Emerging technologies and effective governance for agricultural sustainability in the North West Province

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DECLARATION

I, Ms. Sebonta Francinah Desbo Mohono, declare that this study, '*Emerging technologies and effective governance for agricultural sustainability in the Northwest Province'* is my original work. This dissertation has not been submitted for a degree at this or any other university. All materials used in the study have been duly indicated and acknowledged in the references.

01 November 2024

Signed **Date**

DEDICATION

First of all, I thank God, my creator for affording me good health, determination, and grace for the successful completion of this dissertation. Indeed, He is worthy of my praise and gratitude. I dedicate this thesis to my God.

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LIST OF ACRONYMS

BLE	Bluetooth Low Energy
CEA	Controlled Environmental Agriculture
CRM	Customer Relationship Management
ECLAC	Economic Commission of Latin America and the Caribbean
ERP	Enterprise Resource Planning
FAO	FOOD and Agricultural Organisation
GDP	Gross Domestic Product
ICT	Information and Communication Technology
ISAAA	International Service for the Acquisition of Agri-biotech Applications
NDVI	Normalized Difference Vegetation Index
NWP	North West Province
PA	Participant
PASG	Percent of Average Seasonal Greenness
POS	Point of Sale
RDI	Rural Development Initiative
SDG	Sustainable Development Goals
SMS	Short Message Service
UTUAT	Unified Theory of Acceptance and Use of Technology

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ABSTRACT

This study investigates the integration of emerging technologies and effective governance models to enhance agricultural sustainability in the North West Province of South Africa. The study addresses five research questions which include exploring the types of emerging technologies adopted by farmers, the effectiveness of these technologies in increasing productivity, barriers hindering their adoption, and the governance models facilitating technology integration. The study adopts a mixed-methods approach, combining quantitative and qualitative data collection methods. Data was collected from employees in the Department of Agriculture through interviews while questionnaires were used to collect data from farmers. A total of 25 participants were selected from the Department of Agriculture in the qualitative phase and 340 farmers in the quantitative phase. ATLAS-ti software (version 23) was used to analyse qualitative data and SPSS to analyse quantitative data. This study is an article format where four articles were structured to answer the research questions while the last chapter presented the contributions of the study. Findings obtained from the study confirm that farmers in the North West Province incorporate various emerging technologies, including herbicide-resistant weed management, precision farming techniques, remote sensing applications, automation, and enhanced grains like BT maize. These technologies play a crucial role in improving crop yields, reducing operational costs, and enhancing farm efficiency. The integration of emerging technologies in maize production has led to significant improvements in efficiency, profitability, and safety standards. Farmers affirm the effectiveness of these technologies but emphasize the importance of comprehensive education and support services for optimal utilisation. The study confirmed that key barriers to technology adoption include high initial costs, a deficit in necessary skills and knowledge, limited access to markets and information, insufficient government support, and a lack of innovation and training. Respondents indicated that overcoming these barriers is crucial for widespread adoption and sustainable agricultural development. The study identifies various governance models in the agricultural sector which include the collective model, machine model, performance control model, and network model. These models influence organisational culture and decision-making processes. Additionally, technology transfer models, such as machinery supply, advisory services, funding mechanisms, and training programmes play a pivotal role in disseminating technological innovations. The study contributes to the body of knowledge by providing an integrated model that synthesizes findings on emerging technologies and governance models. This model is a comprehensive guide for enhancing agricultural sustainability in the North West Province. It

addresses the complex interplay of technological adoption, effectiveness, barriers, and governance structures. The study recommends targeted interventions to overcome financial barriers, improve knowledge and information access, and enhance government support. Education and ongoing support programmes should be prioritised to bridge knowledge gaps among farmers. Furthermore, the adoption of effective governance models, considering socio-economic factors, is crucial for the successful integration of emerging technologies in agriculture. In conclusion, this study provides valuable insights into the dynamic relationship between emerging technologies, effective governance, and agricultural sustainability. The integrated model as presented in this study provides a roadmap for policymakers, agricultural practitioners, and stakeholders to navigate the challenges and opportunities in the agricultural practices in the North West province.

Keywords: Emerging technologies; Governance models; Agricultural sustainability; Extension services; Millennium Development Goals; South Africa

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CHAPTER ONE

INTRODUCTION AND SCOPE OF THE STUDY

1.1 INTRODUCTION

Agricultural sustainability would be improved in the North West Province if they would adopt emerging technologies and good governance. In all African countries, the application of technology has been a primary driving force in boosting agricultural production and growth (Food and Agricultural Organisation, 2019). Though this has been held in very low esteem due to lack of exposure, innovation, and financial limitations (Verdier-Chouchane & Boly, 2017). Technology has been shown to be incredibly beneficial in the agricultural sector recently. Farmers can now grow crops in locations where they previously thought it was impossible to cultivate. Genetic engineering, for example, has enabled the introduction of specific trains into the genomes of crops and animals. Crops become more resistant to pests and droughts as a result of such engineering. Agricultural technology has been employed in a variety of ways, including the application of herbicides, pesticides, fertilizers, and enhanced seeds. Other technological approaches applied to agriculture include farm machines, crop sensors, the use of GPS in field documentation, biotechnology, indoor vertical farming, and modern greenhouses; livestock farming technology, block chain farming, artificial intelligence, and others (Ku, 2021). The adoption of these emerging technologies by farmers has increased efficiency and yield.

Policymakers are confronted with difficult decisions today due to the influence of policies on the adoption of these emerging technologies. The finances for agricultural research and consulting services are under increasing strain, which must be met and the possibility of all these depends on governance. Pierre and Peters (2019) affirm that governance is the act of controlling the activities of the state. There has been a limitation on how to speed the process of modern technological adoption in agriculture. This can be attributed to the fact that speeding up this concept involves a lot of knowledge and understanding of some of the elements that influence the decision of farmers to adopt modern technology in farming. Effective governance is one of the factors that influence how fast or slow agricultural technologies are adopted. Small scale farmers face both internal and external challenges as far as the adoption of modern agricultural technologies is concerned. Regardless of these challenges, what matters is whether modern technology has any value in the agricultural sector.

Technology adoption is a broad term; it is influenced by the level of education, training, and information, thus serving as the foundation of farmers' knowledge. The adoption of technologies has the potential to aid in the development of more sustainable farming systems and this study therefore peruses the effect of facilitating emerging technologies and effective governance in an endeavour to sustain agriculture in the North West province. The study will finally propose a framework that will incorporate aspects of governance and technology adoption in an endeavour to improve agricultural sustainability in the North West province. The proposal further highlights the background of the study, the problem statement, aims, and objectives of the study, the relevance of the study, delimitation of the study, as well as the research methodology proposed to achieve the objectives of the study.

1.2 BACKGROUND TO THE STUDY

The background to the study sketches the study area and history of agriculture in the North West province.

1.2.1 Study area

The Republic of South Africa has nine provinces, including the North West. The North West is bordered by Limpopo in the north-east, Gauteng in the east, Free State in the south-east, Northern Cape in the south-west, and Botswana in the north. It covers an area of 104 882 km2 with a population of 3 748 436 people (Local Government Handbook, 2017). The province is endowed with natural resources such as platinum, gold, diamonds, and uranium. Residents of the North West province are largely civil servants while a minority are farmers and mine workers. Four district municipalities make up the North West province and these are Ngaka Modiri Molema, Bojanala Platinum, Dr Kenneth Kaunda, and Dr Ruth Segomotsi Mompati districts. This study will be focused on Ngaka Modiri Molema district municipality which is one of the district municipalities of the North West province. There are five local municipalities in the Ngaka Modiri Molema District which include Mahikeng, Ditsobotla, Ramotshere Moiloa, Tswaing, and Ratlou.

The climatic condition of the province is characterised with hot or warm temperatures during summer and cold and sunny during winters. The temperature ranges from -8°C to above 40°C. Rainfall in the province can be classified into three bands and these are 700 to 600mm/a in the east, between 600 and 500mm/a in the central parts, and 500 to 400mm/a in the west. In addition, the province is said to be

semi-arid with wind erosion presenting a significant environmental issue where damage has been observed on young plants as well as erosion of the top soil. Despite these negative climatic conditions and its endowed relative grassland, 80% of the province is suitable for extensive grazing (Little, Hockey & Jansen, 2013). The province also boasts significant production of maize, sunflower, sorghum, wheat, cotton, groundnut and dry beans with maize production contributing a third to the country's maize production (Van Zyl, 2019). Figure 1.1 presents the map of the North West province.

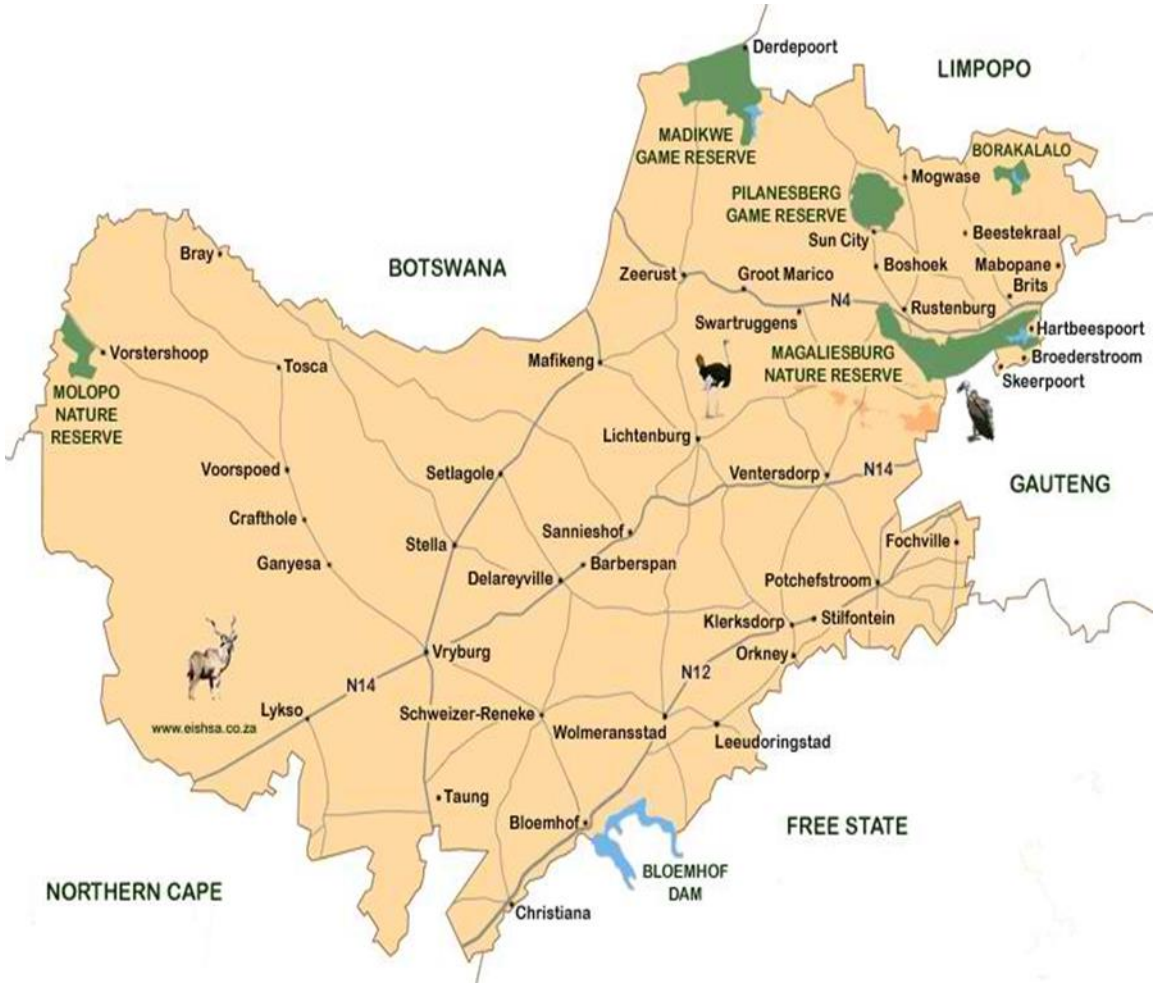

Figure 1.1 Map of the North West province

Source: SA-Venues.com (2017)

1.2.2 History of agriculture in the North West province

Historically, cropping was done by women in the North West province with men working with large animals. Crops that were cultivated were maize, cowpeas, sorghum, melons, pumpkins, sweet sorghum and beans though at a subsistence level. The first introduction of technology was during the arrival of

missionaries who taught methods of farming such as cattle farming for cultural and economic benefit (Makondo & Thomas, 2018.). There was the further introduction of technology that resulted in the transformation of the agricultural sector. For example, the single-shear plough used from the early 1900s was replaced by a double-shear plough in 1919 (Worth, 1994). Some farmers started using tractors and fertilisers in the 1940s, with some hiring out their tractor services for increased income generation.

The Native Agricultural and Lands Branch of the Department of Native Affairs was initiated with a focus on agricultural viability based on the Tomlinson Commission of 1955 (Hebinck, Fay & Kondlo, 2011.). The aim was to help the dwellers of the former Homelands to develop and be efficient in supporting themselves in their respective areas. This was rolled out in the form of transfer of modern technology, access to land as well as commercial marketing. The Department of Agriculture of Bophuthatswana, in 1976, established projects targeting food production. The core drivers of these projects were commercial production with mechanisation and modern cultivation practices (Bastian, Swanepoel & Van Niekerk, 2019). Farmers received support in the form of training, finance, technical aspects, and management. This depicts that farmers had access to production inputs and markets and this was the implementation of the Tomlinson Commission's recommendation. The support led to an increase in permanent and seasonal labour in the agricultural sector since farmers were expanding production.

Studies have shown that agricultural households play a significant role in reducing the impact of food insecurity. In the North West province, 44.1% of agricultural households participate in the activity as the main source of household food, 26.5% participate for extra source of household food, 13.5% for the main source of household income, 8.5% for extra source of household income, 5.3% for leisure and 2.1% were unspecified (Mathebula, Molokomme, Jonas & Nhemachena, 2017). However, studies show that North West province experienced the third highest decline in an agricultural households at a 21.6% decline of 214 049 in 2011 to 167 780 agricultural households in 2016. Activities of these agricultural households in the province chronologically include poultry, livestock, vegetable, fruit, grain and food crops, and industrial crops (Statistics SA, 2019). These activities are mostly in backyards, farmland, communal land, schools, and churches.

Research by Mathebula, Molokomme, Jonas and Nhemachena (2017) shows a 1.5% population increase in the province from 2011 to 2016 with the highest population recorded in Bojanala, followed by Ngaka Modiri Molema District. The majority of the province was found to be dominated by youth

comprising 36% of the province's population. Census showed that in 2016, in-migrations to the North West province were the third highest in the country after Gauteng and Western Cape Province with migrants from Gauteng province (CS 2016). The projection show that this in-migration trend will be the same in 2021. With these said in-migrations, it is important that the provinces must increase agricultural production to ensure the availability of sufficient food for the province's population.

The use of modern technology in agriculture could lead to improving agricultural output and reducing costs. Market forecasts for the next decade suggest a 'digital agricultural revolution' will be the newest shift that could help ensure agriculture meets the needs of the global population into the future (Food and Agricultural Organisation, 2019). Digital technologies are creating new opportunities to integrate smallholders in a digitally driven agro-food system (USAID, 2018). Whether a smallholder farmer or an agro-enterprise involves in the whole agro-value-chain, current and future technological innovations are poised to change how the agriculture business is done. For instance, using artificial intelligence and machine learning to extract data gathered via satellite and drone images, one can get real-time data about pests and activate disease-protection mechanisms (Saiz-Rubio & Rovira-Más, 2020). New tech like mobile apps, wearable devices, and automated sensors can quickly and effortlessly gather data which can, in turn, help banks and insurers assess the risks associated with agricultural business proposals and ventures.

The application of emerging technologies in agriculture by the North West provincial farmers through effective governance will create highly sustainable systems. This, in turn, could lead to greater food security, profitability, and sustainability. Looking at Sustainable Development Goals (SDGs), digital agriculture has the potential to deliver economic benefits through increased agricultural productivity, cost efficiency and market opportunities, social and cultural benefits through increased communication and inclusivity and environmental benefits through optimized resource use as well as adaptation to climate change.

1.3 STATEMENT OF THE PROBLEM

Agriculture fulfils diverse objectives and it must be internationally competitive, produce high-quality products while meeting sustainability goals. To remain competitive, agricultural producers need rapid access to emerging technologies (Shiferaw, Hellin, & Muricho, 2011). Farmers in the Ngaka Modiri Molema District are faced with many constraints in their bid to adopt modern technologies in their

farming practices. In addition, they need to meet environmental standards and regulations, as well as deal with direct and indirect consumer pressures. They may also be flooded with information from the various governments that makes choosing appropriate technologies more difficult. Farmers also need to change their production and management practices in response to agricultural policies that include environmental conditions. This was witnessed in the case of drought and extremely hot weather conditions in 2017 where farmers massively lost their livestock and farm crops (Maluleke & Mokwena, 2017). The production of crops and animal husbandry is harmed as a result of the extreme heat, posing a threat to food security. Masipa (2017) predicts that agricultural output in South Africa could fall due to a shortage of rainfall, which causes fertile lands to be lost to agriculture. South Africa is not resilient to such repercussions in this regard.

To achieve sustainability in the agricultural sector, the South African government has tried to increase productivity, reduce cost, and prioritize crops with high value, reduce risks and make agriculture sustainable (Kephe et al., 2022). The recycling of nitrogen and phosphorus, improving efficiencies of fertilizer applications, and relying on organic nutrient sources (animal and green manures) are important elements of sustainable agriculture. Also, land reforms, tenancy reforms, regulation of rents, provision of credit to local farmers, subsidies, food security act, and public distribution system are included in the sustainability development measures by the government. However, the government has not adequately provided heat tolerant varieties, improved seed, soil management, and smart water management in agriculture (Department of Environment, Forestry and Fisheries, 2020).

Adopting emerging technologies by farmers is an investment. It takes time, however, for the rewards to flow and farmers may be reluctant to invest in an uncertain environment. Technological change has been the basis for increasing agricultural sustainability and promoting agricultural development. The rate of technological growth and the degree of innovation in future technologies will have a significant impact on the stability and productivity of agriculture in the North West province. In the traditional sense, technology encompasses the development and application of nutrients, pest control products, crop cultivars, and farm equipment; however, it also encompasses the vision of genetically modified crops that provide greater nutritional efficiency, the manipulation of natural pest control agents, and the application of farm management techniques that focus on whole-farm productivity. The question arising in this context is “Do the farmers in Ngaka Modiri Molema district municipality adopt emerging technologies in their farming practices?”

While there has been significant research on the importance of adopting emerging technologies for improving agricultural productivity and sustainability, there is a lack of specific studies focusing on the Ngaka Modiri Molema District Municipality. The existing literature often addresses broad challenges faced by farmers in adopting modern technologies, but it does not adequately explore the unique constraints and factors influencing technology adoption in this specific region. Moreover, there is limited research on the effectiveness of government interventions in promoting sustainable farming practices in this district, particularly in the face of extreme weather conditions and other environmental challenges. This study aims to fill these gaps by investigating the extent to which farmers in Ngaka Modiri Molema District Municipality adopt emerging technologies, the barriers they face, and the impact of these technologies on their agricultural productivity and sustainability. **The problem of this study is 'The adoption of emerging technologies in the North West Province has been ineffective due to the government's inability to implement effective governance models. Without the proper application of these governance models, agricultural sustainability will remain unattainable'**.

1.4 AIMS AND OBJECTIVES OF THE STUDY

The aim of this study is twofold, firstly; to establish if the application of emerging technologies and good governance could enhance agricultural sustainability in the North West province. Secondly; the study proposes a framework to enhance technology adoption and effective governance to drive agricultural sustainability in the North West province.

1.5 RESEARCH QUESTIONS

This study is guided by the following research questions:

- What types of emerging technologies do farmers incorporate in their farming practices?
- How effective are these emerging technologies in increasing productivity of agro-products to achieve food security?
- What major barriers hinder the adoption of emerging technologies by farmers in the North West province?
- What governance model should be adopted to effectively help farmers incorporate emerging technologies to achieve agricultural sustainability?
- What recommendations could enhance the adoption of emerging technologies and effective governance to improve agricultural practices in the North West province?

1.6 RESEARCH OBJECTIVES

The study is guided by the following objectives, designed to:

- Investigate the types of emerging technologies farmers incorporate in their farming practices.
- Identify the effectiveness of these emerging technologies in increasing the general sustainability of agro-products to achieve food security.
- Assess the major barriers that hinder the adoption of emerging technologies by farmers in the North West province.
- Explore the governance model to adopt to effectively help farmers to incorporate emerging technologies to achieve agricultural sustainability.
- Develop a framework to enhance the adoption of emerging technologies and effective governance to improve agricultural practices in the North West province.

1.7 SIGNIFICANCE OF THE STUDY

DeCuir-Gunby and Schutz (2017) opine that researchers create main contributions to a study by adding knowledge that provides evidence to substantiate a valuable conclusion. This study empirically assesses the need to facilitate emerging technologies and effective governance for agricultural sustainability in the North West province. The main benefits of this study are illustrated in the table below:

Table 1.1 Meta-analysis of the study

Author(s)	**Constructs of the study**						
	Agriculture	Food production	Sustainability	Digital Technology	Food security	Smart farming	**Governance**
Galhena, D.H., Freed, R. & Maredia, K.M. 2013	√				√		
Parke, C., 2013	√	√		√			
Rotolo, D., Hicks, D. & Martin, B.R., 2015	√			√			
Bastian, R.M., Swanepoel, J.W. & Van Niekerk, J.A. 2019		√	√				

Saiz-Rubio, V. & Rovira-Más, F. 2020	√		√	√	√		
Hutchins, S.C. 2021.	√			√		√	
Khudzari, F., Rahman, R.A. & Ayer, S.K. 2021	√	√		√			
Ku, L. 2021	√	√	√		√	√	
This study	√	√	√	√	√	√	√

Table 1 displays that most studies have focused on agriculture, food production, sustainability, digital technology, food security, and smart farming. There has been no study combining all these factors with governance in the North West province. The novelty of this study is in combining these factors with the level of governance to ensure agricultural sustainability in the North West province. The other significant contributions of this study are outlined in the following segments

Context

The study generates knowledge and awareness of the contextual benefits of adopting emerging technologies in the farming practices in the North West province. It highlights the gap between agricultural development and emerging technology adoption in the North West province. The findings from the study validate the types of emerging technologies adopted by the farmers, the effectiveness of adopting emerging technologies, and the barriers in adopting the emerging technologies. The study identifies effective governance models, and technology transfer models adopted by the government, also the efficiency of these models in an endeavour to encourage farmers to adopt emerging technologies. Finally, a framework is generated from the study to enhance the adoption of emerging technologies and effective governance in the quest to improve agricultural practices in the Ngaka Modiri Molema District.

Academia

The literature review of this study contributes to solutions towards improving farming practices to achieve food security in the North West province. This consolidates research that other scholars could reliably utilise to investigate the field of governance and agriculture. More so, two articles and one conference paper are produced from this study to disseminate the outcomes and recommendations of this study on the adoption of emerging technologies in farming.

Policy formulation

The results of the study assist policy-makers on how best they could draft policies focused on the adoption of emerging technologies in farming practices to actualise food security and meet the Millennium Development Goals (2030). Findings derived from this study are tangible evidence of the measures applied to improve farming practices in the North West province. Furthermore, the challenges of technological adoption are identified, following which recommendations are proffered to help in the formulation of new policies or amendments of existing ones.

Practical challenges

The main research objective of this study is to establish if the application of emerging technologies and effective governance enhance the attainment of agricultural sustainability in the North West province. Findings deduced from this study are practically discussed relative to the existing knowledge. The recommendations of the study become propositions to policymakers, adding pathways for future research.

1.8 DELIMITATION AND ASSUMPTIONS OF THE STUDY

This study is focused on the application of emerging technologies and effective governance to enhance agricultural sustainability in the North West province. The unit analysis comprises the local municipalities of Ngaka Modiri Molema District which is situated in the North West province of South Africa. Twenty five (25) management officials from the Department of Agriculture (five from each selected municipality) and 340 farmers were selected to participate in this study. The study is strictly confined to the adoption of emerging technologies by farmers and the governance capacities of the agricultural boards in the North West province. This study explore the benefits derived from the adoption of the emerging technologies in farming systems. It considers both the responses from farmers and management personnel from the Department of Agriculture before conclusions and recommendations are generated.

The first assumption of this study is that its outcome justifies the development of a framework to enhance the adoption of emerging technologies and effective governance to improve agricultural practices in the North West province. The study differs from other similar studies in other provinces in that the adoption of emerging technologies in the farming practices is critically set against the backdrop of improving agricultural practices and meeting the sustainable millennial goals.

1.8.1 Definition of keywords

Keywords such as agricultural sustainability, effective governance, emerging technology, food security and governance are defined specifically as they are used in this study.

Agricultural sustainability - Sustainable agriculture refers to farming practices that meet society's current food and textile needs without jeopardising current or future generations' ability to meet those needs (Onyango et al., 2021). Sustainable agriculture practitioners strive to achieve three key goals in their work: a healthy environment, economic profitability, and social and economic equality. Growers, food processors, distributors, retailers, consumers, and waste management all have a responsibility to play in creating a sustainable agricultural system (Oliver, 2014). In the context of this study, agricultural sustainability refers to the adoption and implementation of farming practices and technologies that ensure long-term productivity and resilience of maize production in the Ngaka Modiri Molema District. This includes practices that meet the current needs for food production and protect and enhance the environment, ensure economic viability for farmers, and promote social and economic equity within the farming community.

Effective governance - When a state has the capacity, legitimacy, and authority to deliver public services, control the economy, maintain order and the rule of law, collect and use revenue, and act in the public interest, it is said to have effective governance (Azfar et al., 2018) Effective governance gauges how public institutions conduct public affairs and manage public resources in a desired way in international development. In the context of this study, effective governance refers to the ability of local and regional authorities within the Ngaka Modiri Molema District to implement and enforce policies that support sustainable agricultural practices and technology adoption in maize production. This involves the capacity to provide necessary public services, such as agricultural education and support, ensure compliance with environmental and agricultural regulations, manage resources efficiently, and foster an environment where farmers can thrive economically while maintaining social and environmental responsibility. Effective governance in this context is crucial for overcoming barriers to technology adoption and ensuring the long-term sustainability of agriculture in the region.
4o

Emerging technologies - Emerging technology generally refers to a new technology, but it could also refer to the ongoing evolution of an existing technology; it can have slightly varied meanings depending on the context, such as media, business, science, or education (Rotolo, Hicks & Martin, 2015). The term 'emerging technologies' is generally used to describe technologies that are now under development or would be available within the next five to ten years. It is usually reserved for technologies that are having, or will have, substantial societal or economic implications.

Food security - Food insecurity is a measurement of food scarcity and people's ability to obtain such needful food. Food security refers to people having physical and economic access to sufficient amounts of nutritious, safe, and culturally acceptable foods that are produced in an environmentally sustainable and socially just manner at all times, as well as the ability to make informed food choices (Galhena, Freed & Maredia, 2013). Food insecurity is a measure of the lack of access to adequate food and the difficulties people face in obtaining the necessary food to meet their dietary needs. In contrast, food security refers to a situation where all individuals have consistent physical and economic access to sufficient, nutritious, safe, and culturally appropriate food

Governance - Governance is the way a group of people do things. Many groups create a government to decide how things are to be done (Ysa et al., 2014). Structures and processes aimed to provide accountability, transparency, responsiveness, rule of law, stability, equity and inclusiveness, empowerment, and broad-based participation are classified as governance (Levi-Faur, 2012). In the context of this study, governance refers to the structures, processes, and systems through which local authorities, agricultural institutions, and community leaders in the Ngaka Modiri Molema District make decisions and implement policies related to agriculture. This includes the way these entities ensure accountability, transparency, and inclusiveness in promoting sustainable farming practices and the adoption of emerging technologies by farmers. Governance in this context also involves the mechanisms through which stakeholders are empowered to participate in decision-making processes, ensuring that policies are responsive to the needs of the farming community while upholding the rule of law and promoting equitable access to resources and support services.

1.9 RESEARCH METHODOLOGY

This section presents the research methodology of this study. The research paradigm, approach, and designs adopted in this study are explained. Other sections expounded upon include site and participant

selection, data collecting methods, and data analysis. Furthermore, the trustworthiness of the data collecting instruments are explained, as well as the ethical considerations observed during the research process.

1.9.1 Research philosophy

A system of beliefs and assumptions regarding the generation of knowledge is referred to as research philosophy (Saunders et al., 2016). Ontology, epistemology, and axiology are the three main categories of research philosophy. These philosophical perspectives enable the researcher to determine the most appropriate strategy to take relative to the research questions (Maree, 2015). Pragmatism, positivism, realism, and interpretivism are the four types of research philosophies. The most common data gathering strategies for each research philosophy are illustrated in Table 1.2.

Table 1.2 Research Philosophies

	Pragmatism	**Positivism**	**Realism**	**Interpretivism**
Popular data collection method	Mixed or multiple methods design, quantitative or qualitative	Highly structured, large samples, measurement, quantitative, but can use qualitative	Methods chosen must fit the subject matter, quantitative or qualitative	Small samples, in-depth investigations, qualitative

Source: Saunders et al. (2016)

This section provides an overview of the four main research philosophies and outlines the rationale for the interpretivist approach chosen for this study.

According to Saunders et al. (2016), pragmatism is a problem-oriented philosophy that takes the view that the best research methods help to effectively answer the research question. In social science research, this often involves a mixture of quantitative and qualitative methods used to evaluate different aspects of a research problem. Positivism finds its basis in the belief that science is the only method to learn about the truth (Creswell, 2014). The conviction in post positivism is that there is a single reality, which can be measured and known, and therefore positivists are more likely to use quantitative methods to measure data related to research questions. Concerning realism, Gray (2014) affirms that it is based on the scientific approach to the development of knowledge. The idea is that

reality is independent from the human mind. Realism can be broken down into two categories, namely: direct and critical (Novikov & Novikov, 2013). Interpretivism makes use of the qualitative methods in the conviction that individuals shape society; whilst positivists make use of the quantitative methods and believe that society shapes the individual (Creswell, 2014). The purpose of interpretivist research is to create new, richer understandings and interpretations of social worlds and contexts (Saunders et al., 2016). Interpretivist philosophers adopt qualitative approaches and believe that individuals shape society. The goal of interpretivist research is to develop new, comprehensive understandings and interpretations of social environments and contexts (Creswell, 2014; Saunders et al., 2016).

The pragmatist paradigm was adopted in this study since the pragmatist movement believes in the plurality of methods in providing answers to the research questions (Creswell, 2014). The goal of the study was to establish how to facilitate the adoption of emerging technologies and effective governance to enhance agricultural sustainability in the North West province. The pragmatist paradigm combined both principles of qualitative and quantitative research in the quest to resolving the research problem. In this regard, the study used interviews and questionnaires to generate data from employees of the Department of Agriculture and farmers. Since the pragmatist paradigm is problem centred, it provided the opportunity to ask in-depth questions as well as making inferences on the phenomenon under investigation.

1.9.2 Research approach

There are three types of research approaches which are quantitative, qualitative, and mixed methods approach. Quantitative research, according to Saunders et al. (2016), is "a research technique that emphasises quantification in the gathering and interpretation of data." Quantitative research collects numerical data and generalises it across groups of people or to explain a specific event. The quantitative researcher is independent of the actual research, and the results should be replicable regardless of who does the study. “Qualitative research is interested in analysing subjective meanings or the social production of topics, events, or practices by gathering non-standardised data and analysing texts and images instead of numbers and statistics,” according to Flick (2014:542). The qualitative approach, on the other hand, takes a naturalistic, multimethod, and interpretative approach to the research problem. Qualitative research is a social science research in which non-numerical data is used.

The mixed methods research was adopted in this study, combining both qualitative and quantitative research principles to find solutions to the research problems (Creswell, 2014). The adoption of this

research approach helped to gather the in-depth opinions of the participants through interviews and questionnaires as data collection options. It promoted complementarity where one approach compensated the other through comparisons of results from interviews and questionnaires.

1.9.3 Research design

According to Sekaran and Bougie (2016), a research design is a blueprint or plan for gathering, measuring, and analysing data to answer research questions. There are three research designs in the mixed methods research and these include explanatory sequential (where the quantitative study is conducted before the qualitative research), exploratory sequential design (where the qualitative study is conducted before the quantitative research) and the convergent parallel mixed methods research design (where both quantitative and qualitative research is conducted at the same time). In this study, the convergent parallel design was adopted. According to Creswell (2014), the convergent parallel design entails collecting both quantitative and qualitative data concurrently and discussing and presenting them separately. However, the discussion of the outcomes is done in a holistic manner to enhance comparisons and thereby find answers to the research questions. Interviews with subject matter experts (Department of Agriculture employees) were a part of the qualitative study followed by questionnaire administration to the farmers to acquire information on the adoption of new technologies and their challenges. This catered for the differences in jobs, leadership and decision-making responsibilities, where farmers do not hold any governance role.

1.9.3.1 Alignment of research objectives and instruments

The alignment of research objectives with the instruments developed to find solutions to the research problems are addressed in this section. The main instruments used in this study include questionnaires and semi-structured interviews. Table 1.3 presents the alignment of the research aims with the data collecting instruments.

Table 1. 3 Alignment of research objectives and data collecting instruments

Research objective	Instrument
To investigate the types of emerging technologies farmers incorporate in their farming practices.	Questionnaires
To establish the effectiveness of these emerging technologies in increasing the general sustainability of agro-products to achieve food security.	Questionnaires, Interviews

To understand the major barriers that hinder the adoption of emerging technologies by farmers in the North West province.	Questionnaires, Interviews
To explore the governance model that could be adopted to effectively help farmers incorporate emerging technologies to achieve agricultural sustainability.	Interviews
To develop a framework enhancing the adoption of emerging technologies and effective governance to improve agricultural practices in the North West province.	Questionnaires, Interviews

1.9.4 Research site selection

A research site (in qualitative study) or population (in quantitative study) refers to a broad group of people or phenomena that are the subject of a scientific investigation. A research population, according to Maree (2015) is a well-defined group considered to have similar characteristics. A common, linking trait is typically shared by all individuals within a population. O'Leary (2010) and Maree (2015) affirm that a study site refers to the group of people that the researcher wishes to study. Due to financial limitations and time required to collect data from all the district municipalities of the North West province, this study focused on Ngaka Modiri Molema District municipality which comprises five (5) local municipalities. This District municipality served as a representative of other district municipality in the province. The employees of the Agricultural departments were the subject of this investigation. Also, the farmers in the selected municipalities were included in the study. The target population is the complete set of people from whom a sample could be taken, and it is characterised in terms of elements, sampling units, scope, and time. The name suggests that this demographic is the focus of the study inquiry, according to Saunders et al. (2016). Therefore, a total of 85 employees are in the management category in the Department of Agriculture and they were included in this study. A total of 1 340 farmers participated in this study. Table 1.4 provides a representation of the population of this study.

Table 1. 4 Population sets in the study

Population	Composition	Total number

Set 1	Employees from Department of Agriculture	85
Set 2	Farmers from the various district municipalities	1340

Source: The Local Municipal Handbook (2017)

1.9.5 Participant selection

Participant selection (in qualitative study) or sampling (in quantitative study) involves the selection of participants from a site. However, due to the vast size of the research population, it is impossible for researchers to test every single person in the population because it was considerably costly and time-consuming. Burns and Grove (2017) define sampling as "the process of selecting a group of people, objects, or items from a broader population for measurement." Probability and non-probability sampling are the two most used ways used in selecting participants. According to Leedy and Ormrod (2014), probability sampling is also known as random sampling since everyone in the population has an equal chance of being chosen. Non-probability sampling, on the other hand, occurs when the researcher chooses individuals to fit a pre-determined profile (Krishnaswami & Satyaprasad, 2010).

In the qualitative study, a non-probability sampling was adopted in this study. The purposive sampling approach was applied for this study because it is convenient and cost-effective, especially given the study's short duration. According to Creswell (2014), the purposive sampling approach includes selecting participants for a study based on their positions and experience. This study selected participants from the Department of Agriculture in the local municipalities as specified in Table 1.5. Twenty five (25) workers from the Department of Agriculture participated in this study. The purposive sampling assisted in improving the originality and validity of data collection and guaranteed that the data collected is a true reflection of the population. It also allowed the researcher to choose the best candidates for data collection.

Table 1.5 Participant selection from the district municipalities

Local municipality selected	**Department of Agriculture employees selected**

Mahikeng	5
Ditsobotla	5
Ramotshere	5
Twaing	5
Ratlou	5
Total	**25**

In the quantitative phase, farmers from the five local municipalities were selected for this study. Simple random sampling was adopted which enhanced equal opportunity to select any farmer for data collection. The population of the farmers in the Ngaka Modiri Molema district is 1340 but the registered members in the Association of farmers is 540. The sample sizes for the farmers were further compounded using Research Advisor's (2006) sample size calculator by following a 95% confidence interval and a 3.5% degree of accuracy/margin of error. The sample frame was further computed by using proportional sampling strategy based on the sample fraction. Williams (2015) asserts that proportional sampling ensures that the size of each stratum is proportionate to its size in the population. The reason for this is to obtain the exact number of members drawn from each municipality. Table 1.6 presents the summary of the population of employees at the Department of Agriculture and the samples drawn from each municipality.

Sample frame = population × sample fraction

Sample fraction= $\frac{n}{N} = \frac{340}{540}$ 0.6296296296

Table 1. 6 Sample size for farmers

Local municipality selected	**Registered farmers**	**Sample size**
Mahikeng	132	83
Distobotla	202	127
Ramotshere	83	52
Twaing	75	47
Ratlou	48	31
Total	**540**	**340**

1.9.6 Obtaining informed consent and recruitment

This study embarked on direct contact to recruit participants. This was done through various communication options such as letters, emails, Short Message Service (SMS), and telephonic means. The researcher went to the Human Resources Department of the North West Department of Agriculture office to inform them about the intention to conduct a study with their employees. After obtaining a gate pass, the researcher sought the contacts of the participants. Afterward the participants' consent was sought through a mix of communication options such as emails, WhatsApp messages, or phone calls. For the farmers, the researcher visited the office of the Farmers Union and informed them about the study. Also, the contacts of three hundred and forty farmers were collected (from the municipalities) while their consent to participate was sought. During the first communication with all selected participants, the researcher specified that participation in the study was voluntary and that they could quit at will. It was specified that there were no incentives attached to the participants but to contribute towards making policies to improve agricultural sustainability through emerging technological adoption. The main purpose of the study was clarified to the participants and all ethical concepts explained. The participant recruitment was done within two weeks and the day of the interview was scheduled and agreed upon by both parties. The researcher maintained effective communication through various means as explained earlier.

1.9.7 Data collecting instruments

Data collection, according to Gray (2011), is a method for obtaining information from participants. In the qualitative study, interviews were used to collect data. According to Creswell (2014), research interviewing is a process of collecting data from participants by asking series of questions to know their opinions concerning a subject matter. Interviews allow for the collection of content-rich data. As a result, extensive planning in conjunction with the research development was required. Decisions were taken on who to interview and how to interview them, as well as what kinds of interviews to conduct and how to analyse and document them (Creswell, 2014). Furthermore, the interviewer must possess good social skills, listening abilities, and the ability to communicate effectively (Leedy & Ormrod, 2014). Rather than treating participants as subjects, the technique urged them to be treated as individuals. The goal of the interview technique in this study was to obtain deep, comprehensive insights into the perspectives and actions of leaders in the Department of Agricultural employees. The interviews helped in addressing the questions because this technique looked into the behaviours of the participants.

For this study, the researcher adopted semi-structured interviews in the qualitative study as the data-gathering instrument. According to Creswell (2014), the researcher has a list of themes and essential topics to address, which may vary from interview to interview in semi-structured interviews. Due to COVID-19 pandemic, the interviews were conducted online. The interviewer resorted to a variety of mediums, such as Microsoft Teams, Video calls, WhatsApp Calls and messages, Short Message Service (SMS), emails, and phone calls. To avoid fatigue, the interviews lasted no more than 30–40 minutes.

The interview questions were carefully developed by asking appropriate questions to secure significant data, based on the researcher's in-depth understanding of the phenomenon under investigation. The interview questions incorporated two sections. Section 1 sought the biographical information of the participants while section 2 focused on the research questions of the study. The interview questions of both the employees of the Department of Agriculture and the farmers were based on the research questions as specified in section 1.5.

The responses to these questions were documented to ensure that accurate data would be collected. At the end of the interviews, the researcher thanked the participants for their contributions and thoughtful responses.

In the quantitative study, the researcher adopted self-administered questionnaires as the data collecting instrument. Gray (2014) affirms that a self-administered questionnaire is used to ellicit feelings and responses in a survey and consists of lists of questions that represent the inquisition into a study. This instrument was adopted because it is cheap, provides anonymity of responses, easy to administer, saves time, and can be gathered without the physical presence of the researcher. The questionnaires were formulated based on the objectives of the study. Themes in each research question were developed to gather insights on the opinions of the respondents regarding the problem under investigation. A 4-point Likert scale was adopted. The questionnaires were formulated with the guidance of the study leaders and a professional statistician. Also, the questionnaires were formulated using simple English language that was comprehensible. It took respondents approximately 30 minutes to complete the questionnaire.

1.9.8 Data analysis

In the qualitative study, data collected from employees of the Department of Agriculture through interviews was analysed concerning the objectives of the study. ATLAS-ti software (version 9) was

used to analyse data collected from the participants. ATLAS.ti software is a strong workbench for analysing vast amounts of textual, graphical, audio, and video data qualitatively. This was used to interpret, organise, and present data according to themes and categories. The key ideas were explored and corroborated with the literature review findings after creating themes and categories, yielding a detailed view of the research. The stages that were observed during data analysis are as follows:

1) Organising the collected data: In this stage, all interviews were transcribed and kept in a readable format for further analysis.
2) Review of transcripts: Data was checked to master the contents and ensure that they represent the direction of the report.
3) Initial coding: The themes and categories that were identified and labelled.
4) Coding of data: The coding method was used to organise the related data to link related headings with similar information. These developed the thematic categories.
5) Representation of data: The findings that emerged in this study were represented in themes and categories in ATLAS-ti network diagram.
6) Interpretation and summarising of findings: In this section, the interpretations of results were made based on the research questions of the study and these were corroborated in the literature review.

In the quantitative study, the Statistical Package for Social Sciences and Statistical Analysis System was used to analyse data collected from the 340 farmers. The descriptive statistics and the inferential statistics were a part of the analysis.

The descriptive statistics summarised data associated with the population of the study. These data were presented using charts, graphs, and tables. The set of analysis in this category were completely explanatory and consisted of measures of central tendency, measures of variability, and associations.

Furthermore, the inferential statistics measured associations and relationships between one variable and another such that inferences allowed for the researcher to draw informed conclusions about the population under study. In this study, inferential statistics such as reliability analysis, correlation analysis, analysis of variance, chi-square test of independence, and factor analysis were conducted.

1.9.9 Trustworthiness

The following section presents the trustworthiness, reliability and validity of data collecting instruments. The following delineation presents the trustworthiness of data collecting instruments.

The degree of confidence in data, interpretation, and techniques employed to ensure the quality of a study is referred to as the study's trustworthiness or rigour (Sekaran & Bougie, 2016). The four criteria of credibility, reliability, confirmability, and transferability were all met in this study. These are explored subsequently.

Credibility

According to Saunders et al. (2016), semi-structured interviews can reach a high level of trust if they are carefully done with clarifying questions, probing meanings, and investigating feedback from a range of perspectives. The most important purpose of qualitative research is to establish credibility. It refers to trust in the accuracy of the data, as well as interpretations of the data and the researcher's conclusions. For external readers, it is intended to improve the plausibility and accuracy of the findings. Qualitative researchers might utilize triangulation to demonstrate that the findings of a research study are reliable.

Dependability

The second criterion in Denzin and Lincoln's (2011) paradigm is dependability, which relates to how consistent the findings are if other researchers repeat the study. The data gathering instrument for the study will be semi-structured interviews. The researcher was charge of presenting information to the reader that was consistent with the research method, i.e., rational, traceable, and documented. A qualitative researcher can adopt an inquiry audit to establish reliability.

Transferability

The amount to which the researcher can demonstrate that the findings may be transferred to or have relevance in other locations or groups of similar conditions, populations, or occurrences. According to Denzin and Lincoln (2011), it is the researcher's job to give adequate descriptive data in the study report so that readers may assess the data's application to various situations. Purposive sampling was employed to increase the amount of specific data obtained concerning the context. This is in contrast to the aggregate data that would be the result of a quantitative study. The sample respondents' characteristics were directly related to the research questions and objectives.

Confirmability

Confirmability is established when credibility, transferability, and dependability are all met (Denzin & Lincoln, 2011). The degree of neutrality in the research study's conclusions is referred to as confirmability. In other words, confirmability refers to objectivity, or the likelihood of two or more independent people agreeing on the correctness, relevance, or interpretation of data. The researcher adopted an audit trail, which emphasizes the processes of data analysis followed to provide a clear reason for the conclusions made. This proved that the study and its conclusions accurately reflected the responses of the participants. This ensured that the conclusions mirrored the voices of the participants rather than the researcher's biases, intentions, or perspectives.

The next section presents the validity and reliability of data collecting instruments in the quantitative study.

1.9.10 Validity and reliability

According to Kumar (2011), validity refers to an instrument's ability to measure what it claims to assess, however Relmer and Ryzin (2011) argue that research instruments used for data collection should be of good quality and dependable in order to successfully measure respondents' feelings. Construct validity were demonstrated in this study by constructing questionnaires based on the reviewed literature, document analyses, and other observations made by the farmers in the context. The questionnaire was drafted and written in plain English so that they could be read and understood by everyone. Validity was further ensured by guaranteeing that questionnaires were only given to farmers who are currently active in farming.

According to Kumar (2014), the degree of consistency of an instrument is known as its reliability but Gray (2014) and Maree (2015) points out that reliability refers to the dependability, stability, honesty, and precision of measuring devices employed in a study. In the same view, Creswell (2014) affirms that reliability ensures that the data collection procedure is done correctly to ensure that relevant data is aligned with research objectives. In quantitative research, reliability is important because it improves validity, measure clarity, and whether a study produces consistent results over time (Susanne, 2012). The reliability of the questionnaires was upheld by conducting a pilot test on a small group of people before distributing the identical instrument to the complete population. To preserve reliability, the pilot study utilised ten questionnaires to ensure that the questions would be clear, concise, and

understandable to responders. To ensure internal consistency, Cronbach's alpha was used to examine the degree of reliability in each portion of the questionnaire.

