultural sector would be more likely to adopt IoT.

5.4.4 Threats

Reliability

Reliability is pivotal for successful IoT adoption in agriculture. Farmers depend on consistent performance for accurate data and informed decisions. Reliable devices ensure accurate information, fostering trust and confidence in technology. Addressing reliability enhances readiness and effectiveness of technology-driven practices (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020; Mihailova, 2020; Odey, 2021).

The participants highlight the lack of expertise and specialised agricultural IoT companies in South Africa, which poses a challenge for farmers seeking to adopt and maintain advanced technology. Farmers express the need for ongoing support and maintenance of IoT devices, as they may require calibration and interpretation of data. Furthermore, the availability of reliable IoT partners is seen as an opportunity to overcome this challenge.

> *When it comes to technology, we do not have the expertise to constantly maintain advanced technology…. You need to get someone to calibrate …and then if they go out of calibration then you need to have it calibrated again.* - Farmer_1

The study identified IoT device reliability as an issue in South Africa, with few reliable IoT partners and agricultural tailored IoT. Most devices are not specifically designed for farming, leading to inaccuracies and farmer mistrust (Adli et al., 2023; Colizzi et al., 2020; Farooq et al., 2020; Mihailova, 2020; Odey, 2021). This situation highlights the need for IoT devices tailored to agricultural needs. Rogers (2003) reported that complexity and reliability are characteristics that affect adoption of technology. The lack of available IoT experts and Agri-centric IoT solutions further deters farmers from IoT adoption. Therefore, both commercial and SME farmers are not ready to adopt IoT.

5.4.5 Summary

The exploration of the technological dimension in the context of IoT readiness within the South African agricultural sector shows a landscape rich with both opportunities and challenges (see Figure 20).

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^2 The current exchange rate at the time of this dissertation was 1 USD to 18.51 ZAR

Figure 20 – Technological factors influencing the readiness to adopt IoT

These themes collectively influence the sector's readiness to embrace IoT technologies. The technological dimension is characterised by a dynamic interplay of factors influencing IoT readiness in the Western Cape's agricultural sector. The sector recognises the potential benefits of IoT in improving efficiency and production. However, challenges such as cost, connectivity, security, reliability, and trust must be addressed to facilitate widespread adoption. Tailored, comprehensive solutions that accommodate varying farm sizes and a focus on awareness-building are essential for enhancing readiness and ensuring the successful integration of IoT technologies in agriculture.

5.5 Chapter Summary

This study embarked on a comprehensive exploration of IoT readiness within the South African agricultural sector through the lenses of political, social, environmental, and technological dimensions. Each dimension highlighted various strengths, weaknesses, opportunities, and threats that allowed for a distinct set of insights, shedding light on the multifaceted landscape that shapes the sector's readiness for IoT adoption (see Table 3).

Table 4 – An overview of the main PEST-SWOT themes

	Political (P)	Environmental (E)	Social (S)	Technological (T)
Strengths (St)	Government Support	Resource Availability	New Farmer Farmer Support and Influence	Awareness of IoT
Weaknesses (We)	Corruption	Environmental Impact	Age Race	Cost Connectivity Lack of Electricity
Opportunities (Op)	Government Technology Incentives	Sustainability	Education and Upskilling	Full IoT Solution
Threats (Th)	Employment Strategies	Climate Change	Labour Impact Security Farm Size	Reliability

Examining the South African agricultural sector's readiness from a PEST perspective uncovers valuable insights into strengths, weaknesses, opportunities, and threats (see Figure 21).

Figure 21 - The SWOT factors/themes that determine the readiness to adopt IoT

The political dimension calls for a delicate equilibrium between governmental regulations and farmer assistance. Recognising the necessity for a holistic approach that intertwines government support, community engagement, and supportive programs can cultivate readiness and resilience, paving the way for a technologically progressive agricultural sector and effective IoT utilisation. The lack of widespread government support and technological incentives from government positions, coupled with corruption and lack of employment strategies positions the Western Cape as not ready for IoT overall.