1.10 ETHICAL CONSIDERATIONS

Ethical considerations involve the legal side of research practices. Creswell (2014) and Kumar (2014) affirms that research ethics are those practices that are allowed and those that are not allowed in the process of data collection. After collecting the ethical approval for the department, the following ethical concepts would be observed:

Informed consent

The importance of alerting participants on the nature of the research project is referred to as informed consent. Participants in the study can only give informed consent if they have a thorough grasp of the study's nature and why they are being asked to participate in the research project, according to Saunders et al. (2016). This covers the number of time commitments, the nature of the activity, the topics that were discussed, and the hazards that may be involved in participating in the study. Potential participants were duly approached personally for this study and explained the study's purpose and data gathering methodology. Potential participants were notified through a mix of communication options to get their consent. Agreements were made on the time and dates of the interviews.

Voluntary participation and exit

This researcher informed the participants of the study that participating in the study is only voluntary and they were free to quit at any time. During the introduction period, the interviewer and the questionnaire administrator clarified that no participant would be tied to the study, also an explanation was made that participants could quit the interviews/questionnaires.

Protection against harm

Researchers must ensure that the research subjects are not harmed in any way. “Harm may arise through hazards to emotional well-being, mental or physical health, or social or group cohesion (Saunders et al., 2016). It could be created by utilizing an intrusive or zealous research strategy that entails mental or social pressure. The interviews took place in a setting or on a platform that made the participants feel safe. Also, all the COVID-19 protocols were observed during questionnaire administrations.

Confidentiality and anonymity

As a result of this concept, individuals had the right to demand rigorous adherence to pledges of anonymity and confidentiality (Saunders et al., 2016). All participants' identities were kept hidden and secured by the researcher. Access to raw data were restricted and managed to achieve this, security passwords were used to store all data. In the qualitative reporting phase, the researcher ensured that there was no name-calling, rather pseudo-names such as (PA1, PA2…..) were used rather than the actual names of the participants.

1.11 RESEARCH OUTLINE

The following is the dissertation's structure:

Chapter One: Introduction

This chapter is a broad overview of the introduction and background, the statement of the problem, the research aims and objectives, the relevance of the research, the research design and methods used to achieve the purpose of the study.

Chapter Two: Theoretical Background and Literature Review

This chapter expounds upon the theoretical backgrounds that underpin the study. The proposed framework is presented and explained to buttress how the combination of technology adoption and governance/management could enhance agricultural sustainability.

Chapter Three: Investigating the effectiveness of emerging technology in agricultural practice: A case study of the North West province, South Africa.

The study dealt with emerging technologies and its potential to improve farming practices and increase productivity in the North West province of South Africa. There is a need for more education and training on the use of these technologies, as well as increased access to resources to facilitate their adoption. In this chapter, topics such as types of emerging technologies farmers incorporate in their farming practices, the effectiveness of the emerging technologies in increasing the general productivity of agro-products to achieve food security, major barriers that hinder the adoption of emerging technologies, technology-transfer models do the government adopt to facilitate the adoption of emerging technologies, the effectiveness of the technology-transfer models, and the recommendations needed to enhance the adoption of emerging technologies in agricultural practices.

Chapter Four: How effective are these emerging technologies in increasing the general productivity of agro-products to achieve food security?

This section investigated the effectiveness of the emerging technologies adopted by the farmers in the North West province. It also dealt with how the employees at the Department of Agriculture assist these farmers to increase the productivity of agricultural products to achieve food security.

Chapter Five: The major barriers that hinder the adoption of emerging technologies by farmers in the North West province. This study aimed to identify the barriers faced by farmers in the North West Province of South Africa regarding the adoption of emerging agricultural technologies in the production of maize. The research employed a mixed-methods approach, combining quantitative and qualitative data collection methods to obtain comprehensive insights into the challenges inhibiting the adoption of these technologies. The study involved a sample of farmers from various agricultural sectors, and data were collected through surveys, and interviews.

Chapter Six: **The governance model adopted to effectively help farmers incorporate emerging technologies to achieve agricultural sustainability**.

This study investigated the governance models applied by the Department of Agriculture in an endeavour to promote the adoption of emerging technologies in agriculture. A qualitative research approach was adopted and a total of 25 participants were interviewed. The adoption of a qualitative study provided an in-depth exploration through interactions with the participants. The data was analysed thematically with the help of ATLAS-ti software (Version 23).

Chapter Seven: Conclusions and Recommendations

This segment summarises the study's research findings, recommendations, suggestions for potential studies, and conclusions. The final framework developed in this study is presented as a product of both empirical and non-empirical studies.

1.12 SUMMARY

Technology adoption has the potential to help farmers establish more sustainable farming methods all over the world. Based on this assumption, this study is aimed at establishing how emerging technologies and effective governance could be utilised to sustain agricultural practices in the North West province. This study proffers recommendations which guide the improvement of viable agricultural practices in the North West province.

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CHAPTER TWO

LITERATURE REVIEW AND THEORETICAL BACKGROUND

2.1 INTRODUCTION

This chapter presents the literature review and theoretical background to the study. The Unified Theory of Acceptance and Use of Technology (UTAUT) was adopted to underpin this study. In the literature review, the study traced the nature of farming in the North West province and innovations applied to enhance farming practices. Finally, the study assessed the governance models available to steer the affairs of the agricultural sector in the North West province towards sustainability. The following section discusses the study's theoretical framework.

2.2 UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY (UTAUT)

This study is guided by the UTAUT (Unified Theory of Acceptance and Use of Technology). Venkatesh and his colleagues created the UTAUT in 2003, incorporating diverse views on user and innovation acceptability (Williams, Rana, & Dwivedi, 2014). Venkatesh's theories are based on the model presented in Figure 2.1 , which has four key constructs that comprise the theory. These concepts include performance expectancy, effort expectancy, social influence, and facilitating conditions. These constructs improve behavioural intentions and adoption of technology, but their use is influenced by gender, age, experience, and the degree of willingness to use these technologies, including the ways in which they are subsequently used (Williams, Rama, & Dwivedi, 2014: 444).

The four UTAUT model constructs, according to Venkatesh and Davis (2003), are key determinants of behavioural intention to use technology. UTAUT posits that the intention to use technology leads to actual utilisation, which is invariably influenced by the four determinants. Gender, age, and experience are the most important intervening variables that determine the four dimensions of behavioural usage intention. Voluntary system use also acts as a moderator of social effect on users' behavioural intention to use a technological system (Venkatesh & Davis, 2003). Figure 2.1 presents the UTUAT.

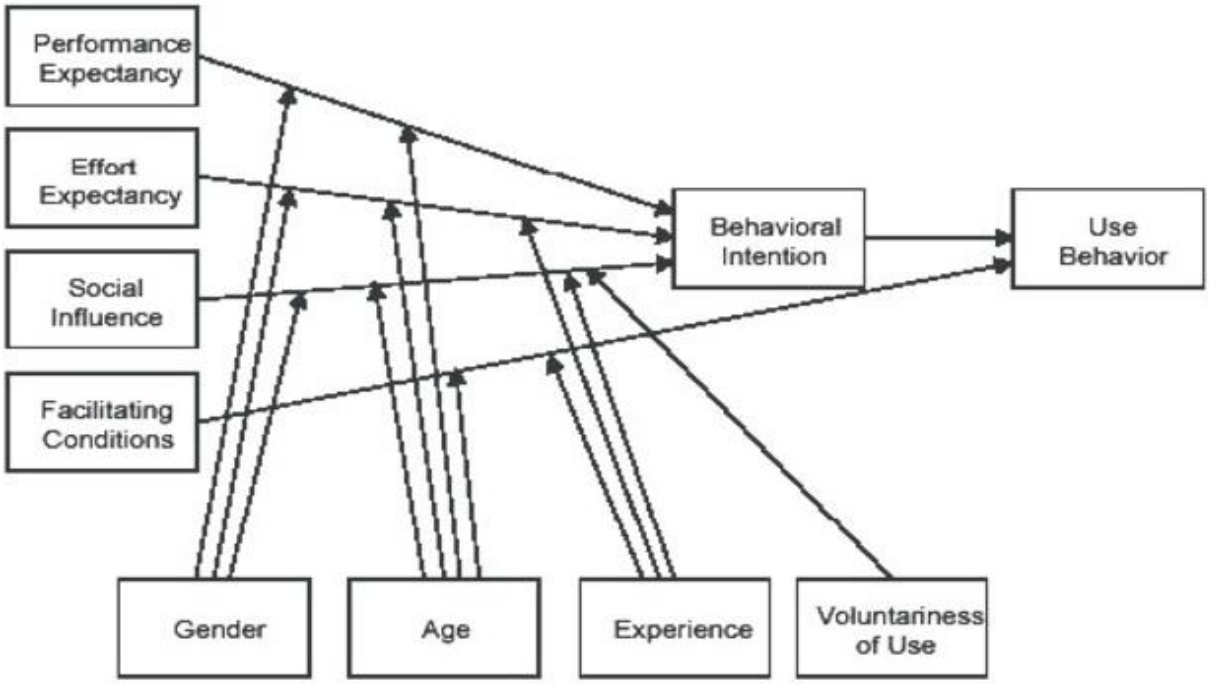


Figure 2.1 The Unified Theory of Technology Acceptance and Use (UTAUT)

Source: Williams, Rana, and Dwivedi (2014).

The four constructs described in UTAUT are ostensibly incorporated in this study because the emphasis is on the owner (government) rather than the user (farmer). This reflects the fact that government pushes technology adoption and use by implementing relevant programmes and making the final decision on whether or not to employ a particular technology. As a result, focusing on behavioural intent to integrate a specific technological system is critical in the adoption of emerging technologies in farmers' agricultural operations in the North West Province. Adopting this theory helps in understanding the desires to implement various technologies in agricultural practices, as well as disclosing subsequent technology usage behaviour in the North West province.

2.2.1 The meaning of Agriculture

Agriculture is the broadest term used to describe the various techniques used to sustain the world's global population by providing agricultural goods from plants and domesticated animals. Agriculture has been an important aspect of the economy for millennia, both before and after the Industrial Revolution. Sustainable growth of global food production has an impact on humanity's long-term existence; thus, care must be taken to ensure that agricultural methods remain environmentally benign. Agriculture has led to the creation of cities as well as commercial relations between diverse locations and ethnic groups, enabling for the evolution of human societies and cultures.

Harris and Fuller (2014) explain that the term "agriculture" originates from the Latin words "ager" (field) and "colo" (cultivate), reflecting the concept of field or land tillage in Latin *agricultura*. Over time, this term has evolved to encompass a wide array of activities integral to agricultural production, each having its specific terminology. These activities include cultivation, domestication, horticulture, arboriculture, and vegeculture, along with various forms of animal production such as mixed grazing. The term "agriculture" currently refers to all processes required to produce food, feed, and fibre, as well as all techniques of raising and processing cattle, according to the New World Encyclopaedia (Harris & Fuller 2014). Agriculture (including farming) is the systematic rearing of plants and animals to produce food, feed, fibre, fuel, and other goods and services. Agricultural products have been the mainstay of human diet for thousands of years. Other definitions of agriculture include, but are not limited to:

"the science, art, or practice of cultivating the soil, growing crops, and raising livestock, as well as the preparation and sale of the resulting goods to varying degrees" by Merriam-Webster. Agriculture has also been defined as the art, science, and business of growing food and raising cattle for financial gain. It is, indeed, a type of art that entails knowing how to carry out farming tasks with expertise. As a science, it utilizes all scientifically-based technologies, such as plant breeding programmes, production technologies, pest and disease management, economics, logistics, and packaging, to maximize yield and revenue, as well as new varieties modified through hybridization, transgenetic crop varieties resistant to pests and diseases, hybrid crops, high fertilization rates, and so on. Agriculture as business seeks to maximize investment returns by managing land, labour, water, and capital while applying scientific knowledge to produce food, feed, fibre, and energy. Agriculture is the world's most important enterprise (Stout, 2012),. Agriculture is a manufacturing industry where natural resources such as land, water, air, soil, and energy are used as components and then transformed into a single essential unit, agricultural plants and their yield, which are required by humans. Animals' milk, meat, eggs, honey, wool, silk skins, and other primary products are collected and transformed into intermediate units. Agriculture is classified into three types: subsistence (for personal consumption), market (for resale), and commercial (crops and animals farmed for a people or nation). This means that agriculture provides a food source for humans, generating employment, generating raw materials for other production levels, driving technological innovation as would be considered in this research, contributing significantly to national income and GDP. Agriculture also plays a role in logistics and distribution, and can lead to food security and hunger reduction if properly harnessed and invested in.

New World Encyclopaedia asserts that contemporary agriculture extends beyond the conventional

production of human food and animal feed. It encompasses a diverse range of products, including cut bouquets, decorative and nursery plants, wood products, agricultural inputs, animal skins, leather, industrial chemicals (such as starch, sugar, ethanol, alcohols, and plastics), fibres like cotton, wool, hemp, and flax, as well as biofuels like methanol and biodiesel.

2.2.2 North West province agricultural sector

One of South Africa's nine provinces is the North West Province (NWP). With an area of 102,881 km2 and a location in the heart of South Africa's northern border with Botswana, it is the fourth-smallest province in the country. The province is well-known for its vast natural resources, which include minerals such as platinum and chromium. The province boasts superior bio - diversity, and it enjoys a competitive advantage over neighbouring provinces in the mining and agriculture sectors of the economy. The North West also has a number of internationally recognised fossils that have been discovered in various locations. North West's capital is Mahikeng (previously Mafikeng) (North West Provincial Department of Rural, Environment and Agricultural Development, 2015).

The NWP is located in the country's summer rainfall zone, with an annual rainfall of 500 to 600 mm, according to the South African Weather Service (2021). It also belongs to the savanna and grassland biomes (National Biodiversity Institute of South Africa, 2018). The NWP vegetation varies with soil type, which is shaped by the underlying geology, according to the Statistics South Africa Census of Commercial Agriculture (2017). Low-lying areas connect the savannah biomes. Grasslands protect the ground from the elements. Grazing pasture is used primarily for domesticated animals and game farming, with arable land used for crop cultivation accounting for nearly half of the landmass. Rainfall is critical for most farmers in the NWP. Droughts, on the other hand, are common in the region and have a significant negative impact on agriculture, resulting in negative socioeconomic outcomes (Rapholo & Makia, 2020). In 2018, the economy of the North West Province was predominantly driven by mining, constituting 32.5 percent of the provincial GDP, followed by manufacturing (5.1 percent), agriculture (2.8 percent), and construction (2.5 percent). Although the North West contributed 23.9 percent to national mining and 6.9 percent to national agriculture, its contributions to manufacturing and construction were relatively lower at 2.3 percent and 3.8 percent, respectively (Cole, Sogayise & Dudumashe 2021).

The North West Province plays a significant role in e Southern African food supply, with approximately 43.9 percent of the province designated as "arable" land. The presence of three distinct

climate zones enables a diverse range of agricultural activities in the region. This province is known for its cattle and game ranches, where hunting has become a commercial venture. Maize and wheat farming dominate the province's central and southern regions, but cash crop production is also significantly developed. The eastern and north-eastern regions, on the other hand, receive enough rain to support a diverse range of crop farming. More than a quarter of South Africa's maize harvest is produced in the Northwest province. Cattle, poultry, and game, sunflower seeds and oils, almonds, citrus, and tobacco are among the various agricultural products.

According to Galal (2021), grain and beef farming are commercially practiced in the North West, and the province's western regions have been dubbed "South Africa's Texas," with vast herds of cattle roaming large farms. The North West is home to over 1.6 million beef cattle, which accounts for roughly 12% of South Africa's herd. A large number of sheep farms, cattle ranches, and game ranches can be found in the province's northern and western parts. The province's goat population is estimated to be 701 587, accounting for 13% of the total goat population in South Africa. There are approximately 318 843 pigs, accounting for nearly 20% of South Africa's total herd. Crops grown in the east and south include maize (corn), sunflowers, tobacco, cotton, and citrus fruits. North West accounts for 33% of South Africa's sunflower seed production, 23% of the country's groundnut production, and 5.4% of the country's potato production. The province accounts for about 11% of South Africa's cotton harvest, which has been declining over the last several years. There are plans to revitalize the sector's growth, particularly in small-scale farming. Cotton industries are possible in the province's north, near Sun City, and in the province's extreme south, near Taung.

The North West produces around 20% of South Africa's maize and 15% of its wheat. Maize and wheat farming are dominant ventures in the province's central and southern regions. In the six years running up to 2015, the North West generated around 20% of total national maize production. The total production in 2014 was 14.2 million tons, which was an extremely high return, although yields were lowered due to the drought. The varying climate regions of the North West support three distinct types of agriculture. The relatively dry western region is home to vast herds of beef cattle, and it is here that the burgeoning game-ranching and hunting industry began. According to ABSA Agribusiness data, an R5-million investment in cattle yields a 4.8 percent return over six years, while buffalo yields a 27.7 percent return and sable yields a 45.2 percent return.

Summer cereals occupied nearly two million hectares of land during the 2017 farming season, with winter cereals occupying approximately 50 000 hectares. In 2017, more maize was planted than was

possible in 2016 (Mucina *et al.,* 2021). This translates to 2.54 million hectares, which is important news for consumers.

Besides the droughts which have a negative impact on food production in the province, other related challenges include insufficient funding, slow adoption of technology and automation, a low level of youth participation, limited knowledge and technical know-how, stock theft, land rights disputes and sparse markets, a lack of technical and infrastructural support, and a lack of veterinary doctors, among others (Nxumalo et al., 2020). However, in accordance with the National Development Plan 2030, the North West Rural, Environment, and Agricultural Development Department has established tailor-made policies and plans to better promote agriculture through dedicated funding, technical assistance, and other initiatives.

2.3 AGRICULTURE AND FOOD PRODUCTION

Food production refers to the process of making food. In this case, raw materials are converted into ready-to-use items for human and animal consumption, either at home or in processing plants. Its approach is scientific in nature. A few things must be taken into account to successfully undertake food production. Cleaning, packing, separating, sorting, preparing, adding appropriate amounts of components and presenting are all examples of the tasks entailed in producing food. A variety of plant and animal products are utilised to boost health. Examples of products essential to human well-being include grains, palsies, spices, cereals, honey, nuts, milk, vegetables, fruits, eggs, meat, chicken, and v other items. This underscores the significant dependence of humans on both plants and animals. Together, plants and animals contribute 90 percent of the world's energy (Food and Agricultural Organisation, 2020). Food production encompasses a wide range of activities, including cultivation, selection, crop management, harvesting, crop production, preservation, baking, pasteurization, pudding and candy making, carving, slaughtering, fermenting, pickling, drink production, and operating food shops. Additionally, food production involves various methods such as vegetable chopping, curing, grinding, marinating, emulsification, fermentation, boiling, broiling, frying, grilling, steaming, mixing, pasteurizing, fruit juice processing, peeling, skinning, gasification of soft drinks, and the preservation and packaging of food products using vacuum packs (Kapur, 2020). Agriculture and food production, according to Kapur (2020), are critical in fostering individual health and well-being, eliminating malnutrition, and strengthening communities. According to the FAO (2017), agriculture is the sector that involves methods and practices considered fundamental to food

production. As a result, persistent efforts must be undertaken to enhance the agricultural sector. Using modern, technical, scientific, and innovative ways is regarded as critical not only for strengthening the agricultural industry, but also for generating more food.

The agricultural sector in South Africa is highly diverse, featuring both corporate and private intensive farming systems involved in the cultivation of vegetables, fruits, nuts, and grains. The commercial farming industry is a crucial pillar of the country's agricultural economy, experiencing the fastest growth rate among all economic sectors in 2020 at 13.1 percent (United States International Trade Administration, 2021). South Africa boasts the most modern, productive, and diverse agricultural sector on the continent, providing a stabilizing force amid economic and meteorological uncertainties. Challenges such as credit rating downgrades, land reform concerns, economic volatility, recurring droughts, and the impact of the COVID-19 pandemic are currently affecting the industry. In the fiscal year 2020, agriculture contributed about 10% to South Africa's total export revenues, amounting to $10.2 billion. Major exports included citrus, wine, table grapes, corn, and apples, along with diverse products like wool, almonds, sugar, mohair, and pears.

The country is home to approximately 32,000 commercial farmers, with a subset of 5,000 to 7,000 contributing around 80% of the total agricultural output. South Africa's market-oriented agricultural sector covers a broad spectrum, encompassing major grains (excluding rice), oilseeds, deciduous and subtropical fruits, sugar, citrus, wine, and a significant portion of vegetable production. Livestock products, including cattle, dairy, pigs, sheep, and a thriving poultry and egg industry, are also prominent. The sector engages in value-added activities such as meat processing, fruit and vegetable preservation, dairy product manufacturing, grain milling, oilseed crushing, animal feed preparation, sugar refining, and the production of cocoa, chocolate, and sugar.

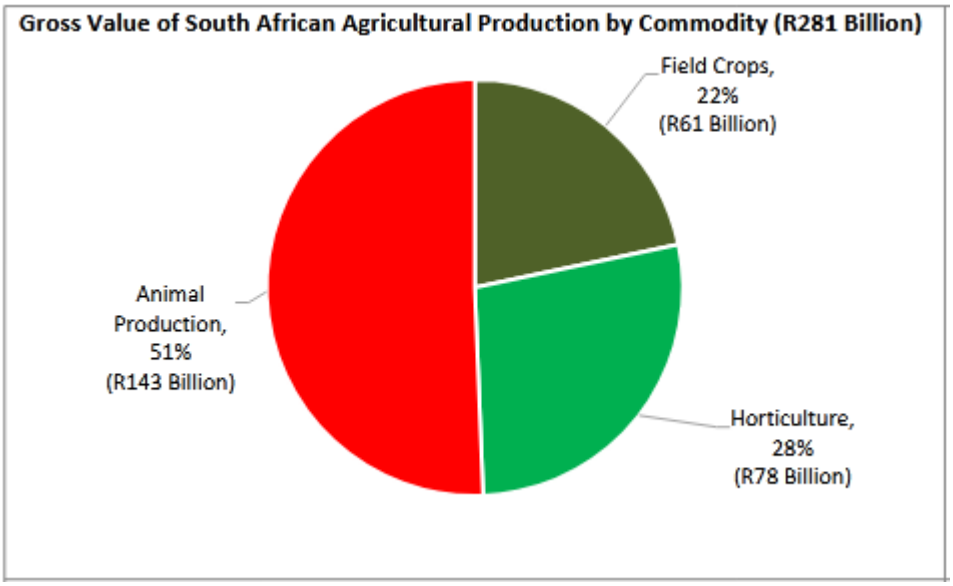


Figure 2.2 Gross value of South African food production.

Source: Global Agricultural Information Network (2019)

2.3.1 Food production in the North West province

The North West Province (NWP) of South Africa has an area of 106 512 square kilometers, with the majority of rainfall falling between October and April. Rainfall decreases from east to west, with an annual average of 539 mm for the province. The climate in the North West Province is semi-arid, making life difficult. From October (the last cold) to the end of April, there is a brief growth season (first frost). Winters are bitterly cold and snowy, while summers are scorching hot. Droughts are a common occurrence in this province (Kruger et al., 2012). All of this adds to the already difficult task of sustaining food production. North West is the leading producer of beetroot, accounting for 65% of the national crop, and the second largest producer of sunflower seeds, trailing only the Free State. Furthermore, the province is the second largest producer of carrots after Gauteng. Maize, sunflower seeds, lucerne, and animals are also important agricultural exports (Kruger et al., 2012). The North West province is a highly productive agricultural region, accounting for approximately 20% of the country's arable land (Sihlobo, 2019). According to the 2017 Census of Commercial Agriculture, the North West province has 4 920 farms (12.3 percent) and 11.5 percent of the country's commercial agricultural area. It accounts for R39.7 billion (11.9 percent) of total agricultural income in South Africa and employs 57,758 (7.6%) of commercial farm workers (StatsSA, 2020).

A large number of sheep farms, cattle ranches, and game ranches can be found in the province's northern and western parts. Maize, sunflowers, tobacco, cotton, and citrus fruits are examples of crops grown in the east and south. Maize (17%), groundnuts (40%), sunflower (34%), dry beans (17%), and grain sorghum (26%) are the province's contributions to national output (Pienaar, 2021). Soya beans, grain sorghum, tobacco, carrots, groundnuts, silage maize, lucerne, beetroot, paprika, pepper, potatoes, onions, cotton, and wheat are among the other crops planted. Cowpea, Bambara groundnuts, cleome (cleome gynandra), amaranths (amaranthus), red milk wood (Mimusops zeyheri), wild medlar (Vangueria infausta), and Num-num are some of the other indigenous vegetables, crops, and fruits. The North West province dominates the poultry industry, accounting for 22% of the country's broilers and 11% of the country's layers (Council, 2021). It is home to 20% of the country's pigs, 13% of its cattle, and 13% of its goats (Pienaar, 2021). Approximately 8% of the country's milk producers and 8% of its dairy processors are in the province (Diniso & Jaja, 2021). In addition, it is home to 13% of South Africa's commercial pork producers (Van Rensburg et al., 2020). Rustenburg and Brits have a lot of mixed-crop farming land around them. The semi-arid central and western parts of the province are primarily devoted to livestock and wildlife farming, with the most common being cattle, pigs, sheep, goats, bees, impala, horses, wildebeest, springbok, and kudu. The Crocodile, Vaal, and Harts rivers all have developed irrigation schemes in place.

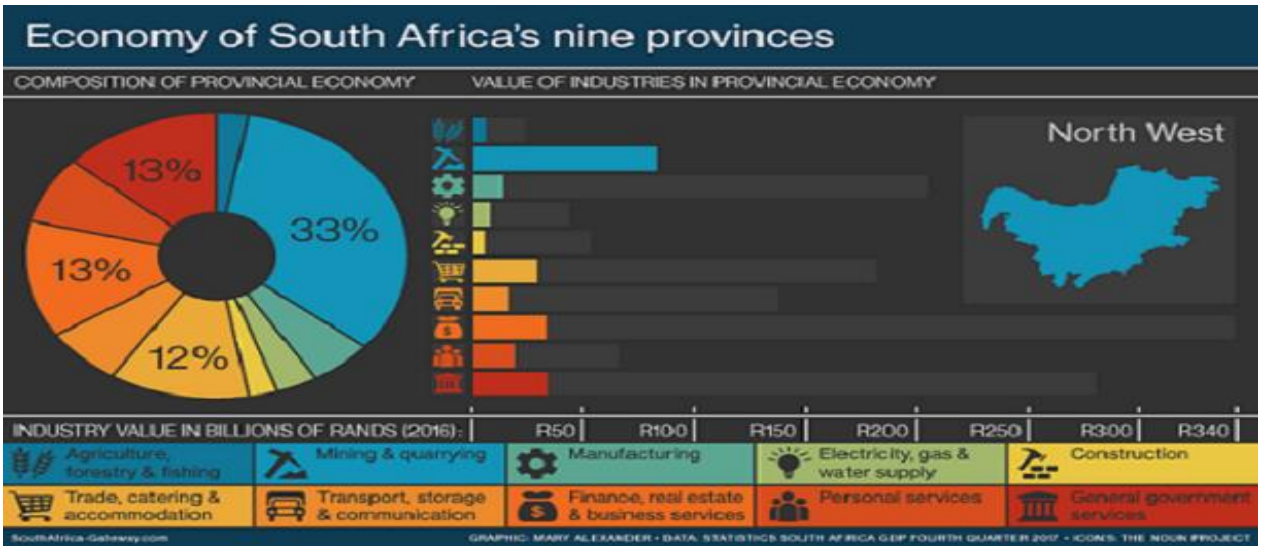


Figure 2.3 Economy of the North West

Source: StatsSA 2020

The current objective of the North West Province is to establish an Agro-Industrial Park that incorporates industrial and commercial facilities tailored for manufacturing and business services,

aiming to attract new enterprises. This goal involves providing state-of-the-art infrastructure in a central location along with specialised safety regulations customised for the industrial zone. The focus is on enhancing cattle beneficiation through the implementation of a world-class, large-scale abattoir, meat processing and packaging plant, and cold storage facilities. Additionally, the plan includes calf hide beneficiation through a large-scale tannery, the production of leather furniture, and the manufacturing of leather footwear.

2.4 MAIZE FARMING IN NORTH WEST PROVINCE

Maize (zea mays) holds a position as the most crucial grain crop in South Africa, serving both as a key livestock feed and a staple food for a substantial portion of the population. In the North West Province, the optimal maize planting period falls between mid-November and the end of November. The timing of the planting is critical, considering the risk of stem borer damage associated with early or late planting and the necessity for sufficient pollination, particularly during the typically hot weather in the North West Province. Planting dates are determined by soil moisture levels.

In South Africa, white maize constitutes about 60% of total production, while yellow maize makes the remaining 40%. Maize is renowned for its efficient use of sunlight, yielding nearly 500 kernels from a single seed and outperforming other grain crops in terms of per-hectare yield. Emerging maize varieties require 450 to 600 mm of water per season, primarily sourced from soil moisture reserves. Maize plants consume around 250 liters of water by maturity, and improving water use efficiency is essential for maximizing maize production with minimal water consumption.

While maize is a staple food in many developing countries, approximately 60% of global maize production is directed toward animal feed. In South Africa, the maize industry significantly contributes to the economy through employment, foreign currency earnings, and various downstream industries like paper, paint, textiles, medicine, and manufacturing. The industry comprises both commercial and emerging agriculture. Wind erosion is a prevalent concern in the North West Province, necessitating the cultivation of stubble or mulch in affected areas.

According to Sihlobo (2019), average maize yields in the North West were 4.4 tonnes per hectare in the 2017/18 season, with a five-year average yield up to 2017/18 of 3.7 tonnes per hectare. Maize production for 2018/19 was expected to yield 3.4 tonnes per hectare. On a global scale, the increasing world population is expected to heighten reliance on maize for both feed and fuel. South Africa leads

the continent in maize production, with the North West Province, Free State, Mpumalanga highveld, and KwaZulu-Natal midlands being primary contributors. The country produces 10-12 million tonnes of maize annually on 2.5 million hectares of land. White maize now constitutes over half of total human consumption output. However, maize production has fluctuated significantly over the past six years across all maize-producing provinces, with a notable decrease in 2017/18 attributed to substantial market carry-over stockpiles prompting many farmers to shift to other crop varieties such as oilseeds.

Table 2.1 Maize output by province from 2012/13 to 2017/18 production season (Tons)

Season	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
PROVINCE						
Free State	6247 000	2264 000	2214 000	7362 000	5 275 000	4 553 000
Mpumalanga	2783 000	2108 000	2319 000	3431 000	2 817 000	2 775 000
North-West	2898 000	914 000	1141 000	3160 000	2 099 000	1 673 000

Source: Statistics and Economic Analysis (2017)

Approximately 98 percent of maize production in South Africa is attributed to commercial agriculture, while emerging agriculture contributes the remaining 2 percent. Maize production has experienced significant fluctuations over the past decade, reaching its lowest point in the 2015/16 season and achieving a record harvest in the 2016/17 season. The 2015/16 season witnessed reduced maize quantities due to decreased cultivated areas, primarily caused by El Niño-induced dry conditions. However, favourable weather conditions in major maize-producing regions led to a record-high yield and increased maize cultivation in the subsequent 2016/17 season. Despite these variations, maize, being a globally traded commodity, is susceptible to the influences of the international market. The dynamics of supply and demand for maize on the global stage directly impact domestic prices in South Africa. An additional factor affecting the domestic market is the import tariff, designed to safeguard domestic producers from the impact of low-cost maize imports (Mapfumo, Chagwiza & Antwi, 2020).

The primary maize-producing regions (Free State, North West, and Mpumalanga) lack adequate export infrastructure for the agricultural goods they produce. A significant amount of maize is shipped through the KwaZulu-Natal port of Durban or the Gauteng grain market of Randfontein.

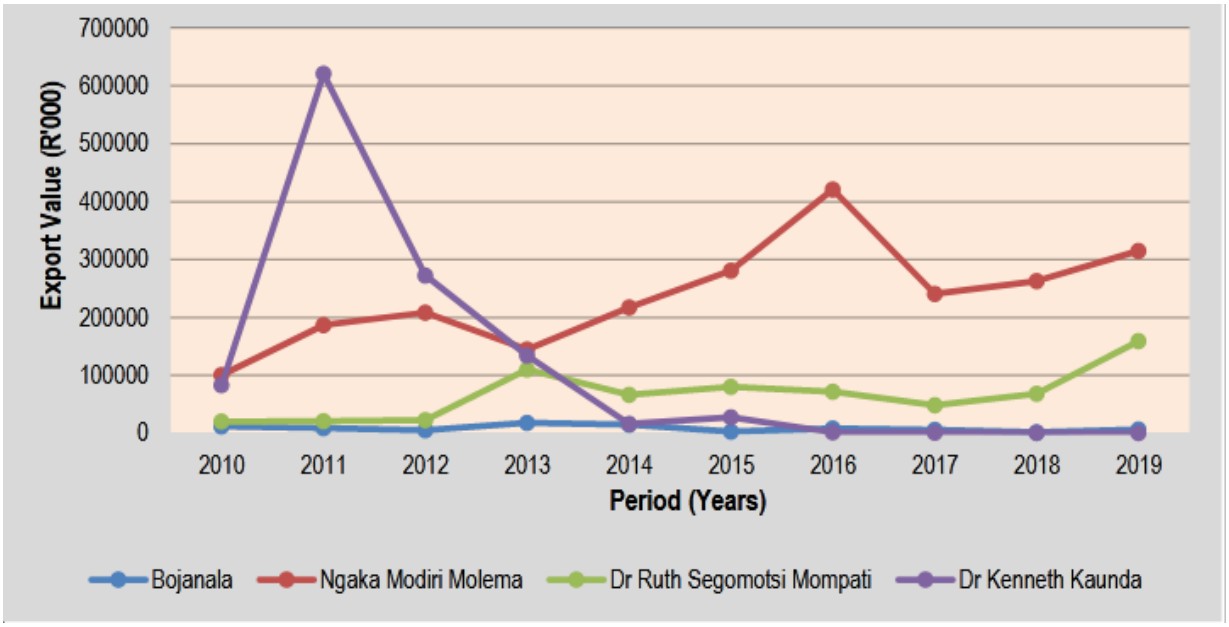


Figure 2.4 Value of North West Province exports

Source: Quantec Easy Data (DAFF 2020)

Maize exports from the North West Province are predominantly sourced from the districts of Dr Kenneth Kaunda, Ngaka Modiri Molema, Bojanala, and Dr Ruth Segomotsi Mompati. Dr Kenneth Kaunda District has consistently been a major maize exporter, with a peak in 2011, owing to its prominence as one of the province's key grain-producing districts. The Ngaka Modiri Molema district follows as the second-highest contributor to maize exports in the North West Province during the same period. In contrast, Bojanala and Dr Ruth Segomotsi Mompati areas exhibited low and unpredictable maize export values. While there were no significant maize exports from the region in 2009, Ngaka Modiri Molema district recorded the highest maize exports during the 2014, 2015, and 2016 marketing seasons. Maize export values from the North West Province experienced a decline in 2017, with increased export values observed in 2018, primarily driven by the Ngaka Modiri Molema district (DAFF, 2019).

In the recent planting season, favourable La Niña rainfall from November 2021 to January 2022 allowed farmers in the North West Province to plant earlier than usual. Crop conditions, ranging from good to exceptional, were confirmed by satellite-derived indices like the Normalized Difference Vegetation Index (NDVI) and the Percent of Average Seasonal Greenness (PASG) in late February. Notably, the North West and Free State provinces, which jointly cultivate 60% of the total crop, experienced crop conditions far above average. If rainfall persists in March, record yields are anticipated in the western regions. The weather forecast for March is favourable, and farmers are

expected to begin harvesting in late April. Typically, from May to August, the majority of the harvest (87 percent) is delivered to grain silos (USDA, 2022).

2.4.1 Enhanced Maize Farming

Each growing season, a maize plant requires 450–600 mm of water, the majority of which is soil moisture reserve. Any amount above that can result in a lower yield per hectare if the crop is not effectively managed. Soil and meteorological conditions influence a farm's overall output, which is referred to as the farm's yield potential. Hybridization has resulted in enormous productivity improvements over many years, which have been supplemented in the last decade by the development of biotech characteristics in North America, Latin America, Asia, and South Africa. To protect their significant investment in novel features, growers require a variety of remedies to protect their crop from weeds, insects, and environmental stress. Because land is scarce and expensive, farmers' value increased maize output.

Corporate farms are increasingly buying family farms as available acreage shrinks. Farmers are under greater pressure than ever to maximize maize yield potential on their farms. Many farmers are dedicated to increasing crop yields and have committed to best practices as well as investing in cutting-edge technologies. Over the past 70 years, hybrid maize varieties have consistently increased agricultural output and nitrogen use efficiency. Hybrid crops hold nitrogen in leaves longer by sustaining leaf function during the grain-filling process, allowing leaves to remain green for ongoing photosynthesis. Because of the longer photosynthetic period, plants can produce more and larger kernels. Maize is valued more than ever as a commodity to help feed the world's rapidly growing population, and farmers can benefit from a variety of agricultural strategies that increase maize yields. These are some examples:

- Farmers must plant at the appropriate times, taking temperature and climate variations into consideration, since maize growers in traditional production areas confront increasingly variable climate in the short and medium term, along with more extreme dry and wet spells, stronger winds, higher temperatures, and more intense rainfall, flooding, drought conditions, and hail incidents. Crop damage is already occurring because of these weather patterns, and crops are becoming more susceptible to disease. Adequate soil testing is required to check for PH levels, the presence of the three basic nutrients nitrogen, phosphorous, and potassium

(NPK), as well as the presence of additional secondary nutrients such as calcium, magnesium, and sulphur.

- Crop rotation is the practice of growing alternating crops to help diversify the soil's demands. Crop rotation produces crops that yield more and produce more consistently, so avoid planting maize over maize in your fields. It is critical to select the best maize-legume crop rotation mixtures based on soil type and nitrogen-fixing properties. Cover crops can also be grown to control and prevent soil erosion, fertility, soil health, water, grass, and pests; some cover crops also provide nitrogen to the soil.
- Farmers must also research and understand the yield potential of the seed varieties they use. It is strongly advised to use seed-specific fertilizers, as these add nutrients such as calcium, phosphorus, and potassium. It is critical to remember that high-quality seeds are the foundation for increasing agricultural production. Hybrid seeds that are naturally inclined to develop faster, stronger, and more efficiently play contribute to crop success. Non-GMO seeds effortlessly combine sustainability and affordability, taking into account both quality and cost.
- Another way to boost crop productivity is to use a variety of herbicides to eliminate roundup-resistant weeds. To combat roundup-resistant weeds, many farmers use non-selective herbicides, which are designed to kill all plants, and the use of multiple selective and/or non-selective herbicides is recommended. To avoid crop damage, weeds must be eradicated early and frequently. Some high-yielding seeds should be treated with fungicides.
- Starting fertilizers have become an essential component of the majority of high-yield maize growing operations. This is because maize normally responds well to the addition of phosphorus, a known immobile nutrient, to the root zone. This positioning improves plant absorption when the roots are small, promoting early growth and plant maturity. When zinc, another immobile nutrient, is added to starter fertilizer, crop responsiveness may be improved. Farmers can improve nitrogen availability by using better nitrogen application timing and procedures for a variety of nitrogen sources. A warm and high-rainfall climate, for example, increases potential nitrogen loss through de-nitrification and leaching significantly more than a dry and cold climate.

2.4.2 Enhanced maize farming in North West province

The optimal period for planting maize in the North West Province falls between mid-November and the end of November. Early plantings are more susceptible to stem borer damage compared to late plantings. When selecting a planting date, it is crucial to consider the growth season of the chosen cultivar to ensure reliable pollination, especially in the face of extremely hot weather common in the North West Province. The decision on the planting date is influenced by the moisture content in the soil. Addressing wind erosion is a constant challenge in the North West Province, and in problem areas, cultivating stubble or mulch is recommended. Applying compost or organic matter, such as manure, is advisable three to four weeks before planting. Fertilizer application should follow once soil analysis results are available, with the choice of fertilizer often based on anticipated yield and the previous crop in the case of crop rotation. Maintaining a pH (KCl) between 5.0 and 5.5 is essential, and soils with a pH (KCl) below 4.5 should undergo liming.

For the North West Province, a recommended plant stand ranges from 14,000 to 18,000 plants per hectare, depending on the area's potential and proportion to the desired output. The typical planting depth in the North West Province is 3 to 5 cm. The most prevalent insect pest for maize is maize stalk borers. According to Moeletsi (2017), temperature is one important environmental factor influencing how a crop develops from one stage to the next. Temperature, and more specifically sums of daily temperatures, has a direct relationship with the amount of time it takes a plant to complete a specific growth stage. It has already been discovered that cool temperatures slow growth whereas warm temperatures accelerate maturation, as a result, farmers must cultivate at optimal times by testing the soil to determine if the temperature is suitable. Adequate preparation of the seedbed and use of appropriate planting equipment are required so that the seed has good soil contact and is planted at the correct depth with adequate row spacing. The planting depth should be between 112 and 2 inches, but no less. For high yields, even planting depth with no seed bounce is critical. Uneven emergence can cause inconsistency in plant competition, which can last all season.

In 1998–1999, South Africa pioneered the commercial introduction of BT yellow maize, followed by the introduction of BT white maize in 2001–2002, making the country the first global producer of genetically modified (GM) subsistence crops (Gouse, 2012). The commercialisation of herbicide-tolerant (HT) maize occurred in 2003–2004, and stacking characteristics were introduced in 2007–2008 (Gouse, 2012). By 2016, HT cultivars constituted 74% of the total maize crop in South Africa, while BT cultivars accounted for 91% (Brookes and Barfoot, 2018). Currently, only a few GM crops,

including papaya, squash, apple, potato, eggplant, and white maize, are commercially cultivated for direct human consumption (ISAAA, 2017). White maize is notably the sole staple crop produced on a large-scale using GM varieties, with South Africa commercially cultivating around 1.1 million hectares (an 85% adoption rate) of GM varieties for direct human consumption in 2017. GM hectares are more prevalent than non-GM hectares, particularly in the key production zones of the North West and Free State provinces (ISAAA, 2018; Ala-Kokko et al., 2021).

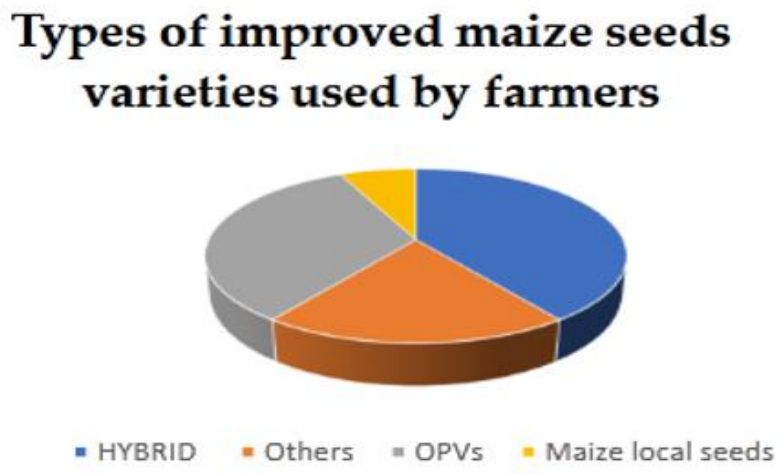


Figure 2.5 Farmers' preferred varieties of enhanced maize seeds

Source: Sigigaba *et al., (*2021)

As depicted in the figure 2.5, the most commonly employed varieties of enhanced maize seeds include HYBRID, OPVs, and others. HYBRID stands out as the predominant high-yielding seed type widely accepted by farmers, who note its availability in markets and its significance in livestock feeding. Smallholder farmers primarily use these modified maize varieties for both market sale and household consumption. The second most utilised enhanced maize variety is OPVs, although farmers express concerns about their limited availability in markets and insufficient awareness about this type of improved maize variety. In contrast, local seeds constitute the least utilised maize variety, accounting for only 7%, with farmers expressing apprehension about their poor yield.

Access to improved maize varieties remains limited across Africa, presenting a challenge, particularly for small-scale farmers who may lack access to advanced farming techniques (Epule, Chehbouni & Dhiba, 2022). Consumer behaviour theory suggests that the adoption of new technology by smallholder farmers is influenced by various factors, encompassing technology, socioeconomic conditions, policy, research, and institutional factors.

The adoption of enhanced maize varieties is perceived as a crucial link that facilitates the flow of information and seeds to farmers, leading to the production of marketable products and income generation to enhance living standards (Kakuru, 2019). The adoption of improved technology is pivotal for agricultural productivity and the livelihoods of small-scale farmers in developing countries. Improved seeds, with higher yields, disease resistance, and drought tolerance, are essential for increasing agricultural production and global food security (Almekinders et al., 2019). While traditional seeds yield less, they are better adapted to the local environment, providing a minimal yield even under adverse conditions such as low soil fertility, which is an argument in favour of smallholder farmers using traditional seeds as opposed to modified ones (Dokyi, Anang & Owusu, 2020).

2.4.3 Benefits of maize farming

Maize (Zea mays L.) is a major agricultural crop grown throughout the world, and an important component of cattle feed. In terms of total global production, maize has outperformed paddy rice (Oryza sativa) and wheat (Triticum aestivum) over the last five years. Global output reached 600 metric tonnes, with developed economies, specifically the United States of America, accounting for 60% of total output. China produces 27% of the world's maize, with the remainder grown in African, Latin American, and South Asian countries, with a large proportion grown in the tropics and subtropics (Humaet al., 2019). Corn, also known as maize, has a plethora of health advantages. The beta-complex vitamins are critical to human health. They play an important role in the health of the hair, skin, heart, and digestive system. These are also beneficial in rheumatism because they help with limb and joint movement. Vitamins K, C, and A, as well as carotenes, have a strong positive impact on immunity and health, including optimal thyroid gland function.

Maize or corn silk also has advantages (Saeed & Saeed, 2020). They are used to treat kidney problems, jaundice, and fluid retention in many countries. Maize also contains phytochemicals, which are active substances that are important to human health because they protect the body from chronic diseases. These phytochemicals include phenolic compounds, carotenoids, and phytosterols. Approximately 260 phytosterols have been studied to date (Balasubashini et al., 2015). Stigmasterol, sitosterol, and compesterol are the most common sterols. Furthermore, Shah, Prasad, and Kumar (2015) estimate that the nutritional value of maize per 100g is Carbohydrates 72 g, Proteins 8.9 g, Fats 5 g, Fibres 2.2 g, Ash 2.4 g, Moisture 11 g, Phosphorus 350 mg, Sodium 16 mg, Sulphur 115 mg, Riboflavin 0.11 mg, Amino acids 1.80 mg, Minerals 1.6 mg The maize plant's leaves, grain, tassel, cob, and stem can be used to make a variety of food and non-food products. Maize cultivation is a major source of food for

most Ghanaians and is thus critical to ensuring household food security in Ghana. Maize is used in the diets of poultry and cattle, as well as in the brewing industry (Angelucci, 2012)

Maize stands out as an ideal candidate for producing therapeutic proteins. Mature maize seeds share common characteristics with other cereals, being dry, devoid of active proteases, and containing a diverse range of molecular chaperones and disulphide isomerases that facilitate protein folding (Dokyi et al., 2020). Additionally, maize possesses a smaller grain size and higher endosperm content compared to other cereals, and the protective husk acts as a barrier against microbial infection. The natural protein storage capacity of maize seeds makes them an excellent vehicle for the consistent accumulation of recombinant proteins, including antibodies (Wei et al., 2014).