A thorough assessment was conducted through an environmental perspective to gauge the readiness of the South African agricultural sector. The environmental dimension underscores the urgency of embracing sustainable farming practices while addressing concerns linked to weather fluctuations and climatic shifts. Addressing the challenges highlighted by the findings necessitates the advocacy and reinforcement of sustainability which presents a gateway for IoT integration within the agricultural realm, owing to its capability to monitor weather trends, improve sustainability, and manage soil degradation. This progression positions the Western Cape for the adoption of IoT.

A comprehensive assessment was undertaken from a social perspective to understand the agricultural sector's IoT readiness. Upon analysing diverse social findings and participants viewpoints, it becomes apparent that embracing IoT technology in farming readiness is intricate and multifaceted. Farmers expressed an array of concerns and factors shaping their willingness to adopt IoT on their farms. Challenges including high unemployment, ethical considerations, limited education, reluctance to invest, elevated costs, issues of reliability and accessibility, and gaps in awareness and trust collectively influence farmers readiness to embrace IoT and reap its benefits. Tackling these concerns could pave the way for an agricultural sector prepared for IoT adoption. Thus, positioning the Western Cape as not ready for IoT.

A technological lens was employed to assess IoT readiness concerning the technological dimension within South Africa's agricultural sector. From these findings, it becomes evident that the path to IoT adoption encounters several challenges. Hindrances such as connectivity issues, elevated costs, the juxtaposition of labour expenses, tailoring cost-effective IoT solutions that cater to farmers specific needs, and technology investments impede successful implementation. Furthermore, inconsistent electricity access and limited alternative power sources hinder the extensive adoption of IoT devices. In addition, the scarcity of expertise to maintain and support IoT devices contributes to the intricate nature of IoT readiness. Therefore, positioning the Western Cape as not ready to adopt IoT.

The PEST-SWOT analysis framework provides a structured and comprehensive approach to addressing the research questions and objectives by evaluating the factors influencing IoT readiness in South African agriculture. Political factors, such as government initiatives to promote technology adoption through subsidies and training programs, are categorised under enabling factors within the PEST analysis. These policies create opportunities for IoT integration, as seen in the Department of Agriculture's efforts to expand access to renewable energy technologies, which mitigate challenges like rolling blackouts. Environmental factors, including South Africa's favourable climatic conditions (e.g. year-round farming due to zero frost days), support IoT adoption by facilitating continuous agricultural activities. In the SWOT framework, these factors are classified as strengths and opportunities, illustrating how external environmental conditions align with IoT readiness within South African agriculture.

Conversely, social and technological factors highlight significant barriers to IoT readiness. For instance, the lack of farmer education and technical skills, particularly in rural areas, coupled with resistance to change, limits the adoption of IoT solutions. These are captured as weaknesses in the SWOT analysis and as social inhibitors within the PEST framework. In addition, technological constraints, such as high initial costs of IoT equipment and inadequate infrastructure in rural areas, are categorised as both threats in SWOT and limitations in PEST. A specific example is the limited availability of affordable connectivity solutions in remote regions, which hinders access to IoT technologies despite the availability of alternatives like LoRaWAN.

Furthermore, environmental challenges, such as water pollution and soil degradation, act as both inhibitors and drivers of IoT adoption. While these issues highlight weaknesses in current farming practices, they also underscore the potential for IoT to address sustainability concerns through tools for precise resource management and environmental monitoring. Technological advancements, such as drones equipped with multispectral cameras, allow farmers to monitor crop health, detect stress, and identify problem areas quickly, enabling timely interventions to prevent soil erosion and degradation. Technological opportunities, when aligned with these environmental needs, can mitigate risks while improving productivity. Connectivity solutions, such as LoRaWAN networks and mobile technology, further support these tools by providing cost-effective communication in rural areas, ensuring that even resource-constrained farmers can access critical IoT technologies.

The interplay between social and technological factors is crucial. While limited technical skills inhibit adoption, the availability of IoT-enabled precision farming tools, such as soil sensors and automated irrigation systems, offers opportunities to improve agricultural efficiency.

These interconnections between political, social, environmental, and technological factors illustrate how external and internal dynamics collectively influence IoT readiness, directly addressing the research objectives and reinforcing the importance of a holistic approach. This interplay directly answers the sub-question on how social factors affect technological readiness, reinforcing the importance of targeted training programs and financial support for small-scale farmers.