Maize plants have undergone selective breeding to enhance their suitability for food and feed production, resulting in increased seed yield and higher biomass production per hectare, ultimately lowering production costs compared to most other cereals (Saeed & Saeed, 2020). In veterinary applications, maize seeds expressing the TGEV antigen protein demonstrated protective effects against transmissible gastroenteritis virus (TGEV) in pigs, showcasing the potential of maize in this regard (Kumar & Jhariya, 2013). Furthermore, maize, like other cereals, can be processed or partially processed into various forms such as flakes or flour for the production of specific products, effectively reducing downstream costs. Examples of such products include bulk industrial enzymes, topical cosmetic/pharmaceutical medications, and oral vaccinations.

2.5 AGRICULTURAL SUSTAINABILITY IN THE NORTH WEST PROVINCE

Achieving sustainable agriculture necessitates the alignment of three key objectives: environmental well-being, economic viability, and social and economic equity. All stakeholders, including farmers, food processors, distributors, retailers, consumers, and waste management, play a crucial role in advancing the cause of making agriculture sustainable. The agricultural industry is modernising, and data-driven weather intelligence is critical to long-term success. Implementing modern agricultural decision-making activities has always been difficult due to the abundance of constraints that are outside of a farmer's direct influence, such as weather and climate change (Setshedi & Modirwa 2020). The concept of sustainable agriculture involves people from a wide range of professions. Practitioners in sustainable agriculture and food systems routinely employ diverse strategies. Farmers can focus on enhancing soil health, practicing water conservation, and minimizing pollution on their farms. Individuals and businesses with a sustainability focus, such as consumers and retailers, may opt for "values-based" foods produced in manners that prioritise the well-being of farm workers,

environmental friendliness, or support the local economy. Researchers in sustainable agriculture often engage in interdisciplinary collaboration, integrating fields such as biology, economics, engineering, chemistry, community development, and various others. In contrast, sustainable agriculture is more than just a set of practices. It is also a negotiating process: a squabble between the often-conflicting priorities of a farmer or members of a community as they strive to resolve complex concerns about how food and fibre are produced.

The North West province, according to Tefft et al. (2017), is home to a wide variety of production facilities, including automobile parts, non-metallic minerals, fabricated metals, food processing, soya protein, cereals, and a variety of other items. According to the NWP Economy (2018), the province's Agro-Industrial Parks have a specific function:

- Springbokpan in Ngaka Modiri Molema District Municipality (grain): The silo at this geographical area has been revived and is now running.
- Vryburg in Dr Ruth Segomotsi Mompati District Municipality is well-known for its cattle and red meat.
- Moretele/Makapanstadt in Bojanala District Municipality is known for its horticulture and red meat.
- Maquassi Hills in Dr Kenneth Kaunda District Municipality boasts of pork and poultry production.

Among the agri-processing enterprises being considered for the city of Mahikeng are a feedlot and a meat processing factory with packing facilities. Taung's plan is to build a plant that manufactures animal feed.

According to Tabane (2017), the North West Province considers quality of life as a powerful predictor of sustainability in the North West Environmental Implementation Plan 2015-2020, and also adheres to the reasoning that the strength of the economy determines the quality of life of a society. A healthy environment and good governance aid these elements. Understanding sustainability, according to Clayton and Radcliffe (2018), requires a systems perspective. The entire system is considered, from the individual farm to the entire ecosystem, as well as the communities impacted through this farming system on a glocal and global scale. A systems-oriented approach allows for a more comprehensive understanding of the impact of farming practices on both humans and ecosystems. A systems approach provides a way to investigate the relationships between agriculture activities and other components of

the environment (Clayton et al., 2018). Future generations will be unable to produce and harness the arable land if the NWP agriculture industry does not advance beyond current techniques. Previously, agriculture was all about maximizing available land and producing as many crops as possible. Long-term crop productivity and land protection received little attention. There was little emphasis on profitability or protecting land and resources from a business standpoint. These two concepts are inextricably linked. Farmers can also practice sustainability by using less non-renewable energy, using fewer chemicals, and conserving scarce resources. Farmers must also cut costs and increase profits by farming more efficiently and moving food from farm to fork in a way that benefits the agricultural value chain. Seed drills, sprayers, soil spreaders, drones, and satellite photography, for example, could all benefit from the internet of things (IoT) sensors.

2.6 DIGITAL TECHNOLOGY

Advancements in digital technologies are faster than any other in history, reaching more than half of the emerging economies in less than two decades and continuously developing society (World Bank Group, 2016). Technology has the potential of becoming a huge equalizer by enhancing communication, access to financial services, agricultural production, import and export access, and access to basic services. In the health industry, for instance, AI-enabled frontier technologies have actively helped in the saving of lives, diagnosis and treatment, and the extension of life expectancy. Students who would otherwise have been excluded from programmes have been able to participate thanks to virtual learning environments and distance learning in education. Government services have become more and more available to the public, accountable, and less bureaucratically strenuous because of AI (Frazier 2018). Big data can also help decision-makers and developers create more adaptable and highly accurate policies and programmes. People who have yet to adopt, on the other hand, are barred from reaping the benefits of this new era and are slipping further behind. Women, the elderly, persons with disabilities, marginalized people or minority language groups, indigenous peoples, and locals living in poor or rural locations make up a large proportion of those left behind. Among some constituencies, the rate of interconnectedness is steadily declining, if not reversing. For instance, the proportion of women who use the internet is 12% lower than that of men worldwide. Whereas the divide shrunk in most regions between 2013 and 2017, it widened in emerging market economies, growing from 30% to 33%. When algorithms are applied to insufficiently diverse data, they may reproduce and even amplify human and ideological bias. Because of some kind of lack of diversity in the IT sector, this concern may go unaddressed.

Currently, digital tools like data pooling and artificial intelligence (AI) can be used to check and diagnose problems in agriculture, health, and the ecosystem, as well as to perform daily tasks like navigating traffic and paying bills (Trendov, Varas & Zeng, 2019). They could be used to protect and exercise human rights, but they can also be used to violate them, such as trying to track movement, purchases, interactions, and behavioural patterns. To achieve financial and other goals, governments and organisations are increasingly armed with data mining and exploitation capabilities. Personal data, on the other hand, could become a person's asset if a model for better control of personal data ownership were established. Depending on the safeguards put in place, data-driven technology has the potential to empower individuals, improve human welfare, and promote universal rights (Newlands, 2020).

Wiener (2016) says that the term "digital" originates from the Latin word "*digitus*," meaning finger, and it is associated with one of the earliest counting tools. At its most basic level, digital technology involves the conversion of information into numerical representation, often expressed as the binaries "zeroes and ones," particularly in microprocessor-based systems such as computers, internet-connected applications, video cameras, smartphones, and other devices. Digital technology encompasses the operating constructs, processes, and standards relevant to the technological sector (Wiener, 2016). Examples of digital technology include websites, smartphones, blockchain, cryptocurrencies, artificial intelligence, cloud technology, 5G data, voice communication protocols, chatbots, robotic systems, unmanned aerial vehicles, e-books, and video streaming devices, automated systems, or technological resources that generate, process, or store information. Digital technology has the potential to enhance both creative abilities and information services.

According to the Economic Commission of Latin America and the Caribbean (ECLAC) study (2021), "Digital Technology" also encompasses software, hardware, or network solutions that support, expand, or facilitate commercial activities. This includes web-based or mobile-based software solutions like Enterprise Resource Planning (ERP), Customer Relationship Management (CRM), Point of Sales (POS), Inventory Management, Accounting, Business Social Media Platforms, HR and Payroll Management Software, ChatBots, Communication Apps, and more. The use of digital technologies has witnessed exponential growth globally, driven by widespread smartphone adoption, providing ubiquitous and continuous connectivity for most of the global population (ECLAC, 2021). The prevalence of devices and applications leveraging cloud computing, big data analysis, blockchain, or artificial intelligence has become commonplace due to the rapid advancements in digital technology.

The advancement of technology has brought about sociological drawbacks, particularly the exclusion of a significant portion of the global population from the benefits of digitalisation. This exclusion is primarily due to a lack of financial resources to afford meaningful connectivity, including access to high-quality internet, devices, standard home connections, and the capacity to utilize these resources regularly. In regions with a substantial reliance on agriculture for rural livelihoods, such as in many economically challenged parts of the world, information and communication play a crucial role in agricultural productivity. Since the inception of agriculture, people have exchanged information on optimal planting techniques, sources for improved seeds, and the prevailing market prices for their produce. Weather patterns and soil conditions evolve over time. Pest and disease outbreaks come and go. Farmers can adapt to and benefit from these changes if they have up-to-date information and the ability to share their knowledge (Lybbert & Sumner, 2012).

Since the late 1980s, digitization has had a remarkable impact on economic growth and humanity. The inception of a connected economy marked by widespread Internet usage and the rollout of broadband networks laid the foundation. Simultaneously, there was a surge in the automated economy, characterised by an increased reliance on digital tools as integral business strategies for delivering goods and services. The prevailing economic trajectory now appears to be shifting towards a digitalized economic system, where manufacturing and consumption patterns are shaped by the integration of digital technology across economic, sociocultural, and environmental dimensions. The successful adoption of advanced digital technologies, including fifth generation (5G) mobile networks, the Internet of Things (IoT), cloud computing, artificial intelligence, big data analysis, robotics, among others, signifies a shift from a hyperconnected to a digitalized world. This transition involves a cultural shift where the traditional economic system, encompassing institutional, productive, and governance structures, integrates with the digital economy, encompassing technology innovation, manufacturing, business enterprise, and governance. As a natural consequence, a unique, digitally connected system emerges in which frameworks from both areas of the economy interact, resulting in interconnected ecosystems that are experiencing rapid organizational, systemic, and governance development (ECLAC, 2018).

The dynamics of digitalization are in constant flux, influencing socioeconomic, production, and governance activities. Consequently, the digital transformation process is highly adaptable and intricate, presenting challenges for government policies that need continual adjustments and a systematic approach for a country's economic growth. At a macro level, disruptive technologies reshape information exchange, connectivity, and consumption patterns, leading to increased demand

for devices, more functional software, cloud technology, data traffic services, and the fundamental digital skills necessary for utilizing these technologies. The digital economy offers consumers access to extensive information, expertise, goods, services, and more efficient forms of remote consumption. The shift to a digital economy implies that smart devices, often linked with advanced, personalized services, can cater to consumer needs, contributing to increased consumer well-being. This also requires an evolution in digital skills for more sophisticated technological consumption and new labour requirements arising from innovative production models. Concurrently, emerging consumption patterns align with potential benefits such as reduced material use and environmentally sustainable alternatives.

Ananyin (2018) asserts that digital technologies facilitate ecological innovations that promote environmental sustainability by reducing environmental impact and optimising resource utilization. As these technologies advance and intersect with biotechnology and nanotechnology, they hold the potential for exponential advancements contributing to a more sustainable future. Digitalization impacts the environment both positively and negatively. On the positive side, it can dematerialize the economy by enabling the provision of digital goods and services, a significant part of the economy and exports. The rise of the product-as-a-service (PaaS) model allows users to assess the intended outcomes of using a product without purchasing it, leading to a significant shift in consumption. Mobility as a service (MaaS) applies this paradigm to integrate transportation services, reducing greenhouse gas emissions, promoting sustainable cities, and influencing agricultural practices. According to the Global e-Sustainability Initiative (GeSI) report, implementing digital solutions across various sectors could reduce global CO2 equivalent emissions by 12 gigatonnes by 2030, with mobility solutions contributing the most, followed by applications in manufacturing and agriculture. Real-time traffic data, smart logistics, and digitally enabled solutions have the potential to cut CO2 equivalent emissions by 3.6 gigatonnes, including savings from avoided trips (Ananyin 2018).

There are various types of digital technology, according to Kapur (2017). Computers, laptop computers, smart phones, and cell phones are by far the most used gadgets in all industries. Individuals must recognise what technologies are used within the organisation, how they function, and how their use will vary. In his study, Kapur (2017) asserted that there are three major digital obstacles to overcome: cyber-safety, conduct or behavioural concerns. The second type is cybercrime, which entails criminal behaviours, and the third type is cyber-security, which entails unauthorised and illegal system use. When using digital technologies as preventive measures, people should understand how to use them appropriately, cultivate a pro-social culture, and collaborate with the larger society to

prepare for and respond to incidents (Deichmann, Goyal & Mishra, 2016). The internet, mobile phones, and other similar technologies that make it easier to capture, store, analyse, and share data and information are altering many aspects of life for a sizable and growing portion of the world's population. These digital technologies are gaining traction. In 70% of cases, mobile phones are available to even the poorest 20% of developing-country residents (World Bank, 2016). People immediately benefit from digital technologies as they can converse with friends and family more easily and have access to various sources of entertainment and information. These are highly valued characteristics that explain the widespread use of mobile phones, even among those with inadequate funds (Mwangi & Kariuki, 2015; Deichmann et al., 2016).

Traditional economic principles, according to Deichmann *et al.* (2016), adequately explain the influence of the internet and related technologies. Most notably, these technologies reduce the monetary and time costs of purchasing and communicating data, thereby lowering transaction costs. They include the costs of seeking and exchanging information, negotiations and decision making, as well as policing and enforcement, according to a common definition. Despite a few special cases, such as intricate contract negotiations, the internet has simplified, accelerated, and reduced the cost of many types of transactions. A lender may be hesitant to make a loan to a small-scale farmer because there is no clear way to determine creditworthiness. Today's technology enables the disabled to interact via text, speech, and video; people can work from home more conveniently for customers halfway around the world; and new data sources, such as phone records, help extend credit to those who do not have access to traditional financial services (Mwangi & Kariuki, 2015).

2.6.1 Digital technology in the North West province

The digital transformation of the manufacturing sector is evolving into new models of management, business, and production, fostering innovation and market entry while disrupting traditional industries (Kapur, 2017). The increased integration of the industrial Internet, smart systems, virtual value chains, and artificial intelligence within manufacturing processes is accelerating innovation, enhancing productivity, and contributing to overall economic growth. This rapid transformation is particularly evident in traditional industries like automotive technology (autotech), agricultural technology (agritech), and financial technology (fintech). Smart production models have the potential to enhance competitiveness while reducing environmental impact. Organisations are leveraging digital technologies to analyze and mitigate their environmental footprint, as well as to adapt their production methods in response to climate change. Modern digital technologies are regarded as the primary source

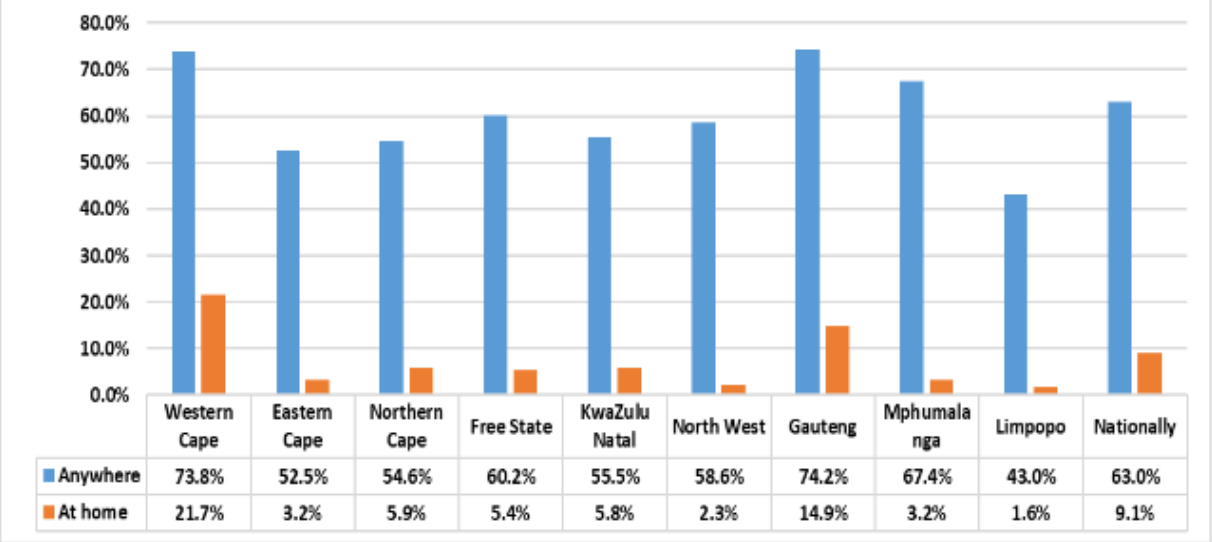
of sustainable competitive advantage that defines the increase in social welfare in the new paradigm of global economic development. The following are the main technological trends in digital technology use, according to the Eurasian Economic Commission:

- ✓ Smart sensors in manufacturing plants, machinery, and assembly lines;
- ✓ Information storage, processing, and administration using "cloud" resources;
- ✓ Full automation throughout the entire agricultural process, along with the integration of agribusiness, production, and management operations in a unified information system.
- ✓ Utilisation of both structured and unstructured data to generate analytics for informed managerial decision-making.
- ✓ Adoption of standardised digital formats for technical documentation and electronic document management.
- ✓ Implementation of mobile technologies for monitoring, controlling, and overseeing production processes.
- ✓ the application of mobile technologies to the tracking, control, and management of manufacturing activities.

Participation in online business fora and having a personal email account are the most important digital income factors, according to StatsSA (2019), 85.5 percent of employed people do not use the internet for business, while 60.4 percent do. Digital technology, according to Kapur (2017), is widely used in businesses to carry out work activities. Individuals can use applications to communicate with others. Household bills such as electricity and water are now paid using digital technology. People can now order groceries and other items online, demonstrating how digital technology has improved their daily lives. Twinomurinzi et al. (2021) suggests that the level of digital social inclusion, defined as the perception that digital technologies enable individuals to feel connected to society, is at its highest in KwaZulu-Natal (66.9 percent) and lowest in North West (21.5 percent).

Technological advancements have the capacity to enhance global equity, peace, and justice. Each of the 17 Sustainable Development Goals, ranging from eliminating extreme poverty to reducing maternal and infant mortality, fostering sustainable agriculture and decent work, and achieving universal literacy, can be facilitated, and improved through technological progress. Conversely, technology also carries the risk of compromising privacy, bypassing security measures, and exacerbating existing inequalities. Farmers in the North West province can benefit from digital technology by gaining access to new and existing farming information used around the world and

sharing their experiences. It also allows farmers to maintain partnerships and establish channels or links for shared learning among farmers, scientists, and other agricultural stakeholders. Customers who participate in this sector and provide feedback to farmers as well as expand on customer satisfaction by sharing their experiences are considered stakeholders. Digital technologies have been a critical enabler of connectivity throughout the global pandemic, allowing us to go about our daily lives while attempting to connect more people than ever before (ICASA 2021). Access to a dependable and consistent digital infrastructure has therefore become more and more crucial, and in an era of isolation, some aspects of ICTs - like the expanded opportunities for ICT in telework, telemedicine, food delivery and logistics, online and contactless payments, remote learning, and entertainment - have become critically important (ICASA 2021).



	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu Natal	North West	Gauteng	Mphumalanga	Limpopo	Nationally
Anywhere	73.8%	52.5%	54.6%	60.2%	55.5%	58.6%	74.2%	67.4%	43.0%	63.0%
At home	21.7%	3.2%	5.9%	5.4%	5.8%	2.3%	14.9%	3.2%	1.6%	9.1%

Figure 2.6 Shows that the 2019, proportion of households with home Internet access, or that has at least one user who has access to or uses the Internet, differs significantly by province.

Source: StatsSA GHS, 2019.

Grain producers in South Africa's North West province have adopted precision farming for their dryland crops since 2001, as indicated by Clayton et al. (2018) and Ungerer et al. (2018). This approach involves the use of satellite imagery and yield monitors to cultivate alternating crops of soya beans and sunflowers. The advanced system creates maps and monitors the physical and chemical properties of the soil. Spatial features are digitized, and computerised algorithms are employed to predict maize production based on the soil's water-holding capacity. Areas with low potential are converted to pastures, and soil nutrient levels are assessed and enhanced to maximize the land's productivity.

Additionally, some farmers utilize soil moisture sensors to manage low moisture content, indicating the necessity for a fallow system to conserve water in cultivated areas. Technological advancements have led to increased average maize production and improved water utilisation by farmers (Ungerer et al., 2018).

2.6.2 Smart farming in the North West province

The North West Provincial government is making significant efforts to fulfil its commitment to embracing digital technologies, as highlighted by Lobelo (2020). The initiative is focused on imparting skills in software, app and web development, artificial intelligence, and robotics, all of which play a crucial role in the country's Fourth Industrial Revolution (4IR), contributing to economic growth and job creation. Various programmes have been implemented to enhance the integration of digital technologies across multiple sectors, including agriculture. Farmers are taught how to use IoT systems, drones, and other agritech and digital technology. According to Lobelo (2020), this heps farmers use digital technologies to increase yields, reduce farm waste, increase profits, process their own raw materials, and gain quick access to new markets.

Climate variability has resulted in a consistent shift in total crop area in South Africa's production of different varieties of field crops. The white maize crop area witnessed a reduction from 1.5 million hectares to 1.1 million hectares, as reported by the Department of Environmental Affairs in 2016. Additionally, dryland wheat production in the Free State, Limpopo, and North West provinces decreased from around one million hectares in the late 1990s to 200,000 hectares by 2013. The Gauteng province experienced a 57 mm decline in rainfall between 1985 and 2014, signifying a substantial impact of climate variability. Furthermore, the province encountered a temperature increase of approximately 0.5 degrees Celsius, potentially contributing to heightened drought occurrences (Elum, Modise & Marr, 2017). Potato and cabbage production faced challenges due to high/extreme temperatures, affecting 77 percent of potato farmers and 67 percent of cabbage farmers across the provinces (Elum et al., 2017). The observed patterns are attributed to farmers' failure to implement risk-mitigation measures, leaving crops susceptible to climatic risks, as noted by the Department of Environmental Affairs in 2016. Consequently, the vulnerabilities of South African farmers, particularly smallholders, in terms of production and socioeconomic aspects, were exposed. To address the potential adverse impacts of climate change on food production, security, the environment, adaptability, sustainability, and livelihoods, farmers need to adopt drastic measures. Implementing climate-smart agriculture (CSA), which addresses integrated goals such as agricultural production and

yields, minimizing greenhouse gas emissions, enhancing overall adaptability, and promoting farmer and agricultural system adaptation, is a sustainable action option that has gained prominence in the last decade (FAO, 2010; Barnard et al., 2015; Andrieu et al., 2017). Several nations around the globe have deployed CSA strategies and technologies to overcome climate change challenges while also improving economic and agricultural growth (World Bank et al., 2014). Smart farming's goal is to improve the dependability, predictability, and sustainability of all aspects of farming. Farmers all over the world have long been expected to make critical decisions as to what to grow and how to grow it based on incomplete, frequently incorrect information (Khanna & Kaur 2019). The role of new agricultural technologies is to bridge this knowledge gap by providing precise measurements of the factors that influence farming outcomes. These measurements serve as the foundation for recommendations on fertiliser types, crop rotation strategies, and a variety of other field management issues. Smart technologies include precision irrigation, Climate Smart, greenhouse technology management and control, sensors for soil, water, light, moisture, and thermal management, software platforms (SaaS), location systems (GPS, satellite, etc.), and communication systems based on mobile connections.

Smart farming provides numerous opportunities for reducing one's ecological footprint. The use of site-specific inputs, as well as the sparing use of resources such as pesticides and fertilisers, could all reduce leaching and the release of harmful greenhouse gases into the environment (Ojha, Misra & Raghuwanshi, 2021). With the advancement of ICT, farmers can now interconnect and observe the status of soils, animals, and plants, as well as match it with the needs of production inputs such as medicines, fertiliser, and water. Second, agricultural profitability is simple to achieve with smart farming. Certain resource input reduction techniques help farmers save a lot of money on labour and the need for reliable spatial data in risk reduction. This is because smart farming promotes the use of technology in site-specific weather forecasting, disaster and disease probability mapping, and yield forecast. Smart farming adoption and implementation are not hampered by information technology. Smart farming has enormous potential to increase agricultural profitability and sustainability, increase consumer acceptance, and reduce resource inputs and costs (Wolfert *et al.*, 2017).

- The Digital Agriculture Profile of South Africa (2020) categorises digital agriculture end users into four hubs to streamline coordination and production efforts, each facing distinct challenges and having unique resources and digital needs:
- Input Hub: This encompasses all entities providing agricultural inputs like seeds, feed, agrochemicals, machinery, and finance. Challenges in this hub include a deficiency in robust

decision support tools and poor monitoring and traceability of inputs. Advanced applications for this hub involve tracking, traceability, remote sensing, and online platforms such as Bluetooth Low Energy (BLE) or Bluetooth Smart. Precision agriculture utilises remote sensing, drone imagery, and artificial intelligence for improved field input management. Collaborative online platforms with the government facilitate better communication between agricultural departments and farmers.

- Production Hub: The hub involves crop farmers and livestock keepers. Challenges include a lack of decision-making tools, financial services, access to markets, and high startup risks aggravated by climate change. Promising solutions for this hub include mobile platforms and accessible networks connecting farmers to markets, input suppliers, and service providers, especially advisory and finance services. Integrated climate and weather forecasting (Climate Smart Agriculture) and online training in agribusiness and farm management are crucial, particularly in regions prone to drought like South Africa's North West Province. Farmers will require low-power, wide-area network approaches to gather information from IoT ONE sensors like weather, soil, and livestock.
- Distribution Hub: This has all players in the value chain between producers and consumers, such as market participants, logistics providers, processing units, and retailers. Common issues in this hub include poor market access, marginal value addition, high costs, inefficiencies, and postharvest waste. Technologies like vehicle tracking using GNSS for geolocation and GSM or satellite communication for real-time communication are required. IoT systems for tasks like temperature sensing in vehicle fleets, database technologies, bar-coding, and IoT solutions for product tracking and traceability are crucial. These technologies optimize value chains, enhance efficiency and transparency, and increase accessibility for farmers in the value chain.
- Consumer Hub: This brings under the umbrella consumers of raw and processed agricultural products, including the entire population. Challenges in this hub involve a lack of procurement decision support tools, food waste, limited market access, and concerns about food quality and safety. Blockchain technology would simplify and accurately trace products in the Consumer Hub's supply chain. South Africans are careful and aware of low-quality inputs that produce low-quality output. Traceability provides product transparency to consumers while also enabling producers to charge a premium for the additional cost of high-quality products in niche markets. Furthermore, product recalls of poor quality or contaminated food would be near instantaneous, and consumers would be able to rely on value chain participants to supply safe food (Born *et al.,* 2020).

2.7 THE MEANING OF GOVERNANCE

Governance has become a central paradigm in various social sciences since the 1980s, sparking numerous discussions, articles, books, and research endeavours. The definition of governance is multifaceted, varying across disciplines, approaches, and contexts. Its roots go back to ancient civilizations, with the term deriving from the Greek "*kybernan*," meaning "to steer or pilot a ship," and the Latin "*gubernare*," signifying "to direct, rule, and guide." Evolving over time, governance now encompasses the intricate interactions among governments, businesses, and non-profit organisations to facilitate policy implementation. Widely embraced in fields such as public administration, economics, political science, management, law, and sociology, governance is generally perceived as the systems and processes governing both self-governing entities and government institutions.

Distinguishing between governance as an end and governance as a means is crucial: governance as an end emphasizes the value of open, democratic government. Interventions in this context aim to make governance more inclusive, addressing concerns about the exclusion of the poor from political processes. Governance as a means views the practice as a tool for achieving better livelihoods, jobs, housing, and services for the poor. Improved collaborations between governments and other sectors are seen as instrumental in achieving these outcomes.

The term "governance" is widely recognised and utilised by international organisations and democratic governments to describe the intricate processes involved in addressing complex issues. The overarching goal is to exercise political and administrative authority effectively at all levels to manage a country's affairs. Burne (2014) defines true governance as the process of directing and controlling activities within an organization, with the governing body responsible for organisational performance and compliance.

In essence, governance involves the exercise of authority to maintain peace, fulfil public demands, and regulate activities to maximize the public good through various systems and relationships. In political science, governance pertains to the normative foundations of political power, problem-solving techniques, and the management of public resources. This understanding highlights the role of political authority in maintaining social order and emphasizes how effective governance facilitates the integration of emerging technologies for agricultural sustainability.

2.7.1 Governance models

A governance model comprises policies, systems, and structures as well as strategic and operational frameworks (Asaduzzaman & Virtanen, 2016). It describes the interaction between the authority chain and the framework. When a company or organisation selects the best governance model for them; it can be extremely beneficial, especially if it aligns with the right executives. According to Asaduzzaman and Virtanen (2016), a governance model ensures that decisions are made effectively and that executives are held accountable. It should be noted that each board governance style is distinct and serves a distinct function (Burne, 2014). Certain governance models are designed to assist non-profit organisations whose boards and employees may lack corporate knowledge but are passionate about the cause and willing to assist. Meintzberg (1996) asserts that governance must be strictly adhered to. Meintzberg (1996) elaborates on five models, which include the government as machine model, the government as network model, the performance control model, the virtual government model, and the normative control model. These models are explained in the following segments.

1) **The government-as-machine model:** In this model, government is seen as a machine regulated by various laws and standards. Despite its popularity at the turn of the century, this strategy is severely lacking in flexibility and responsiveness to individual efforts.
2) **The government as a network model:** This is the inverse of the previous model. Here, governance is depicted as a tangled system, a complex web of ad hoc interactions designed to solve problems as they arise and linked by ad hoc communication channels. Its mission is to assist people in connecting, communicating, and collaborating with one another. This model is holographic in the sense that the components collaborate to form the whole: individual initiatives are linked to a larger web of projects.
3) **The performance-control model**: According to this model, government should be run like a business. The entire organisation is divided into business units that are given performance goals and held accountable by their managers in this model. The performance model decentralises to centralise; it loosens to tighten. As a result, individual initiative, adaptability, and inventiveness suffer.
4) Unlike other models, the normative-control model prioritises values and norms over structure and systems. This model is made up of five major components, which are listed below:
    (i) Selection: People are selected based on their values and attitudes rather than their credentials.
    (ii) Socialisation: This component ensures that members are committed to a social system that is interconnected.

(iii) Guidance: Guidance is based on agreed-upon principles rather than imposed initiatives, and visions rather than targets.

(iv) Responsibility: All guidance is based on agreed-upon principles rather than mandated initiatives, and visions rather than goals.

(v) Judgment: Performance is evaluated by experienced professionals, including service recipients, some of whom serve on representative oversight boards.

2.7.2 Other governance models

Experienced professionals, including service recipients, assess performance, with some participating in representative oversight boards. Good governance involves accountability, legitimacy, transparency, adherence to the rule of law, and fostering an open environment to address socioeconomic challenges. This requires participatory democracy and government's ability to meet the increasing demands for development. A political environment in which trust exists between the government and the governed is the ultimate manifestation of transparency. At this time, each citizen takes responsibility for every aspect of development and develops a sense of ownership in the country's development process (Rogers, 2014 & Gill 2002). The following are some other relevant governance models:

- Operational Model: The organisation's board of directors manages and executes its operations.
- Collective Model: Collaboration between the board and staff, working together seamlessly in governance and organisational activities. Board members may be involved in service operations or management.
- Management Model: The board operates through functional committees, possibly with assistance from a staff facilitator.
- Constituent Representational Model: Employed by duly elected public officials or boards elected by constituencies, balancing constituents' interests with organisational priorities.
- Traditional Model: The board governs and oversees business functions through committees organized by function (finance, human resources, programs). Management responsibilities are delegated to the executive director.
- Results-based Model: The executive director, a non-voting board member, holds significant influence over policy decisions and is considered a full partner. Committees focus on governance, monitoring, and auditing the performance of the board, executive director, and organization.
- Policy Governance (Carver) Model: The board uses policies to define organisational goals, governance methods, and management constraints. The executive director has broad discretion

in achieving goals, and the board's relationship with the executive director is defined by these policies.

- Advisory Board Model: The executive director appoints and controls the board. This board lends legitimacy to the organisation but governs only nominally. Board members provide advice to the executive director and vote on his or her recommendations.
- Cooperative Model: A cooperative board is one in which all members make decisions as equals, which is uncommon in larger nonprofit organisations. It is the most democratic governance model, acting only on decisions made after proper voting procedures and requiring all members to be committed to the organisation's mission. A cooperative board has no formal hierarchy; instead, it is guided by group consensus.
- The multi-stakeholder governance model is an important but underutilized tool for managing governance-social and economic sustainability. Smart solutions, as well as training and engagements, are developed to promote collaboration among various governance levels, sectors, and internal government departments. According to Tasan-Kok and Vranken (2011), organisations and groups at various governance levels (national, regional (provincial), local (districts), and neighborhood/community) can use this model. It is primarily aimed at provincial, district, and municipal public authorities, which are critical players in achieving sustainability; other stakeholders include private sector players, and government agencies. Multi-level governance was first proposed in the early 1990s. Everyone is involved in the decision-making process. Tiran, Kallay, and Szuppinger (2017) agree with Biard, Molteni, and Croci (2015) that multi-level governance is defined as a decision-making structure that embraces a plurality of politically independent but otherwise interdependent actors - private and public - at various levels of geographic aggregation in more-or-less continuous negotiation and implementation and does not assert a stable hierarchy of political authority (Lindberg, 2017).

Peters (2001) presented four well-known governance models in his work on governance. Here are some examples of the governance models that he proposes:

- Market Model: Argues that the private sector can deliver services more effectively than traditional government.
- Participatory State Model: Differs from the market model by emphasizing increased individual and collective participation by government organisations traditionally excluded from decision-making.

- Flexible Government Model: Advocates for a context-aware and adaptable government, addressing environmental challenges and changes while meeting people's demands through appropriate policies.
- Deregulated Government Model: Emphasizes less bureaucratic control, increased managerial autonomy, and recommendations based on societal needs and collective decision-making.

Peters' governance models have laid the groundwork for a more comprehensive understanding of governance, with Farazmand noting that while the models have unique implications in terms of structure, management, policymaking, and public interest, they also share many characteristics.

2.7.3 Models of governance that the North West province's government should adopt

According to De Schutter (2012), the North West province and South Africa as a whole are distinguished by highly unequal farming systems, specifically the commercial farming sector and the emerging smallholder sector, as a result of a history of racial discrimination and inequality. Bridging this gap is the main challenge, with strong governance structures viewed as critical to finding long-term solutions. Governance, as outlined by Moyo (2016), is a systematic process aimed at providing organisational direction through structures and processes. It plays a crucial role in maintaining a controlled environment with the involvement of members within an organisation, all geared towards achieving municipal objectives. This becomes particularly significant in addressing governance challenges faced by local municipalities, notably in service delivery, with a specific focus on the North West Province's ability to meet its goals. Accountability, among other governance principles, holds considerable importance. Recognising the need for reviving institutional capacity and consistently adapting to changing circumstances is acknowledged by those in positions of authority. Furthermore, the effective utilization and close monitoring of available resources are deemed essential. Strategic interventions, such as the Turn-Around-Strategy, as well as Rebranding, Repositioning, and Renewal, should be duly considered in this context (Moyo, 2016). Accountability is crucial in most cases, regardless of how important other governance principles are. The powers that be recognise the importance of reviving institutional capacity and regularly assessing it in response to changing times. It is necessary to make resources available and to closely monitor their use.

According to Cloete (2013), poor governance is a significant obstacle to agricultural development success in the North West Province NWP. As a matter of fact, one might assert that the responsible institutions are not reflecting an equilibrium state, resulting in unfavourable social and economic outcomes for the province's rural agricultural development. As a result, changing the institutional

setting is necessary to improve the current situation. This implies that substitute institutional structures could aid in the improvement of current institutional performance in areas such as human capacity, equity sharing, rural finance, telecommunications, and water supply, roads, infrastructure, and production constraints. Multi-level governance is a dynamic process that promotes shared ownership and execution. Its guiding principles are openness, participation, accountability, effectiveness, and coherence, implying that an integrated approach is required for effective policy development. MLG can benefit the NWP and its efforts by ensuring policy coherence at the local, regional, and national levels; developing clear and consistent visions that reflect local realities and strategic needs; establishing more favourable financing mechanisms (collaboration among a variety of actors can create more secure and stable conditions for attracting funds and investments); ensuring effective, comprehensive and coherent communication among stakeholders; and instituting regular monitoring and reporting practices; sharing/providing of expertise, skills, and knowledge; pooling/providing of resources and modern techniques; and establishing clear roles and relationships, resulting in greater ownership of actors and actions.

Multi-stakeholder systems can play a key role in building an inclusive policy environment that stimulates change, by presenting multiple voices from the rural areas to convince and lobby central government into collaborative and supportive systems for adaptable and differentiated policy initiatives. Multi-stakeholder forums, such as scenario workshops, enable stakeholders to gain knowledge about policy, engage in decision-making, and cross-pollinate ideologies, all the while ensuring that all voices are heard and promoting an interdependent culture. After identifying multi-stakeholder institutions as a gap in the watershed programme at the national, state, and district levels, the India – Gujarat and National studies have been using this governance model (Tasan -Kok & Vranken 2011). Multi-stakeholder institutions can emerge organically from grassroots movements, as exemplified by Senegal's CNCR, or be established by the government, as seen in Rebouças, Brazil, where the Municipal Committee on Rural Development (CMDR) was formed due to decentralization policies at the federal and state levels (Tasan-Kok & Vranken, 2011). The government often plays the role of a facilitator, and participants in these mechanisms include donors, agribusinesses, other transnational actors, and grassroots organisations. Entities that can engage from a position of strength, possessing legal recognition and easy access to information, are likely to benefit the most from multi-stakeholder dialogue. It is politically delusional to assume that simple exchanges of power and resources between stakeholders with significantly different endowments of power and resources can democratise the policy process (Coopenergy, 2015). According to World Bank data on agri-business policies and guidelines, economies with stricter agricultural production input regulatory frameworks

have higher average rates of food security (World Bank, 2019). This aligns with the earlier argument on the importance of functional legal frameworks in supporting farmers to generate surplus production for commercial purposes (World Bank, 2020). Thus far, there has been some success in formulating and implementing standardised, consistent, and beneficial agricultural policies, laws, and regulations to enhance production on a global scale (Cloete, 2013).

Community oriented development process tailored toward agricultural development, as well as consultative and frequent dialogue with key actors, is required. Facilitating learning visits and knowledge sharing among countries that have made significant strides in governance structures would be advantageous. To promote good governance for sustainable production and food security, understanding the roles of key players like civil society and the corporate sector is essential. Civil society participation, for instance, plays a crucial role in the successful implementation of policies and programmes aimed at agricultural sustainability, resource conservation, and the exchange of knowledge within agricultural systems (OECD, 2019; Warshawsky, 2014). Civil society involvement is often necessary to advocate for sustainable agricultural practices, connect farmers and agro-businesses, and promote market-oriented initiatives aligned with environmental and social sustainability (Warshawsky, 2016). The role of the corporate sector in agricultural development and food security is a subject for further debate. Some argue that corporate investment has increased productivity, created jobs, and improved environmental outcomes, while others contend that it poses risks to food security and the environment. Corporate investments may exacerbate tenure insecurity for small farmers, especially when made in countries with lax labor and environmental regulations (Szuppinger & Kállay, 2017).

South Africa's Rural Development Initiative (RDI), launched in 1998, aimed to mobilize rural communities and organisations for rural development. The National Land Committee, among others, coordinated the RDI for land and rural development. A Rural People's Charter, expressing the desires and needs of rural communities on various issues, was drafted during a national conference in April 1999. These issues included agriculture and food security, rural environment, economic growth, water and sanitation, healthcare, governance, and farm worker rights and conditions. Despite existing rural policies and laws, the Rural Charter highlighted that there had been limited improvement in the lives of the rural poor (Szuppinger & Kállay, 2017). It remains to be seen whether the RDI could develop into a broad-based movement that is legitimate and capable of influencing government policy and programmes through lobbying. South Africa has the typical middle-class champions working with non-governmental organisations to create liberal policies from the ground up. Despite the Freedom

Charter's and the Reconstruction and Development Programme's explicit goals of focusing development on people's needs through bottom-up approaches, there has not been much stakeholder involvement. Municipalities in South Africa, such as the NWP, should have access to a wide variety of alternatives and methodologies for strengthening and improving democratic participation, as well as the political stamina to experiment with the techniques and methodologies deemed appropriate for their specific geographic locations. Equally as important is a devotion to the spirit of collaborative local democracy, which cannot be enshrined beyond establishing a public service ethos.

The following are relevant measures to guide the province in adopting and effectively implementing the model:

- Property rights to key resources (such as land, water, seed, and machinery) should be protected, and their commercial use should be advanced. Appropriate policies are required in this regard to prevent monopolies over property rights.
- Contract enforcement and production technology regulation (pesticides, veterinary drugs, seed certification, fertilizer quality control, mechanization).
- Creating suitable incentive structures for both domestic and international investors, as well as upgrading existing regulations governing such incentives (e.g., subsidies, taxes or price-related policies).
- The formation of agencies to carry out agricultural development programmes and projects, as well as to handle legal issues.
- Civil society organisations and capacity-building activities are promoted to assist smallholders in becoming more self-sufficient.
- Increase the effectiveness of coordination structures to ensure that operations and resources are used effectively.
- Corruption management and accountability are critical for improving the efficiency with which infrastructure and services are provided for agricultural development.
- Investments in information and communication technology (ICT) and energy, as well as the development of electronic systems and online platforms to ensure transparency and accountability, as well as compliance with regulatory requirements, are critical interventions to improve agricultural service delivery.
- Women, youth, and marginalised groups, such as pastoralists, should be given voice and opportunities, and agricultural development programmes should include them. Improving and expanding such groups' inclusion requires intervention programmes such as training women

farmers and boosting their involvement in the decision processes at different levels, as well as mainstreaming gender issues in policies and programmes.

- Making the regulatory environment more conducive to civil society and the private sector playing a larger role in driving agricultural development. This requires government control to be relaxed, top-level leadership support, the formation of inter-sectoral collaboration and accountability measures, and investments in skilled labour to develop and improve Farmer Organizations' advocacy and lobbying capacity.
- Public officials need training in policymaking and engaging with multiple stakeholders. This should include cross-cultural education and exchange programmes covering areas such as agricultural policies, advocacy, technical and practical agricultural training, and organizational strengthening.
- Establishment and enforcement of a set of rules and a code of conduct with penalties and rewards. Financial sustainability requires motivating members' commitment, including their financial contributions through fees.
- Investments to help FOs provide economic services to their members. Among these are the following:
  - Production-related services (access to inputs, productive equipment, and advisory services),
  - Value-adding services (processing and certification, post-harvest management, storage facilities, and processing facilities for fresh commodities),
  - Marketing services (collection of supply, identification of potential buyers, negotiation of contracts with buyers, and provision of market price information).

Additionally, policymakers and programme implementers advocate for policies and programmes supporting the rule of law, transparency, public access to information, public participation, and accountability. Integration also ensures a cohesive approach to future policies and programmes, preventing fragmentation and duplication of efforts. The effective integration of these policies and programmes into agricultural and nutrition interventions relies on two complementary aspects of governance:

Supply-side governance: This involves a government's ability to implement policies and services effectively, addressing the needs of stakeholders along agricultural and nutrition value chains, particularly women and vulnerable populations involved in farming.

Demand-side governance: This pertains to institutions and practices that assist farmers and groups experiencing chronic hunger in structuring and effectively communicating their issues to government

representatives, exercising their legal rights, participating in political processes, and holding governments accountable.

The successful implementation of these aspects is exemplified by Morocco's Green Plan, which showcases the integration of governance, agriculture, and nutrition through a contractual agricultural system. This system emphasizes the development of large-scale commercial farms and the transformation of smallholder farms into family businesses. Consequently, the expansion of smallholder farms has led to increased rural income diversification and improved access to agricultural inputs, credit, technologies, and markets. As capabilities and skills have improved, rural people's awareness and participation have grown, resulting in greater independence for local farmers, with villages actively involved in all planning stages. The Green Plan has also contributed to a 48 percent increase in agricultural GDP per capita in rural areas and a 4.9 percent reduction in malnutrition. This success has motivated the Moroccan government to further address poverty, including increased emphasis on "solidarity agriculture" through government engagement with civil society and a focus on marginalized areas. Future integration efforts should coordinate development endeavours with key stakeholders to alleviate rural poverty and contribute to the achievement of Sustainable Development Goals (SDGs).

2.7.4 Effective governance and agriculture

The Food and Agriculture Organisation's (FAO) definition of food security as "all people, at all times, having physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" includes the relationship between chronic hunger and governance. Governments are primary actors in the physical, social, and economic aspects of a nation's food security, according to Candel (2016) and Mazenda (2021), so any efforts to improve agriculture and food security outcomes must take governance into account. Key elements such as participation, accountability, transparency, effectiveness, and adherence to the rule of law should be integrated into agricultural and food security programs. By incorporating multi-sector actors and food systems, these initiatives empower stakeholders to implement changes that enhance food security and mitigate malnutrition (Candel, 2016). A specific emphasis on governance and agricultural public policies can assist governments in achieving their food security objectives. Traditional approaches that overlook governance in food security have proven ineffective in preventing food crises. The 2007-2008 food crisis underscored the necessity of effective governance at all levels to ensure food security. Thus, the coordinated efforts of governance, food security, and agriculture are

essential for effectively addressing global food demand challenges (Mandemaker, Bakker & Stoorvogel, 2011).

Recent developments have underscored the crucial importance of ensuring food safety, access to food, and consequently, agricultural productivity. Governance has emerged as a prominent subject due to its pivotal role in determining social welfare. The existing literature has numerous studies on agricultural productivity, and it has become increasingly evident that good governance significantly influences a country's agricultural productivity. Poor governance has the potential to exacerbate food insecurity, with a majority of armed conflicts occurring in low-income, food-deficit countries heavily reliant on domestic agricultural production. Conversely, effective governance plays a positive role in promoting agriculture and food security through various channels. To eradicate hunger, a robust governance system must be capable of responding to a food crisis and addressing the intricate issues of food insecurity by aligning goals and outcomes across all levels of government. At the local level, civil society organisations collaborating with authorities can contribute significantly to food security by improving relationships between decision-makers and the affected population, enhancing the efforts of multi-sector actors collaborating with different government levels, and providing resources and knowledge that government agencies may lack. Governmental agricultural programmes, according to Binswanger-Mkhize (2014), have little impact on production, food security, employment, and access to markets because strategies that focus on the entire farm as a business are ignored. Furthermore, investments are frequently misaligned with beneficiary expectations, inputs are delivered late, and marketing support is insufficient (Binswanger-Mkhize, 2014).

As a result, effective agriculture governance (accountability, citizen participation, multi-stakeholder programming) can improve sector service delivery while also enhancing positive development outcomes. For example, in Senegal, Bolivia, Brazil, and Niger, the decentralisation of authority related to food and nutritional security, as well as farmers' active participation in the design of agricultural policies, has resulted in inclusive agricultural policies that have improved farmers' access to agricultural and food value chains. Decentralization enables citizens, including women and other vulnerable groups engaged as small farmers in rural areas, to engage with policymakers and the private sector in evaluating and crafting solutions to local food security challenges. These initiatives prioritize collaboration and shared accountability at all levels, steering clear of top-down approaches where policymakers and government officials exclusively dictate solutions and resource ownership.

Liu's research (2008 & 2017), based on aggregate governance indicators from the World Bank across 118 countries, illustrates that countries with robust governance infrastructure tend to yield higher agricultural outputs. This suggests that investments in governance infrastructure can enhance agricultural productivity. Among governance indicators, the rule of law and corruption control exhibit a more pronounced impact on agricultural output compared to factors like political stability, voice, and accountability. According to the African Governance Report, enhancing transparency, accountability, and securing property rights is crucial for sustainable agricultural production and productivity growth (APRM and AGA, 2019). AGRA emphasizes the improvement of governance infrastructure, welfare, and anti-corruption policies as essential elements for advancing food and nutrition security and fostering a conducive agribusiness environment. Additionally, good governance aspects such as voice and accountability, as well as peace and stability, play pivotal roles in shaping agricultural assistance policies and influencing agrarian relations, including taxation, subsidies, and the provision of public infrastructure. Conversely, instability can hinder agricultural production by diminishing investment, escalating production costs, and restricting access to finance and trade. It is noteworthy that long-term increases in agricultural productivity can contribute to conflict reduction by mitigating competition for scarce resources like land (Fuglie et al., 2019).

The various governance indicators are intertwined in that the efficacy of one governance dimension influences the efficacy of others. Corruption, for example, reduces agricultural output by raising transaction costs and lowering agricultural profits. Corruption, on the other hand, reduces a government's ability to provide infrastructure such as rural roads and other related services, raising agricultural production costs. A good governance structure promotes and facilitates agricultural transformation by allowing for the development of sound agricultural policies and strategies It thus necessitates the development of skills in innovation policy analysis and priority setting. Good political leadership fosters governments' ability to improve the business environment, such as the creation of forums for producers and consumers to frame and articulate their interests, as well as the channeling of investments that strengthen institutional capabilities. International organisations and institutions (AGRA, FAO, World Bank, and other UN agencies), civil society, and the private sector all play important roles in providing training and development on how to sustain evidence-based policy change for agricultural transformation (AGRA, 2019; OECD, 2013).

2.7 CHAPTER SUMMARY

In the realm of agricultural development, technology has become a driving force for economic growth and stability in many developing countries. The transformative impact of modern technologies on agriculture is evident in the evolution of machinery, processing techniques, and agribusiness innovations. Continuous advancements in technology, marked by the development of new tools and processes, contribute to making agriculture more sustainable, profitable, and competitive. As global food demand challenges persist, the agricultural industry is compelled to embrace technological innovations to meet evolving needs.

While emerging technologies hold the potential to address challenges faced by farmers, such as climate change, land scarcity, and rising input costs, adoption barriers persist, economic, infrastructure, and regulatory challenges hinder the widespread integration of new technologies. Globalisation has heightened farmers' awareness of opportunities to enhance income, and forward-thinking farmers play a pivotal role in disseminating innovative agricultural technologies within their communities.

Targeting experienced farmers for the introduction of technologies like maize hybrid seeds is strategic due to their greater appreciation for innovation. Efficient use of Information and Communication Technologies (ICTs) in agriculture requires comprehensive knowledge of information handling and utilization skills, along with access to well-designed digital infrastructure. Policymakers can support innovation in the agricultural sector through policies, legislative measures, and incentives such as tax breaks.

South Africa's agricultural sector has demonstrated significant progress in digital agriculture, particularly in precision agriculture technologies. Despite existing challenges, the country's favourable policy, infrastructure, and funding environments pave the way for digital solutions. The future of digital agriculture lies in integrating various technologies, including remote sensing, drone imagery, mobile platforms, vehicle tracking, database technology, blockchain, Bluetooth Low Energy, artificial intelligence, and weather forecasting. However, the success of digital agricultural solutions depends on tailoring them to the specific needs and priorities of different stakeholders, considering variations between smallholders and larger-scale commercial farmers (Born et al., 2020).

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CHAPTER THREE

ARTICLE ONE

Investigating the emerging technologies farmers incorporate in their farming practices in the North West province, South Africa

Abstract

This study investigated the types of emerging technologies that farmers in the North West province of South Africa incorporate into their farming practices. The study adopted a mixed-methods approach, combining both qualitative and quantitative data collection methods. A convergent parallel mixed methods design was adopted which helped the researchers to collect both quantitative and qualitative data at the same time interval. A sample of 340 farmers was selected from four local municipalities in the Ngaka Modiri Molema District in the quantitative study while 25 employees from the Department of Agriculture were selected to participate in the study in the qualitative study. Data were collected using questionnaires and interviews respectively. The findings of the study indicate that farmers in the North West province have started to adopt emerging technologies in their farming practices. The most used technologies include herbicide-resistant weed control, precision farming, remote sensing, automation, and improved grains such as BT maize, DHM – 103, and DHM – 105. These technologies are used to improve crop yields, reduce costs, and increase efficiency in farm operations. The study also identified factors that influence the adoption of emerging technologies by farmers, including access to information, financial resources, and technical support. Farmers who have access to financial resources and skills are more likely to adopt emerging technologies than those who do not. Also, the study discovered that lack of information, lack of funding, poverty, lack of innovation and training, droughts and inadequate government intervention constitutes a lack of technological adoption. The study concludes that emerging technologies have the potential to improve farming practices and increase productivity in the North West province of South Africa.

Keywords: Technological adoption, Emerging technologies, Information technology, Incorporation of technology, Farming practices, South Africa

1. Introduction

The agricultural sector is constantly evolving with the adoption of emerging technologies, and the North West farmers are not exempt from this trend. The North West Province of South Africa has a long history of agricultural production, with a diverse range of farming activities (Materechera, 2018). In recent years, there has been a growing interest in the adoption of emerging technologies in farming by the North West farmers and this interest is driven by the need to increase productivity, reduce costs, and minimize the negative impact of agriculture on the environment. The North West Province of South Africa is one of the country's leading agricultural areas, with a range of farming activities including crop farming, livestock farming, and horticulture. The emerging technologies adopted in this province are to optimize crop yields, make data-driven decisions, and minimize input costs (Tantalaki, Souravlas & Roumeliotis, 2019). According to Zhao et al. (2020), the adoption of emerging technologies in farming practices has the potential to revolutionize the agricultural sector and transform the way farming is done in the North West Province.

In the view of Tripathi et al. (2019), by the year 2050, there will be 9 billion people on the planet, meaning that the demand for food would likely increase by 102%. This implies that a 60% to 70% increase in agricultural output is also essential to ensure the availability of food, feed, and fibre (Pinotti et al., 2019). To ensure a sustainable future despite the ongoing and escalating pressure on the world's resources, Béné (2022) avers that each actor in the food chain is expected to make a commitment to creating and enforcing procedures that would enhance food productivity. Governmental and non-governmental organisations can support these initiatives by crafting national and local policies and strategies for effective adoption of farming emerging technologies (Cockburn et al., 2019). Global adoption of sustainable farming methods helps the agroecosystem meet the world's present food needs while also assuring that future generations can do the same with the limited resources. These approaches also emphasize holistic development, which includes the three main pillars of sustainable development: environmental, social, and economic sustainability (Siegel & Lima, 2020).

Emerging agricultural technologies refer to those innovations, machinery, and other equipment designed for a practical and innovative application in agriculture, natural resources, and food-related to the study and development of qualified products and projects (van Loon et al., 2020). The ways that food is produced, processed, and distributed could be dramatically altered by these technologies. These technologies, according to Demestichas et al. (2020), include robots, biotechnology, blockchain, vertical farming, and precision agriculture. It is possible to boost agricultural output, cut waste, and

improve sustainability in the North West province by implementing innovative agricultural technologies. Farmers in this area could eventually manage their resources more effectively and adapt to the problems posed by climate change, water shortage, and market instability by implementing these emerging technologies. Campbell et al. (2018) maintain that technological developments are essential to achieving agricultural sustainability goals (Campbell et al., 2018). For example, precision agriculture is made possible by satellite and GPS technologies, sensors, intelligent irrigation, drones, and automation. These technological adoptions enhance the efficient use of resources through the conservation of non-renewable resources and the reduction in the usage of toxic agrochemicals. They also assist farmers in making preparations for unseasonal or extreme weather events, which minimizes crop losses during such situations. Biotechnology, controlled environmental agriculture (CEA), blockchain technologies, and 3D printing, enable the production of food products while conserving time and energy (Zimny et al., 2019). These are additional technologies that show promise for the adoption of emerging technologies. Farmers may now use the finest practices of both conventional and technologically-driven agricultural production to produce crops that are nutritious, high-yielding, and cost-effective while still inflicting the least amount of environmental harm feasible (Green et al., 2021). Even remote rural farmers can embrace climate-resilient, sustainable farming methods that also produce financial rewards if they have access to accurate and timely information.

The increase in agricultural sustainability and support for development has been made possible through technological advancement and this has been proven by farmers all over the world (Rose & Chilvers, 2018). The rate of technological development and the level of adopting the emerging technologies could be key factors in determining the stability and productivity of agriculture in the North West province. Due to the need to integrate emerging technologies in farming practices all over the world to ensure food security, this study investigates the types of emerging technologies farmers in the North West province incorporate into their farming practices to enhance food production. The focus is on grain production (maize) and emerging technologies adopted to increase productivity.

2. Literature review

The literature review of this study focused on scanning the landscape of the research area, emerging technologies incorporated by farmers in their agricultural practices in the study area, and grain production in the North West Province.

2.1 The research area landscape

The North West Province (NWP) is one of nine provinces that make up the Republic of South Africa. It is the fourth-smallest province in South Africa, with a total size of 102,881 square kilometres, and it shares a border with Botswana to the north (Local Government Handbook, 2020). The province has an advantage over other provinces in the mining and agricultural industries because of its abundant natural resources, which include platinum and chromium as well as its diverse biodiversity. The NWP is in the country's summer rainfall region, with an average annual rainfall of between 500 and 600 mm, according to the South African Meteorological Service (2021). The South African National Biodiversity Institute (2018) classify the NWP as belonging to the savanna and grassland biomes. The NWP's vegetation and soil types differ, and these differences are as a result of the underlying geology and more climate-resistant terrain which is covered with grasslands. A little over 50% of the total land area is used for commercial agriculture, primarily consisting of grazing land for raising cattle and hunting game, then arable land for growing crops. Rainfall is a major source of agricultural activity for many of the NWP's farmers. Unfortunately, droughts frequently occur in the area and have a significant influence on agricultural activities, which has detrimental socioeconomic effects (Cole et al., 2021). Mining activities dominate the economy of the North West Province, providing 32.5% of the province's GDP in 2018, manufacturing at 5.1%, agriculture at 2.8%, and building at 2.5% (Van Zyl, 2019). In terms of its contribution to the national economy, the North West made up only 2.3% of manufacturing and 3.8% of construction but contributed 23.9% of the nation's mining and 6.9% of its agricultural (Cole et al., 2021).

With an estimated 43.9% of its land classified as "arable," North West is a significant food producer for Southern Africa (Adisa et al., 2019). Three different climate zones allow for a wide range of agricultural activities. Together with hunting, the area has a sizable cattle and game farming industry. While cash crops are also produced in the province's centre and southern regions, maize and wheat farming predominate the NWP (Oduniyi, 2018). On the other hand, the eastern and north-eastern region receives a decent amount of rainfall and may therefore support the cultivation of a range of crops. This province produces more than 20% of South Africa's maize. Livestock (including cattle, poultry, and game), sunflower seeds and oils, almonds, citrus, and tobacco are among the other agricultural commodities produced.

Galal (2021) claims that grain and beef farming are conducted on a considerable scale in the North West and that the westernmost regions of the province - often referred to as "South Africa's Texas" have enormous herds of grazing cattle. Over 1.6 million beef cattle, or 12% of South Africa's herd, are in the North West. Many sheep farms, cattle ranches, and game ranches may be found in the province's

northern and western regions. According to estimates, the province has 701 587 goats, or 12% of all the goats in South Africa (Bumunang et al., 2019). The projected number of pigs is 318 843, or 20% of South Africa's entire drive. Crops grown in the eastern and southern portions include maize (corn), sunflower, cotton, tobacco, and citrus fruits and 33% of South Africa's stock of sunflower seeds, 23% of the country's supply of groundnuts, and 5.4% of the country's supply of potatoes come from the North West. About 11% of South Africa's cotton crop, which has been declining for many years, is produced in the province. Also, 15% of South Africa's wheat and 20% of its maize are produced in the North West. Maize and wheat farming predominate in the province's central and southern regions (Adisa et al., 2019).

Three diverse styles of agriculture are practiced in the various climate regions of the North West. Large beef cattle herds can be found in the dry western region, which is also the foundation of the expanding hunting and game-ranching industries. According to a study by Abafe (2021), an investment of R5 million in cattle over six years yields a 4.8% return as opposed to 27.7% for buffalo and 45.2% for sable. Almost two million hectares of land were utilized to grow summer cereals during the 2017 growing season, and 50,000 hectares were dedicated to growing winter cereals compared to the harvest in 2016, while 31% more maize was sown for 2017 (Meyer et al., 2019). Besides the droughts that negatively affect agriculture in the province, other related challenges include a lack of funding, poor mechanisation and ICT adoption, low levels of youth participation, inadequate knowledge and technical know-how, stock theft, lack of access to land and markets, a lack of technical and infrastructural support, and a shortage of veterinarian doctors, among others (Nxumalo et al., 2020). Nonetheless, following the National Development Plan 2030, the North West Rural, Environment, and Agricultural Development has implemented policies and plans to better promote agriculture in terms of finance, technical support, and other initiatives (Simanjuntak et al., 2022).

2.2 The emerging technologies in agriculture in the North West province of South Africa

The North West province of South Africa has a significant agricultural sector, with a focus on crop farming, livestock farming, and horticulture (Mathinya et al., 2022). Some of the emerging technologies in agriculture currenttly adopted in the province include precision agriculture to optimize crop growth and reduce input use. Farmers use precision agricultural tools such as GPS mapping, soil sensors, and yield monitors to gather data about their fields and adjust their inputs accordingly (Lowenberg-DeBoer & Erickson, 2019). This helps to increase yields and reduce costs, particularly in water-stressed areas. Another emerging technology adopted is biotechnology and this is applied to improve crop yields, reduce disease, and increase resistance to pests and environmental stress (Zhao

et al. 2020). One example is the development of genetically modified maize that is resistant to the maize stalk borer, a major pest in the region. Hydroponics is another soilless farming technique adopted in Molote City North West province, particularly to produce high-value crops such as lettuce and herbs. Hydroponic systems use nutrient-rich water to grow plants, which can reduce water use and improve yields (Monsees et al., 2019). Hydroponics can also be used to grow crops in urban areas or areas with limited access to arable land. Farmers use mobile and web-based applications to provide real-time information about weather patterns, market prices, and pest outbreaks (Adamides et al. 2020). These technologies help farmers to make informed decisions about when to plant, harvest, and sell their crops, thereby improving their profitability. Also, livestock monitoring systems are being adopted in the North West province to track the health and location of livestock. These systems use sensors and GPS tracking to monitor the movement and behaviour of animals, which assists farmers to identify and treat health problems more quickly (Sharma & Koundal, 2018). This can improve the overall health and productivity of the herd. These emerging technologies have helped to improve agricultural productivity, sustainability, and profitability in the North West province of South Africa. Through the adoption of these technologies, farmers in the region can better manage their resources and respond to the challenges of climate change, water scarcity, market volatility and food security.

Farms are increasingly using drone technology, often known as small, unmanned aircraft systems (sUAS) (Prudden et al., 2018) to monitor crops, apply pesticides and fertilizers. This most recent development in farming and agricultural technology is revolutionizing farming practices by lowering the labour intensity needed to raise a crop (Hardin et al., 2019). Farmers can view a 3D digital recreation of the entire farm and continuously monitor and respond to crop conditions directly without taking any physical activity. This electronic monitoring allows for promoting plant growth or changing the temperature and water supply. The North West province can achieve economic sustainability in several ways, one of which is by obtaining optimal output levels at lower production costs. To optimize agricultural operations and use the fewest resources possible, data from satellite photos, sensors, and IoT devices helps decision-makers make more informed choices (Hardin et al., 2019). It also helps to reduce risks to achieve the highest crop yields. Traceability solutions give stakeholders greater control over operations and quality compliance while increasing the transparency of agricultural supply chains.

2.3 Grain production in the North West Province

Grain production is an important agricultural activity in the North West Province. The main grains grown in the region include maize (corn), sunflower, and sorghum (Adeleke & Babalola, 2020). Other crops grown in the region include wheat, soyabeans, and groundnuts. According to the South African

Crop Estimates Committee (2022), the North West Province produced 2.3 million tonnes of maize, 484,000 tonnes of sunflower, and 91,000 tonnes of sorghum during the 2020/2021 production season. The North West Province has several natural advantages that make it well-suited for grain production, including a warm climate, fertile soils, and access to water from major rivers like the Vaal and the Molopo. The region also has a well-developed agricultural infrastructure, with several large commercial farms and agribusinesses operating in the area (Adeleke & Babalola, 2020).

However, like all agricultural regions in South Africa, the North West Province is vulnerable to a range of factors that exert an impact on crop yields, including drought, pests and diseases, and changes in global commodity prices (Elum, Nhamo & Antwi, 2018). Additionally, Strauss et al. (2021) affirm that the region faces a few socio-economic challenges, including high levels of poverty and inequality, which impact the productivity and profitability of local farmers. Maize (corn) is one of the most important crops grown in the North West Province of South Africa, both for subsistence farming and commercial agriculture (Alberts et al. 2019). The province is among the major maize-producing regions in South Africa, which is one of the world's leading maize-producing countries (Elum, Nhamo & Antwi, 2018). In the view of Hoffmann et al. (2020), the North West Province has favourable climatic conditions for maize production, with warm temperatures, moderate rainfall, and fertile soils. The province is also well-served by irrigation schemes that provide water for maize production, particularly in areas where rainfall is unreliable.

According to the South African Crop Estimates Committee (2022), maize production in the North West Province is largely concentrated in the eastern and central parts of the province, particularly in the districts of Dr Kenneth Kaunda, Bojanala, and Ngaka Modiri Molema. These districts have a combination of large commercial farms and smallholder farmers who produce maize for subsistence and local markets. Maize production in the North West Province faces several challenges, including droughts, pests, and diseases (Mapfumo et al. 2020). The province also faces socio-economic challenges, including high levels of poverty and inequality, which could affect the productivity and profitability of local farmers. Nonetheless, maize production remains a vital economic undertaking in the province, providing income and food security for many rural households (Strauss et al. 2021).

The adoption of emerging technologies in maize production in the North West Province of South Africa is increasing, as farmers seek to improve their productivity and profitability. Some of the emerging technologies adopted include precision farming, digital agriculture, and biotechnology. However, there are several challenges in applying emerging technologies in maize production,

amongst them the high costs of equipment. Many emerging technologies in agriculture, such as precision farming equipment and biotech seeds, can be expensive to acquire and maintain. This can make it difficult for small-scale farmers in the North West Province to access and benefit from these technologies. Farmers in the North West Province may not have access to the latest information on emerging technologies, or the skills and training needed to use them effectively. This can make it challenging for farmers to adopt and integrate new technologies into their farming practices. Some emerging technologies in agriculture, such as digital agriculture platforms, require reliable internet connectivity and other infrastructure that may not be available in all areas of the North West Province. Concerning regulatory barriers, some emerging technologies, such as genetically modified crops, are subject to regulatory frameworks that limit their use or adoption. This makes it difficult for farmers in the North West Province to access and benefit from these technologies. Poverty, inequality, and other socio-economic factors can limit the ability of farmers in the North West Province to invest in and benefit from emerging technologies. In some cases, farmers may lack the resources or incentives to adopt new technologies or may face other pressing challenges that constrain their ability to focus on technological innovation. Addressing these challenges requires a coordinated effort by farmers, agricultural extension services, policymakers, and the private sector to promote the adoption of emerging technologies in maize production in the North West Province. This may involve improving access to information and training, promoting public-private partnerships to develop and deploy new technologies, and addressing regulatory and infrastructure barriers to technology adoption. Throughout the six years leading up to 2015, the average contribution of the North West to the national maize crop was 20%. 14.2 million tonnes were produced overall in 2014, which was a very strong return on investment. However, the drought caused yields to decline.

3. Research methods

This study investigated the types of emerging technologies farmers in the North West province incorporate into their farming practices to enhance food production. The pragmatist research paradigm was selected to guide this study. According to Creswell (2014), pragmatist researchers adopt the approaches that work best to provide answers to the research questions. In this regard, a mixed methods study was applied through an explanatory sequential design. Due to financial limitations and the time required to collect data from all the district municipalities of the North West province, this study focused on Ngaka Modiri Molema District municipality which comprises five (5) local municipalities. The employees of the Agricultural departments were participants in this investigation through a qualitative study. Also, the farmers in the 5 municipalities were selected to participate in the study.

Regarding the population, 85 employees in the management category of the Department of Agriculture were included in this study. Also, 1 340 farmers constitute the population in the quantitative phase. Concerning the sample frame, a total of 5 participants each was selected from the Agricultural Departments to participate from the 5 local municipalities of Ngaka Modiri Molema District making a total of 25 participants. In the quantitative phase, a total sample of 340 respondents was approached to participate in the study. In the qualitative and qualitative phases, response rates of 70% and 80% were attained respectively. Data were analysed using Statistical Package for Social Sciences in the quantitative phase while ATLAS-ti Software (Version 22) was used in the qualitative data analysis. Validity and reliability were maintained, as well as the ethical principles. The following section presents the results.

4. Presentation of research results

This section presents the empirical results obtained from the survey with the farmers in the study area as well as interviews with the employees in the Department of Agriculture. The presentation of the results was based on the research objectives of the study which focused on investigating the types of emerging technologies farmers in the North West province adopt and making recommendations on how to improve the agricultural output in the area. The next section presents the reliability test of the study.

4.1 Quantitative findings

This section presents the results obtained from the questionnaires administered to the farmers in the North West province. Out of the 384 questionnaires administered, the study attained an 80% response rate which is reliable to make reasonable conclusions. Table 4.1 presents the reliability statistics.

Table 3. 1 Reliability Statistics

Cronbach's Alpha	N of Items
.842	16

The interpretation of Cronbach's Alpha is based on the benchmark described by Burns and Burns (2008) who recommended that values of at least 0.7 indicate that the items in the construct are reliable. According to the table above, all items in the scale measuring the types of emerging technologies that farmers incorporate in their farming practices are reliable enough for factor analysis to be conducted. The next section presents the KMO and Bartlett’s test.

Table 3. 2 KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.878
Bartlett's Test of Sphericity	Approx. Chi-Square	5193.789
	Df	120
	Sig.	.000

Ma et al. (2011) recommend that a KMO of 0.7 is acceptable, therefore, the results in the Table above show that the sample is adequate for EFA to be conducted (.878). Also, the p-value of Bartlett's test is significant at a 5% level of significance, and according to Montshiwa and Moroke (2014), this result implies that the items are factorable. The next section presents the total variance explained.

Table 3. 3 Total Variance Explained						
Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.480	40.499	40.499	6.475	40.470	40.470
2	3.923	24.517	65.016	3.927	24.546	65.016
Extraction Method: Principal Component Analysis.						

The table above shows that there are two factors with eigenvalues greater than one which implies that two factors should be extracted from the scale describing the types of emerging technologies that farmers incorporate in their farming practices. These two factors explain 65.016% of the total variation which is sufficient because it is more than the recommended minimum of 50% used in the study by Bandalos and Finney (2018).

Table 3.4 Rotated Component Matrix		
	Component	
	1	2
TET1	**.841**	-.034

TET2	**.830**	-.012
TET3	**.569**	.018
TET4	**.610**	-.026
TET5	**.531**	.065
TET6	**.831**	-.039
TET7	**.714**	-.058
TET8	**.704**	.078
TET9	**.737**	.010
TET10	**.727**	-.013
TET11	**.781**	.094
TET12	**.849**	.017
TET13	.006	**.992**
TET14	-.004	**.978**
TET15	.049	**.987**
TET16	.000	**.992**

The numbers in the component matrix above are factor loadings. An item is allocated to a factor on which it has the highest loading. The component matrix shows that 12 items from the scale of the types of emerging technologies that farmers incorporate in their farming practices were allocated to the first factor which we termed Types of emerging technologies 1 whereas the remaining four items were allocated to the second factor which we term Types of emerging technologies 2. Following EFA, we conducted the reliability analysis again to ascertain whether the items allocated to the two constructs are indeed measuring the same traits, and the results are presented below.

Table 3.5 Reliability analysis for Types of emerging technologies 1 & 2

Cronbach's Alpha		N of Items
Technology 1	.910	12
Technology 2	.992	4

The interpretation of Cronbach's Alpha is based on the benchmark described by Burns and Burns (2008) who recommended that values of at least 0.7 indicate that the items in the construct are reliable. As such, according to the table above; all items in the scale measuring the Types of emerging

technologies 1 are reliable and this implies that they are internally consistent within this construct and can be regarded as measuring the same construct.

In technology 2, the interpretation of Cronbach's Alpha is based on the benchmark described by Burns and Burns (2008) who recommended that values of at least 0.7 indicate that the items in the construct are reliable. As such, according to the table above; all items in the scale measuring the Types of emerging technologies 2 are reliable and this implies that they are internally consistent within this construct and can be regarded as measuring the same construct. The CFA results are presented next.

Table 3.6 The CFA results

Path			**Parameter estimate**	**Standard error**	**t value**	**P-value**
Types_of_emerging_technologies_1	===>	TET1	0.83517	0.01966	42.4734	<.0001
Types_of_emerging_technologies_1	===>	TET2	0.81154	0.02180	37.2289	<.0001
Types_of_emerging_technologies_1	===>	TET3	0.51802	0.04379	11.8294	<.0001
Types_of_emerging_technologies_1	===>	TET4	0.56288	0.04104	13.7166	<.0001
Types_of_emerging_technologies_1	===>	TET5	0.48662	0.04558	10.6751	<.0001
Types_of_emerging_technologies_1	===>	TET6	0.82821	0.02030	40.8053	<.0001
Types_of_emerging_technologies_1	===>	TET7	0.67978	0.03281	20.7212	<.0001
Types_of_emerging_technologies_1	===>	TET8	0.67211	0.03339	20.1279	<.0001
Types_of_emerging_technologies_1	===>	TET9	0.70241	0.03104	22.6289	<.0001

Types_of_emerging_technologies_1	===>	TET10	0.69197	0.03186	21.7180	<.0001
Types_of_emerging_technologies_1	===>	TET11	0.75307	0.02689	28.0025	<.0001
Types_of_emerging_technologies_1	===>	TET12	0.83693	0.01950	42.9131	<.0001
Types_of_emerging_technologies_2	===>	TET13	0.98794	0.00161	613.6	<.0001
Types_of_emerging_technologies_2	===>	TET14	0.96372	0.00425	226.8	<.0001
Types_of_emerging_technologies_2	===>	TET15	0.99065	0.00135	735.7	<.0001
Types_of_emerging_technologies_2	===>	TET16	0.99336	0.00111	896.1	<.0001

The p-values for all the items are significant at a 5% level of significance, meaning that all the items significantly belong to the factors to which EFA have allocated them. To ascertain the goodness of fit of the CFA model, the study used fit indices. For a model that fits the data well, according to Ahmad et al. (2016), the root mean square error of approximation (RMSEA) should be less than 0.0 whereas the comparative fit index (CFI), non-normed fit index (NFI) and the Tuker-Lewis Index (TLI) should all be greater than 0.9. The CFA results for the scale measuring the types of emerging technologies that farmers incorporate in their farming practices yielded an RMSEA of 0.1128 which is greater than 0.08 and does not indicate a good fit. However, the CFI was 0.9240, NFI was 0.9067 and TLI was 0.9098 and all these indices show that the model is a good fit for the data. As such, although the RMSEA doesn't imply a good fit, all other indices do, and all p-values of the items are significant, therefore; the factor structure is valid. The participants' responses towards the types of emerging technologies that farmers incorporate in their farming practices are presented next.

Table 3. 7 Types of emerging technologies farmers incorporate in their farming practices

	Designations	**SD**	**D**	**A**	**SA**

1	I am using/will use high-performing, herbicide-resistant seed trait that effectively helps protect crop from damaging above-ground insects.	21(6.8%)	35(11.4%)	173(56.4%)	69 (22.5%)
2	I am using/will use high yielding drought-tolerant variety	15(4.9%)	42(13.7%)	161(52.4%)	69(22.5%)
3	I am using/will use high yielding heat-tolerant variety	18(5.9%)	28(9.1%)	175(57%)	76(24.8%)
4	I am using/will use improved conventional hybrid and open-pollinated varieties	16(5.2%)	33(10.7%)	165(53.7%)	71(23.1%)
5	I am using/will use genetically modified maize grain varieties	15(4.9%)	35(11.4%)	167(54.4%)	81(26.4%)
6	I practice/will practice minimum soil cultivation or zero-tillage techniques to enhance soil sustainability.	11(3.6%)	19(6.2%)	170(55.4%)	99(32.2%)
7	I adopt timely planting to escape harmful extreme weather conditions like drought, flood, frost, and heat stress.	11(3.6%)	18(5.9%)	155(50.5%)	106(34.5%)
8	Application of appropriate planting methods and plant spacing to enhance high yield	11(3.6%)	20(6.5%)	146(47.6%)	121(39.4%
9	I am applying/will apply integrated weed management practices to ensure sustainability for food security.	6(2%)	25(8.1%)	168 (54.7%)	94(30.6%)
10	Timely harvesting of produce and storage	10(3.3%)	16(5.2%)	172(56%)	97(31.6%)

11	I am using/will use climate information services	11(3.6%)	25(8.1%)	155(50.5%)	105(34.2%)
12	I am using/will use precision agriculture technologies.	15(4.9%)	42(13.7%)	161(52.4%)	69(22.5%)

The table above shows that items measuring Types_of_emerging_technologies_1 who strongly disagreed with these statements in this construct comprise 2% to 7% of the total and participants who disagreed comprise 5% to 16% of the total. The table shows that participants who agreed with the sentiments in the Types_of_emerging_technologies_1 construct comprise 48% to 57% of all participants and those who strongly agreed with these sentiments comprise 22% to 39% of the total. As such, most of the participants who responded to the questions in these constructs agreed (agree to strongly agree) which implies that most participants perceive the sentiments in this construct as being the types of emerging technologies that farmers incorporate in their farming practices, as opposed to those who disagree (disagree to strongly disagree).

Table 3.8 Additional emerging technologies adopted

Q2	**Designations**	**SD**	**D**	**A**	**SA**
13	I am using/will use irrigation to supplement rainfall	7(2%)	14(5%)	60(20%)	33(11%)
14	I am using/will use water management and water harvesting technologies	4(1%)	11(4%)	54(18%)	40(13%)
15	I have purchased/will purchase a crop insurance policy	6(2%)	11(4%)	53(17%)	43(14%)
16	The use of hydroponic for commercial maize fodder production	6(2%)	10(3%)	60(20%)	37(12%)

The table above shows that participants who agreed with the sentiments in the Types_of_emerging_technologies_2 construct comprise 17% to 20% of all participants and those who strongly agreed with these sentiments comprise 11% to 14% of the total. As such, most of the participants did not respond to the questions in this construct, but the second highest percentage

comprise those who agreed (agree to strongly agree) which implies that besides most participants not having responded to the sentiments under this construct, a relatively high percentage of the participants perceive the sentiments in this construct as being the types of emerging technologies that farmers incorporate in their farming practices, as opposed to those who are in disagreement (disagree to strongly disagree).

4.2 Qualitative research results

This section presents the qualitative data collected from the employees in the Department of Agriculture through semi-structured interviews. The study selected 25 participants in this study out of which a 70% response rate was attained. The following themes emerged from the study:

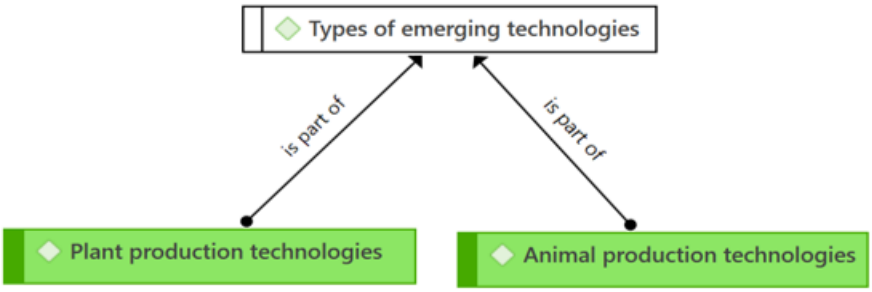

Figure 3.1 Types of emerging technologies adopted by farmers in the NW province

Figure 3.1 presents the emerging technologies adopted by farmers in the NWP. Two themes emerged in this research objective, but the emphasis was on the plant production technologies. Figure 3.2 presents the outcome of plant production technologies.

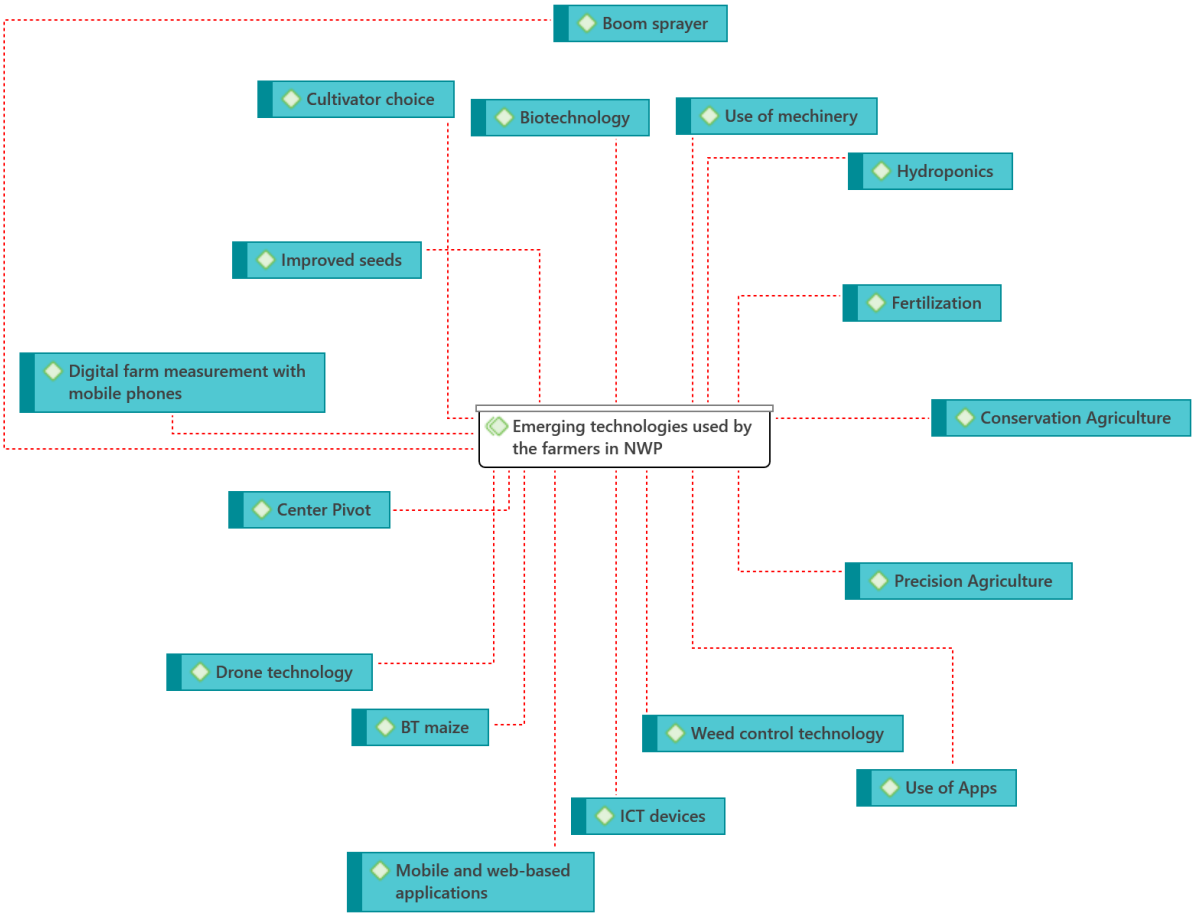

Figure 3.2 The emerging technologies adopted by farmers in the NWP

The Department of Agriculture employees in the NWP concurred that they have facilitated innovation programmes that have resulted in the adoption of several emerging technologies by NWP farmers as depicted in Figure 2. These have helped to enhance their farm outputs. The following are the direct excerpts of the participants.

> ***P1 said,*** *"After the seminar, we facilitated for the farmers, they started to incorporate emerging technologies and these include fertilization, digital devices in measurement, and weed control technologies.*
>
> ***P2 confirmed, "****Our department has been introducing special grains to the farmers to improve their output and these include BT maize, DHM – 103, and DHM – 105. These species have proved to protect against insect pests, tolerant to leaf blight and stem rot diseases, tolerant to leaf blight and wilt, and a short-duration hybrid, tolerant to leaf blight disease.*
>
> ***P8 said, "So many farmers have started using*** *these technologies for over 5 years. Farmers are mostly using traditional methods in the North West Province. The problem we have is the*

lack of finance, sensitization, communication, and training. Due to these challenges, emerging technologies are mostly used by younger farmers who understand the impacts of technologies.

The following section provides a discussion of the results.

5. Discussion of results

Emerging technologies are transforming the agricultural industry, thus enabling farmers to adopt more efficient and sustainable practices. According to Adamides et al. (2020), these technologies offer new opportunities for farmers to increase crop yield, reduce waste, and lower costs. In this study, the investigation sought to establish if the farmers in the North West province incorporate emerging technologies in their farming practices. By adopting such technologies, Zhao et al. (2020) confirm that farmers can keep up with the ever-changing landscape of modern agriculture and stay competitive in the market. In the same view, Adeleke and Babalola (2020) posit that the use of these technologies can promote sustainable farming practices, protect the environment, and enhance the resilience of the agricultural sector to the impacts of climate change.

In the quantitative phase, farmers confirmed that they have been applying emerging technologies in their farming practices over the years. According to their responses, some of the emerging technologies applied include high-performing, herbicide-resistant seed, high-yielding drought-tolerant variety, improved conventional hybrid, and open-pollinated varieties, genetically modified maize grain varieties, minimum soil cultivation or zero-tillage techniques to enhance soil sustainability, timely planting to escape harmful extreme weather conditions like drought, flood, frost, appropriate planting methods, and plant spacing to enhance high yield, timely harvesting of produce and storage, climate information services, and precision agriculture. Other technologies include the use of irrigation to supplement rainfall, the use of water management and water harvesting technologies, the purchase of a crop insurance policy, and the adoption of hydroponics for commercial maize fodder production. The findings in this section corroborate those of Zhao et al. (2020) who affirm that farmers have started to adopt emerging technologies to improve crop yield. In the view of Lowenberg-DeBoer and Erickson (2019), farmers use precision farming such as GPS mapping, soil sensors, and yield monitors to gather data about their crops. It was also revealed that farmers have started to adopt the use of climate information services, and this is confirmed by Adamides et al. (2020) who affirmed that farmers use this service for real-time information about weather patterns.

In the qualitative phase, the employees in the Department of Agriculture also confirmed that farmers in the North West province have been using emerging technologies in their farming practices over the years. Some of the emerging technologies include boom sprayers, use of machinery, hydroponics, fertilization, conservation agriculture, precision agriculture, weed control technology, use of Apps, ICT devices, mobile and web-based applications, BT-maize, drone technology, centre pivot, digital farm measurement, improved seeds, and cultivator choice. Findings from the qualitative study conform with that of Monsees et al. (2019) who confirm that hydroponics is an emerging technology that farmers have finally adopted. Concerning the use of machinery, Prudden et al. (2018) and Hardin et al. (2019) aver that drone technology systems and other technologies are highly accepted and applied in the North West province. In the aspect of grain production, weed control, and the use of improved grains, Adeleke and Babalola (2020) confirm that the technology is available in the North West province. The study further established that the farmers are using improved maize grains such as *BT maize, DHM – 103, and DHM – 105* and this was confirmed by Alberts et al (2019) who state that the improved maize grains are used to increase productivity. However, participants confirmed that most emerging technologies are used by high-merchant farmers and are yet to be incorporated by middle-income farmers. Also, the study noted that most farmers face several challenges to adopt emerging technologies in their practices. These challenges include lack of finance, lack of information and training, drought, high cost of equipment, inadequate skills, and Internet connectivity.

6. Recommendations

The recommendation of this study is made to farmers and employees of the Department of Agriculture.

6.1 Recommendations to farmers

The following recommendations are made to the farmers:

- Farmers should embrace emerging technologies in their farming practices. In the study, it was established that old farmers are reluctant to adopt the recent farming practices, and the Department of Education must train and sensitize them.
- Farmers should adopt precision agriculture to obtain accurate data about soil moisture, temperature, and nutrient levels, allowing them to apply fertilizer and irrigation only where it is needed. By utilizing precision agriculture, farmers can reduce costs and increase yields.
- Climate-Smart Agriculture such as farmers should adopt conservation agriculture, agroforestry, and crop diversification to mitigate the impact of climate change on their farms. With the effects of climate change becoming increasingly severe, farmers need to adopt practices that are resilient to the impacts of extreme weather.

- Farm Management Software should be adopted to keep track of farm inventory, crop yields, financial records, and equipment maintenance schedules. By accessing such data, farmers can make informed decisions that can increase efficiency and reduce costs.
- The Internet of Things (IoT) allows farmers to collect data in real time about their crops, soil moisture, temperature, and other factors. Also, it helps farmers to monitor their crops' health and optimize their growing conditions, leading to higher yields and quality crops. IoT can also help farmers automate irrigation and fertilizer application, reducing waste and increasing efficiency.
- Farmers should incorporate vertical farming to grow their crops in vertically stacked layers using artificial lighting and controlled environment agriculture technology. Vertical farming enables farmers to grow crops all year-round and in urban areas, reducing transportation costs and increasing access to fresh produce. Vertical farming also uses less water and land than traditional farming methods.
- Farmers should seek help from co-farmers or report to the government through the Department of Agriculture in case of emergencies, distress, training, or financial assistance.

6.2 Recommendations to the employees of the Department of Agriculture

The recommendations proposed in this section could help the Department of Agriculture to promote sustainable farming practices, increase efficiency, and improve the quality of crops.

- The Department of Agriculture could encourage the use of precision agriculture to help farmers obtain accurate data about their crops and soil. They can do this by facilitating training programmes and financial incentives for farmers who adopt these technologies. The Department can also collaborate with private companies to provide affordable access to precision agriculture tools to small-scale farmers.
- The Department of Agriculture can promote Climate-Smart Agriculture to help farmers mitigate the impact of climate change on their farms while reducing greenhouse gas emissions. The department can also promote research on climate-smart farming practices and their impact on crop yield, quality, and resilience to extreme weather.
- The Department of Agriculture should invest in farm management software to help farmers manage their operations more efficiently by providing real-time data about crop yields, financial records, and equipment maintenance schedules.
- They should support the adoption of IoT technology to assist in collecting data in real time about crops, soil moisture, temperature, and other factors.

- They should also explore the potential of vertical farming to assist farmers to grow crops year-round and in urban areas, reducing transportation costs and increasing access to fresh produce. The Department of Agriculture can explore the potential of vertical farming by investing in research, pilot programs, and collaborations with private companies. The department can also offer technical assistance and financial incentives to farmers who adopt Vertical Farming practices.
- The Department of Agriculture to embark on regular sensitisation, training, provision of improved seed, and financial assistance to ensure that greater output of farmers in the study area.

7. Conclusions

This study investigated the types of emerging technologies farmers incorporate into their farming practices in the North West province. A mixed methods study was applied and a convergent parallel mixed methods design. This methodological approach helped to collect both quantitative and qualitative data in an endeavour to find answers to the research objectives. The respondents of the study were farmers in the North West province while the employees of the Department of Agriculture were interviewed to confirm the types of technologies known to have been adopted by the farmers. Findings from the study revealed that so many farmers incorporate emerging technologies in their farming practices, and these include precision agriculture, mechanization, improved seed application, drone technology, weed/pest control, and ICT application among others. The study further established that the farmers, especially the old farmers struggle to use these technologies due to a lack of information and an inability to adopt emerging technologies. The study concludes that the incorporation of emerging technology would be a success if the Department of Agriculture communicated with the farmers adequately, facilitate training, provide improved seeds/fertilizers, and above all, funding so that farmers can afford to buy farm equipment.

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CHAPTER FOUR

ARTICLE TWO

Effectiveness of emerging technologies in maize production: A case of the North West province, South Africa

Abstract

This study investigates the effectiveness of emerging technologies in maize production and agricultural practices in the North West province of South Africa. The study employs a mixed-methods approach incorporating both quantitative and qualitative principles. An explanatory consequential mixed methods design was used which enhanced the collection and analysing of quantitative data before the qualitative phase. Data were collected from 384 farmers using questionnaires in the quantitative phase while interviews were used to collect data from 25 employees from the Department of Agriculture. The findings suggest that the adoption of emerging technologies in maize production significantly enhances the efficiency and profitability of farming practices, through the reduction of input costs, optimisation of resource use, and improvement of safety. The positive feedback from participants regarding the effectiveness of these technologies highlights the potential for their widespread adoption in maize production. However, the successful implementation of emerging technologies requires the provision of adequate education and support services to farmers, as well as the consideration of contextual, socio-economic, cultural, and political factors. Based on the findings, the study highlights the importance of promoting emerging technologies in maize production, particularly through clearly defined channels such as education and support services. It is essential that these channels are effectively communicated and leveraged to ensure widespread adoption. Further research is needed to investigate potential barriers to adoption of technologies and to develop strategies to overcome them.

Keywords: emerging technologies, smart agriculture, precision farming, maize farming; North West province, South Africa.

1. Introduction

Agriculture is a significant contributor to the economy of many countries, including South Africa. Masipa (2017) affirms that increasing the productivity of agricultural products is necessary to achieve food security in the North West province of South Africa. The North West Province of South Africa is one of the country's most significant agricultural regions, producing various crops such as maize, sunflower, and vegetables. However, the region faces various challenges such as water scarcity, climate change, and limited access to resources, leading to low productivity and food insecurity (Hadebe, Modi & Mabhaudhi, 2017). Food security is a significant challenge in the North West Province of South Africa as the region is characterised by high levels of poverty, unemployment, and underdevelopment, making it difficult for most people to access sufficient and nutritious food (Enwereji & Uwizeyimana, 2021). The primary cause of food insecurity in the region is the low productivity of the agricultural sector, which is the main source of food for the population. In the view of Qaim (2020), emerging technologies could increase the productivity of agricultural products and contribute to achieving food security in the region.