Collectively, the exploration of these dimensions provides a comprehensive understanding of IoT readiness within the South African agricultural sector. The intertwined interplay between political, social, environmental, and technological factors underscores the intricate nature of this readiness. It is through recognising and addressing the challenges and opportunities across these dimensions that the agricultural sector can truly position itself for the transformative potential that IoT adoption promises.

Chapter 6

6 Conclusion

This chapter offers an overview of the study. Section 6.1 provides a concise recap of the research, while section 6.2 outlines the implications of the research, and 6.3 details it's significance and contribution. In section 6.4, the researcher outlines the limitations, while section 6.5 details the recommendations for future research, and the chapter concludes with a final recap in section 6.6.

6.1 Summary of the research

The global recognition of food scarcity attributed to climate change has spurred urgent attention to address this critical concern. As the repercussions of climate change ripple through various dimensions - encompassing the environment, technology, policy, and societal progress - its impact on food production within the agricultural sector is particularly dire. This challenge is exacerbated by a growing global population that escalates the demand for agricultural output, thereby intensifying the industry's responsibility to meet this pressing need. To navigate this complex landscape, the agricultural sector is compelled to pivot towards sustainable farming practices that bolster productivity while harmonising with ecological well-being (Farooq et al., 2020; Goedde et al., 2020; Kuschke, 2020; Montmasson-Clair et al., 2019; Von Bormann, 2019).

Central to this paradigm shift is the pivotal role of technology integration, specifically through the adoption of the Internet of Things (IoT). An extensive body of research underscores that the implementation of IoT within agriculture yields multifaceted benefits, enhancing food production, productivity, and sustainability. Furthermore, IoT equips farmers with tools to counteract the adverse impacts of climate change and mitigate food scarcity challenges, rendering them competitive and economically viable. However, the readiness of the agricultural sector to embrace IoT emerges as a decisive factor. Despite the promising prospects, there exists a scarcity of research exploring the South African agricultural sector's readiness for IoT adoption, creating a critical research gap that this study aims to address (Antony et al., 2020; Ayaz et al., 2019; Farooq et al., 2020; Liang & Shah, 2023; Pillai, & Sivathanu, 2020; Torky & Hassanein, 2020; Xu et al., 2022; Pillai & Sivathanu, 2020)

6.2 Implications for theory

This study hinged on a systematic PEST-SWOT analysis, a multidimensional lens that examined IoT readiness from political, environmental, social, and technological standpoints. Each dimension underwent meticulous scrutiny, evaluating its strengths, weaknesses, opportunities, and threats concerning IoT integration. The synthesis of these analyses culminated in positioning the agricultural sector's readiness within the Western Cape, encapsulating all dimensions (Kuschke, 2020).

The analysis of the political dimension unveiled the significance of governmental support, funding, and collaborative partnerships. Fostering an environment that balances legislation with farmer empowerment is pivotal for successful IoT integration. Collaboration with trusted community members, coupled with investments in education and training, emerged as key drivers to equip farmers with the necessary skills and readiness to embrace IoT. The political lens showcased the critical role of developing comprehensive approaches intertwined with government support, community involvement, and supportive programs to foster resilience in embracing IoT technologies.

Within the environmental dimension, a focus on sustainable farming practices, climate change, and weather variability emerged as pivotal considerations. The findings accentuated the need to promote and endorse sustainable farming techniques, providing an opportunity for IoT implementation. The capacity of IoT to monitor weather patterns and combat soil degradation positions it as a solution for addressing the challenges presented by the environment. Consequently, the readiness for IoT adoption becomes entwined with the agricultural sector’s ability to embrace sustainable practices.

The exploration of the social dimension delved into the intricate fabric of farmer readiness, unveiling an array of concerns that influence IoT adoption. From challenges related to unemployment, education, and costs to issues of reliability, accessibility, and awareness, the social landscape presented a complex array of factors shaping readiness. Addressing these concerns emerges as a pathway toward an IoT-ready agricultural sector, highlighting the need for tailored approaches that encompass training, support, and cultivating trust within the farming community.