Emerging agricultural technology refers to new and innovative technologies developed to improve the productivity and sustainability of agricultural production (Zhang, Wang & Duan, 2016). These technologies directly address challenges such as climate change, water scarcity, soil degradation, and increasing demand for food. Precision agriculture, digital farming, and automation, could significantly increase productivity, improve efficiency, reduce costs in the agricultural sector, and increase yields, leading to increased profitability for farmers (Hedley, 2015). According to Rose and Chilvers (2018), emerging agricultural technologies reduce detrimental environmental impacts. For instance, precision agriculture reduces the use of fertilizers, pesticides, and water, thus minimising the risk of soil and water contamination. Similarly, Al-Kodmany (2018) affirms that vertical farming and aquaponics reduce the need for land, making them ideal for urban agriculture in limited spaces. Emerging agricultural technology offers numerous benefits that could reduce the many challenges facing agriculture and food production today (Brandenburg et al., 2019). However, it is essential to recognise that there may also be potential risks and drawbacks associated with these technologies, and careful evaluation is necessary before their widespread adoption.

This study investigates the effectiveness of emerging technologies such as precision agriculture, digital farming, and automation in increasing the general productivity of agricultural products in the North West Province of South Africa. The study assesses the benefits and potential of these emerging technologies in addressing the region's agricultural challenges and achieving food security. The study

then investigates the relevance of these emerging technologies in the production of maize in the North West province of South Africa. The study's findings contribute to the understanding of the effectiveness of emerging technologies in increasing productivity of agricultural products to achieve food security in the North West province. The study's recommendations inform policymakers, farmers, and other stakeholders in the agriculture sector about the adoption of emerging technologies to increase productivity and achieve food security in the region.

2. The importance of adopting emerging agricultural technologies

Agriculture has always been an essential aspect of human life, providing food, fibre, and other resources vital for our survival. However, with a rapidly growing global population and climate change, the agricultural industry faces unprecedented challenges (Tian et al., 2021). In this context, the adoption of emerging technologies in agriculture is critical for enhancing productivity, reducing environmental impact, and ensuring long-term sustainability (Lindblom et al., 2017). From precision agriculture and autonomous equipment to machine learning and artificial intelligence, Piñeiro et al. (2020) affirm that these technologies offer new ways to optimise resource use, improve crop yields, and promote sustainable farming practices. This section explores the importance of adopting emerging technologies in agriculture and the benefits they can provide for farmers, the industry, and society.

According to Naresh et al. (2020), emerging technologies, such as precision agriculture and autonomous equipment, and data-driven decision-making can help farmers optimize their use of resources such as water, fertiliser, and energy, reduce waste, and boost yields. This culminates in more efficient use of resources, lower costs, and higher yields. One of the key benefits of adopting emerging technologies in agriculture is increased efficiency. For example, soil sensors can measure moisture levels and nutrient content, allowing farmers to apply water and fertiliser precisely where and when these are needed, reducing costs and improving yields.

In the view of Sinha and Dhanalakshmi (2022), emerging technologies help farmers reduce waste by minimising losses due to pests, disease, and weather conditions. For example, Shang et al. (2019) confirm that satellite imagery assists farmers identify areas of their fields that are experiencing stress, allowing them to target interventions with precision. Through the application of emerging technologies, farmers achieve higher yields, and this is critical for meeting the growing demand for food and other agricultural products, despite climate change and other challenges (Anderson, Bayer & Edwards, 2020). Furthermore, farmers have drastically reduced their production costs and optimised

resource use by adopting emerging technologies. In tandem, this has led to higher profits and improved financial stability for farmers (Goedde et al., 2020).

The use of emerging technologies can help farmers reduce their environmental impact by minimising the use of harmful chemicals, reducing waste, and promoting sustainable farming practices (Sharma et al., 2019). Another benefit of adopting emerging technologies in agriculture is improved sustainability. Agriculture has a significant impact on the environment, and emerging technologies reduce farmers' environmental footprint while still meeting the demand for food and other agricultural products (Singh et al., 2021). In reducing the use of chemicals, McLennon et al. (2021) aver that precision agriculture technologies help farmers apply these inputs more precisely, reducing the quantity of chemicals applied to crops thus minimizing the impact on the environment. By reducing inputs and improving resource use efficiency, emerging technologies can also help farmers lower their carbon footprint. This is important for addressing climate change and reducing the environmental impact of agriculture (Usman & Makhdum, 2021). Emerging technologies help farmers adopt more sustainable practices such as conservation tillage, cover cropping, and crop rotation, and these practices help improve soil health, reduce erosion, and promote biodiversity (Crystal-Ornelas, Thapa & Tully, 2021). However, Virnodkar et al. (2020) affirm that water scarcity is a significant challenge in many agricultural regions, and adopting emerging technologies can help farmers manage water more effectively. For example, soil sensors and weather data can help farmers optimise the irrigation timetable and reduce water wastage. In the view of Hegde (2019), emerging technologies can also help farmers manage their livestock more sustainably through precision feeding technologies, which help reduce the environmental impact of livestock production by minimising the amount of feed needed.

In the aspect of achieving higher levels of output with fewer resources, the adoption of emerging technologies has improved farmer productivity by monitoring crops, livestock, and equipment more closely, identifying problems earlier, and making data-driven decisions (Niloofar et al., 2021). Emerging technologies such as precision agriculture, data-driven decision-making, and automation can help optimise agricultural operations, increase yields, and reduce costs (Niloofar et al. 2021). The use of sensors and drones can monitor crop health, yield potential, and irrigation needs, while livestock monitoring systems can help farmers optimise feed and reduce disease (Monteiro, Santos & Gonçalves, 2021). In the view of Javaid et al. (2023), emerging technologies such as machine learning and artificial intelligence can help farmers analyse large amounts of data quickly and make informed decisions about planting, harvesting, and other farming practices, leading to more efficient and effective decision-making. By optimizing the use of resources such as water, fertiliser, and energy, emerging technologies

have significantly reduced production costs and increased yields. In the aspect of automation, the equipment can be used autonomously for tasks such as planting, harvesting, and spraying, thus reducing labour inputs for other tasks (Moysiadis et al., 2021). Through the adoption of emerging technologies such as blockchain and RFID, farmers have improved their supply chain management, ensuring that products are delivered to the market more efficiently and with greater accuracy (Reyes, Visich & Jaska, 2020).

According to Javaid (2023), technologies such as machine learning and artificial intelligence can be used to analyse large amounts of data to make more informed decisions about planting, harvesting, and other farming practices that is critical for the success of agricultural operations. Emerging technologies such as data analytics, machine learning, and artificial intelligence assist in making more informed decisions about everything from planting and irrigation to pest management and supply chain management (Dutta & Mitra, 2021). The use of resources such as water, fertiliser, and energy reduces waste and improves efficiency. Also, by analysing data on soil moisture, nutrient content, and other factors, farmers can make more informed decisions about when and where to apply inputs (Reshma et al. (2020). By making better decisions about inputs, irrigation, and other factors, farmers can increase yields and improve crop quality, and this remains crucial for meeting the growing demand for food and other agricultural products (Goedde al., 2020). According to Yazdani, Gonzalez, and Chatterjee (2021), better decision-making can also help farmers reduce risk by identifying potential problems earlier and taking action to prevent or mitigate them. Through analysing weather data and soil conditions, farmers can identify areas of their fields that are at risk of drought or flooding and take steps to mitigate those risks (Neethirajan & Kemp, 2021). By making more informed decisions about inputs, timing, and other factors, Malak-Rawlikowska et al. (2021) confirm that farmers can improve their profitability and financial stability, and this is needed for the long-term success of agricultural operations. This, however, helps farmers adopt more sustainable practices, reducing the environmental impact of agriculture and ensuring that it remains viable for future generations.

Concerning competitive advantage, Bolfe et al. (2020) affirm that emerging technologies help farmers and agribusinesses to achieve a competitive advantage by enabling them to produce higher-quality crops at a lower cost, which can lead to higher profits. In achieving increased efficiency, emerging technologies such as precision agriculture, robotics, and artificial intelligence enable farmers to optimise resource use, reduce waste, and increase productivity (Raj, Appadurai & Athiappan, 2022). Through the adoption of gene editing and biotechnology, farmers can develop crops and livestock that are more disease-resistant, to pests, and environmental stressors, resulting in higher-quality products

(Mueller & Van Eenennaam, 2022). Smart irrigation systems, biodegradable packaging, and renewable energy sources are examples of emerging technologies, which help farmers reduce their environmental footprint and comply with increasingly stringent regulations (Singh et al., 2021). Furthermore, big data analytics and machine learning provide farmers with valuable insights into crop and livestock performance, weather patterns, and market trends, allowing them to make more informed decisions (Mekonnen et al., 2019). By adopting emerging technologies, Paunov and Planes-Satorra (2019) concur that farmers and agribusinesses can differentiate themselves from competitors and offer innovative products and services that meet the evolving needs of consumers.

The adoption of emerging technologies in agriculture is critical for the industry's long-term success and sustainability, which can revolutionize the agriculture industry and provide numerous benefits to farmers and agribusinesses. The adoption of these technologies can lead to increased efficiency, improved product quality, enhanced sustainability, better decision-making, and increased market competitiveness. As the world's population continues to grow and resources become scarcer, agriculture needs to embrace innovation and leverage the latest technologies to meet the demands of a changing world. By doing so, farmers and agribusinesses can improve their bottom line while contributing to a more sustainable future. It is, therefore, crucial for policymakers, researchers, and industry stakeholders to support the adoption and integration of emerging technologies in agriculture to ensure the sector's long-term growth and success.

3. Improved maize farming in North West province

In the North West Province, maize planting should occur between mid- and late November. Early seedlings experience greater stem borer damage than late plantings do. Consider the cultivar's growing season when selecting a planting date because pollination may be problematic if the plants flower in excessively hot weather (as is common in the North West Province). The planting date is determined by the soil's moisture content. In the North West Province, wind erosion is a significant problem that requires attention. It is best to cultivate mulch or stubble in regions where it is a concern. Three to four weeks before planting, apply compost or organic materials. (manure). After knowing the outcomes of the soil analyses, fertiliser can be administered. The predicted yield and previous crops are usually used to decide the type of fertiliser. The pH (KCl) must range from 5.0 to 5.5. Liming is recommended for soils with a pH (KCl) lower than 4.5. In the North West Province, a stand of 14 000–18 000 plants per ha is advised. In addition, it must be proportional to the desired result. In the North West Province, the standard planting depth ranged from 3 to 5 cm. The most widespread insect pest is maize stalk borers.

According to Moeletsi (2017), temperature is an environmental factor influencing how a crop develops from one stage to the next. Temperature, and more specifically sums of daily temperatures, has a direct relationship with the amount of time it takes a plant to complete a specific growth stage. It has already been discovered that cool temperatures slow growth whereas warm temperatures accelerate maturation, as a result, farmers must cultivate at optimal times by testing the soil to determine if the temperature is suitable; adequate preparation of the seedbed and/or use of appropriate planting equipment is required so that the seed has good soil contact at the correct depth with adequate row spacing. The planting depth should be between 112 and 2 inches, but no less. For high yields, even planting depth with no seed bounce is critical. Uneven emergence can cause inconsistency in plant competition, which can last all seasons.

In 1998–1998, BT yellow maize was commercially introduced in South Africa. With the introduction of BT white maize in 2001–2002, South Africa became the world's first GM subsistence crop producer (Gouse, 2012). Commercialisation of HT maize and stacking characteristics followed in 2003–2004 and 2007–2008, respectively (Gouse, 2012). In 2016, HT cultivars accounted for 74% of the total maize crop in the country, while BT cultivars accounted for 91% of the total maize crop (Brookes and Barfoot, 2018). Papaya, squash, apple, potato, eggplant, and white maize are the only GM crops commercially grown for direct human consumption (ISAAA, 2017). Except for BT eggplant in Bangladesh, white maize is the only staple crop produced commercially on a large-scale using GM varieties, and in 2017, South Africa commercially produced approximately 1.1 million hectares (an 85 percent adoption rate) of GM varieties for direct human consumption. GM hectares break down even more frequently than non-GM hectares in the key production zones of the North West and Free State provinces (International Service for the Acquisition of Agri-biotech Applications (ISAAA), 2018 & Ala-Kokko et al., 2021).

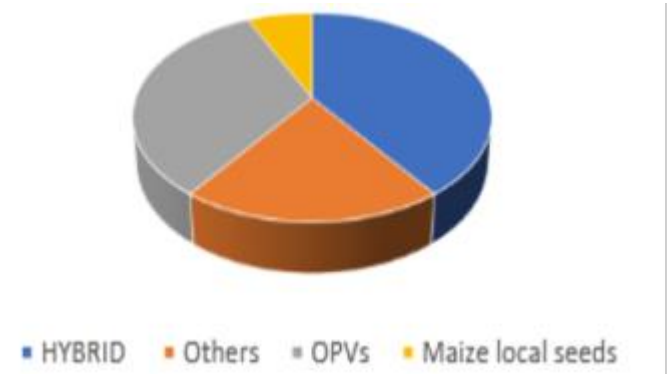

Figure 4.1 Farmers' preferred varieties of enhanced maize seeds

Source: Sigigaba *et al. (*2021)

According to the figure above, the most often used enhanced maize seed variety types were HYBRID, OPVs, and others. HYBRID is the most widely used and accepted high-yielding seed variety, and most farmers stated that this variety is widely available in markets. Farmers grow this type of modified maize variety because it feeds livestock. Most of the modified maize varieties chosen were utilized for market and household consumption by smallholder farmers. OPVs were the second most utilised enhanced maize variety, although farmers complain that this variety is not widely available in markets and that there is a lack of understanding of this maize variety. Finally, with 7%, local seeds were the least used maize variety, and many farmers worry about poor yield when utilising this type of maize variety.

Access to improved options for enhancing maize yields is limited throughout Africa (Food and Agriculture Organisation (FAO), 2020, 2019). This is challenging because most of the maize is grown by small-scale farmers who may not have access to sophisticated farming techniques (Epule, Chehbouni & Dhiba, 2022). According to consumer behaviour theory, smallholder farmers' adoption of new technology is influenced by a variety of factors, including technology, socioeconomic factors, policy, research, and institutional factors. The adoption of improved maize varieties is viewed as a link between multiple players that enables the transmission of information and seed to farmers, and then products from farmers to markets in exchange for money to improve living standards (Kakuru, 2019). The adoption of improved technology is critical for agricultural productivity and the livelihoods of small-scale farmers in developing countries. Improved seeds must increase agricultural production and global food security (Almekinders et al., 2019). Improved seeds are higher yielding, disease-resistant, and drought-tolerant, and they respond well to inorganic fertilizer (Lee, 2020; Simtowe, Amondo, Marenya, Sonder, & Erenstein, 2019), whereas traditional seeds yield less but are better adapted to the local environment (Anang, 2019). One of the arguments in favour of smallholder farmers using traditional seeds is that they can produce a minimum yield even under adverse conditions such as low soil fertility, as opposed to modified seeds, which require more favourable conditions to produce a good yield (Dokyi, Anang & Owusu, 2021).

4. Research Methodology

This study investigated the effectiveness of emerging technologies in agricultural practices in the North West province of South Africa. A pragmatist research paradigm was selected to guide this study. According to Creswell (2014), pragmatism focuses on the practical implications of knowledge and

bridges the gap between theory and practice. It emphasizes the importance of practical problem-solving and real-world solutions (Kelly & Cordeiro, 2020). In this context, the study is a mixed-method research approach and an explanatory sequential design. In an explanatory sequential mixed methods design, the quantitative data is gathered and analysed followed by the collection and analysis of qualitative data, with the aim of explaining or expanding on the quantitative findings (Dawadi, Shrestha & Giri, 2021). In the first phase, quantitative data was collected from the local farmers through surveys and analysed, to generate statistical information about the research question. Furthermore, qualitative data were collected and analysed through semi-structured interviews to help explain or elaborate on the quantitative findings. This design was adopted to gain a more comprehensive understanding of the research question by building on the strengths of both quantitative and qualitative research methods. Due to the financial limitations and time required to collect data from the district municipalities of the Northwest province, this study focused on the Ngaka Modiri Molema District municipality which comprises five (5) local municipalities. Regarding the population, 85 employees in the management category of the Department of Agriculture were included in this study, whereas only 25 employees (5 from each municipality) participated in the study. Additionally, the farmers in the selected municipalities (1 340) formed the population of the study in the quantitative phase. A total sample of 340 respondents was approached to participate in the quantitative phase of the study. In the qualitative and qualitative phases, response rates of 70% and 80% were attained respectively which was deemed efficient to attain credible conclusions. Data were analysed using the Statistical Package for Social Sciences in the quantitative phase, while ATLAS-ti Software (Version 22) was used in the qualitative data analysis. Validity and reliability were maintained, as well as the ethical concepts. The following section presents the research results.

5. Presentation of results

This section presents both the quantitative and qualitative results obtained from the surveys with the farmers and interviews with the agriculture employees. The next section presents the quantitative results.

5.1 Presentation of quantitative results

This section presents the empirical results obtained from the survey with farmers in the study area as well as interviews with employees in the Department of Agriculture. The presentation of the results was based on the research objectives of the study, which investigated the effectiveness of emerging technologies in agricultural practices in the North West province of South Africa. The subsequent

sections interpret the research results and proffer recommendations on how to improve the agricultural output in the area. The next section presents the reliability test for the study.

Table 4.1 Reliability Statistics

Cronbach's Alpha	N of Items
.995	6

The interpretation of Cronbach's Alpha is based on the benchmark described by Burns and Burns (2008), who recommended that values of at least 0.7 indicate that the items in the construct are reliable. As such, according to the table above, all items in the scale measuring the effectiveness of these emerging technologies in increasing the general sustainability of agricultural products to achieve food security are reliable for factor analysis to be conducted. Table 4.2 presents the KMO and Bartlett's Test.

Table 4. 2 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.927
Bartlett's Test of Sphericity	Approx. Chi-Square	5159.516
	Df	15
	Six.	.000

Ma et al. (2011) recommend that a KMO of 0.7 is acceptable; therefore, the results in the table above show that the sample is adequate for EFA to be conducted. Also, the p-value of Bartlett's test is significant at a 5% level of significance, and according to Montshiwa and Moroke (2014), this result implies that the items are factorable. Table 4.3 presents the component Matrix.

Table 4. 3 Component Matrixa

	Component

	1
Using emerging technologies can improve yield	.986
Using emerging technologies decreases yield variability	.984
Using emerging technologies saves fuel	.991
Using emerging technologies saves seed and fertiliser	.974
Using emerging technologies improves field speed, results in greater productivity	.991
Using emerging technologies helps a single driver to get more done through reduced fatigue	.996

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

The results above show that EFA retained the scale measuring of the emerging technologies in increasing the general sustainability of agricultural products to achieve food security as it is without segmenting it into factors/constructs. As such, the items of this scale are regarded as measuring only one construct and interpreted as such in subsequent analysis. Since no factors were extracted by EFA, no need to conduct CFA, and the responses from the participants are presented in Table 4.4.

Table 4. 4 Responses from participants on the effectiveness of emerging technologies

Designations	**SD**	**D**	**A**	**SA**	**NR**
Using emerging technologies can improve yield	2%	2%	1%	12%	63%
Using emerging technologies decreases yield variability	2%	2%	8%	17%	63%
Using emerging technologies saves fuel	1%	4%	17%	15%	63%
Using emerging technologies saves seed and fertiliser	1%	4%	18%	12%	64%
Using emerging technologies improves field speed, results in greater productivity	1%	3%	19%	14%	63%
Using emerging technologies helps a single driver to get more done through reduced fatigue	1%	3%	18%	15%	63%

Table 4.4 shows that the participants who did not respond to items measuring the effectiveness of these emerging technologies in increasing the general sustainability of agricultural products to achieve food security comprise 63% of the total, those who strongly disagreed with these statements in this construct

comprise 1% to 2% of the total, and participants who disagreed comprised 1% to 8% of the total. The table shows that participants who agreed with the sentiments in this construct comprise 17% to 22% of all participants and those who strongly agreed with these sentiments comprise 10% to 15% of the total. As such, most of the participants did not respond to the questions in this construct, but the second highest percentage comprised those in agreement (agree to strongly agree), which implies that besides most participants not having responded to the sentiments under this construct, a relatively high percentage of the participants concur that the emerging technologies that they have identified in the previous section are effective in increasing the general sustainability of agricultural products to achieve food security, as opposed to those who are in disagreement (disagree to strongly disagree). These results are summarised in Figure 4.2:

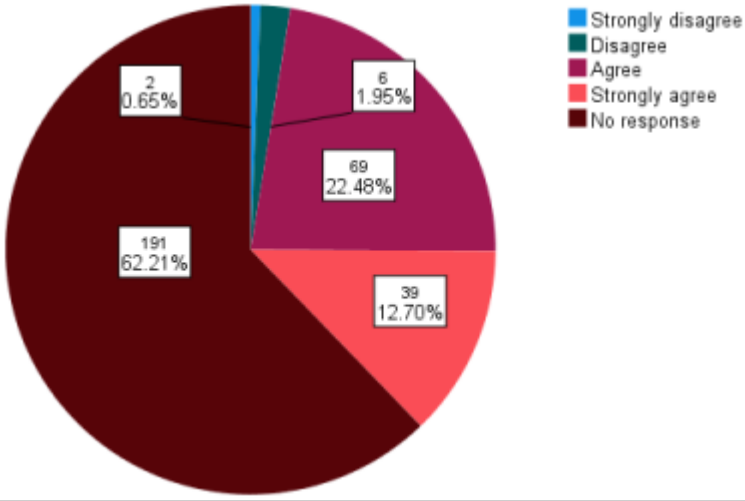

Figure 4.2 Summary of farmers' responses to the adoption of emerging technologies

5.2. Presentation of qualitative results

This section presents the qualitative results obtained from the interviews with employees in the Department of Agriculture in the five local municipalities. The study was designed to determine the effectiveness of emerging technologies in increasing the production of maize. The responses from the participants are summarised in Figure 4.3.

Figure 4.3 Effectiveness of adopting emerging technologies in farming practices

According to Figure 3, the participants concurred that the adoption of emerging technologies in maize production has improved farmers' yields. The participants highlighted that emerging technologies-ensure long-term sustainability and enhances productivity. The technology has been effective, it has helped increase their output, promotes sustainable farm practices, provides new ways to optimise resource use, and reduces environmental impacts. In conclusion, the participants attested that they could rely on emerging technologies for greater output in maize production.

6. Discussion of research results

The responses of farmers regarding the effectiveness of adopting emerging technologies in the production of maize are encouraging. According to the farmers and the Agricultural employees, these emerging technologies have a significant impact on the yield, cost, and overall efficiency of maize production. One benefit of using emerging technologies according to Naresh et al. (2020), is the decrease in yield variability. These technologies help farmers identify and address factors that contribute to yield variability, such as nutrient deficiencies, pests, and diseases. By using precision agriculture techniques, farmers can optimise their crop management practices and achieve more consistent yields from year to year (Sinha & Dhanalakshmi, 2022). Another advantage of adopting emerging technologies is the ability to save fuel. Advanced machinery and equipment, such as

autonomous tractors and drones, can help farmers reduce the amount of fuel used during planting, harvesting, and other activities (Goedde et al., 2020). This not only saves money for farmers but also has a positive environmental impact by reducing greenhouse gas emissions. In addition, using emerging technologies can save seeds and fertiliser (Singh et al., 2021). The farmers affirm that with precision agriculture techniques, they can more accurately apply seeds and fertilizers to their fields, ensuring that they are using only the amount needed for optimal plant growth. According to McLennon et al. (2021), this not only reduces input costs but also has environmental benefits by reducing the amount of excess nutrients and seeds that can leach into surrounding ecosystems.

More findings from the farmers verified that another benefit of adopting emerging technologies is the improvement of field speed, resulting in greater productivity. This is consistent with the findings of Niloofar et al. (2021), who confirm that modern machineries such as high-speed planters and harvesters, help farmers cover more ground in less time. This means that they can complete planting and harvesting operations more quickly, allowing them to move on to other tasks or expand their operations. Emerging technologies can help reduce driver fatigue, which can improve safety and increase productivity (Mekonnen et al., 2019). Autonomous machinery and equipment, such as self-driving tractors, allow farmers to delegate repetitive tasks to machines, freeing up their time and reducing the risk of accidents caused by fatigue or distraction. The responses of farmers regarding the effectiveness of adopting emerging technologies in the production of maize suggest that these technologies have a significant impact on the efficiency and profitability of maize production. By reducing input costs, increasing productivity, and improving safety, emerging technologies help farmers achieve more sustainable and profitable farming practices.

In the qualitative phase, the feedback of the participants from the Department of Agriculture on the effectiveness of emerging technologies in maize production underscores the numerous benefits associated with the adoption of these technologies. These benefits include long-term sustainability, increased productivity, and reduced environmental impacts. The farmers concurred that the adoption of emerging technologies promotes sustainable farming practices by enabling them to optimise their use of resources such as water, fertilisers, and pesticides. With precision agriculture, according to Bolfe et al. (2020), farmers can tailor their use of these resources to the specific needs of their crops, and this results in more efficient use of resources and lower costs, thereby increasing the sustainability of the farm. The participants also highlighted that emerging technologies are effective and have helped increase their output. The use of advanced machineries, such as high-speed planters and harvesters,

has enabled farmers to cover more ground and complete planting and harvesting operations more quickly. This has increased the overall yield of their maize crops, thereby improving their bottom line.

Moreover, the participants noted that emerging technologies provide new ways to optimize resource use such as precision agriculture techniques, i.e., variable-rate fertilisation allows farmers to apply fertilisers more precisely, reducing waste and increasing the efficiency of the application process. This leads to improved crop health, greater yields, and reduced costs. Finally, the participants attested that the adoption of emerging technologies helps reduce environmental impacts. With precision agriculture techniques and the use of autonomous machinery, Bolfe et al. (2020) affirm that farmers can reduce the quantity of pesticides and fertilizers applied to their fields, resulting in less runoff and fewer negative impacts on surrounding ecosystems. This promotes sustainability and contributes to the long-term health of the farm and the surrounding environment. By promoting sustainable farming practices, increasing productivity, optimising resource use, and reducing environmental impacts, emerging technologies enable farmers to achieve greater output and profitability in maize production.

7. Conclusion

Recently, the adoption of emerging technologies in agriculture has gained traction due to its potential to transform the way farmers produce crops. This study explored the effectiveness of adopting emerging technologies in farming practices and in maize production by analysing the responses of farmers and North West provincial employees in the Department of Agriculture on the impact of these technologies on their farming operations. The results of this study highlight that the adoption of emerging technologies brings numerous benefits to maize production. Participants noted that these technologies promote sustainable farming practices, increase productivity, optimise resource use, and reduce environmental impacts. By enabling farmers to use precision agriculture techniques, advanced machinery, and other innovative solutions, emerging technologies improve crop yields, reduce input costs, and promote more efficient and sustainable farming practices. Moreover, participants highlighted that emerging technologies have a significant impact on the efficiency and profitability of maize production. By reducing yield variability, saving fuel, seed, and fertiliser, improving field speed, and reducing driver fatigue, these technologies help farmers to achieve more sustainable and profitable farming practices. In conclusion, the findings of this study suggest that the adoption of emerging technologies in maize production brings significant benefits to farmers. These benefits include improved productivity, reduced input costs, and more sustainable farming practices.

8. Recommendations

Based on the findings of this study, it is recommended that policymakers, industry stakeholders, and farmers work together to promote the adoption of emerging technologies in maize production. This can be achieved through a range of measures, including providing training and education, improving access to finance, and creating supportive policies and regulations. Furthermore, there is a need to enhance the utilization of existing innovative technologies that address specific challenges in maize production, such as reducing pest and disease pressure, improving soil health, and reducing water consumption. The focus should be on increasing farmer adoption and effective implementation of these technologies to overcome the challenges they face. This can be achieved through partnerships between research institutions, industry stakeholders, and farmers to drive innovation and accelerate the adoption of emerging technologies in maize production. It is also important to emphasize that continued research and evaluation of the effectiveness of emerging technologies in maize production should be pursued further. This can help to identify areas for improvement, address any challenges or barriers to adoption, and ensure that farmers can realize the full potential of these technologies. The adoption of emerging technologies in maize production has the potential to bring significant benefits to farmers, including increased productivity, reduced input costs, and more sustainable farming practices. By promoting the adoption of these technologies and supporting ongoing research and development, policymakers and industry stakeholders can help to ensure that maize production is able to meet the growing demand for food while also promoting sustainable and profitable farming practices.

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CHAPTER FIVE

ARTICLE THREE

Exploring key barriers to the adoption of emerging technologies by farmers in the North West Province

South Africa

Abstract

This study aimed to identify the barriers faced by farmers in the North West Province of South Africa regarding the adoption of emerging agricultural technologies in the production of maize. The research employed a mixed-methods approach, combining quantitative and qualitative data collection methods to obtain comprehensive insights into the challenges inhibiting the adoption of these technologies. The study involved a sample of farmers from various agricultural sectors, and data were collected through surveys, and interviews. The quantitative analysis identified several barriers perceived by farmers, including the high initial cost of emerging technologies, lack of necessary skills and knowledge, unavailability of extension agents, limited access to markets and information, and inadequate government support. Additionally, factors such as poor recordkeeping and data management, limited user-friendliness of technologies, and shortages of labour were identified as impediments to technology adoption. The qualitative analysis further supported these findings and highlighted additional themes, including education, finance, resources, and support. Based on the findings, several recommendations are provided to address these barriers. Farmers are encouraged to invest in continuous learning and skills development, seek financial support, foster collaboration and networking, and embrace gradual adoption and adaptability. Moreover, the government should develop supportive policies and regulatory frameworks, strengthen extension services, facilitate access to credit and financial resources, and promote research and development in the agricultural sector. The findings provide valuable insights for farmers, policymakers, and agricultural organisations to develop targeted interventions and strategies to enhance technology adoption. By addressing these barriers, farmers can unlock the potential of emerging technologies, improve agricultural productivity, enhance sustainability, and contribute to the overall development of the agricultural sector in the North West Province and beyond.

Keywords: emerging technologies; technology adoption; barriers to technology adoption; farming community; maize production; South Africa

1. Introduction

Agriculture is crucial for economic growth and development, especially in developing regions like Sub-Saharan Africa (Watts & Scales, 2020). Emerging technologies, such as precision agriculture, data analytics, and remote sensing, have become increasingly important in the sector, offering potential benefits such as improved crop yields, reduced costs, and increased efficiency (Triantafyllou, Sarigiannidis & Bibi, 2019). However, many farmers in South Africa's North West province have been slow to adopt these technologies, leading to concerns about their competitiveness and ability to meet growing demand (Oduniyi, Antwi & Tekana, 2020). This slow adoption has been attributed to factors such as lack of knowledge, high acquisition and maintenance costs, inadequate infrastructure, and poor access to credit facilities. According to Molieleng, Fourie and Nwafor (2021), addressing these barriers is critical to enhancing the uptake of emerging technologies and improving agricultural productivity in the region.

The adoption of emerging technologies refers to the process by which farmers incorporate new technologies into their farming practices to increase efficiency, productivity, and profitability (Takahashi, Muraoka & Otsuka, 2020). Several factors, including resource availability, information access, market conditions, and government policies, may influence the adoption of emerging technologies in agricultural activities (Kumar, Engle & Tucker, 2018). Farmers with reliable internet connectivity and access to finance, for instance, may be better positioned to adopt and benefit from technologies that rely on data and analytics. However, Senyolo et al. (2018) affirm that there may also be impediments to adoption, such as acquisition costs, lack of knowledge and skills, and uncertainty about the technology's effectiveness.

Identifying the major barriers to technology adoption by farmers is crucial for policymakers and agricultural stakeholders to encourage technology uptake and increase productivity. This study aims to investigate the barriers to technology adoption by farmers in the North West province of South Africa, especially in maize production. The study identifies the major factors that influence farmers' decision-making when adopting new technologies to fathom the specific challenges they face in the adoption process. By identifying barriers to technology adoption, this study provides insights into how to overcome these challenges and promote the adoption of emerging technologies by farmers in the region. Ultimately, this could help to improve agricultural productivity, reduce poverty, and contribute to economic growth and development in the region.

2. Literature Review

Agriculture is a crucial contributor to economic growth, food security, poverty alleviation, and rural development in many countries, and smallholder agriculture has been identified as a vital tool to achieve the Millennium Development Goals (Gassner et al., 2019). Myeni et al. (2019) confirm that a significant number of smallholder farmers still rely on traditional farming practices, resulting in lower productivity levels. Therefore, the adoption of modern agricultural technologies, such as precision agriculture, data analytics, and remote sensing, has the potential to enhance crop yields, reduce costs, and improve efficiency. Improved agricultural technologies cover a wide range of techniques and practices, including the development and promotion of new crop varieties, management regimes, soil and soil fertility management, weed and pest management, and irrigation and water management (Triantafyllou et al., 2019). The adoption of new technology could increase output while reducing average production costs, resulting in significant gains in farm income. Failure to adopt improved agricultural technologies can lead to socioeconomic stagnation, lower earnings, and poverty (Takahashi, Muraoka & Otsuka, 2020).

According to Khonje et al. (2018), the adoption of improved agricultural technologies has been linked to higher earnings, lower poverty rates, improved nutritional status, lower staple food prices, and more employment opportunities. The success of the green revolution in Asian countries has been largely attributed to the widespread adoption of improved agricultural technologies (Wise, 2020). Thus, there is a need to investigate impediments to the adoption of emerging technologies by farmers in the North West province of South Africa to promote agricultural growth, enhance productivity levels, and ensure food security. In the view of Born et al. (2021), the three significant bottlenecks to scaling digital agricultural solutions in South Africa are limited network coverage, exorbitant data costs, and low digital literacy. Additionally, there is a significant digital divide between wealthy large-scale farmers and smallholders due to financial constraints, familiarity with technology, education levels, and farm size (Mabhaudhi et al., 2018). Mobile platforms, vehicle tracking, database technology, and blockchain technology are the most promising technologies for developing digital solutions in South Africa. The private sector, non-profit organisations, the public sector, and the international community all play critical and distinct roles in the development of long-term digital agricultural solutions in South Africa (Haywood et al., 2019).

The greatest gap in agricultural ICT adoption occurs among developing-country medium and small farms that do not use motorized mechanization (Myeni et al., 2019). Despite existing barriers to the use of agricultural ICTs, Watts and Scales (2020) confirm that a growing body of evidence shows that agricultural ICT access progress is a key enabler of agricultural sector change. Born et al. (2021) study

affirm that farmers in South Africa are willing to transition to digital agriculture and use agricultural ICTs to improve agribusiness outputs, particularly those from developing countries and with small-scale agribusinesses. The adoption of emerging technologies in the agricultural sector faces various barriers, including a lack of foresight or urgency, a loss of ability to develop feasible roadmaps towards ICT integration, overdependence on legacy technology, and a lack of knowledge, funds, or affordability (Sinha & Dhanalakshmi, 2022). Additionally, the industry faces challenges such as rising supply costs, a shrinking workforce, shifting consumer preferences, negative environmental impacts, unpredictable climate, high maintenance costs, and complex government policies and regulations (Abraham & Pingali, 2020).

Farmers must navigate through a plethora of potential production technologies and practices to choose those most suitable for their plots, each with its risk profile. Farmers need to be aware of the technology, believe in its benefits, and understand how to use it effectively to make informed decisions (Kaler & Ruston, 2019). In the view of Takahashi, Muraoka and Otsuka (2020), the availability of information encourages farmers to make profitable decisions, but traditional extension systems have had low farmer uptake and have frequently promoted technologies that are either unprofitable or whose costs and benefits are well understood by farmers. Furthermore, Kahan, Bymolt, and Zaal (2018) assert that the lack of financially viable business models for private sector investment in offering innovative solutions for small-scale agriculture hinders the adoption of new technologies. Foreign-made farm technologies remain unappealing to African farmers, who typically own an average of 1.6 hectares of farmland and cannot afford costly tools due to agriculture receiving less than 1% of commercial lending (James, 2018). When defining agricultural technology adoption, it is important to consider whether it is a discrete state with binary response variables or not. Farmers' decisions about whether and how to adopt new technology are influenced by various conditions and circumstances, including the technology's characteristics and the farmers' familiarity with it (Senyolo et al., 2018). Access to information creates transparency about a technology's effectiveness, but it is crucial to ensure that the information is consistent, reliable, and accurate. To adopt technology, farmers must be aware of its existence, benefits, and applications (Baumüller & Kah, 2019).

Access to credit is a key factor in increasing technology adoption. Credit can alleviate liquidity constraints and enable households to take on greater risk when adopting new technologies (Tshikala, Kostandini & Fonsah, 2019). Access to credit is currently biased against female-headed households in some countries, leading to low adoption rates for yield-raising technologies (Chweya, 2018). Age also plays a role in technology adoption, with older farmers having greater knowledge and experience to

evaluate technological information (Kumar, Engle and Tucker, 2018). Adebayo et al. (2022) claim that older farmers may be more risk-averse and less interested in long-term farm investments, while younger farmers may be more willing to try out new technologies. In the view of Yu (2022), South Africa has several supply-side advantages in terms of digital infrastructure, affordability, and access, including favourable policies, a substantial investment, and adequate Internet bandwidth and connectivity. Also, improvements can be made in areas such as 4G coverage and investment in IoT and fibre optic infrastructure. Another significant area for improvement is the cost of Internet data, which is perceived as prohibitively expensive for many in South Africa (Dube, 2020). The Competition Commission has described South Africa's data costs as "anti-poor," with 1GB of data costing about US$10.37, equivalent to 2.2 percent of GDP (Born et al., 2021). This cost makes even basic data usage inaccessible to most of the population. According to Smidt and Jokonya (2022), technology adoption in agriculture is influenced by various factors, including access to credit, age, gender, and digital infrastructure. Farmers' decisions to adopt new technologies are dynamic and influenced by a range of circumstances and conditions, highlighting the need for reliable and accurate information to facilitate their adoption (Kumar, Engle & Tucker, 2018). Other impediments to technology adoption in the North West province of South Africa are as follows:

Technological factors: Technological factors impede the adoption of emerging technologies by small-scale farmers in the North West province of South Africa (Mdoda et al., 2022). One barrier is the lack of technical knowledge and skills among farmers were they to adopt emerging technologies (Nxumalo, Akwasi Antwi, Rubhara, 2020). Small-scale farmers in the region typically use traditional farming practices, which make them less familiar with emerging technologies. Additionally, Mdoda et al. (2022) opine that the inability to access relevant and up-to-date information about emerging technologies limits adoption rates. The characteristics of the technology itself also play a critical role in the adoption decision process. According to Senyolo eta l. (2018), farmers who see the technology as consistent with their needs and compatible with their environment are more likely to adopt it as a good investment. Farmers' perceptions of the performance of the technologies have a significant impact on their decision to adopt them. Trial-ability is also a major determinant of technology adoption, as testing something out on a small scale before fully committing determines adoption (Abied et al., 2022). Access to infrastructure such as electricity and the Internet is also a significant technological barrier for farmers in the North West province (NVE & MA, 2019). Without access to electricity, Oduniyi (2018) confirms that it can be difficult for farmers to power the necessary equipment and devices needed for emerging technologies. In the view of Dube (2020), lack of access to the internet also limits farmers from obtaining relevant and up-to-date information about new

technologies, impeding their ability to make informed decisions about adoption. The high cost of adopting emerging technologies is a significant technological barrier for small-scale farmers in the region. The cost of acquiring and maintaining emerging technologies such as precision agriculture equipment and sensors is prohibitive for farmers with limited financial resources (Smidt & Jokonya, 2022). The lack of access to financing options further compounds adoption, limiting the ability of farmers to invest in emerging technologies. In some cases, Sinha and Dhanalakshmi (2022) highlight that farmers may be reluctant to adopt new technologies because of the perceived high costs, even if the long-term benefits outweigh the initial investment. Addressing technological barriers such as lack of technical knowledge, infrastructure, high costs, and limited access to financing options is crucial to improving adoption rates of emerging technologies by farmers in the North West province of South Africa. According to Mathinya et al. (2022), overcoming these barriers can promote sustainable agricultural practices and improve the livelihoods of small-scale farmers in the region.

Economic factors: According to Molieleng, Fourie and Nwafor (2021), high costs associated with adopting emerging technologies are a major economic barrier for many farmers in the North West province. The lack of financial resources to invest in new technologies results in slow adoption rates. According to Rusere et al. (2019), the absence of access to credit facilities and market opportunities due to poor infrastructure further limits the adoption of emerging technologies. Farm size has been identified as a crucial factor in technology adoption. Many researchers indicate that farm size is a key factor in technology adoption, as it can both influence and be influenced by other adoption factors (Pathak, Brown & Best, 2019). Farmers with larger farms are more likely to adopt new technology than those with smaller farms because they can afford to allocate a portion of their land to experimenting with new technology. On the other hand, farmers with small plots of land may prefer to use land-saving technologies such as greenhouse technology and zero grazing to increase productivity (Ahmad et al., 2018). The farmer's net gain from adoption, which includes all costs associated with using the new technology, is a critical determinant of adoption. The cost of implementing agricultural technology has been identified as a significant barrier to technology adoption (Molieleng et al., 2021).

Institutional barriers: According to Yaméogo, Fonta and Wünscher (2018), belonging to a social group can increase social capital by promoting the exchange of trust, ideas, and information among farmers. Zhang et al. (2020) argues that through information sharing, farmers learn about the benefits and applications of new technology from their peers. Involvement in community-based organisations can also encourage social learning and increase the likelihood of adopting emerging technologies.

Institutional factors, both formal and informal, also play a significant role in farmers' decisions to adopt new technologies (Zossou et al., 2020). Formal government policies, regulations, and support programmes provide incentives, such as subsidies, tax exemptions, and training programmes, to encourage or dissuade farmers to adopt new technologies (Zhang et al., 2020). Social networks, community-based organisations, and traditional authorities can also shape attitudes and behaviours towards new technologies by building trust and facilitating the exchange of information and knowledge (Waititu, 2021) For example, Waititu (2021) further affirms that the use of social networks like WhatsApp groups, Facebook pages, and farmer associations can enhance knowledge sharing and promote the adoption of new technologies in agriculture. Community-based organizations, like farmer cooperatives and field schools, can promote adoption through peer learning, group demonstrations, and field days (Zossou et al., 2020). In Uganda, Galabuzi et al. (2021) found that the use of farmer field schools led to increased adoption of improved crop varieties, pest and disease management practices, and soil conservation techniques. Traditional authorities, such as chiefs, clan leaders, and village elders, are respected and trusted by their communities in many African societies. Their endorsement of new technologies certainly influences farmers' decisions to adopt them (Enwereji & Uwizeyimana, 2020). In Zambia, Nkomoki, Bavorová and Banout (2018) confirm that the involvement of traditional authorities in promoting the adoption of conservation agriculture led to increased adoption rates among smallholder farmers. Institutional factors, whether formal or informal, play a crucial role in influencing farmers' decisions to adopt emerging technologies. Formal institutions offer support and incentives, while informal institutions encourage the sharing of information and peer learning among farmers. However, when institutions fail to collaborate and exchange information on agricultural practices, it can create barriers that hinder the adoption of emerging technologies.

Social barriers: These are significant impediments to the adoption of emerging technologies in agriculture. Some farmers may perceive emerging technologies as complicated and challenging to use, leading to a lack of interest in adopting them (Watititu, 2021). For instance, a study by Galabuzi et al. (2021) found that farmers in Uganda perceived precision agriculture technologies as too complicated to implement on their farms, limiting their adoption. Additionally, a lack of trust in new technologies is another social barrier that can discourage farmers from adopting emerging technologies. For example, in a study by Balabathina et al. (2020) in Ethiopia, farmers' trust in remote sensing technologies was found to be a significant factor affecting their adoption, with farmers who did not trust the technology being less likely to adopt it. Preference for traditional methods is another barrier to the adoption of emerging technologies. Farmers who are entrenched in traditional farming methods may be reluctant to try out new technologies, limiting their adoption. According to Muimba-

Kankolongo (2018), farmers' preference for traditional methods of farming inhibits the adoption of modern technologies. Furthermore, social norms and cultural beliefs can also affect the adoption of emerging technologies. For instance, in some cultures, the use of technology is perceived as a threat to traditional ways of life, leading to resistance to its adoption (Muimba-Kankolongo, 2018). Overcoming social barriers requires addressing farmers' concerns and promoting awareness and education about the benefits of emerging technologies. To increase adoption rates, Kernecker et al. (2020) posit that it is crucial to understand and address social barriers such as farmers' attitudes towards emerging technologies, lack of trust in new technologies, preference for traditional methods, social norms, and cultural beliefs.

3. Research Method

This study aimed to investigate the barriers that prevent farmers in the Northwest province from adopting emerging technologies in their farming practices. The pragmatist research paradigm was used to guide this study. As suggested by Creswell (2014), pragmatist researchers adopt the best approach that provides answers to the research questions. Therefore, a mixed methods study was employed, specifically an explanatory sequential design. Due to financial and time constraints, the study focused on Ngaka Modiri Molema District municipality, which consists of five local municipalities. The employees of the Department of Agriculture were included in the qualitative study, while farmers in the selected municipalities were chosen to participate in the quantitative phase. The population of the study comprised 85 employees in the management category of the Department of Agriculture and 1340 farmers for the quantitative phase. For the sample frame, five participants were selected from each of the five local municipalities in Ngaka Modiri Molema District. In the quantitative phase, 384 respondents were approached to participate in the study. The response rates were 70% and 80% for the qualitative and quantitative phases, respectively. The data were analysed using Statistical Package for Social Sciences for the quantitative phase, while ATLAS-ti Software (Version 22) was used for the qualitative data analysis. The study upheld ethical concepts such as informed consent, confidentiality, privacy, respect for human dignity, minimising harm, and ensuring justice and fairness. Furthermore, validity and reliability were adequately maintained in the study.

4. Research Results

This section contains the research findings obtained from a survey of farmers and interviews with officials from the Department of Agriculture. This section presents the major barriers that hinder the adoption of emerging technologies by farmers in the North West province. The study followed a mixed methods approach, specifically an explanatory sequential design. Accordingly, the first section

presents the quantitative results, while the subsequent section presents the qualitative results to complement and enrich the quantitative findings. Table 1 presents the reliability statistics.

4.1 Quantitative results

In this section, the findings of the quantitative analysis that was conducted to understand the barriers hindering the adoption of emerging technologies by farmers in the North West province were presented. The data collected from the farmers was analysed using the Statistical Package for Social Sciences (SPSS), which is a widely used software package for statistical analysis. The analysis aimed to provide insights into the perceptions of farmers towards emerging technologies and identify the factors that hinder the adoption of these technologies. The results of the quantitative analysis are presented in the form of tables which provide a visual representation of the data. The findings of the study will be used to inform recommendations aimed at addressing the barriers hindering the adoption of emerging technologies by farmers in the North West province. Table 5.1 presents the reliability statistics.

Table 5.1 Reliability Statistics

Cronbach's Alpha	N of Items
.890	18

The interpretation of Cronbach's Alpha is based on the benchmark describe by Burns and Burns (2008) who recommended that values of at least 0.7 indicate that the items in the construct are reliable. As such, according to the table above; all items in in the scale measuring the major barriers that hinder the adoption of emerging technologies by farmers in the North West province are reliable for factor analysis to be conducted. Table 5.2 presents the KMO and Bartlett's Test.

Table 5.2 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.896
Bartlett's Test of Sphericity	Approx. Chi-Square	7970.682
	Df	153
	Sig.	.000

Ma et al. (2011) recommend that a KMO of 0.7 is acceptable, therefore, the results in the Table above show that the sample is adequate for EFA to be conducted. Also, the p-value of Bartlett's test is significant at a 5% level of significance, and according to Montshiwa and Moroke (2014), this result implies that the items are factorable. Table 5.3 presents the Total Variance Explained.

Table 5. 3 Total Variance Explained

Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.544	36.354	36.354	5.916	32.867	32.867
2	5.156	28.642	64.996	4.150	23.056	55.923
3	1.090	6.056	71.052	2.723	15.129	71.052
Extraction Method: Principal Component Analysis.						

Using Kaiser's rule of eigenvalues (total column) greater than one as in the study by Braktia et al. (2021), the table above shows that there are three factors with eigenvalues greater than one which implies that three factors should be extracted from the scale describing the major barriers that hinder the adoption of emerging technologies by farmers in the North West province. These three factors explain 71.052% of the total variation which is sufficient because it is more than the recommended minimum of 50% used in the study by Bandalos and Finney (2018). Table 5.4 presents the Rotated Component Matrix[a]

Table 5. 4 Rotated Component Matrixa

		Component		
		1	2	3
BET13	I will likely adopt a new variety if my community participated in the breeding process.	**.996**	.041	.046
BET14	the initial cost of emerging technologies is high	**.989**	.040	.044
BET15	I do not have the necessary skills and knowledge to adopt emerging technology	**.991**	.045	.053
BET16	Extension agents/farm consultants are not readily available to guide me on how to use new technologies.	**.987**	.040	.044
BET17	emerging technologies will not/does not help me to improve on my current practices since I can manage my farm well.	**.992**	.040	.044
BET18	I cannot handle the extra recordkeeping and data management associated with emerging technologies.	**.989**	.039	.043
BET5	Lack of knowledge and education on emerging agricultural technologies	.011	**.541**	.402
BET7	Limited access to ready markets and market information	.056	**.757**	.155
BET8	Limited access to weather and climate information	.054	**.627**	.220
BET9	Limited government support with farm inputs	.015	**.739**	.153
BET10	Limited user-friendliness of emerging agricultural technologies	.040	**.731**	.517
BET11	Shortages of timely labour for emerging agricultural technologies	.028	**.876**	.365
BET12	Inadequate training of extension staff and farm consultants can hinder the adoption of emerging technologies.	.064	**.795**	.251
BET1	Unavailability of improved crop varieties	.083	.335	**.666**
BET2	High cost of improved crop varieties	.059	.192	**.805**
BET3	High illiteracy level of smallholder farmers	-.010	.333	**.339**
BET4	Inadequate access to agricultural credit	.009	.104	**.750**
BET6	Limited access to emerging agricultural emerging technologies	.068	.361	**.469**

The numbers in the component matrix above are factor loadings. An item is allocated to a factor on which it has the highest loading. The component matrix shows that six items from the scale of the major barriers that hinder the adoption of emerging technologies by farmers in the North West province

were allocated to the first factor which we termed **Major Barriers 1**, seven items were allocated to the second construct which we named **Major Barriers 2** whereas the remaining 5 items were allocated to the third factor which we term **Major Barriers 3**. Following EFA, we conducted the reliability analysis again to ascertain whether the items allocated to the three constructs are indeed measuring the same traits and the results are presented below.

Table 5. 5 Reliability analysis for major barriers 1, 2 and 3

Barriers	Cronbach's Alpha	N of Items
Major Barrier 1	.997	6
Major Barrier 2	.880	7
Major Barrier 3	.702	5

Derived from this table, all items in the scale measuring the Major Barriers 1,2 and 3 are reliable since the Cronbach Alpha is greater than 0.7 (Burns and Burns, 2008) and this implies that they are internally consistent within this construct and can be regarded as measuring the same construct. The CFA results are presented below.

Table 5.6 The CFA Results

Path			Parameter estimate	Standard error	t value	P-value
BET_1	===>	BET13	0.99975	0.0001997	5006.8	<.0001
BET_1	===>	BET14	0.98669	0.00153	643.6	<.0001
BET_1	===>	BET15	0.99328	0.0007965	1247.1	<.0001
BET_1	===>	BET16	0.98628	0.00158	624.8	<.0001
BET_1	===>	BET17	0.99310	0.0008158	1217.3	<.0001
BET_1	===>	BET18	0.98651	0.00155	635.3	<.0001
BET_2	===>	BET5	0.61499	0.03638	16.9066	<.0001
BET_2	===>	BET7	0.67131	0.03226	20.8087	<.0001
BET_2	===>	BET8	0.58130	0.03867	15.0334	<.0001

BET_2	===>	BET9	0.66719	0.03257	20.4817	<.0001
BET_2	===>	BET10	0.90220	0.01212	74.4432	<.0001
BET_2	===>	BET11	0.98230	0.00613	160.3	<.0001
BET_2	===>	BET12	0.81949	0.01981	41.3714	<.0001
BET_3	===>	BET1	0.69570	0.03819	18.2181	<.0001
BET_3	===>	BET2	0.69985	0.03794	18.4486	<.0001
BET_3	===>	BET3	0.42889	0.05331	8.0455	<.0001
BET_3	===>	BET4	0.54566	0.04728	11.5423	<.0001
BET_3	===>	BET6	0.54599	0.04726	11.5537	<.0001

The p-values for all the items are significant at a 5% level of significance, meaning that all the items significantly belong to the factors to which EFA have allocated them. The CFA results for the scale measuring major barriers that hinder the adoption of emerging technologies by farmers in the North West province yielded an RMSEA of 0.0809 which is almost equal to 0.08 and it indicates that the goodness of fit lies on the border line. However, the CFI was 0.9677, NFI was 0.9525 and TLI was 0.9617 and all of these indices show that the model is a good fit for the data. As such, although the RMSEA implies a border line fit, all other indices indicate a good fit, and all p-values of the items are significant, therefore; the factor structure is valid.

4.2 Qualitative results

In this section, the qualitative results obtained from the employees at the Department of Agriculture in the North West province were presented. The data collected through interviews was analysed using ATLAS-ti software version 22. The software was used to identify patterns and themes in the data, as well as to code and categorize the responses according to the research question. The qualitative data provided a valuable perspective on the issues surrounding the adoption of emerging technologies in agriculture, which complemented the findings from the quantitative data. The use of ATLAS-ti software ensured that the analysis was systematic, rigorous, and grounded in the data, thereby enhancing the credibility and trustworthiness of the findings. Figure 5.1 presents the major barriers to adopting emerging technologies by farmers in the North West province.

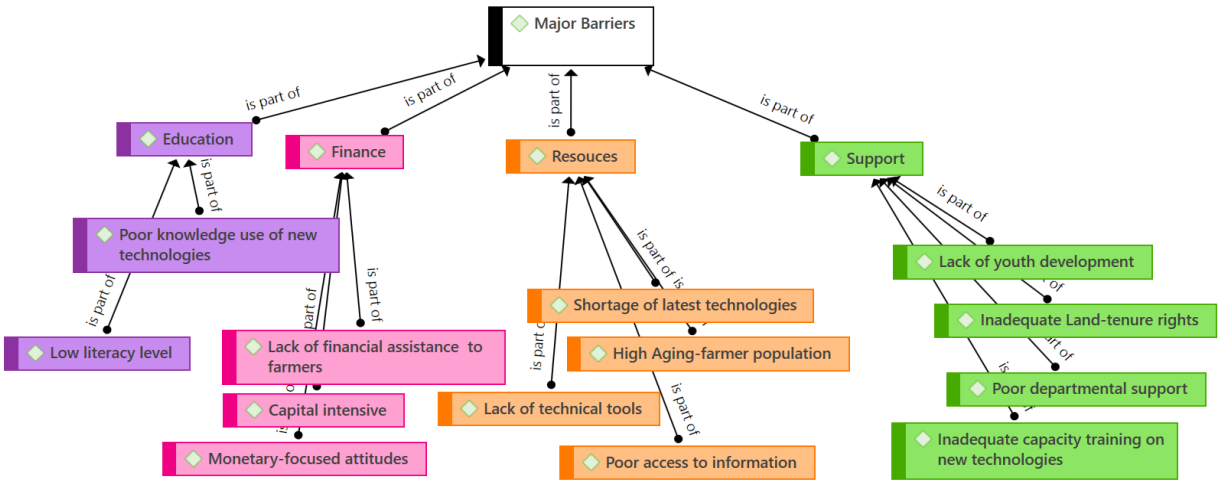

Figure 5.1 Major Barriers to adopting emerging technologies

Based on the analysis conducted using ATLAS-ti software, the findings revealed four main themes: education, finance, resources, and support. In terms of education, participants identified inadequate knowledge of the use of technologies and low literacy levels as the primary reasons for the poor adoption of emerging technologies. Regarding finance, participants highlighted the lack of financial assistance, high costs of emerging technologies, and a monetary-focused mindset as barriers to adoption.

Concerning resources, participants noted the shortage of modern technologies, an ageing farmer population, limited technical tools, and poor access to information as factors contributing to low adoption rates. Lastly, in terms of support, participants emphasized the lack of youth development, inadequate job opportunities and land tenure, insufficient departmental support, and a lack of capacity training on new technologies as hindrances to the adoption of emerging technologies in agriculture in the North West province.

5. Discussion of results

The study established several significant barriers that impede farmers' adoption of emerging technologies. The quantitative analysis reveals that high initial costs associated with these technologies discourage farmers from investing in new varieties or equipment. Sinha and Dhanalakshmi (2022) affirm that the adoption of emerging technologies in the agricultural sector faces various barriers such as loss of ability to develop feasible roadmaps towards ICT integration, a lack of knowledge, funds, or affordability. The study verified that the lack of necessary skills and knowledge poses a challenge, as farmers may feel ill-equipped to adopt and utilize emerging technologies effectively. This highlights

the need for comprehensive training programs and supports to address the knowledge gap. In the view of Mabhaudhi et al. (2018), there is a significant digital divide between wealthy large-scale farmers and smallholders due to financial constraints, familiarity with technology and education levels. Another crucial barrier identified is the limited availability of extension agents or farm consultants who can guide on using emerging technologies. The lack of mentoring has limited the knowledge of the farmers on adopting the improved maize varieties as indicated by the study. The absence of expert assistance hinders farmers' ability to adopt and integrate these technologies into their practices.

Takahashi, Muraoka and Otsuka (2020) show that the availability of information encourages farmers to make profitable decisions, but traditional extension systems have had low farmer usage and have frequently promoted technologies that are either unprofitable or whose costs and benefits are grasped by farmers. Furthermore, farmers may perceive the benefits of emerging technologies as insignificant compared to their existing methods, leading to resistance or reluctance to embrace them. However, Myeni et al. (2019) verify that a sizable proportion of smallholder farmers continue to employ conventional agricultural methods, leading to lower productivity levels. Precision agriculture, data analytics, and remote sensing are examples of current agricultural technology that could be adopted to increase crop yields, lower costs, and increase efficiency. The potential improvements and advantages offered by these technologies to incentivize adoption must be privileged. Recordkeeping and data management present additional challenges, as farmers may feel overwhelmed by the additional workload involved in managing and analysing data generated by emerging technologies. This extra burden can deter adoption, especially among farmers already facing time and resource constraints. Streamlining data management processes and providing user-friendly tools and resources can alleviate this barrier. According to Takahashi, Muraoka, and Otsuka (2020), farmers are encouraged to make profitable decisions by the availability of information, but traditional extension systems have not been widely used by farmers and frequently promoted technologies that are either unprofitable or whose costs and benefits are known to farmers.

The qualitative findings align with the quantitative results and highlight the themes of education, finance, resources, and support. Inadequate knowledge and low literacy levels emerge as fundamental issues inhibiting farmers' understanding and adoption of emerging technologies. Financial constraints, such as the lack of financial assistance and limited access to agricultural credit, further hinder adoption. Resource limitations, including the scarcity of modern technologies, an ageing farmer population, and restricted access to information and markets, pose additional obstacles. According to Molieleng, Fourie, and Nwafor (2021), the high costs associated with adopting emerging technologies, coupled

with the lack of financial resources, pose a major economic barrier for many farmers in the North West province, while Rusere et al. (2019) emphasize that the absence of access to credit facilities and market opportunities, primarily due to poor infrastructure, further limits the adoption of emerging technologies in the region. Strengthening education and training programs, improving financial assistance mechanisms, and enhancing access to resources and support systems are essential for overcoming these barriers.

According to Kernecker et al. (2020), overcoming social barriers to the adoption of emerging technologies requires addressing farmers' concerns, promoting awareness, and providing education about the benefits of these technologies. This involves understanding and addressing factors such as farmers' attitudes towards emerging technologies, lack of trust in new technologies, preference for traditional methods, adherence to social norms, and cultural beliefs, to effectively increase adoption rates. Addressing the multifaceted barriers to farmers' adoption of emerging technologies requires a comprehensive approach involving collaboration between farmers, government agencies, agricultural organizations, and other stakeholders. This approach should encompass financial support mechanisms, targeted training programmes, improved access to resources, and the establishment of robust support systems. By addressing these barriers, stakeholders can create an enabling environment that promotes the successful adoption of emerging technologies in agriculture, leading to enhanced productivity, sustainability, and overall development in the North West province.

6. Major findings of the study

The study confirmed significant findings regarding the barriers to farmers' adoption of emerging technologies in agriculture. The quantitative findings shed light on various obstacles faced by farmers, including the high initial cost of emerging technologies, limited skills and knowledge, lack of guidance from extension agents, and concerns about the added burden of recordkeeping and data management. These quantitative findings underscore the need for targeted interventions to address financial constraints, enhance farmers' capabilities, and provide adequate support structures to facilitate technology adoption. Additionally, the study highlighted the challenges posed by limited access to markets, weather and climate information, improved crop varieties, and agricultural credit, which further hinder the adoption process.

Furthermore, the qualitative findings confirmed four main themes: education, finance, resources, and support. In terms of education, the study emphasized the importance of addressing inadequate knowledge and low literacy levels among farmers, as these factors significantly impact their ability to

adopt emerging technologies effectively. The finance theme highlighted the need for financial assistance and a shift away from a monetary-focused mindset to alleviate financial barriers. The resources' theme emphasized the importance of providing farmers with access to modern technologies, technical tools, and relevant information. Lastly, the support theme emphasized the significance of addressing youth development, job opportunities, departmental support, and capacity training to enhance farmers' adoption of emerging technologies.

These findings provide valuable insights for policymakers, extension services, and stakeholders in formulating strategies and programs to overcome the identified barriers. By focusing on reducing costs, improving access to knowledge and resources, and strengthening support systems, it is possible to create an enabling environment that promotes the widespread adoption of emerging technologies in agriculture. This, in turn, can lead to enhanced productivity, sustainable practices, and improved outcomes for farmers and the agricultural sector as a whole**.**

7. Conclusions

In conclusion, this study examined the barriers to farmers' adoption of emerging technologies in agriculture and provided valuable insights into the challenges faced by farmers in the North West province. The findings from both the quantitative and qualitative analyses highlighted several key factors that hinder technology adoption. The quantitative analysis revealed that high initial costs, limited skills and knowledge, lack of guidance from extension agents, and concerns about recordkeeping and data management were significant barriers to technology adoption. These findings underscore the importance of addressing financial constraints, enhancing farmers' capabilities through training and education, and providing adequate support structures to facilitate technology adoption. The qualitative analysis identified four main themes: education, finance, resources, and support. In terms of education, the study emphasized the need to address inadequate knowledge and low literacy levels among farmers. The finance theme highlighted the importance of financial assistance and a shift in mindset towards investing in emerging technologies. The resources theme emphasized providing farmers with access to modern technologies, technical tools, and information. Lastly, the support theme underscored youth development, job opportunities, departmental support, and capacity training. Overall, the findings of this study contribute to our understanding of the barriers to technology adoption in agriculture. They provide valuable insights for policymakers, extension services, and stakeholders in formulating targeted interventions and strategies to overcome these barriers. By addressing these challenges and creating an enabling environment that promotes technology adoption, it is possible to unlock the potential of emerging technologies in agriculture, leading to improved

productivity, sustainable practices, and enhanced livelihoods for farmers in the North West province and beyond.

8. Recommendations of the study

Based on the findings of the study, the study proposes recommendations to farmers and the government.

8.1 Recommendations to the farmers

Engage in continuous learning and skill development: Farmers should prioritize continuous learning and skill development to stay updated with emerging technologies and their applications in agriculture. This can be achieved through attending workshops, training programs, and agricultural conferences. Farmers can also form farmer groups or cooperatives to share knowledge, experiences, and best practices.

Seek financial support and explore funding options: Farmers should actively explore various funding options available to them, such as agricultural loans, grants, and subsidies provided by government agencies, financial institutions, and agricultural organisations. It is essential to develop a solid business plan highlighting the benefits and potential returns on investment in emerging technologies to attract financial support.

Foster collaboration and networking: Farmers should actively engage in networking activities and collaborate with other farmers, research institutions, and technology providers. By forming partnerships and sharing resources, farmers can collectively address challenges, access new technologies, and share costs associated with adopting emerging technologies. Collaboration can also facilitate access to market opportunities and enhance the collective bargaining power of farmers.

Embrace gradual adoption and adaptability: Instead of adopting emerging technologies all at once, farmers should consider a phased approach, starting with small-scale implementation and gradually expanding as they gain experience and confidence. It is important to assess the compatibility of new technologies with existing farming practices and adapt them to suit local conditions. Farmers should also stay open to feedback, adapt to challenges, and continually refine their adoption strategies.

8.2 Recommendations to the government

Develop supportive policies and regulatory frameworks: The government should establish policies and regulatory frameworks that encourage and incentivize the adoption of emerging technologies in

agriculture. This includes providing financial incentives, tax breaks, and subsidies for farmers investing in emerging technologies. Clear guidelines should be developed to streamline the approval and adoption processes for new technologies, ensuring they meet safety and environmental standards.

Strengthen extension services: The government should invest in strengthening extension services to provide farmers with accurate and timely information on emerging technologies. Extension officers should receive adequate training on new technologies and be equipped with the necessary resources to effectively disseminate information and provide technical support to farmers. Information centres and helplines can be established to address farmers' queries and provide guidance.

Facilitate access to credit and financial resources: The government should collaborate with financial institutions to develop tailored financial products, including low-interest loans and flexible repayment options, specifically designed for farmers adopting emerging technologies. The government can also establish credit guarantee schemes to mitigate risks associated with lending to farmers and promote financial inclusion in rural areas.

Promote research and development: The government should invest in research and development initiatives focused on adapting emerging technologies to local agricultural practices, addressing specific challenges faced by farmers, and developing cost-effective solutions. Collaboration between research institutions, universities, and farmers should be relevant and practical in terms of research outcomes. Government funding should be allocated to support research projects and promote technology transfer to the farming community.

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CHAPTER SIX

ARTICLE FOUR

Incorporating emerging technologies to achieve agricultural sustainability: The roles of governance models

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Abstract

Agriculture serves as a cornerstone of economic development and food security in nations worldwide. In this context, the Department of Agriculture plays a pivotal role in shaping policies and practices that directly impact farmers and the agricultural sector. This study investigated the governance models applied by the Department of Agriculture in an endeavour to promote the adoption of emerging technologies in agriculture. A qualitative research approach was adopted and a total of 25 participants were interviewed. The adoption of a qualitative study provided an in-depth exploration through interactions with the participants. The data was analysed thematically with the help of ATLAS-ti software (Version 23). The analysis revealed a diverse spectrum of models, including the collective model, machine model, performance control model, and network model. Each of these models reflects distinct approaches to governance, offering insights into the organisational ethos and its approach to agricultural management. A crucial aspect of agricultural development lies in the adoption of emerging technologies. The study further explores technology transfer models such as machinery supply, agricultural advisory services, funding mechanisms, and training programmes. The study recommends strengthening technology transfer, fostering research and innovation, supporting farmer cooperatives, advocating sustainable agricultural practices, and improving financial access within the department. Government-level actions like prioritizing agriculture, investing in rural infrastructure, expanding market access, enhancing education and training, funding research and development, fostering a supportive regulatory environment, and addressing climate change resilience are also proposed. The study presents a comprehensive roadmap to enhance agricultural development, emphasising the value of partnerships, and urges the department and government to implement these measures for sustainable agriculture, improved food security, and the prosperity of the agricultural sector and its stakeholders.

Keywords: agricultural governance; innovation in agriculture; sustainable agricultural practices; governance models; Department of Agriculture; South Africa

1. Introduction

In the face of escalating global population growth, climate change, resource depletion, and shifting consumer demands, the agricultural sector is confronted with the imperative to revolutionize its practices and systems (Serraj, Krishnan & Pingali, 2019). In the view of Imathui (2020), ensuring food security, safeguarding natural resources, and mitigating environmental degradation have become paramount challenges. Emerging technologies, characterized by their rapid evolution and transformative potential, offer promising avenues to address these challenges and transition toward a sustainable agricultural future. However, the effective integration of these technologies hinges not only on technological prowess but also on the governance models that underpin their deployment. The term "agricultural sustainability" encapsulates the pursuit of agricultural practices that meet present needs without compromising the ability of future generations to meet their own needs (Sijpestijn, Wezel, & Chriki, 2022). Achieving this noble objective demands a multi-dimensional approach, and the incorporation of emerging technologies stands as a pivotal strategy within this framework. Emerging technologies, encompassing artificial intelligence, precision agriculture, biotechnology, blockchain, remote sensing, and more, hold the potential to enhance productivity, optimize resource utilisation, reduce waste, and minimize the ecological footprint of agricultural activities (Bhatt & Karki, 2023).

The potential benefits of emerging technologies in agriculture cannot be realised in isolation. The governance models that oversee the adoption, implementation, and regulation of these technologies play a pivotal role in determining their impact on sustainability (Luthra & Mangla, 2018). Governance models encompass a broad spectrum of mechanisms, ranging from policy frameworks, legal regulations, and industry standards to collaborative networks, stakeholder engagement, and decision-making structures (Reddy et al., 2020). These models establish the rules of the game, allocate responsibilities, manage risks, and shape the ethical and social dimensions of technology deployment. This study investigates the interplay between emerging technologies and governance models to enhance agricultural sustainability in the North West province of South Africa. The study is framed by the understanding that technical developments do not necessarily revolutionise society; rather, their potential is realised through strategic, knowledgeable, and adaptive governing techniques. This study enhances the understanding of how governance models can either help or impede the effective integration of emerging technology for sustainable agriculture by looking at some of the governance models applied by the Department of Agriculture in the North West Province.

The importance of this study rests in providing policymakers, academics, practitioners, and other interested parties research-based information regarding the dynamics underlying the effective adoption of innovative technologies in agriculture. The research provides insights into how governments, businesses, and communities could cooperate to harness the full potential of technology while upholding sustainability principles by analysing governance, from legal and regulatory frameworks to participatory decision-making processes. This study illuminates the routes that lead to a more resilient, fruitful, and sustainable agricultural future because the agriculture sector currently stands at the nexus of technology innovation and environmental stewardship. The study contributes to the general objective of agricultural sustainability in a time of rapid technological advancement by offering practical recommendations for policy formulation, stakeholder involvement, and governance adoption through a detailed analysis.

2. The role of technology in agriculture

According to the Food and Agricultural Organisation (2017), a sufficient supply of food is essential for the survival of people, which makes agriculture a top concern in every nation in the world. Niet et al. (2021) state that human society has attempted to depart from the Hunter model of existence, which focuses primarily on the use of land and labour to produce food. Today, countries around the world, including South Africa, are embracing technological developments to advance agricultural methods. Biological, artificial intelligence, and chemical sciences have all been used to modern agriculture by new technologies (McLennon et al., 2021) These technological developments have not only increased food production in actual terms but have also significantly decreased the number of people directly involved in food production/processing. This has allowed society to diversify and address social issues that are not directly related to "survival," but are generally seen as improving people's quality of life (Martin-Rios, Hofmann & Mackenzie, 2020).

The rate of technological adoption and the degree of innovation in future technologies will have a significant impact on the stability and, most importantly, the productivity of agricultural products (Kumar, Engle & Turcker, 2018). In the traditional sense, technology in agriculture encompasses the development and application of nutrients, pest control products, crop cultivars, and farm equipment; however, it also encompasses the vision of genetically modified crops that provide greater nutritional efficiency, the manipulation of natural pest control agents, and the application of farm management techniques that focus on productivity (Michelmore et al., 2017). Reflecting on the basic premise of biotechnology, the sun is the cheapest and most renewable source of energy on Earth, and photosynthesis is the most abundant and predictable mechanism for converting solar energy to usable

energy. The application of biotechnology to agriculture has enabled more effective methods for directing abundant natural energy to new, more efficient, or unique food products. Others include the production of quality products, input reduction, maximum yield products, super-nutritious animal feed, plants that produce the subtractive influence of pests (making "tolerance" a key pest management tactic), physiological adaptation to out-compete adjacent species, drought stress tolerance, and overall improvement in photosynthesis rate (Napier, Mordecai & Heckman, 2016).

Agricultural technology development is not delimited to genetic modification. Indeed, the use of computational technology, in combination with geographic positioning devices and remote sensing developments, has the potential to completely transform the way all crops are maintained (Pajares, 2015). The integration of 'Precision Agriculture' has tapped into data to develop management knowledge in addressing site-specific production goals (Onyango *et al.,* 2021). Environmental uncertainty will always be a major issue in agriculture, but modern technologies have addressed this through environmental modelling mixed with risk management algorithms, resulting in the best use of genetics on specific soils in identified weather conditions. There have been outstanding breakthroughs witnessed in agricultural practices, such as improved food production through the adoption of emerging technologies (Food & Agricultural Organisation, 2017).

The assimilation of emerging technologies in agricultural practices has been slow in Africa. This is a result of issues related to governance and diffusion. Theorists such as Brent and Lewis (2014) affirm that culture is subject to change through invention and diffusion. According to Brent and Lewis (2014), diffusion is the spread of a new concept, habit, or technology among groups of people. Relative advantage, complexity, divisibility, observability, and compatibility are factors that affect the diffusion of technologies. Farmers in the North West Province could be willing to use emerging technologies in their agricultural practices if the correct information is circulated effectively. The support of environmental rules by the government that define performance standards for certain technology adoption tends to foster innovation (Food & Agricultural Organisation, 2017). In the case of the invention of new technology, the government needs to disseminate information to the extension agents, and others who are responsible for presenting the benefits of the technology to farmers. Science, economics, and human behaviour; all play a role in the assimilation and adoption of new and available technologies at the farm level, but governance is highly needed to coordinate the activities of the citizenry, as noted by Gui and MacGill (2018).

3. The meaning of governance

Since the 1980s, when public sector reforms were implemented, governance has become a significant paradigm across the social sciences, and the focus of countless articles, books, monographs, and issues (Ikeanyibe, Eze & Okoye, 2017). The definition of governance, on the other hand, is ambiguous and elastic depending on the field, approach, and area under consideration. It could be argued that governance is an ancient concept that dates back to the dawn of civilisation. The term "governance" is derived from the Greek word "kybernan," which means "to steer or pilot a ship," but it was also used during the Roman Empire under the Latin term "gubernare," which meant "to direct, rule, and guide" (Yousif & Mohammed, 2022). It is obvious that the definition of governance has changed over time, and it may today be widely defined as the interaction between governments, commercial stakeholders, and non-profit organisations that make it easier to put policy decisions into effect. Governance has become a popular concept among academics and practitioners in a wide range of disciplines, including public administration, economics, political science, management, law, and sociology.

The term "governance" is well-known, having been used by almost every international organisation and democratic government to describe how intricately interwoven and extraordinarily complicated issues are handled (Zingraff-Hamed et al., 2021). Therefore, the goal of governance is to demonstrate the use of political and administrative power at all levels to manage the affairs of nations (Gray, 2019). It encompasses the techniques, procedures, and institutions that people and groups employ to communicate their needs, assert their legal rights, carry out their duties, and settle disputes (Ju, Liu & Feng, 2018). According to Turnbull (2019), the act of governance is the practice of managing influence to lead and regulate the operations of management and employees inside an organisation. In the same vein, Ju et al. (2018) reiterate that the management of organisational performance and compliance procedures falls completely under the purview of the "governing body".

The definitions of governance provided above only serve to highlight that it entails the use of power to maintain order and satisfy public needs within a certain bound. Governance aims to enhance the common good by harnessing the influence of numerous systems and connections to direct, steer, and control citizen behaviour. In terms of political science, governance refers to the procedure of political administration, the normative foundations of political authority, methods for resolving political conflicts, and the administration of public funds (Rosenbloom, Kravchuk, & Clerkin, 2022). To maintain social order and the executive part of government, Larsson (2019) emphasizes the function of political authority. According to this justification, promoting effective governance can aid in integrating developing technology into agricultural sustainability.

4. Governance Models

A governance model is made up of policies, systems, and structures as well as strategic and operational frameworks (Asaduzzaman & Virtanen, 2016). Newig et al. (2018) posit that a governance model describes the interaction between the authority chain and the framework. When nations or organisations select the best governance model for them, it can be extremely beneficial, especially if it aligns with the right executives. According to Asaduzzaman and Virtanen (2016), a governance model ensures that decisions are made effectively and that executives are held accountable. It should be noted that each board governance style is distinct and serves a distinct function (Burne, 2014). Certain governance models are designed to assist non-profit organizations whose boards and employees may lack corporate knowledge but are passionate about the cause and willing to assist. Mintzberg (1996) argues that governance should be strictly adhered to, and he elaborates on five distinct models: the government as a machine model, the government-as-network model, the performance control model, the virtual government model, and the normative control model. These five distinct models according to Mintzberg (1996) are expounded upon consequently.

The government-as-machine model views government as a mechanistic system governed by laws, regulations, and standards. Although popular in the past, it lacks adaptability and responsiveness to individual initiatives (Meintzberg, 1996). In contrast to the machine model, the government as a network model portrays governance as a complex web of ad hoc interactions designed to address emerging problems, linked by flexible communication channels. It aims to foster connections, communication, and collaboration among individuals within a larger web of projects. Concerning the performance-control model, Mintzberg (1996) affirms that this model likens government to a business, where the organisation is composed of business units assigned performance objectives and held accountable by their managers. However, this model can sacrifice individual initiative, adaptability, and creativity in the pursuit of centralisation. The virtual government model seeks to privatise, contract out, and negotiate services to escape the constraints of the machine-like government mode and deliver better services to the public. Under this theory, government microstructures would dissolve, and all work would be outsourced to the private sector. Compared to other models, the normative-control paradigm places greater emphasis on values and norms rather than organisational structure and systems. This model comprises five key components such as selection (individuals are chosen based on their values and attitudes rather than just their credentials), socialisation (ensuring that members are committed to an integrated social system), guidance (providing guidance based on agreed-upon principles and visions rather than imposed initiatives), responsibility (all members share responsibility, placing trust in leaders who use a hands-on management approach based on experience) and judgment

(evaluation of performance is conducted by seasoned professionals, including service recipients and representatives on oversight boards).

Another definition of governance is "the processes, structures, and traditions that determine how power is exercised, stakeholders have a voice, decisions are made, and decision-makers are held accountable" (Jiménez et al., 2020). To achieve effective citizen engagement in public decision-making and administration, as well as ensure accountability, legitimacy, transparency, adherence to the rule of law, and a conducive atmosphere for addressing socioeconomic issues, several essential elements of good governance are required (Huque & Jongruck, 2018). This entails embracing participatory democracy and enhancing government capabilities to meet the growing demands of development. Sanders (2019) confirms that the goal of transparency is the establishment of a political environment characterized by trust between the government and its citizens. During this period, citizens naturally assume responsibility for various aspects of development and develop a sense of ownership in their country's progress.

Governance encompasses a spectrum of models, each offering a distinctive approach to managing organisations and making decisions. These models provide frameworks for understanding how authority is structured, roles are defined, and decision-making processes are shaped within various institutions. The following governance models were introduced by Gill (2002) to enhance how processes are smoothly executed. According to Gill (2002), the Operational Model places the responsibility for managing, governing, and executing the work of an organization solely in the hands of its board. This model assumes a highly engaged and hands-on board, deeply involved in the day-to-day affairs of the organisation. In contrast, the Collective Model promotes collaboration between the board and staff, viewing them as a unified team. Board members in this model may actively participate in service operations or take on management functions, blurring the traditional lines between governance and execution. The Management Model, on the other hand, organises governance through functional committees, sometimes with support from a staff facilitator (Cameron & Green, 2019). These committees oversee specific aspects of the organization's operations, allowing for more specialised attention to different areas. The Constituent Representational Model is often employed by elected public officials. Here, boards are tasked with balancing the interests of their constituents with those of the organization (Gill, 2002). This model calls for careful consideration of the broader community's needs. In the Traditional Model, the board governs and provides oversight through committees that align with functional areas such as finance, human resources, and programs (Gill, 2002). However, the day-to-day management functions are typically delegated to an executive director.

The Results-based Model positions the executive director as a non-voting member of the board but grants them significant influence over policy decisions. Committees are instrumental in monitoring and auditing the performance of the board, the executive director, and the organisation as a whole. Policy Governance, often associated with the Carver Model, is characterised by the board's governance through policies. These policies define organizational goals (ends), governance methods, and management constraints (Gill, 2002). The executive director is granted substantial latitude in determining how to achieve these goals. In the Advisory Board Model, the executive director plays a dominant role in selecting and shaping the board. This board serves primarily in an advisory capacity, providing input and advice on the executive director's recommendations. The Cooperative Model is marked by consensual decision-making among board members. It is most commonly found in smaller nonprofit organisations, where all members make decisions as equals (Gill, 2002). This model prioritizes democratic decision-making processes and requires adherence to formal voting procedures. Additionally, the Multi-stakeholder Governance Model emerges as a tool for enhancing governance sustainability (Gill, 2002). It fosters cooperation among different governance levels, sectors, and departments of authority. This approach is adaptable and can be applied at various governance levels, such as national, regional, local, and community levels. It engages multiple independent but interdependent actors in continuous negotiation and implementation without imposing a rigid hierarchy of authority levels.

Furthermore, Peters (2001) introduced four significant governance paradigms such as the Market Model which advocates that the private sector can provide services more efficiently than the government. It calls for a shift towards privatization. The Participatory State Model emphasises greater participation by historically excluded segments of government organisations, making decision-making more inclusive. The Flexible Government Model stresses adaptability and contextuality in government policies to address environmental challenges and meet evolving societal demands. The Deregulated Government Model promotes less bureaucratic control, greater managerial freedom, and collective decision-making based on societal needs rather than rigid regulations. These governance models and paradigms offer diverse approaches to structuring and managing organisations and provide important insights into how governance can be adapted to meet varying needs and contexts. While each model comes with its unique implications, they all contribute to the ongoing evolution and improvement of governance practices and can be applied by the Department of Agriculture of the North West province to adopt emerging technologies in agriculture.

5. Effective governance in agriculture

The Food and Agriculture Organisation (FAO) (2017) defines food security as ensuring that everyone has consistent access to enough safe and nutritious food to maintain a healthy and active life. This concept highlights the connection between chronic hunger and governance. According to Candel (2016) and Mazenda (2021), governments play a central role in ensuring physical, social, and economic aspects of food security. Therefore, any efforts to enhance agriculture and food security must consider governance as a critical factor. Elements like participation, accountability, transparency, effectiveness, and the rule of law should be integral parts of agricultural and food security programs. These initiatives should involve various stakeholders and food systems to empower them to make changes to improve food security and reduce malnutrition (Candel, 2016). Explicit attention to governance and agricultural policies can also help governments achieve their food security goals. Traditional approaches that did not prioritize governance have been proven insufficient, particularly following the food crisis of 2007-2008. Effective coordination among governance, food security, and agriculture is essential to address global food demand issues (Mandemaker, Bakker, & Stoorvogel, 2011).

Recent developments highlight the importance of food safety, access, and agricultural productivity in social welfare (Calicioglu et al., 2019). Governance has gained significant attention due to its critical role in these areas. Numerous studies in the literature have shown that good governance significantly impacts a country's agricultural productivity (Chandio et al., 2020; Kumar et al., 2021; Abbass et al., 2022). Poor governance can worsen food insecurity, especially in low-income, food-deficit countries prone to domestic agricultural problems (FAO, 2017). Conversely, effective governance promotes agriculture and food security through various channels. To eliminate hunger, there must be an alignment of goals and outcomes at all government levels. At the local level, civil society organisations working with the government can contribute significantly to food security by enhancing collaboration between decision-makers and the affected population and by providing resources and knowledge that government agencies may lack (Bahta, Jordaa & Muyambo, 2016).

Effective agricultural governance, focusing on accountability, citizen participation, and multi-stakeholder programs, can improve service delivery and development outcomes. For instance, in countries like Senegal, Bolivia, Brazil, and Niger, decentralisation of authority related to food and nutritional security, along with active farmer participation in policy design, has led to inclusive agricultural policies and improved access to agricultural and food value chains. These initiatives emphasize collaboration and shared accountability at all levels instead of top-down approaches (Liu, 2017). Research by Liu (2017) using governance indicators from the World Bank for 118 countries

revealed that countries with stronger governance infrastructure tend to have higher agricultural outputs, indicating that investments in governance infrastructure boosts agricultural productivity. The rule of law and control of corruption were found to have the most significant impact on agricultural production. Securing property rights and enhancing transparency and accountability are also crucial for long-term agricultural production and productivity growth, as highlighted by Sjah and Zainuri (2020).

The Alliance for a Green Revolution in Africa (AGRA) emphasizes the importance of improving governance infrastructure, welfare, and anti-corruption policies to enhance food and nutrition security and the agribusiness environment. Other aspects of good governance relevant to agricultural development include voice and accountability, as well as peace and stability, which shape agricultural support policies and agrarian relations. Instability can hinder agricultural production by reducing investment, increasing production costs, and limiting access to finance and trade (Fuglie, Gautam, Goyal, & Maloney, 2019). The various governance indicators are interconnected. For example, corruption can reduce agricultural production by increasing transaction costs and decreasing profits. It also hampers the government's ability to provide essential infrastructure, such as rural roads. A robust governance structure supports agricultural transformation by enabling the development of sound agricultural policies and strategies. This involves building capacity for innovative policy analysis and priority setting. Effective political leadership enhances a government's ability to create a favourable business environment and facilitate forums for stakeholders to express their interests and channel investments that strengthen institutional capabilities. International organisations, civil society, and the corporate sector all have crucial roles in transferring skills to support evidence-based policy changes for agricultural transformation (Adenle, Wedig & Azadi, 2019).

6. Research methods

This study investigates how to incorporate emerging technologies in agricultural practices through the application of effective governance models. The study was rooted in the interpretivist research paradigm. The interpretive research paradigm, also known as the qualitative paradigm, is a philosophical and methodological approach used in social sciences, particularly in fields like sociology, anthropology, psychology, and education. It focuses on understanding and interpreting human behaviour, experiences, and the social world in a nuanced and context-specific manner (Creswell, 2014; Ivankova, 2015). This helped in understanding the governance models adopted by the role-players in the Department of Agriculture and how effective these models are in achieving the mandates of the department. The qualitative research approach and a case study design were applied

to gain an in-depth understanding of the problem of the study. The employees of the Department of Agriculture were only included in the qualitative study to understand their views on the governance models, and how they apply these models towards the adoption of emerging technology. A total of 25 officers from the Department of Agriculture were selected for this study. For the sample frame, five participants were selected from each of the five local municipalities in Ngaka Modiri Molema District. In this study, data was collected through semi-structured interviews to allow participants to express their views and experiences in detail. The interviews focused on topics related to governance models and their practical application in the adoption of emerging technology within the Department of Agriculture. Qualitative data collected through interviews were analysed thematically. This involved an inductive analysis by identifying common themes and patterns from the responses of the participants. Data was further coded to categorize responses and identify key concepts related to governance models and technology adoption. Regarding the ethical concepts, informed Consent, anonymity and confidentiality of responses were observed adequately. More so, trustworthiness such as member checking, and peer debriefing was maintained to ensure the rigour of the study. The findings were presented through narrative descriptions, highlighting key themes and quotes from the participants to illustrate their views.

7. Presentation of research results

In this section, the qualitative data collected from interviews with employees at the Department of Agriculture in the North West province was presented. The data was analysed using Atlas-ti software version 22 to identify patterns and themes, as well as to code and categorize responses according to the research question. The qualitative data provided a valuable perspective on the issues surrounding the governance models adopted to improve the adoption of emerging technologies in agriculture. The use of ATLAS-ti software ensured that the analysis was systematic, rigorous, and grounded in the data, thereby enhancing the credibility and trustworthiness of the findings. Figure 6.1 presents the governance models adopted by the Department of Agriculture in the adoption of emerging technological practices.

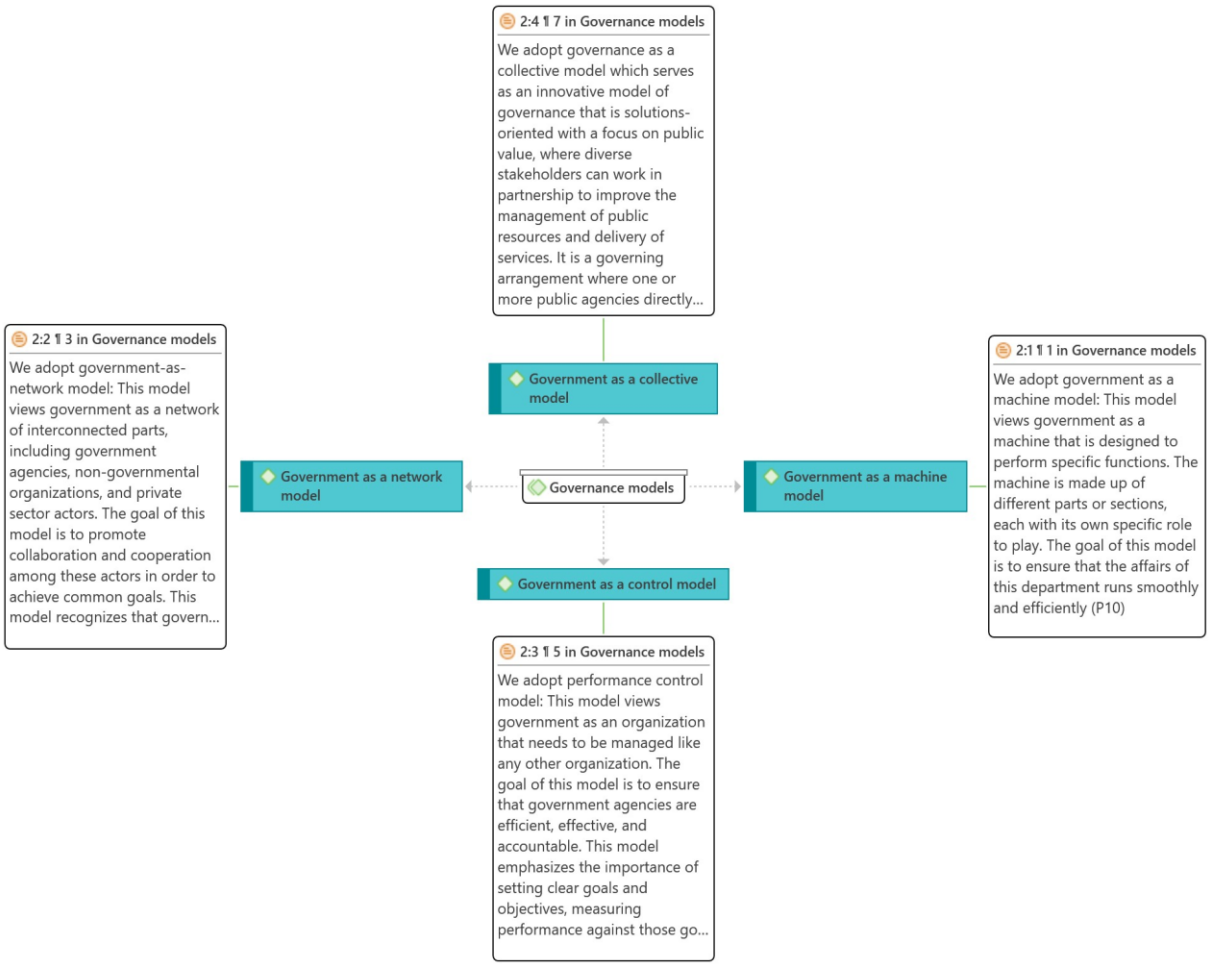

Figure 6.1 Technology-transfer models to facilitate the adoption of emerging technologies

According to the participants, as illustrated in Figure 6.1, they concurred that they adopt government as a collective model, government as a machine model, government as a performance control model and government as a network model. These models provide different perspectives on the role of government in society, and each has its strengths and weaknesses. Through the adoption of these models, governments can better understand their role in society and work towards achieving their goals effectively and efficiently. The Department of Agriculture has adopted these models to ensure effective performance in the agricultural sector. Figure 6.2 illustrates the technology transfer models the government adopted to facilitate the adoption of emerging technologies in commercial farming in the North West province.

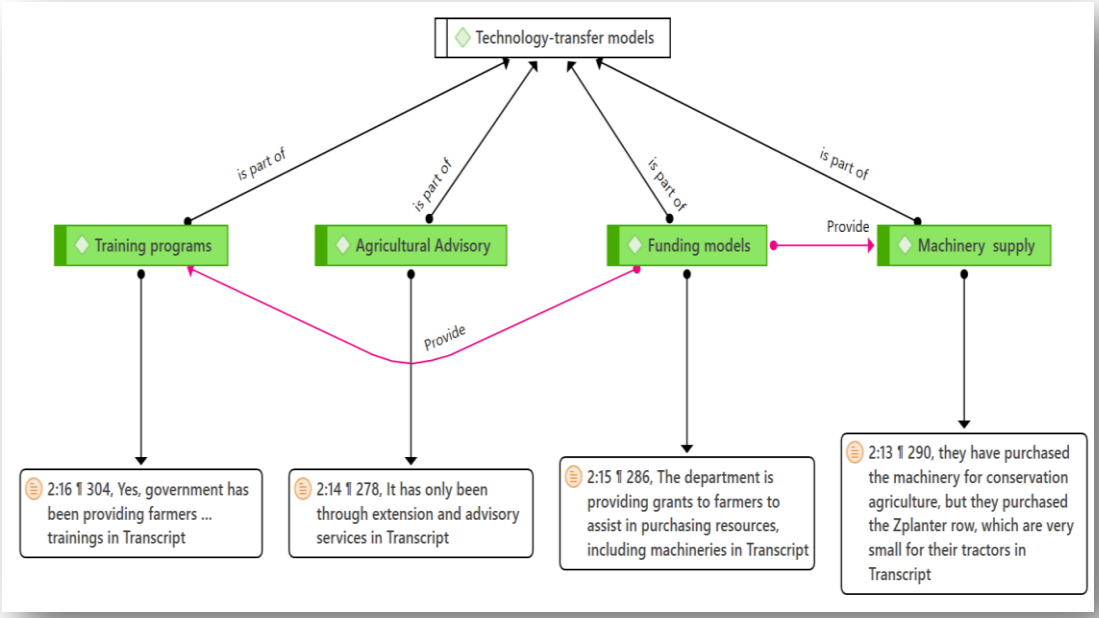

Figure 6.2 Technology transfer models

According to the responses in Figure 6.2, the participants confirmed that the department adopts the technology-transfer models consisting of machinery supply, agricultural advisory, funding models and training programs. Technology transfer is the process of disseminating or absorbing new technologies, new applicable knowledge, and/or the result of its implementation, generating new products, processes, or services. The government facilitates the adoption of emerging technologies by implementing technology transfer models such as machinery supply, agricultural advisory, funding models, and training programs. Machinery supply involves providing machinery and equipment to farmers to improve their productivity and efficiency. Agricultural advisory services provide farmers with information on best practices for crop production and management. Funding models can be used to provide financial support to farmers for the purchase of machinery and equipment or research and development activities. Lastly, training programs can be used to provide farmers with the necessary skills and knowledge to adopt emerging technologies. Following are the direct excerpts of the participants on the technology transfer model.