The technological perspective unveiled a landscape marked by challenges and opportunities. From connectivity barriers and cost constraints to the competition between labour expenses and technological investments, the technological lens highlighted barriers to IoT adoption. The lack of consistent electricity and expertise added to the complexity of readiness. However, the avenue for overcoming these challenges resides in the development of improved connectivity infrastructure, customised IoT solutions, accessible expertise, and cross-sector collaboration. Raising awareness among farmers and fostering digital literacy also emerged as instrumental to wider acceptance and adoption.

The findings unveil a notable diversification in South Africa’s developmental states, characterised by both developed and developing segments. This divide manifests through the readiness disparity—the developed portion of the agricultural sector exhibits tangible readiness for IoT integration, while the developing portion encounters challenges necessitating comprehensive mitigation. This dichotomy mirrors the distinction between the commercial and SME sectors, accentuating the role of historical legacies in shaping this landscape (Adli et al., 2023; AgriSETA, 2019; Colizzi et al., 2020; Farooq et al., 2020; Kuschke, 2020). Hence, this study concludes that while certain portions of the Western Cape's agricultural sector demonstrate robust IoT readiness, the developing segments await the holistic resolution of weaknesses and threats (AgriSETA, 2019; Kuschke, 2020; Sutherland, 2020).

This research enhances our understanding of IoT adoption readiness within the South African agricultural sector, highlighting unexplored themes and revealing the nuanced dynamics of its readiness landscape. By integrating the outcomes of a comprehensive PEST-SWOT analysis, this study underscores the need for tailored strategies that bridge the readiness gap, enabling a harmonised and cohesive embrace of IoT technology across the diverse fabric of South Africa's agricultural domain.

6.3 Significance and contribution of research

The research on IoT readiness within the South African agricultural sector has made contributions by highlighting various facets of readiness and its determinants. This study has underscored several strengths within the PEST framework that position the sector favourably for IoT adoption. These strengths encompass critical elements like robust government support, the availability of resources, and an increasing awareness of technology among farmers, alongside an encouraging willingness to upskill and invest, ultimately driving Improvements in efficiency and production in the agricultural sector.

Conversely, the research has also shed light on several weaknesses that hinder the sector's readiness to embrace IoT. These weaknesses encompass issues such as corruption, attacks against farmers, lack of awareness of government interventions, environmental impact, environmental legislation, generational farmer dynamics, and the challenges associated with farm size, race, cost, connectivity, security, and the availability of electricity. Furthermore, this study has identified opportunities that offer the agricultural sector the potential to enhance its readiness for IoT adoption. These opportunities encompass avenues like full IoT solutions, which can contribute to sustainability, comprehensive Education initiatives, and holistic Full Solutions for IoT implementation. However, the research also underscored critical threats that could undermine the sector's potential readiness for IoT. These threats include employment rates, the looming challenges of climate change, security, farm size, labour-related concerns, and issues of reliability and trust.

6.4 Limitations of the study

Limitations of this research should be considered and reflected upon when considering its contributions. Some of the limitations include generalisations and interpretations made by the researcher. Due to the exploratory nature of the study, more participants could have been included in this study to get a better overview of the Western Cape agricultural sector. Furthermore, the number of participants interviewed was limited, due to the lack of willingness to participate in this study. In addition, this research predominantly relied on qualitative data obtained through interviews. While this approach offers in-depth insights, it might not capture the full spectrum of quantitative data that could provide a more comprehensive understanding.

This study was limited to the Western Cape which may not fully represent the diversity of agricultural practices and challenges across the entire country, thus generalisations made to this province should be used with caution. All farmers that participated in this study were male which could influence the answers. IoT technology and its readiness in the agricultural sector are dynamic and subject to rapid changes. Thus, the findings may not reflect the current situation.

Constraints in terms of budget, time, and resources have limited the scope of the study and the ability to conduct more extensive data collection, such as reaching out to a larger and more diverse group of participants. Language and cultural differences may have affected the interpretation of responses and the effectiveness of communication during interviews. This could introduce potential bias or misinterpretation of data. The research may not have accounted for all external factors that could influence IoT readiness in the agricultural sector, including global economic trends, international policies, or unforeseen events like the COVID-19 pandemic. The study focused on the current state of IoT readiness. It may not have explored the long-term impacts or consequences of IoT adoption within the agricultural sector.