Yes, they have purchased the machinery for conservation agriculture, but they purchased the planter row, which is very small for their tractors (P9)

Yes, the government has provided some farmers with no-till planters and the sustainable agriculture directorate pushes for the smart agriculture agenda (P10)

The government has intervened by procuring C.A. planters, but it was for a handful of farmers. More budget is needed (P12)

Agricultural advisors are doing their best to transfer these technologies to farmers. However, the implementation of projects sometimes makes them lose focus (P5)

The department is providing grants to farmers to assist in purchasing resources, including machinery (P7)

Yes, funding models will allow more farmers access to new technologies as well as non-financial support such as training whilst working together with the private sector (P16)

Through mentorship and experiential training of both men, women, youth, and people living with disabilities (P3)

Through adopting new technologies, through attending symposiums, farmers' days, and farm visits (P22).

Figure 6.3 presents the effectiveness of the technology-transfer models in encouraging farmers to adopt emerging innovation options in their farming practices.

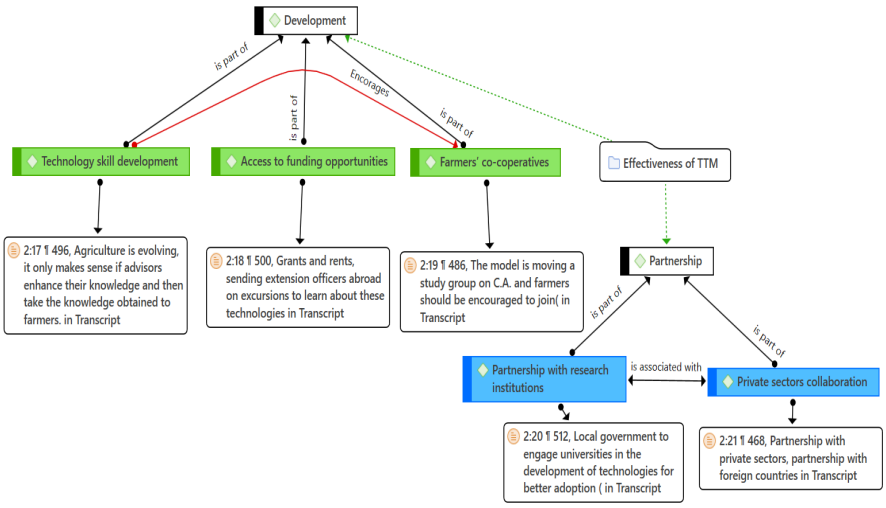

Figure 6.3 The effectiveness of the technology-transfer models

Figure 6.3 depicts evaluating the effectiveness of technology-transfer models in farming practices. This theme is broken down into two key sub-themes which include Technology Skill Development and Access to Funding Opportunities. Technology Skill Development suggests that the effectiveness of technology-transfer models in farming practice is closely linked to the development of farmers' skills in utilizing new agricultural technologies. This could involve training and capacity-building programs to enhance farmers' technical know-how. Access to Funding Opportunities implies that access to financial resources or funding is an important factor in determining how well technology-transfer models work. Farmers may need financial support to acquire and implement new technologies effectively. Farmers' Cooperatives highlights the role of cooperative farming arrangements in technology transfer. Farmers working together in cooperatives may find it more effective to adopt and share new technologies. Concerning partnership with Research Institutions, it emphasizes the importance of collaboration between farmers and research institutions. Effective technology transfer often involves sharing knowledge and research findings between these two groups. Private Sector Collaboration suggests that involving the private sector in technology-transfer models can be beneficial. Private companies may have the resources and expertise to support farmers in adopting and implementing new technologies. Furthermore, based on the views of participants on the effectiveness of technology-transfer models in farming practice, partnerships with research institutions and Private sector collaboration emerged as subcategories of partnership. Following are the excerpts from the participants on the effectiveness of technology transfer models.

Issuing bursaries to advisors. Agriculture is evolving, it only makes sense if advisors enhance their knowledge and then take the knowledge obtained to farmers. In so doing, farmers will develop confidence in adopting new technologies (P17)

Grants and rents, sending extension officers abroad on excursions to learn about these technologies (P19)

Study groups, work as co-operatives, advance training and Study groups help farmers to learn from one another (P3)

Local government to engage universities in the development of technologies for better adoption (P25).

Partnering with universities and institutions, such as ARC, CSIR, etc. (P29).

The following section presents the discussion of the results presented above.

8. Discussion of results

The results of the study indicate that participants acknowledge and apply various government models within their departments. These models include the collective model, machine model, performance control model, and network model. Each of these models represents a different approach to governance. For instance, the collective model suggests a collaborative and consensus-driven approach within the department, while the machine model implies a structured and efficient operation similar to a well-oiled machine (Meintzberg, 1996). The adoption of these models reflects the organisational philosophy and approach to governance of the department. However, it's important to note that not all governance models are utilized within the department, as mentioned in the text. This suggests that some models might not align with the Department's objectives or operational framework. However, the department does not apply other governance models. Instead, they adopt technology-transfer models consisting of machinery supply, agricultural advisory, funding models, and training programs. The effectiveness of the transfer model was measured, and it was revealed that partnerships with research institutions and private sector collaboration emerged as subcategories of partnership. The participants' views on the effectiveness of technology transfer models in farming practice were also highlighted.

The study also explored the technology-transfer models implemented within the department, which include machinery supply, agricultural advisory services, funding models, and training programs. These models are crucial for facilitating the adoption of emerging agricultural technologies by farmers (Van Loon et al., 2020). The effectiveness of these transfer models was assessed, revealing valuable insights into their impact. This assessment is vital for ensuring that the resources and efforts of the department are directed towards methods that effectively promote technological adoption in the agricultural sector. Effective technology transfer is essential for improving farming practices and overall agricultural productivity. Furthermore, the study delves into the perspectives of the participants on the effectiveness of technology-transfer models, specifically highlighting the importance of partnerships with research institutions and private sector collaboration. These emerged as subcategories under the broader theme of partnership. Partnerships with research institutions imply that the department recognises the value of knowledge sharing and collaboration with experts in the field to enhance technology transfer. Private-sector collaboration suggests that involving businesses can provide additional resources and expertise for successful technology adoption. These findings highlight the significance of collaborative efforts in promoting agricultural innovation and technology diffusion, ultimately benefiting both farmers and the agricultural sector.

According to Koutsouris (2018), technology transfer (TT) is an integral part of the extension process involving the transfer and spread of technical innovation and know-how to the farming population. Collaborative projects are sharing practical agricultural information and cultivation of best practices among public and private sector organizations and farmers. Partnerships with private-sector actors are widely considered crucial for achieving the 2030 Agenda for Sustainable Development. They offer a mechanism to share the costs of infrastructure and diffusion, and also an opportunity to increase the effectiveness of technologies over time. It can be inferred that partnerships with research institutions and private sector collaboration improve technology transfer models in farming practice based on the findings of the study. These partnerships bridge public and private sector competencies and interests, resulting in resilient innovation pipelines, efficient technology diffusion, continuous improvement, and effective application of technology.

9. Recommendations

This study made recommendations to the Department of Agriculture and the government.

9.1 Recommendations to the Department of Agriculture

The following recommendations are made to the Department of Agriculture:

Enhance Technology Transfer Programmes: Strengthen and expand technology-transfer models such as machinery supply, agricultural advisory services, funding models, and training programs. Ensure that these programs are accessible, effective, and well-targeted to the needs of farmers.

Promote Research and Innovation: Invest in research and development initiatives to continually advance agricultural technologies and practices. Foster partnerships with research institutions to facilitate knowledge exchange and innovation.

Support Farmer Cooperatives: Encourage the formation and growth of farmer cooperatives. These cooperative structures can help farmers pool resources, share knowledge, and collectively adopt emerging technologies.

Sustainable Agriculture Practices: Promote sustainable and environmentally friendly agricultural practices. Provide guidance and incentives for farmers to adopt practices that conserve natural resources and reduce the environmental impact of farming.

Access to Finance: Facilitate easier access to funding opportunities for farmers, particularly smallholders. This can be achieved through government-backed loan programs, grants, or financial support mechanisms.

9.2 Recommendations for the Government

The following recommendations are made to the government:

Policy Support: Develop and implement policies that prioritize agricultural development and technology adoption. Ensure that these policies are flexible, adaptive to changing circumstances, and aligned with the goals of sustainable agriculture.

Investment in Rural Infrastructure: Allocate resources to improve rural infrastructure, including roads, irrigation, and storage facilities. Improved infrastructure enhances the efficiency of agricultural supply chains and reduce post-harvest losses.

Market Access: Support farmers in accessing local and international markets. Establish trade agreements that facilitate the export of agricultural products and ensure fair prices for farmers.

Education and Training: Invest in agricultural education and training programmes. Equip farmers with the knowledge and skills to effectively adopt and utilize emerging technologies.

Research and Development Funding: Allocate funding for agricultural research and development. Support research institutions, universities, and private sector organizations engaged in agricultural innovation.

Regulatory Environment: Create a supportive regulatory environment that encourages responsible innovation in agriculture. Ensure that regulations are clear, transparent, and conducive to the adoption of new technologies.

Climate Resilience: Develop strategies to address climate change challenges in agriculture. Promote practices that enhance resilience to climate-related risks, such as droughts and extreme weather events.

Monitoring and Evaluation: Establish a robust system for monitoring and evaluating the impact of agricultural policies and programs. Use data-driven insights to continually improve agricultural practices and policies.

These recommendations aim to foster a conducive environment for the Department of Agriculture and the government to effectively promote sustainable agriculture, technology adoption, and rural development.

10. Conclusion

In conclusion, this study shed light on the complex landscape of agricultural governance and technology adoption within the Department of Agriculture and the broader governmental context. Through an exploration of various government models, the study provided valuable insights into the department's organisational philosophy and governance approaches. Additionally, the examination of technology-transfer models, encompassing machinery supply, agricultural advisory services, funding mechanisms, and training programmes, has highlighted the crucial role these models play in facilitating the integration of emerging agricultural technologies. Understanding their effectiveness is paramount in guiding resource allocation and strategic planning within the department. Furthermore, findings from the study highlighted the significance of partnerships, particularly with research institutions and the private sector, in ensuring the successful transfer of agricultural technologies. These collaborations not only enhance knowledge exchange but also bring additional resources and expertise to the forefront, ultimately benefiting both farmers and the agricultural sector as a whole. However, the Department of Agriculture and the government must consider the recommendations outlined in this report. The key steps to advancing the agricultural sector include strengthening technology transfer, promoting sustainable agricultural practices, and supporting farmer cooperatives. Additionally, policy support, investment in rural infrastructure, and a commitment to climate resilience are vital components of a comprehensive strategy to foster agricultural development and enhance food security. In a rapidly changing world, the role of agriculture in sustaining our future cannot be overstated. The Department of Agriculture and the government can play a pivotal role in ensuring the growth and resilience of the agricultural sector, ultimately improving the livelihoods of farmers and contributing to the well-being of the entire nation through embracing innovation, collaboration, and sustainable practices.

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CHAPTER SEVEN

CONCLUSIONS AND POLICY IMPLICATIONS

7.1 INTRODUCTION

Enhancing agricultural sustainability in the North West Province can be achieved through the adoption of emerging technologies and implementation of effective governance. Across African nations and other parts of the world, the significant role of technology in enhancing agricultural production and fostering growth has been noted while its full potential has been hindered by limited exposure, a lack of innovation, and financial constraints. Recent advancements in technology have proven immensely beneficial to the agricultural sector. Farmers now have the capability to cultivate crops in previously challenging environments, a feat attributed to innovations such as genetic engineering. Genetic engineering facilitates the incorporation of specific traits into the genomes of crops and animals, rendering them more resilient to pests and droughts. Various technological applications, including the use of herbicides, pesticides, fertilizers, and improved seeds, have significantly contributed to innovative and productive agricultural practices. Moreover, a range of technological approaches have been integrated into agriculture which include farm machinery, crop sensors, GPS utilisation for field documentation, biotechnology, indoor vertical farming, and modern greenhouse practices. Livestock farming has also witnessed the integration of technology, with advancements such as blockchain farming and artificial intelligence playing pivotal roles. Embracing these technologies not only augments productivity but also fosters a more sustainable and resilient agricultural ecosystem.

This study was aimed to assess if the application of emerging technologies and good governance would enhance achieving agricultural sustainability in the North West province. The study was guided by five research questions: the types of emerging technologies farmers incorporate into their farming practices; the effectiveness of the emerging technologies in increasing the general productivity of agro-products to achieve food security; the major barriers hindering the adoption of emerging technologies by farmers in the North West province; and the governance model that could be adopted to effectively help farmers incorporate emerging technologies to achieve agricultural sustainability. This section presents the summary of all the findings in the articles that cumulatively constitute the study. This section proffers recommendations on enhancing the adoption of emerging technologies and effective governance to improve agricultural practices in the North West province.

7.2 SUMMARY OF FINDINGS

This section presents the summary of findings according to the order of the research questions as presented in chapter one of this study.

7.2.1 Summary of findings on research objective one

This section of the study investigated the types of emerging technologies that farmers in the North West province of South Africa incorporate into their farming practices. The study adopted a mixed-methods approach which combines both qualitative and quantitative data collection methods. Findings from the study established a discernible trend in the adoption of emerging technologies among farmers in the North West Province. Notably, farmers have started incorporating various technologies into their farming practices. The prevalent technologies adopted include herbicide-resistant weed management, precision farming techniques, remote sensing applications, automation, and the utilisation of enhanced grains like BT maize, DHM – 103, and DHM – 105. These technologies play a pivotal role in enhancing crop yields, cutting operational costs, and improving overall farm efficiency. Factors influencing the adoption of emerging technologies by farmers were also identified in the study. Key determinants include access to information, financial resources, and technical support. Farmers endowed with adequate financial resources and skills exhibit a higher likelihood of embracing emerging technologies compared to those lacking such resources. Furthermore, the study highlights that the absence of information, financial constraints, poverty, insufficient innovation and training, recurring droughts, and inadequate government intervention collectively contribute to reluctance to adopt emerging technologies. In addition, the adoption of emerging technologies improves productivity and sustainable agricultural development in the North West Province

7.2.2 Summary of findings on research objective two

This section investigated the effectiveness of emerging technologies in maize production and agricultural practices in the North West province of South Africa. An explanatory consequential mixed methods design was used for the collection and analysing of quantitative data before the qualitative phase. Incorporating emerging technologies into maize production has led to notable improvements in the efficiency and profitability of farming operations. This is achieved through the significant reduction of input costs, the optimisation of resource utilisation, and an enhancement of all safety standards. The participants affirmed the effectiveness of these technologies and emphasized their potential for widespread adoption in maize production. The successful integration of emerging

technologies depends on the provision of comprehensive education and support services to farmers. Bridging the knowledge gap and offering ongoing assistance are key components in ensuring that farmers can fully harness the benefits of technological advancements in maize production. Additionally, contextual factors such as socio-economic, cultural, and political considerations must be considered as they play a pivotal role in shaping the likelihood to adopt emerging technologies within the diverse agricultural setting.

7.2.3 Summary of findings on research objective three

This objective strove to identify barriers faced by farmers i regarding the adoption of emerging agricultural technologies in the production of maize. The research employed a mixed-methods approach to obtain comprehensive insights into the challenges inhibiting the adoption of these technologies. The study sampled farmers from various agricultural sectors, and data were collected through surveys, and interviews. The quantitative analysis established various barriers faced by farmers such as the substantial initial cost associated with emerging technologies, a deficit in necessary skills and knowledge, the absence of accessible extension agents, restricted entry to markets and information, and insufficient government support. Furthermore, barriers to technology adoption were identified which include inadequate recordkeeping and data management, the lack of user-friendliness of technologies, and labour shortages. Complementing these quantitative findings, the qualitative analysis confirmed more barriers related to education, finance, resources, and support.

7.2.4 Summary of findings on research objective four

This study investigated the governance models applied by the Department of Agriculture in an endeavour to promote the adoption of emerging technologies in agriculture. A qualitative research approach was adopted and a total of 25 participants were interviewed. The qualitative study provided an in-depth exploration through interactions with the participants. Findings identified a variety of governance models adopted in the agricultural sector amongst these the collective model, machine model, performance control model, and network model. Each of these models signifies unique governance approaches, providing valuable insights into the organisational culture and strategies for agricultural management. Understanding these models is instrumental in appreciating the diverse ways in which agricultural entities structure their operations and decision-making processes. Developments in agricultural productivity are anchored in the effective adoption of emerging technologies. In this context, the study delves into various technology transfer models, encompassing machinery supply, agricultural advisory services, funding mechanisms, and training programs. These models serve as instrumental pathways for disseminating technological innovations throughout the agricultural sector.

Examining these transfer mechanisms offers insights into how knowledge, resources, and support are channelled to farmers to influence the successful integration of emerging technologies.

7.3 OVERVIEW OF THE STUDY

As clarified in Chapter one, this study investigated the adoption of emerging technologies and effective governance models for agricultural sustainability in the North West province. The study adopts the article format to investigate the problem. Chapter one of this study was the introduction and scope of the study. The background to the study, statement of the problem, research aims, questions and objectives were provided. Other facets embedded in chapter relate to the relevance of the study, delimitation and the concept clarification. Lastly, chapter one provided the research methodology adopted to address the conundrum. The study adopted a mixed methods study where both qualitative and quantitative strands were incorporated. Finally, chapter one presented the structure which guided how the objectives were achieved through a brief literature review and four articles. This entire study comprises a total of seven chapters.

The second chapter presented the theoretical background and literature review. The UTAUT (Unified Theory of Acceptance and Use of Technology) was adopted as the theoretical background of the study. The study reviewed related literature tracing the nature of farming in the North West province, emerging technologies in agriculture, agricultural sustainability and the effective governance models to enhance emerging technologies in the North West province.

Chapter three investigated the types of emerging technologies farmers incorporate in their farming practices in the North West province. This chapter assumed an article format where both findings from quantitative and qualitative studies were triangulated. Chapter four is an article which investigated the effectiveness of emerging technologies in agricultural practices in the North West province. The study applied a mixed method study to investigate the level of effectiveness of emerging technologies applied by farmers. Chapter five, also in article format, explored the key barriers to the adoption of emerging technologies by farmers in the North West province using a mixed methods study to elicit the feelings and perceptions of both the employees in the agricultural department and farmers on the barriers and challenges in the adoption of emerging technologies. In Chapter six, the roles of governance models in achieving agricultural sustainability was investigated. This article adopted a qualitative perspective where the employees from the department of agriculture were interviewed to identify the models they adopt in pioneering agricultural practices to achieve success. Chapter seven

provides the summary of findings, overview of the study, policy implications and the contribution to the body of knowledge. The next section presents the contributions of the study.

7.4 CONTRIBUTIONS TO THE BODY OF KNOWLEDGE

Indeed, the main aim of research is to fill a gap in the body of knowledge that has not been explored before. Accordingly, the reason for investigating the emerging technologies and effective governance for agricultural sustainability in the North West province was to proffer epistemological contributions that could be used to enhance the performance of the agricultural sector and to enhance sustainability as indicated in the Sustainable Development Goals of South Africa. The contribution of this study to the body of knowledge is presented in Table 7.1 below:

Table 7.1 Integrated model for emerging technologies and effective governance

Types of emerging technologies incorporated by farmers	**Effectiveness of emerging technologies in agricultural practice**	**The key barriers to the adoption of emerging technologies**	**Governance models and its roles**
Emerging technologies • Herbicide-resistant weed management Precision farming techniques • Remote sensing applications • Automation agriculture Enhanced grains (e.g., BT maize, DHM – 103, DHM – 105). **Factors influencing adoption** • *Access to information* • *Financial resources*	• Notable improvements in efficiency and profitability • Significant reduction of input costs • Optimised resource utilization • Enhanced safety standards. **Dependency on Education and Support** - *Successful integration depends on the provision of comprehensive education and support services to farmers,*	**Financial Barriers** • High initial costs associated with technology. • Lack of financial resources hinders adoption. **Knowledge and Information Gaps** • Deficit in necessary skills and knowledge • Unavailability of extension agents • Limited access to markets and information	• Collective model • Machine model, • Performance control model • Network model. **Technology Transfer Models** • Machinery supply • Agricultural advisory services, • Funding mechanisms • Training programs. *These models are instrumental pathways for disseminating*

• *Technical support*	*considering socio-economic, cultural, and political factors*	**Government Support** • Insufficient government support Lack of innovation and training • Inadequate intervention	*technological innovations throughout the agricultural sector*

Table 7.1 displays the integrated model for emerging technologies and effective governance in the North West province which is the ultimate contribution of the study. Table 7.1 forms a coherent extract from previous literature and results from empirical data analysis and findings of this study. This study conceptualises the themes under the emerging technologies and governance models which should be adopted and implemented for effective agricultural performance and sustainability in the North West province. Thus, the study contributes four themes, which are epistemological and academic concepts into the body of knowledge. As such, in considering ways to improve agricultural practices, the themes provided by this study should be adopted. Hence, the recommendation of the study is presented subsequently.

7.5 RECOMMENDATIONS OF THE STUDY

The recommendations of this study are made to the Department of Agriculture and the farmers in the North West Province.

7.5.1 Recommendation to the Department of Agriculture

Based on the comprehensive findings of the study, the following recommendations are proposed for the Department of Agriculture in the North West Province:

Promotion of financial support programs: The Department of Agriculture should design and implement financial support programmes to facilitate the adoption of emerging technologies. This could include subsidies, low-interest loans, or grants tailored to the specific needs of farmers.

Enhanced extension services: The Department should invest in expanding and improving extension services and ensure that farmers have easy access to the necessary information, skills, and technical support for the successful integration of emerging technologies.

Facilitating market access: To overcome the limited entry to markets and information, the Department of Agriculture should establish initiatives that facilitate market access for farmers utilizing emerging technologies. This could involve creating platforms for information exchange, networking opportunities, and partnerships to enhance market linkages.

Capacity building programs: The Department of Agriculture should develop and implement comprehensive capacity-building programmes considering the influence of skills and knowledge on technology adoption. These should focus on educating farmers about the benefits and practical aspects of emerging technologies.

Government intervention strategies: The Department of Agriculture should actively engage in strategies to address barriers related to government support. This could involve policy adjustments, streamlined support mechanisms, and proactive initiatives to ensure a conducive environment for technological adoption.

7.5.2 Recommendation to Farmers

The recommendations of the study to the farmers are as follows:

1. **Participation in educational programmes:** Farmers in the North West province should actively participate in educational programmes initiated by the Department or other relevant organizations. These could enhance their understanding of emerging technologies and provide valuable insights into their practical applications.
2. **Exploration of financial support:** Farmers should explore available financial support mechanisms to alleviate the initial cost burden associated with adopting emerging technologies. This could involve seeking information on subsidies, loans, or grants offered by the government entities or other financial institutions.
3. **Engagement in extension services:** Farmers are advised to engage with extension services to bridge knowledge gaps and access technical support. Establishing regular communication channels with extension agents facilitates the exchange of information and expertise.

4. **Collaboration and networking:** Farmers in the North West province should build networks with fellow farmers, agricultural organisations and market stakeholders. These collaborations help overcome challenges related to market access and information. Collaborative efforts lead to shared resources and knowledge.
5. **Advocacy for government support:** Farmers in the North West province are encouraged to advocate for increased government support and intervention in addressing barriers to technology adoption. Active involvement in agricultural associations and community forums amplifies the collective voice of farmers in influencing policy changes.

7.6 LIMITATIONS OF THE STUDY

This study was limited to the North West province; therefore, the findings may not be generalised to other provinces. Despite the small scope, the issues with logistics limited the collection of data from both the farmers and the employees of the Department of Agriculture. During the study, it was difficult to secure appointments with the respondents due to their commitments while most of them did not respond to the questionnaires as promised. This extended the duration of data collection, and this had significant financial implications on the study.

7.7 CONCLUSION OF THE STUDY

This study investigated the emerging technologies and effective governance for agricultural sustainability in the North West province. A pragmatist research paradigm underpinned this study, and a mixed methods study was adopted. The research was structured around specific objectives exploring the types of emerging technologies adopted by farmers, assessing the effectiveness of these technologies in maize production, identifying barriers faced by farmers, and examining the governance models applied by the Department of Agriculture. Findings from the study verified a remarkable success in the adoption of emerging technologies among farmers in the North West Province. Some emerging technologies such as herbicide-resistant weed management, precision farming techniques, remote sensing applications, and the utilization of enhanced grains, which collectively contribute to enhanced crop yields, reduced operational costs, and improved farm efficiency. The study highlights the critical role of access to information, financial resources, and technical support in influencing technology adoption. Farmers with adequate financial resources and skills exhibit a higher likelihood of embracing emerging technologies, emphasizing the need for targeted support mechanisms and educational programmes. Furthermore, the research highlights the barriers hindering the adoption of

emerging technologies, including financial constraints, knowledge gaps and inadequate government support. These barriers demand collaborative efforts between the agricultural sector and stakeholders to address financial challenges, enhance education, and streamline support services. The governance models identified within the Department of Agriculture, including collective, machine, performance control, and network models. It is crucial to understand these models and their applications for aligning strategies that facilitate the effective transfer of technology to farmers. The study emphasised a holistic approach to agricultural development, one that considers not only technological advancements but also addresses the socio-economic, cultural, and political contexts. The Department of Agriculture and farmers can contribute to the sustainable integration of emerging technologies, fostering a resilient and productive agricultural sector in the North West Province and serving as a model for agricultural development more broadly by adopting the recommendations of this study.

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APPENDIX 1 TURNITIN REPORT

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APPENDIX 2 INTERVIEW GUIDE

EMERGING FARMER TECHNOLOGIES IN THE NORTH WEST PROVINCE

These face-to-face interviews are aimed at gaining insight and knowledge on the incorporation of emerging technologies and effective governance for agricultural sustainability in the North West province. The main aim of this study is to find solutions on how to increase maize production to enhance food security in the North West province. This interview allows individual participants some freedom to talk about what is of interest or importance to them. The interviewer controls the pace of the interview by treating the interview questions in a standardised and straightforward manner. The same set of questions will be used for all interviews and these will be asked in the same order or sequence.

Participants: The participants selected to participate in this study include the employees at the Department of Agriculture.

These participants have been selected in the study to gain insights on how they have pioneered the effective governance to ensure remarkable improvement in the agricultural sector. Also, an inquiry would be made to know how emerging technologies have been applied to enhance maize production in the North West province.

Resources required

A suitable venue would be required for conducting the in-depth interviews. Ideally the venue should be on the premises of the organisations involved or alternatively, a suitable place close to the organisation will be selected. Furthermore, due to the emergence of COVID-19, online interviews would be adopted. During the process of the interviews, a notepad and audio recorder will be used with prior approval of the participant.

Introduction Phase

Good day, my name is Ms SFD Mohono, a PhD research student from the North-West University, Mafikeng Campus. This face-to-face interview is aimed at gaining your insights on how your office have incorporated emerging technologies and effective governance to enhance agricultural

sustainability in the North West province. This interview, however, is not meant to probe your job specification but to find solutions on how to enhance the production of maize while applying effective governance and emerging technologies. This interview will only last for 20 minutes and your concise and unbiased responses will be appreciated. Any information provided in this exercise is considered confidential, it will not be used against you in any way. More so, participation is only voluntary, you may withdraw at any point in time, also the results of this study will be open for scrutiny, you may request a copy of the results if you wish.

Please note that this interview is recorded to ensure that your comments and contributions are adequately captured for processing purposes. However, your name will not be attached to any comments, views presented and/or perceptions expressed. Do you have any questions in this regard before we continue?

Interview Phase

[Ensuring that adequate notes are taken and the tape recorder is recording correctly.]

Section A: Demographic data

1. Gender

Male		V1
Female		V2

2. Age

Below 18 years	V3
Between 19 and 25	V4
Between 26 and 35	V5
Between 36 and 45	V6
Above 46	V7

3. Current position in the department (government)

Assistant extension practitioner	V8
	V9
	V10
	V11

	V12

4. Year of appointment to this position?

Before 1994	V13
Between 1995 and 2000	V14
Between 2001 and 2005	V15
Between 2006 and 2010	V16
	V17

[Explain any previous experience related to your current position?]

Section B1: Research Questions

1. Do farmers incorporate emerging technologies in their farming practices?

Yes	V18
No	V19

2. If yes, what type of emerging technologies do farmers incorporate in their farming practices?

a. **Animal Production**

b. **Plant Production**

3. How long have they incorporated these emerging technologies in the North West province?

Section B2

1. How effective are these emerging technologies in increasing the general productivity of agro-products to achieve food security?

.
.
.
.
.

Very effective	
Moderately effective	
Neither effective nor ineffective	
Moderately ineffective	
Very ineffective	

2. What can you say about the productivity of their agricultural products since they started incorporating the emerging technologies, especially maize?

Very productive	
Moderately productive	
Neither productive nor unproductive	
Moderately unproductive	
Very unproductive	

3. What can you say about the adoption of these technologies?

Highly adopted	
Moderately adopted	
Neither adopted nor not adopted	
Moderately not adopted	
Not adopted	

4. To what extend are these technologies beneficial to the general public?

Highly beneficial	
Moderately beneficial	
Neither beneficial nor not beneficial	
Moderately not beneficial	
Not beneficial	

Section B3

1. What are the major barriers that hinder the adoption of emerging technologies by farmers in the North West province?
2. Has there been any intervention by the government or agricultural authorities to alleviate these barriers?
3. Do these barriers have direct impact on the annual productivity?

Section B4

1. Are there governance models that could be adopted to alleviate the barriers of adopting the emerging technologies in the farming practices?
2. What governance models should be adopted to effectively help farmers to incorporate emerging technologies to achieve agricultural sustainability?
3. Can you specifically mention the particular model to be adopted?
4. Can you specify your reasons to recommend such governance model?
5. What are the recommendations needed to enhance the adoption of emerging technologies and effective governance to improve agricultural practices in the North West province?

THANKS FOR YOUR THOUGHTFUL RESPONSES

1) Gender

Male	Female
11	18

2) Age

Below 18	
19-25	
26-35	5
36-45	10
Above 46	10

3) Position in the Department

Director	1
Deputy Director	4
Extension practitioner	3
Assistant extension practitioner	2
Extension officer	3
Agricultural Advisor	8
Agriculture technician	1
Senior practitioner	1
Specialist agricultural advisor	1
DD project coordinator	1
Production scientist	2
Senior Agricultural Advisor	1

4) Year of appointment

Before 1994	3
Between 1995 and 2000	2
Between 2001 and 2005	2
Between 2006 and 2010	5
After 2010	13

5) Experience related to current position

Corporate Secretary
Contract worker for four years at Department of Agriculture – Free State
Cleaner
Three years contract appointment at Gauteng Department of Agriculture and Rural Development
Senior Agricultural Advisor
Extension officer
Agricultural educator, project coordinator
intern in livestock and vegetable production, broiler, beef, and goat production
Primary animal health technician
Agricultural extension
LAO manager are not accountable for their budget.
Struggles with resources, including vehicle
No security at work because the department hired women security who had no experience, no support from the department
5 years Agribusiness manager, 3 years Assistant Director
Researcher, Advisor in Agripark
No clear process or objective to follow, lack of proper reporting templates and consistency
None
Research trainee, develop research projects, monitoring, and reporting progress reports
Teaching and learning, senior lecturer, clinical state veterinarian in Mpumalanga, provincial animal health veterinarian
Intern, assisting farmers on management of poultry and pigs, facilitating workshops on record keeping
Lack of support to the higher structures in terms of resources, uneven distribution of resources within the North West province, political influence
Experience in general agriculture for 37 years
Intern with DARD for 2 years, permanent employment as an advisor
Water is the main scarce resource that hampers production
Extension, special program, Bee-keeping coordinator

B1

1) Do farmers incorporate emerging technologies in their farming process?

Yes	No
18	7

2) If yes, what kind of emerging technologies do farmers incorporate in their farming practices in the production of maize?

a) Animal Production	b) Plant production
Irrigation scheme	Digital farm measurement with mobile phones
Animal production	using of Apps
WhatsApp and Google	Cultivar choice, crop spacing, fertilization, weed control, grading
Automatic feeders	Boom sprayer
Branding, dipping and dosing, weaning and selection	No till planter, center pivot, tunnels
Artificial insemination	No till or conservation agriculture
Beef, poultry, animal identification	Applications for precision farming
Artificial insemination, genetic improvement, immunization, animal identification	Improved seeds, using machinery, using weed control
Beef, dehorning, identification,	
Artificial insemination	
Use of new medicines/products, digitalization, current market information, modern methods	
ICT, animal production, energy sourcing	ICT
Animal identification, price checking from buyers and banks, market information	price of grains from SAFFEX and online
	BT maize, roundup ready
Follow feed/medication program	Sampling, using new machineries

3) How long have you incorporated these emerging technologies in the North West province?

Recently
10 years
None
Since 2018
Recently
10 years
10 years
3-5 years
3 years
2 farming seasons
Not practiced at all
2 years
Most emerging farmers in the province use traditional methods
None of the technologies have been incorporated
None so far
From 2010

Younger farmers have been the ones using these technologies since 2015
Has continued since 2009
Gradually since 1994
5 years
Some farmers have used it since 1994 to date
10 years for BT maize, over 10 years for roundup ready maize
Over 5 years

B2

1) How effective are these emerging technologies in increasing the production of maize?

Very effective	7
Moderately effective	11
Neutral	6
Moderately ineffective	0
Very ineffective	2

2) What can about the productivity of maize since they started incorporating emerging technologies?

Very productive	6
Moderately productive	13
Neutral	3
Moderately unproductive	0
Very unproductive	1

3) What can you say about the adoption of these technologies?

Highly adopted	2
Moderately adopted	15
Neutral	3
Moderately not adopted	5
Not adopted	1

4) To what extent are these technologies beneficial to the general public?

Highly beneficial	8
Moderately beneficial	14
Neutral	3
Moderately not beneficial	1
Not beneficial	1

Section B3

Question 1: What are the major barriers that hinder the adoption of emerging technologies by farmers in the North West province?

Responses:

P1	Level of education for farmers and age of practicing old farming practices. Change should be incorporated in or areas, move focus on youth interested in farming to change to new technological practices
P2	They adopt slowly due to certain challenges they face in their communities, for instance, there is shortage of smartphones
P3	Most farmers are old so they still believe in the old indigenous ways of farming
P4	Literacy level is very low and extension is not capacitated in terms of emerging technologies. We highlight every year on PDP what the latest courses we need to attend but nothing is done about it
P5	The farmers are mostly interested only in funding. When you sight a problem and try to advise, they show no interest
P6	1. Farmers are mostly interested in accessing production grants than technologies from DARD, 2. More trials should be by specialists at the production site
P7	Methods are expensive. Most farmers cannot afford the costs
P8	Most of the communal farmers do farming as part-time job. Hence, they do not pay full attention to their farming activities
P9	High cost of machinery, especially the no-till machinery
P10	Lack of technical knowhow, lack of capital, lack of land-tenure rights
P11	Lack of information, lack of understanding
P12	Suitable conservation, agricultural equipment/mechanization, farmers should be assisted with relevant planters
P13	Establishment of smaller research station at the local level
P14	Lack of education, less skilled extension officers, lack of relevant training for extension workers and farmers
P15	Lack of departmental support
P16	These technologies are capital intensive and emerging farmers face serious funding constraints
P17	I think the advisory services are somehow unjust to the farmers by not exposing them to emerging technologies. Also, advisor/extension officers should keep abreast of latest technologies in the industry
P18	Lack of access to information by farmers, inadequate training of extension workers, technologies are not incorporated into the reporting templates so that the performance can be measured
P19	Extension officers are not provided with the technical tools to carry out those technologies. There is absolutely no new/emerging technology
P20	Lack of adequate budget, land, markets, etc., makes the adoption of technologies to become ineffective
P21	The cost of these technologies is high, conflicting cost of inputs, e.g. seeds, climate, advertising
P22	Lack of financial assistance to farmers, lack of access to information to farmers
P23	There is increase in aging farmers, wherein young farmers are not really taking the opportunities. There is an outcry for youth development and people with

	disability. For instance, a farmer with disability, who is willing to improve farming but live with disability
P24	Literacy, affordable smartphones, and best products
P25	The rate of adoption is at a slow pace, knowledge on how to use those technologies
P26	Inadequate communication, lack of infrastructure, low level of literacy, reluctance to embrace change
P27	New technologies are very expensive, lack of finance
P28	Funding or having enough budget to adopt new technologies
P29	No access to finance in some cases, trainings, partnerships with commercial farmers
P30	Inadequate dissemination of information and capacity building

Question 2: Has there been any intervention by the government or agricultural authorities to alleviate these barriers?

Response:

P1	Little to no success as most of the projects or interventions are not followed up or monitored
P2	Food security helps farmers who do not have food on the table
P3	It has only been through extension and advisory services
P4	None that I know of
P5	No, I am saying this because I have been the only extension officer. I love extension but I cannot perform the best of my ability for the sake of the farmers
P6	Agricultural advisors are doing their best to transfer these technologies to farmers. However, implementation of projects sometimes makes them lose focus
P7	The department is providing grants to farmers to assist in purchasing resources, including machineries
P8	Yes. Farmers day, information day, demonstration, and continuous visits
P9	Yes, they have purchased the machinery for conservation agriculture, but they purchased the Zplanter row, which are very small for their tractors
P10	Yes, government has provided some farmers with no-till planters and the sustainable agriculture directorate pushes for the smart agriculture agenda
P11	Yes, but not to all farmers
P12	Government has intervened by procuring C.A. planters but it was for a handful of farmers. More budget is needed
P13	Lack of training for agricultural advisors on the various agricultural commodities
P14	Not really. I am working on the other side the fence which does not allow us to work together
P15	No
P16	Yes, government has been providing farmers with funding and trainings
P17	No
P18	No
P19	No
P20	Yes, through extension, economics, and research
P21	Limited assistance is provided to only few farmers, there is however, increase in extension supplies to farmers, increase in the supply of technologies, such as AI

P22	Intervention is provided through extension officers, research personnel
P23	Government has programmes to support farming communities, especially youths, women with disability, developing farmers but this is not enough and has no impact
P24	Yes, it provides information
P25	No
P26	None that I am aware of
P27	Yes, funding has been provided to a very few farmers
P28	Yes, by funding farmers
P29	Yes, through funding of conditional grants and equitable share
P30	Yes, but not to a satisfactory level

Question 3: Do these barriers have direct impact on the annual productivity?

Responses:

P1	Yes
P2	No
P3	It has an impact on production
P4	High impact
P5	Yes, these barriers have a negative impact on annual productivity. May you intervene (MME DESBO). I wanted to say more but I couldn't because they gave only six people a chance. Many people are qualified with crop but are unemployed
P6	The moderate implementation of these projects by farmers hinders them from reaching their maximum annual productivity
P7	Yes, limited resources limit production
P8	No. Low calving rate, overstocking, and overgrazing
P9	Yes
P10	Yes, farmers are unable to grow and tap into new markets because of lack of land
P11	Yes
P12	The budget barrier has direct impact on productivity
P13	Agricultural advisors are the frontline of the department, if they are not properly trained, then production will be negatively affected
P14	Barriers always impact productivity. Yes, it has direct impact
P15	Yes
P16	Yes, these barriers makes it difficult for farmers to adopt new technologies which means they are unable to increase their productivity and efficiency
P17	Yes
P18	Yes, because production becomes limited and farmers cannot make enough profit
P19	Definitely, because when farmers see those technologies elsewhere, they tend to think that extension officers are not performing their duties
P20	Yes
P21	Yes, limited assistance will lead to decreased production, people in communal areas do not have means to secure their assets
P22	Yes

P23	No, because the way I see it, there is no productivity
P24	Yes
P25	Yes, as producers who are residing in rural areas have no infrastructure to access these technologies, resulting in a negative impact
P26	Yes, as an example, some cannot use the tractors to their full capacity, e.g., ripping and correct planting based on plant population per hectare
P27	Yes
P28	
P29	Yes, to a certain extent
P30	Yes

Section B4

Question 1: Are there government models that could be adopted to alleviate the barriers of adopting the emerging technologies in the farming practices?

Responses:

P1	Suggestions could be that agricultural advisors be based at local communities that they serve to be hands-on on how to deal with these emerging technologies
P2	Yes
P3	Through mentorship and experiential training of both men, women, youth, and people living with disabilities
P4	Advisory board
P5	
P6	Commodity specialization by agricultural advisors
P7	Make more funds available for farmers to enable them to get money to purchase those machineries
P8	Yes. By training, increasing together as farmers, not as silos
P9	In the farms, they are not practiced
P10	Incentives should be given to farmers who adopt smart agricultural practices
P11	Yes, advisory model
P12	The governance model that should be adopted is changing the mindset of the farmers. Officials should make the farmers aware of emerging technologies
P13	Working in collaboration with other sister departments
P14	Specialist working together with agricultural advisors, and also with scientists, by training advisors and farmers
P15	Not sure
P16	Yes, funding models will allow more farmers access to new technologies as well as non-financial support such as training whilst working together with the private sector
P17	If managers can allow advisors to study further or expose them to activities, like conferences and trainings
P18	Not aware
P19	Not aware of any. But at least when available, they can guide and help to fast track the adoption of such technologies
P20	Through adopting to new technologies, through attending symposiums, farmers' days, and farm visits

P21	Increase in the provision of assistance, adoption of breeding improvement technologies like artificial insemination
P22	Yes and that is through extension , departmental conferences and symposium
P23	This needs to be researched and implemented at the appropriate place
P24	Yes, by involving children and youth
P25	Yes
P26	None that I am aware of
P27	Selection of beneficiaries should not be influenced by management and political influence
P28	Funding/in-service training of extension officers
P29	Partnering with commercial sector
P30	Participative planning and implementation model

Question 2: What governance models should be adopted to effectively help farmers to incorporate emerging technologies to achieve agricultural sustainability?

Responses:

P1	Farmers need training on those new technologies and project development plans should be incorporated and be followed
P2	Technology, stakeholders
P3	Partnership with private sectors, partnership with foreign countries
P4	Advisory board
P5	
P6	1. Trials conducted by specialists and researchers, especially at the production site, 2. Individual site visits, and 3. Information and farmers days
P7	Funding and training should be taken seriously
P8	Study groups, work as co-operatives, advance training
P9	Trainings and travels should be done for farmers what the models look like and how they work
P10	Communicate the change and its benefits to farmers
P11	Advisory model
P12	The model is moving a study group on C.A. and farmers should be encouraged to join
P13	Monitoring
P14	
P15	
P16	Financial and non-financial support model
P17	Issuing of bursaries to advisors. Agriculture is evolving, it only makes sense if advisors enhance their knowledge and then take the knowledge obtained to farmers. In so doing, farmers will develop confidence in adopting new technologies
P18	I do not know
P19	Grants and rents, sending extension officers abroad on excursions to learn about these technologies. Budgeting to ensure that such technologies are provided
P20	Farmers' day, conference, farm visits, and monitoring
P21	
P22	Through farmers' days and information days

P23	None
P24	Through trainings, tours, involvement of other relevant stakeholders
P25	Local government to engage universities in the development of technologies for better adoption
P26	Develop a policy that addresses the training of farmers in the use of new technologies, access to all the agricultural enterprises
P27	Policy on mechanization program should be put in place, avoid haphazard implementation of the program
P28	Skills development, funding
P29	Partnering with universities and institutions, such as ARC, CSIR, etc.
P30	Integrated development model

Question 3: Can you specifically mention the particular model to be adopted?

Response:

P1	Number of agricultural advisors should be increased in order to be hands-on in assisting farmers
P2	Household food security, help needed
P3	Farmers to actively participate in livestock improvement through ARC initiative
P4	Mathematical algorithms that capture the quantitative information of agronomy and physiology experiments to predict crop growth and development
P5	
P6	Commodity specialization by agricultural advisors. There should be a special unit responsible for project implementation
P7	Funding, training, support, and monitoring of the resources to ensure they are ready and available for others
P8	Study groups help farmers to learn from one another
P9	They should purchase the relevant machinery for farmers
P10	Carbon reduction initiatives/tax rebates
P11	Advisory through: farmers' days, information days, and workshops
P12	C.A. model
P13	Monitoring
P14	
P15	
P16	Financial and non-financial support model
P17	Skills development, form partnerships with research institutions
P18	Not aware
P19	None
P20	Climate change, adaptability of animal breeds
P21	
P22	Smart/precision agriculture
P23	One-stop shop where all departmental activities happen in the same place. This could enhance service delivery
P24	Inter-governmental governance, breaking of silos in the same department
P25	
P26	
P27	Participatory approach

P28	
P29	Through MOU/SLA
P30	A combination of model 1 and 2

Question 4: Can you specify your reasons to recommend such governance models?

Responses:

P1	Specialization of extension officers on their specific communities to carry out these new technologies
P2	Yes
P3	Farmers will increase their production to be profitable, avoid inbreeding that occurs mostly in communal setups
P4	We are just stuck, we are no growing as custodian of agriculture
P5	
P6	Agricultural advisors will master their subject matter better when they are specializing
P7	Most advanced machinery are very expensive and farmers cannot afford them
P8	Farmers should learn from one another, there could be competition in production
P9	The trials will assist our farmers so that they can be able to see how they work
P10	Farmers will want to be part of the green revolution if they set results and commitment by government to assist them
P11	Most farmers rely on extension for advancing in their economy
P12	My reasons include creating more awareness to farmers and training them
P13	Knowledge is power, more trainings will lead to the improvement of their abilities
P14	That does not help because my views will not be heard
P15	
P16	This model will ensure a holistic approach to supporting farmers, firstly, by ensuring that farmers have the technical know-how of new technologies and also providing access to funding to enable farmers to use capital-intensive technologies
P17	Advisors work as link between government and farmers. If advisors are well equipped with knowledge and skills, I believe our farmers will also have the confidence to adopt new technologies with the help of advisors
P18	I can't specify any model because I do not know any
P19	None
P20	To acquaint farmers with the present technologies that ultimately enhance the effective end results
P21	
P22	The results of the model will be efficient and effective
P23	There is a silo available within the departments e.g., agricultural municipalities involved in the distribution of packages, social development distribute packages, including livestock, agricultural products and this is only to reduce service delivery
P24	To update farmers with modern products and methods
P25	Disjoined local government
P26	
P27	

P28	Skills development, funding
P29	Sharing best practices in order to improve service delivery
P30	To facilitate joint information dissemination and planning

Question 5: What are the recommendations needed to enhance the adoption of emerging technologies and effective governance to improve agricultural practices in the North West province?