6.5 Recommendations for future areas of research

Based on the limitations outlined, this study could have derived substantial benefit by using a larger sample size, expanding the location to include other provinces within South Africa or other countries, or by including both quantitative and qualitative data.

Future areas of research could include farmers perceptions to implement IoT in the agricultural sector of South Africa, or in-depth research on each dimension within the South African agricultural sector for the adoption of IoT. These findings highlight specific initiatives related to farmer affluency levels, government support and funding, technological awareness, and agricultural career promotion that could be used for future research. In addition, this research did not predict future developments in technology, policy, or social dynamics that could impact IoT readiness in the agricultural sector. Longitudinal studies tracking the progress of IoT adoption in the South African agricultural sector over time could be another future area of research. This would provide insights into how readiness evolves and whether the identified weaknesses and threats are mitigated or exacerbated. Furthermore, assessing the actual impact of IoT adoption on agricultural productivity, sustainability, and economic development, as well as investigating whether the anticipated benefits materialise and whether any unintended consequences emerge as points of interest for further research.

These insights can serve as a point of departure for further exploration of government strategies, programs, and political decisions in the agricultural sector.

6.6 Final Summary

This research conducted a comprehensive examination was conducted to gauge the readiness of the South African agricultural sector for the adoption of Internet of Things (IoT) technologies. The study delved into multiple dimensions, including political, environmental, social, and technological aspects, to assess the factors influencing IoT adoption readiness. This research contributes valuable insights into the readiness of the South African agricultural sector for IoT adoption. By dissecting the political, environmental, social, and technological dimensions, the study offers a comprehensive understanding of the factors influencing readiness. The findings underscore the need for holistic approaches that integrate political support, community engagement, sustainable practices, and technological solutions to pave the way for a resilient and technologically advanced agricultural sector embracing IoT technologies.

The integration of the PEST-SWOT framework underscores the complex interconnections between external and internal factors influencing IoT readiness, directly linking these

constructs to this study's objectives. Political enablers, such as government funding and job restructuring programs, align with SWOT opportunities, emphasising the importance of policy-driven incentives to enhance technological adoption. However, threats like loadshedding and corruption pose significant barriers, necessitating transparent and sustainable governance to support readiness.
Social dimensions further highlight how farmer education, support, and willingness to learn affect technological adoption. The alignment between social factors in PEST and weaknesses in SWOT, such as resistance to change and limited upskilling, underscores the need for community-driven initiatives and targeted training programs. Similarly, the interdependence between social and technological factors demonstrates that improving connectivity, reliability, and affordability directly impacts farmer perceptions and willingness to invest in IoT. Environmental factors, such as sustainability and soil fertility, provide a strong foundation for IoT adoption, aligning with strengths and opportunities in SWOT. However, threats like climate change and soil degradation necessitate solutions such as IoT-based monitoring systems to mitigate risks. These insights highlight the role of IoT in addressing environmental challenges while improving productivity.

By explicitly addressing these relationships, the study validates the conceptual framework and demonstrates how the PEST-SWOT constructs interact to shape IoT readiness in South African agriculture. This alignment with the research objectives provides actionable insights, such as prioritising affordable IoT solutions, expanding farmer education programs, and fostering policy reforms, to enable sustainable technological adoption.

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Appendices

Appendix 1: Cover Letter

Department of Information Systems

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REQUEST TO PARTICIPATE IN A RESEARCH STUDY

Dear Participant,

I am an Information Systems Masters student at the University of Cape Town. I am conducting research on the readiness of the South African agricultural industry to adopt the Internet of Things (IoT). The Internet of Things (IoT) is a technological tool said to achieve sustainability by increasing productivity. Your participation in this research will be greatly appreciated and is important for on-going research in the South African agricultural sector as it will provide insight/benefits such as increased agricultural productivity, reduced costs, and will allow for effective, efficient, and sustainable farming practices. The study will collect information through semi-structured telephonic calls/video calls/face-to-face interviews.

This is to request your participation in the interview survey. The interview may take up to 50 minutes to finish. The data gathered will be kept confidential. Your identity will remain anonymous and no recognisable details such as name, address and phone will be demanded. The gathered data will be processed with strict secrecy.
Your involvement in the survey is voluntary. The set of questions have been approved by Commerce Faculty Ethics in Research Committee. I will gladly send you a copy the final report. I thank you in advance for your expected participation.

The session will be recorded and discarded once the research has been concluded.

Kind Regards,

In'aam Soeker
University of Cape Town
For inquiries, please contact:
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Supervisor: Professor Wallace Chigona
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Appendix 2: Consent Form

PARTICIPANT CONSENT FORM

I/we ……………………………………certify that I/we am/are in a sound state of mind to participate in the study of the "Readiness of the South African agricultural industry to adopt the Internet of Things (IoT)".

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

By signing this form you confirm your participation in the research on "The Internet of Things Adoption Readiness in South African Agriculture" either through face to face/virtual interviews, telephonic calls and/or questionnaires in exceptional situations.

Signature.. Date: ....

Appendix 3: Farmer Interview Questions

A. Demographic Information:

1. Age:
2. Race:
3. Gender:
4. Highest level of education?
5. How long have you been farming for?
6. What is your position/role on this farm?

B. General Farming Information

7. Number of permanent employees on the farm?
8. What type of field crop are you specialised in?
9. Do you specialise in commercial or subsistence farming?
10. What technologies are you using on your farm?

C. IoT in farming

11. What is your understanding of IoT in farming?
12. In your opinion, how aware are farmers in South Africa about IoT?
13. What factors do you think influence whether a farm is ready/not ready for IoT?
14. What current farming practices, do you think, are suitable for IoT implementation?
15. What would support your intention to use technology, such as IoT, in your farming?
16. How do you think technology, such as IoT, would benefit/improve your farming practices?
17. What would prevent you from using technology, such as IoT, in your current farming practices?
18. How do you feel about using IoT on farms?

D. Social Dimension:

19. What social factors influences the use of IoT on farms?
20. How do these social factors affect the use of IoT in farming practices?
21. What demographic factors, do you think, influences the use of IoT on farms?
22. How do you think these demographic factors affect the use of IoT technology in farming practices?
23. What community support do you have that enables you to use technology, such as IoT, on farms?
24. What impact do you think IoT will have on social factors?

E. Political Dimension:

25. What is the government policy/views about technology in farming?
26. What kind of support from the government would encourage you adopt IoT?
27. What do you think government regulation is lacking in when it comes to technology in the agricultural sector?

F. Environmental Dimension:

28. What environmental issues are you experiencing in the agricultural sector?
29. What past/present environmental issues would make you think of adopting IoT technology to address these issues?
30. How do you think the use of IoT will address these environmental issues?

31. What consumer pressure do you experience which might cause you to move toward using IoT in your farming?
32. How do you think you can achieve sustainable farming?

G. Technological Dimension:

33. What technological infrastructure currently exists on the farm?
34. Where do you think the technological infrastructure lacks?
35. How would you like to improve on the current technological infrastructure?
36. What technological infrastructure do you think you would need to support the use of IoT?
37. How do you think the technological infrastructure can be improved in the agricultural sector?

Appendix 4: Expert Interview Questions

A. **General Questions:**
1. What IoT technologies are currently on the market that you think would be relevant to the agricultural sector?
2. Do you think farmers in South Africa are aware of IoT? What are your reasons for this?
3. What factors do you think influence whether a farm is ready for IoT?
4. How do you think IoT technology will benefit/improve farming practices?
5. What do you think would prevent farmers from using IoT technology?
6. What farming practices, do you think, are suitable for IoT adoption?
7. What do you think are opportunities in agriculture for IoT adoption?
8. What are some of the gaps in agriculture that would enable farmers to use IoT?
9. What do you think are some of the problem’s farmers would face with this type of technology?

B. **Social Dimension:**
10. How do social factors affect the use of IoT?
11. What social factors, do you think, affects the use of IoT in farming practices?
12. How do you think the demographic factors affect the use of IoT technology in farming practices?
13. What do you think technology offers the agricultural sector that people do not?
14. How do you think IoT technology will impact the job security of farm workers?

C. **Political Dimension:**
15. What technology programmes/subsidies are offered by government that would enable farmers to adopt IoT?
16. What kind of support from the government, do you think, would encourage farmers to adopt IoT?
17. What, do you think, government regulation is lacking in when it comes to technology in the agricultural sector?

D. **Environmental Dimension:**
18. What environmental issues, do you think, are experienced in the agricultural sector?
19. What past/present environmental issues would make farmers adopt IoT technology to address these issues?
20. What environmental circumstances enable IoT adoption, in your opinion?
21. What consumer pressure might cause farmers to move toward using IoT in farming?
22. How do you think you IoT can achieve sustainable farming?

H. **Technological Dimension:**
23. What technological infrastructure are currently in place that may support the use of IoT by farmers?
24. How do you think the technological infrastructure of SA can be improved generally and in the agricultural sector?
25. What technological infrastructure, do you think, would enable the use IoT technology in agricultural practices by farmers?
26. What technological infrastructure inhibits/limits the adoption of IoT? How does this limit the technology adoption in the agricultural sector?

27. How wide is the internet coverage for farmers in our country?
28. What do you think of IoT adoption if farmers could use it readily on mobile phones?

Appendix 5: Commerce Ethics Approval

5A. Ethics Approval 2022

Faculty of Commerce

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28 06 2021

Inaam Soeker

Department of Information Systems

University of Cape Town

REF: REC 2021/06/012

Internet of Things Readiness in South African Agriculture

We are pleased to inform you that your ethics application has been approved. Unless otherwise specified this ethical clearance is valid until 31-Jul-2022 .

Your clearance may be renewed upon application.

Please be aware that you need to notify the Ethics Committee immediately should any aspect of your study regarding the engagement with participants as approved in this application, change. This may include aspects such as changes to the research design, questionnaires, or choice of participants.

The ongoing ethical conduct throughout the duration of the study remains the responsibility of the principal investigator.

We wish you well for your research.

2021.06.28
16:44:33 +02'00'

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

5B. Ethics Approval 2023

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03 08 2022

In'aam Soeker

Department of Information Systems

University of Cape Town

REF: REC 2022/08/004

Internet of Things Readiness in South African Agriculture

We are pleased to inform you that your ethics application has been approved. Unless otherwise specified this ethical clearance is valid until 31-Dec-2023 .

Your clearance may be renewed upon application.

Please be aware that you need to notify the Ethics Committee immediately should any aspect of your study regarding the engagement with participants as approved in this application, change. This may include aspects such as changes to the research design, questionnaires, or choice of participants.

The ongoing ethical conduct throughout the duration of the study remains the responsibility of the principal investigator.

We wish you well for your research.

2022.08.03
16:26:11 +02'00'

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

Appendix 6: Cover Participants Demographic Data

6A. Interview Detail

Codes	Gender	Role	Interview Type
F1	Male	Farmer	Face to Face
F2	Male	Farmer/ Farmer Manager	Face to Face
F3	Male	Farmer Technology Researcher	Call
F4	Male	Farmer	Call
F5	Male	Farmer	Face to Face
E1	Female	IoT Expert	Online
E2	Male	IoT Expert	Online
E3	Female	IoT Expert	Online
E4	Male	IoT Expert	Online
E5	Male	IoT Expert	Call
G1	Male	Government Official	Call
G2	Male	Government Official	Call

6B. Farmer Demographics

Codes	Gender	Role on Farm	Age	Race	Education Level	Duration Farming	Type of Crop	Technology on Farms	No. of Employees	Type of Farm
F1	Male	Farmer	26	Coloured	Bachelors Degree	2 years	Chillies	Computerised pumps	2	SME
F2	Male	Farmer/ Farmer Manager	33	White	Bachelors Degree	5 months	Berries	Water pumps, sensors, software, temperature sensors, solar panels	20	Commercial
F3	Male	Farmer Tech Researcher	25	White	Masters Degree	1.5 years	Fruits	Sensors, software systems, data management tools, farm management tools	many	Commercial
F4	Male	Farmer	40+	Black	unknown	7 years	Seasonal	Irrigation systems	6	SME
F5	Male	Farmer	69	White	Equivalent to Degree	5.5 - 10 years	Vegetables	Computers	14	SME