Responses:

P1	Information about the productivity of these technologies. Those who are willing to teach should be empowered with financial assistance for these technologies. Project coordinators should monitor these projects from start to finish while ensuring that there focus is solely on these projects
P2	New technology, improved agricultural practices, Grain South Africa, NWK
P3	Farming is a business, move from being subsistence to commercial farmers, eat today and thank a farmer
P4	Capacitate extension officials and farmers
P5	
P6	1. Implementation of projects should be separated from the field of agricultural advice, 2. Training of officers and farmers to equipped with the relevant training institutes, for example, ARC and universities
P7	Training of farmers on the use of technology should be given a better attention
P8	Provision of resources, water for livestock, fences, handling facilities, 2. Continuous training and workshop, 3. Experienced farmers should be used as demonstrators in farms
P9	Good machineries, conservation agriculture
P10	To train extension officers who are the trainers and open the lines of communication between internal and external stakeholders. Do not hold back extension officers when doing their work. Managers are guilty of this. AAs should be the ones choosing their beneficiaries for government support.
P11	To train agricultural advisors, training farmers
P12	The recommendation needed is to empower extension officers so as to impact knowledge to the farmers
P13	Proper training for both local farmers and agricultural advisors
P14	
P15	Supervisors should not be selfish with the money that does not belong to them
P16	Private partnerships, engaging all relevant stakeholders, ensuring skills transfer to farmers, adoption of funding model by the department
P17	If someone is appointed as a crop advisor, it should be kept that way. The situation whereby people change their stream once they are adopted kills the farmer's hope of becoming a commercial farmer someday. Also managers should consult with advisors from time to time to check on their qualifications and recommend relevant courses
P18	Training extension officers so that they can transfer the technologies to farmers through agri-shows, showcasing of those emerging technologies, promotion of exercise, start providing drafts
P19	None
P20	Ensuring that farmers have the correct skills and that they farm with a specific commodity/breed

P21	
P22	Through stakeholder engagements and officials in the department of agriculture and farmers, including smallholder and commercial farmers
P23	There is no succession in governance, e.g., MEC and HOD have no common interest. After a certain period, the new approaches do not follow-up on the vision and mission of the previous administrators. Succession is important. The organogram or structure of all departments should be reviewed every year in order to have new objectives and missions
P24	Simplify information, involve children (farmers' children), trainings
P25	
P26	
P27	Engaging in excursions, attending information sessions,
P28	Planning, budgeting, training of both extension officers and farmers
P29	Should be closely monitored with strong evaluation of each project
P30	

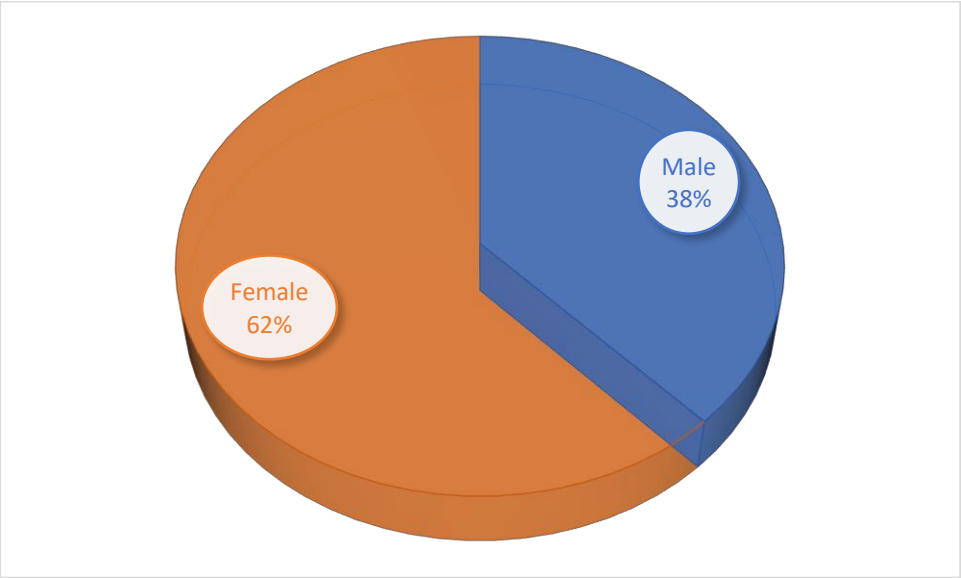
QUALITATIVE FINDING

AIM

The main aim of this study is to peruse if the application of emerging technologies and good governance would enhance achieving agricultural sustainability in the North West province

DEMOGRAPHIC PROFILE OF PARTICIPANTS

FIGURE ON GENDER



Majority of the participants are female farmers (n=18,62%) The male participants in the study represent 38% (n=11) of the total sample.

FIGURE ON AGE

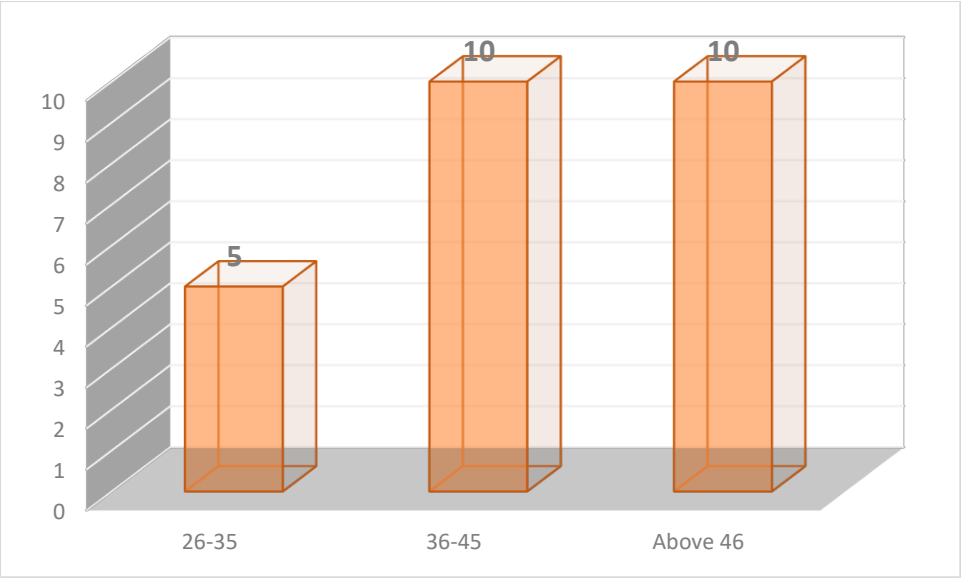


FIGURE ON Position in the Department

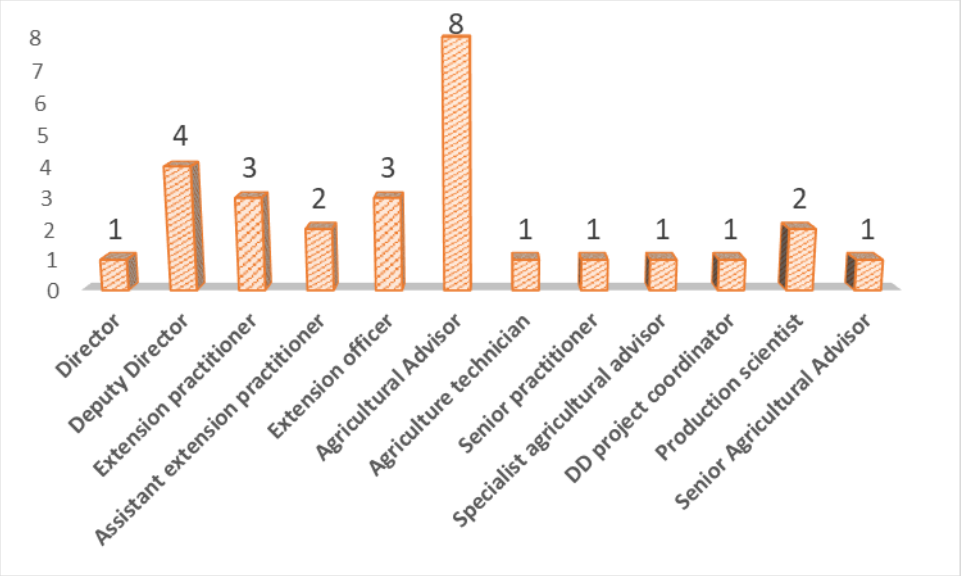


FIGURE ON Year of appointment

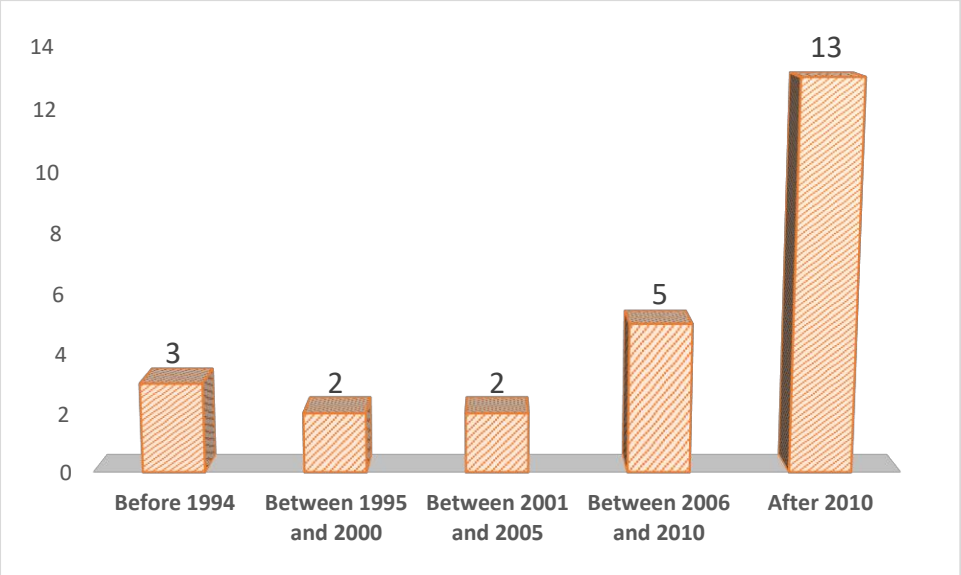
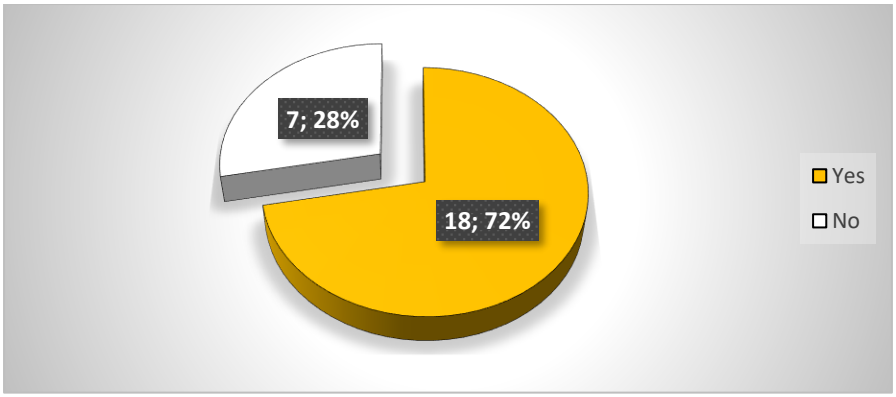


Figure on farmers incorporating emerging technologies in their farming process



The majority (n=18, 72%) of the farmers are incorporating emerging technologies in their farming practice.

5.3 CODING

In this study, the interview transcripts were analyzed (coded) using Atlas-Ti version 22. According to Soratto, Pires, and Friese (2020:2), ATLAS.ti is a valuable tool for data analysis in qualitative research and can be used with a variety of theoretical frameworks and data analysis methods including thematic analysis.

Thematic analysis is the method of data analysis for the present study. The thematic analysis describes a research technique for the arbitrary interpretation of the data through a methodological coding and theme- or pattern-identification process (Braun & Clarke, 2022). The coding process was effectively managed in Atlas Ti. software.

The transcript was auto-coded through the use of a text search tool to depict participants' understanding and opinions on the application of emerging technologies and agricultural sustainability. Using the text search tool allowed the researcher to become more familiar with how farmers and employees at the Department of agriculture understands the application of emerging technologies in farming practice. This exercise allowed the researcher to hear participants' voices and to begin the coding process.

According to Saldaña (2015:4), a code is a word or a brief phrase to which the researcher assigns a particular piece of data. Whether the researcher uses lump or split coding affects how much code is produced. Split coding refers to breaking the part up into separate portions, whereas lump coding refers

to assigning a single code that encapsulates the substance of a section (Saldaña, 2015:23). The researcher used a lump coding approach for this exploration. Saldaña (2015:3) describes 32 different coding techniques used in the guidebook. The descriptive coding method was mostly used in this study, which Saldaña (2015:88) notes is appropriate for practically all qualitative investigations and is especially helpful for a researcher who is still learning how to code. Words or short phrases are used in descriptive codes to describe the data.

Following the initial coding, the codes were categorized into (6) main themes, (11) sub-themes (32) categories. These are presented in Table 2 As a general rule, these three organizational levels were used. These codes and sub-categories are presented in Table 2 .as the themes and sub-themes for this study.

Table of study themes and sub-themes

MAIN THEME 1: TYPES OF EMERGING TECHNOLOGIES IN FARMING PRACTICE	
Themes	Sub-Themes
1.1 Types of emerging technologies	• Animal production technologies • Plant production technologies
MAIN THEME 2: EFFECTIVENESS OF EMERGING TECHNOLOGIES IN AGRO-PRODUCTS	
MAIN THEME 3: MAJOR BARRIERS OF EMERGING TECHNOLOGIES	
3.1 Education	• Low literacy level • Poor knowledge use of new technologies
3.2 Finance	• Capital intensive • Lack of financial assistance to farmers • Monetary-focused negative attitudes
3.3 Resources	• Shortage of latest technologies • Lack of technical tools • Poor access to information • High Aging-farmer population

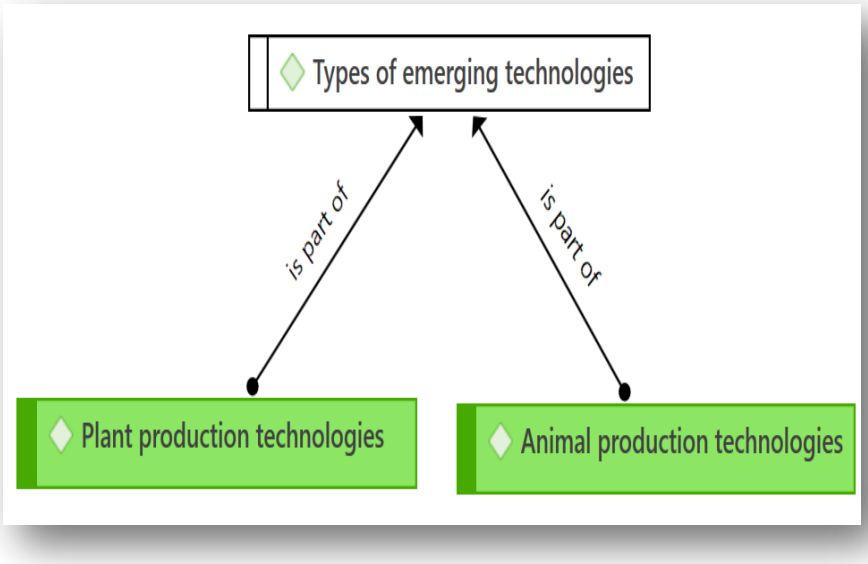
3.4 Support	• Lack of youth development • Poor departmental support • Inadequate capacity training on new technology • Inadequate Land-tenure rights
MAIN THEME 4: GOVERNMENTAL TECHNOLOGY-TRANSFER MODELS IN COMMERCIAL FARMING	
4.1 Technology-transfer models	• Machinery supply • Agricultural Advisory • Funding models • Training programs
MAIN THEME 5: EFFECTIVENESS OF THE TECHNOLOGY-TRANSFER MODELS IN FARMING PRACTICE	
Effectiveness of technology-transfer models	
5.1 Development	• Technology skill development • Access to funding opportunities • Farmers' co-operatives
5.2 Partnership	• Partnership with research institutions • Private sectors collaboration
MAIN THEME 6: RECOMMENDATIONS	
6.1 Governance and management	• Regular monitoring & supervision • Active stakeholders' engagement • Proper management & restructuring.
6.2 Training & Development	• Capacitate extension officials and farmers on latest technology • Youth development programs
6.3 Resources	• Adequate provision of agricultural resources • Sufficient provision of latest machinery & technologies • Funding

Findings for research question ONE

RQ1=What types of emerging technologies do farmers in the North West province incorporate in their farming practices?

Themes	Sub-Themes
Types of emerging technologies	• Animal production technologies • Plant production technologies

FIGURE 1 Types of EMERGING TECHNOLOGY



Source: Created by the researcher in Atlas. ti

Participants of the study mentioned several kinds of emerging technology that are used by farmers in farming practices as presented in Table 2. These consists of two categories - Animal production and plant production as presented in Figure 1

Table 2 Farmers emerging technologies

Animal Production	Plant production
Irrigation scheme	Digital farm measurement with mobile phones
Animal production	using of Apps
WhatsApp and Google	Cultivar choice
Automatic feeders	Boom sprayer
Branding	No -till planter,
dipping and dosing	Tunnels
weaning and selection	grading
Artificial insemination	No till or conservation agriculture
animal identification	Applications for precision farming
Follow feed/medication program	Improved seeds
genetic improvement,	fertilization,
immunization,	weed control,
Dehorning	Using new Machinery,
Use of new medicines/products,	center pivot
Digitalization	ICT
current market information,	price of grains from SAFFEX and online
ICT,	BT maize,
animal production,	roundup ready
energy sourcing	Sampling,
price checking from buyers and banks,	
market information	

The majority of the farmers (9) have incorporated emerging technology in their farming practices for 10 years and above. In fact, two of the farmers have used these technologies Since 1994. 8 of the participants have recently started using these technologies. They mentioned that they have incorporated the technology in their farming practice since 2 -5 years.

Although the aforementioned opinion was contradicted by the view of 2 of the farmers who felt that farmers are using traditional methods in the North West Province. They also expressed that emerging technologies are only used by the younger farmer as reflected in the quotations below

"Younger farmers have been the ones using these technologies since 2015"(P…)

"Most emerging farmers in the province use traditional methods" (P…)

Table 2 on summary of use of emerging technology in North West

Recently
10 years
None
Since 2018
Recently
10 years
10 years
3-5 years
3 years
2 farming seasons
Not practiced at all
2 years
Most emerging farmers in the province use traditional methods
None of the technologies have been incorporated
None so far
From 2010
Younger farmers have been the ones using these technologies since 2015
Has continued since 2009
Gradually since 1994
5 years
Some farmers have used it since 1994 to date
10 years for BT maize, over 10 years for roundup ready maize
Over 5 years

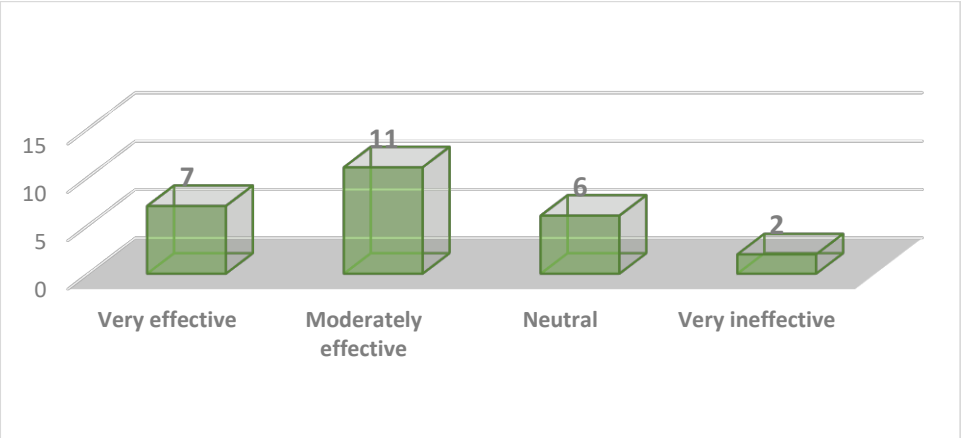
RESEARCH QUESTION 2

RQ2= How effective are these emerging technologies in increasing the general productivity of agro-products to achieve food security?

MAIN THEME 2: EFFECTIVENESS OF EMERGING TECHNOLOGIES IN AGRO-PRODUCTS	

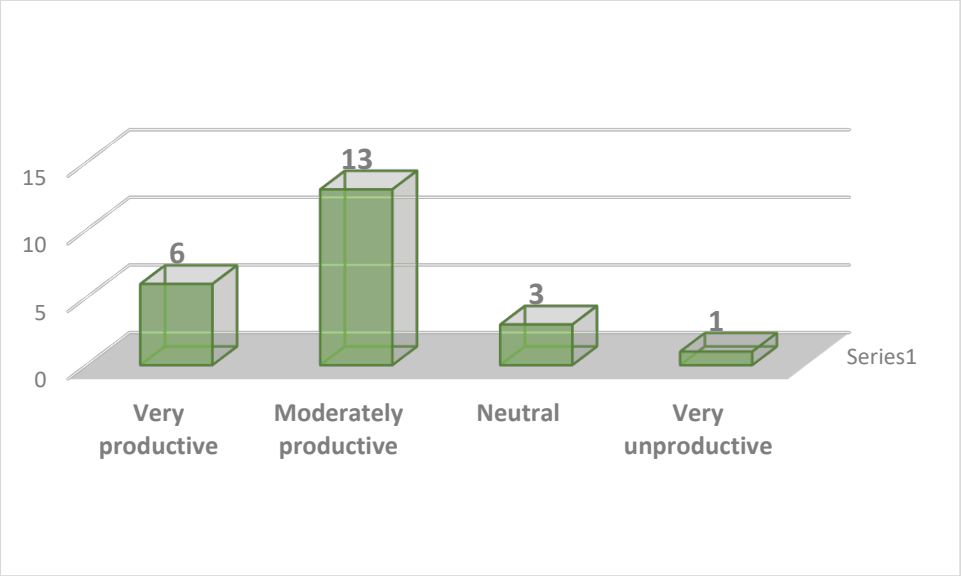
1) How effective are these emerging technologies in increasing the production of maize?

Figure on effectiveness of emerging technologies



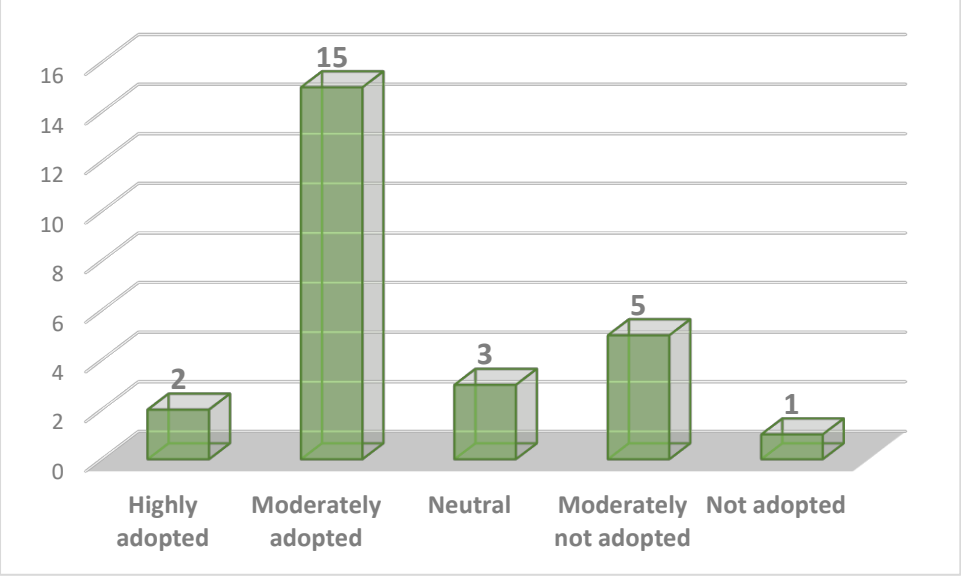
2) What can about the productivity of maize since they started incorporating emerging technologies?

FIGURE ON the productivity of maize since they started incorporating emerging technologies?



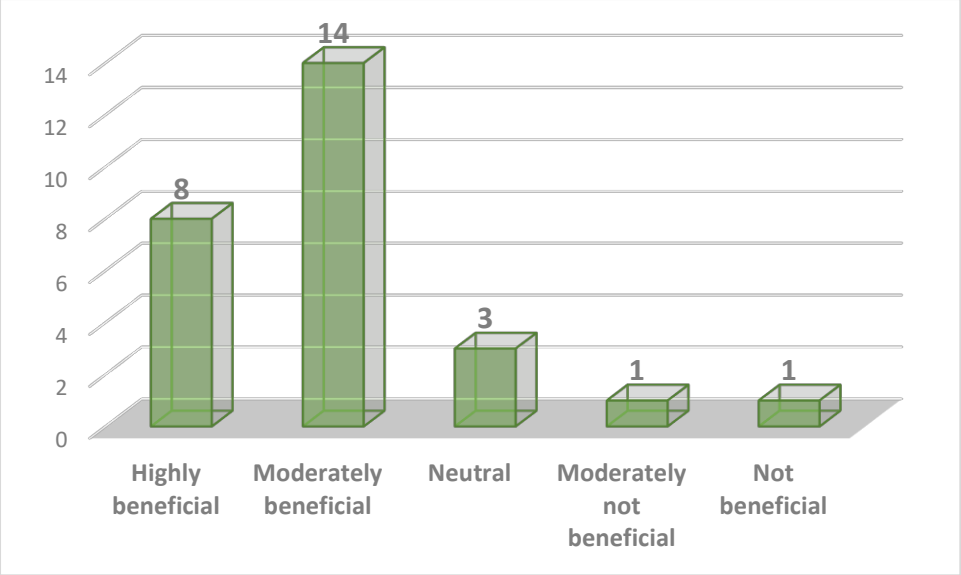
3)What can you say about the adoption of these technologies?

***FIGURE ON* the adoption of these technologies**



4)To what extent are these technologies beneficial to the general public?

FIGURE ON THE BENEFIT OF TECHNOLOHIES TO THE GENERAL PUBLIC



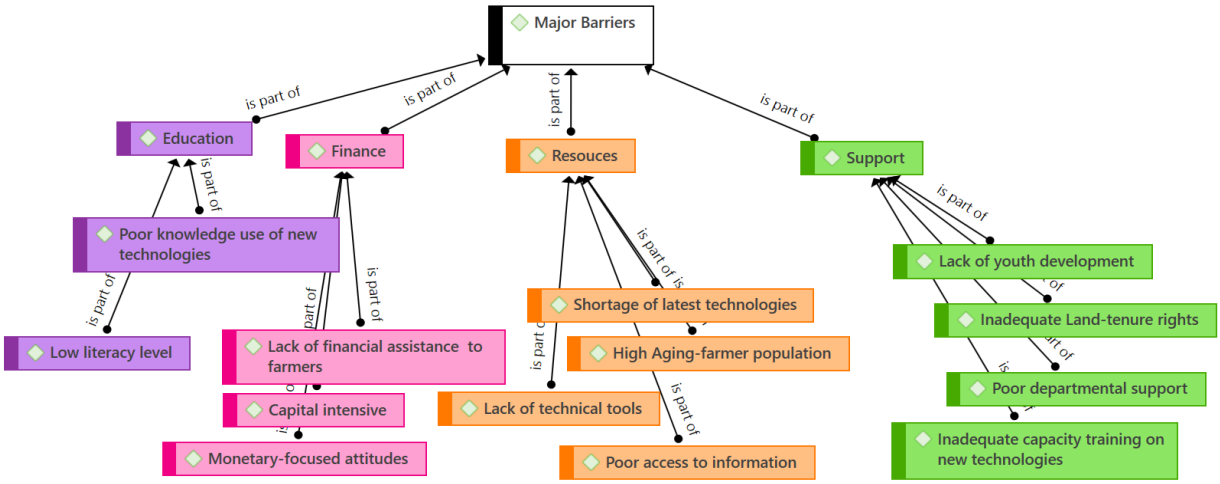
FINDINGS ON RESEARCH QUESTION 3

RQ 3 = What are the major barriers that hinder the adoption of emerging technologies by farmers in the North West province?

MAIN THEME 3: MAJOR BARRIERS OF EMERGING TECHNOLOGIES	
3.1 Education	• Low literacy level • Poor knowledge use of new technologies
3.2 Finance	• Capital intensive • Lack of financial assistance to farmers • Monetary-focused negative attitudes
3.3 Resources	• Shortage of latest technologies • Lack of technical tools • Poor access to information • High Aging-farmer population
3.4 Support	• Lack of youth development • Poor departmental support

	• Inadequate capacity training on new technology • Inadequate Land-tenure rights

Figure 3.1 major Barriers

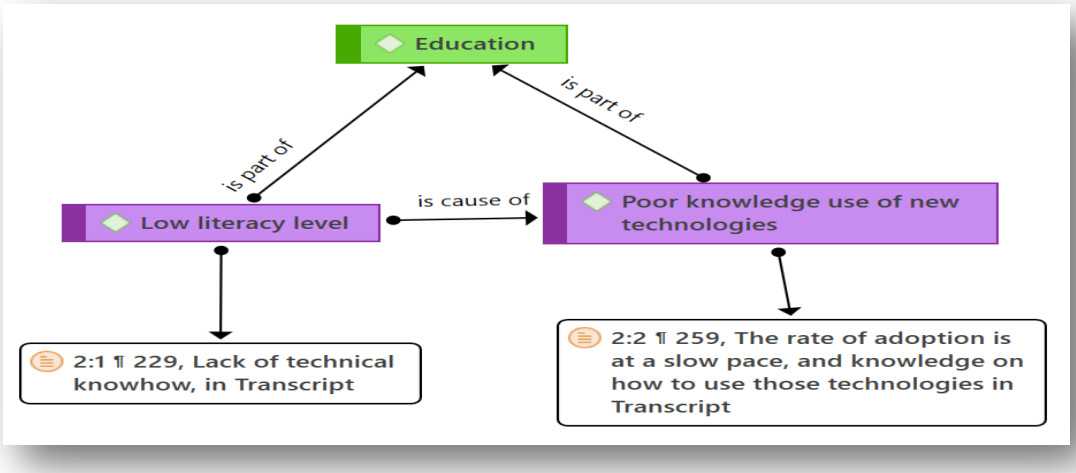


Source: Created by the researcher in Atlas. ti

3.1 EDUCATION

Referring to Figure 3.1, the theme education consists of two categories -low literacy level, and poor knowledge use of new technologies

FIGURE EDUCATION



Source: Created by the researcher in Atlas. ti

3.1.1 LOW LITERACY LEVEL

Level of education for farmers and age of practicing old farming practices. Change should be incorporated in or areas, move focus on youth interested in farming to change to new technological practices (P1)

Literacy level is very low and extension is not capacitated in terms of emerging technologies. We highlight every year on PDP what the latest courses we need to attend but nothing is done about it (P4)

More trials should be by specialists at the production site (P6)

Lack of technical knowhow (P10)

lack of understanding (P11)

Lack of education (P14)

low level of literacy (P26)

participants mentioned that farmers are reluctant to embrace technological change. the fear of change is reflected in P26 below

reluctance to embrace change (P26)

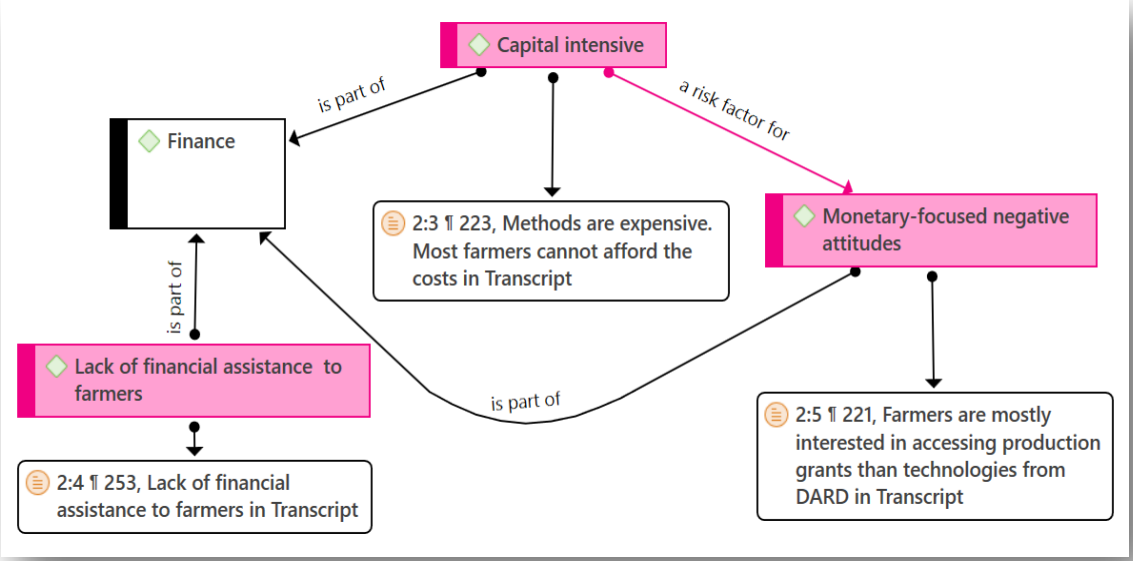
3.1.2 POOR KNOWLEDGE USE OF NEW TECHNOLOGIES

They adopt slowly due to certain challenges they face in their communities, for instance, there is shortage of smartphones (P2)

The rate of adoption is at a slow pace, and knowledge on how to use those technologies (P25)

3.2 FINANCE

FIGURE FINANCE



Source: Created by the researcher in Atlas. ti

3.2.1 CAPITAL INTENSIVE

Methods are expensive. Most farmers cannot afford the costs (P7)

lack of capital (P10)

These technologies are capital intensive and emerging farmers face serious funding constraints (P16)

Lack of adequate budget, land, markets, etc., makes the adoption of technologies to become ineffective (P20)

High cost of machinery, especially the no-till machinery (P9)

These technologies are capital intensive and emerging farmers face serious funding constraints (P16)

New technologies are very expensive (P27)

Participants also expressed that they experience conflicting costs of inputs such as seed adverting as reflected by participant 21

The cost of these technologies is high, conflicting cost of inputs, e.g. seeds, climate, advertising (P21)

3.2.2 LACK OF FINANCIAL ASSISTANCE

Lack of financial assistance to farmers, lack of access to information to farmers (P22)

lack of finance (P27)

No access to finance in some cases (P29)

Funding or having enough budget to adopt new technologies (P28)

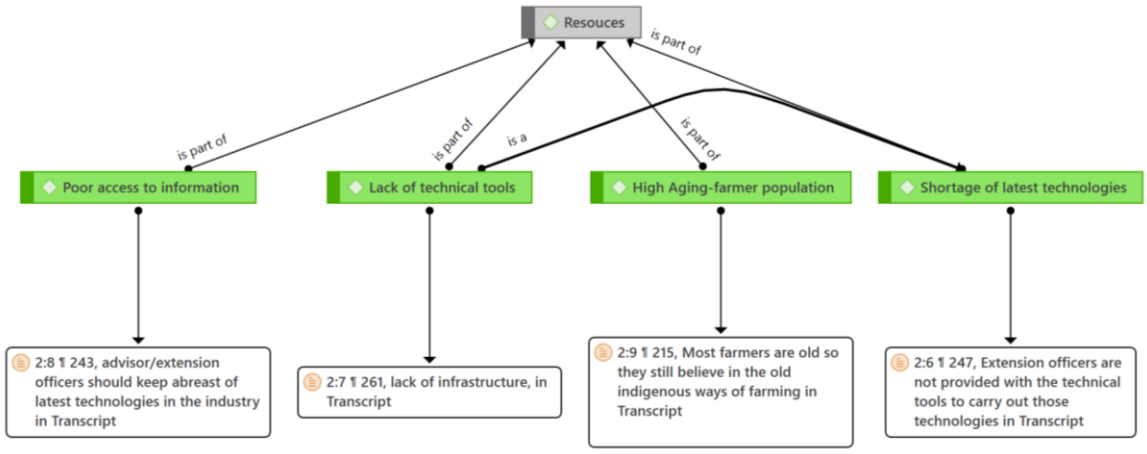
3.2.3 MONETARY-FOCUSED ATTITUDES

The farmers are mostly interested only in funding. When you sight a problem and try to advise, they show no interest (P5)

Farmers are mostly interested in accessing production grants than technologies from DARD (P6)

3.3 RESOURCES

FIGURE ON RESOURCES



Source: Created by the researcher in Atlas. ti

3.3.1 SHORTAGE OF LATEST TECHNOLOGIES

Suitable conservation, agricultural equipment/mechanization, farmers should be assisted with relevant planters (P12)

Extension officers are not provided with the technical tools to carry out those technologies. There is absolutely no new/emerging technology (P19)

3.3.2 LACK OF TECHNICAL TOOLS

Suitable conservation, agricultural equipment/mechanization, farmers should be assisted with relevant planters (P12)

lack of infrastructure (P26)

3.3.3 POOR ACCESS TO INFORMATION

Lack of technical knowhow (P10)

Lack of information (P11)

Also, advisor/extension officers should keep abreast of latest technologies in the industry (P17)

Lack of access to information by farmers ...workers, technologies are not incorporated into the reporting templates so that the performance can be measured (P18)

lack of access to information to farmers (P22)

Inadequate communication (P26)

Inadequate dissemination of information (P30)

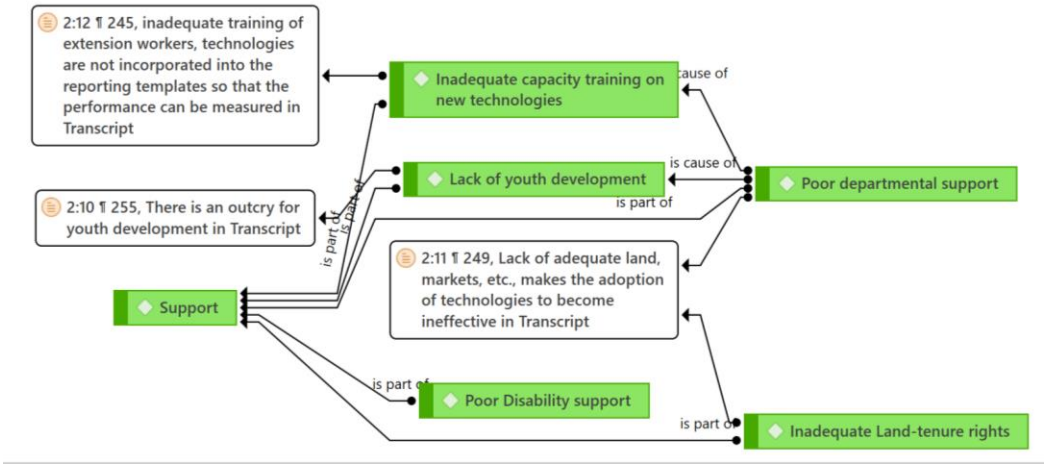
3.3.4 HIGH AGING-FARMER POPULATION

Most farmers are old so they still believe in the old indigenous ways of farming (P3)

There is increase in aging farmers, wherein young farmers are not really taking the opportunities (P23)

3.4 SUPPORT

FIGURE ON SUPPORT



Source: Created by the researcher in Atlas. ti

3.4.1 LACK OF YOUTH DEVELOPMENT

Lack of departmental support (P15)

There is an outcry for youth development (P23)

3.4.2 POOR DEPARTMENTAL SUPPORT

Lack of departmental support (P15)

Lack of adequate budget, land, markets, etc., makes the adoption of technologies to become ineffective (P20)

I think the advisory services are somehow unjust to the farmers by not exposing them to emerging technologies (17)

Participants also expressed that The lack of support prevents vulnerable populations such as those living with disabilities to improve their farming practice as reflected in participant 23 views:

There is an outcry for people with disability. For instance, a farmer with disability, who is willing to improve farming but live with disability (P23)

3.4.3 INADEQUATE CAPACITY TRAINING ON NEW TECHNOLOGY

Lack of information, lack of understanding (P11)

less skilled extension officers, lack of relevant training for extension workers and farmers (P14)

inadequate training of extension workers, technologies are not incorporated into the reporting templates so that the performance can be measured (P18)

No access to trainings, partnerships with commercial farmers (P29)

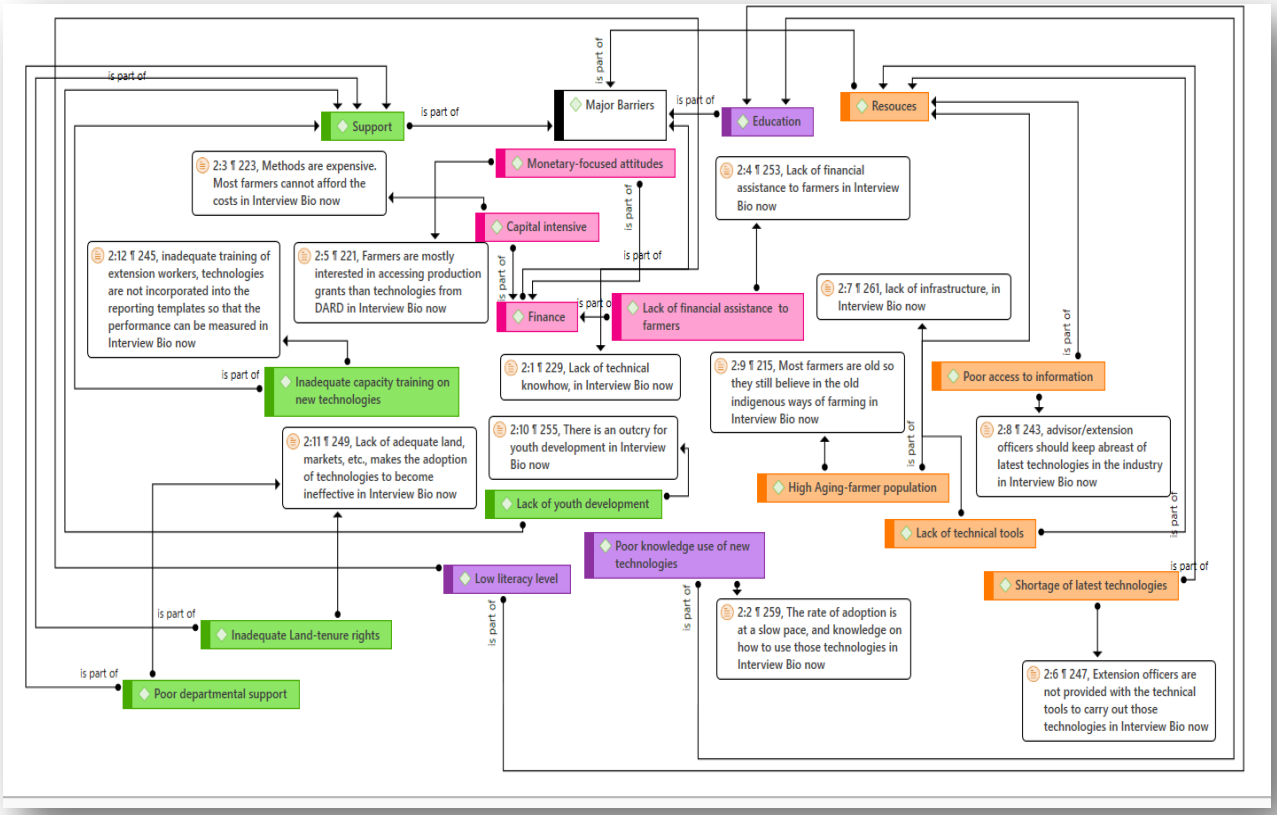
Inadequate ..capacity building (P30)

3.4 .4 INADEQUATE LAND-TENURE RIGHTS

lack of land-tenure rights (P10)

Lack of adequate land, markets, etc., makes the adoption of technologies to become ineffective (20)

FIGURE ON OVERVIEW ON MAJOR BARRIERS



Source: Created by the researcher in Atlas. ti

RESEARCH QUESTION 4 FINDINGS

MAIN THEME 4: RQ4= What technology-transfer models do the government adopt to facilitate the adoption of emerging technologies in commercial farming in the North West province?

MAIN THEME 4: GOVERNMENTAL TECHNOLOGY-TRANSFER MODELS IN COMMERCIAL FARMING	
4.1 Technology-transfer models	• Machinery supply • Agricultural Advisory • Funding models • Training programs

4.1 TECHNOLOGY-TRANSFER MODELS

Technology-transfer models consist of machinery supply, agricultural advisory, funding models, and training programs.

4.1.1 MACHINERY SUPPLY

Yes, they have purchased the machinery for conservation agriculture, but they purchased the Zplanter row, which are very small for their tractors (P9, Sec .B3-Q2)

Yes, government has provided some farmers with no-till planters and the sustainable agriculture directorate pushes for the smart agriculture agenda (P10, Sec .B3-Q2)

Government has intervened by procuring C.A. planters but it was for a handful of farmers. More budget is needed (P12, Sec .B3- Q2)

4.1.2 AGRICULTURAL ADVISORY

It has only been through extension and advisory services (P3. Sec .B3-Q2)

Agricultural advisors are doing their best to transfer these technologies to farmers. However, implementation of projects sometimes makes them lose focus (P5.Sec .B3, Q2)

Advisory board (P4, Sec B4- Q1)

Commodity specialization by agricultural advisors (P6, Sec B4- Q1)

Yes, advisory model (P11, Sec B-Q1)

Participants mentioned farmers' day and demonstration visits as important. The agricultural advisory may advise on farmers' visits to be a frequent event.

Yes. Farmers day, information day, demonstration, and continuous visits (P8, Sec .B3-Q2)

4.1.3 FUNDING MODELS

The department is providing grants to farmers to assist in purchasing resources, including machineries (P7, Sec .B3- Q2)

Yes, government has been providing farmers with funding (P16, Sec .B3- Q2)

Yes, funding has been provided to a very few farmers (P27, Sec .B3-Q2

Yes, government has been providing farmers with funding (P16, Sec .B3-Q2)

Yes, by funding farmers (P27, Sec .B3-Q2)

Yes, through funding of conditional grants and equitable share (P29, Sec .B3-Q2)

Yes, but not to a satisfactory level (Q30, Sec .B3-Q2)

Yes, funding models will allow more farmers access to new technologies as well as non-financial support such as training whilst working together with the private sector(P16, SecB-Q1)

4.1.4 TRAINING PROGRAMS

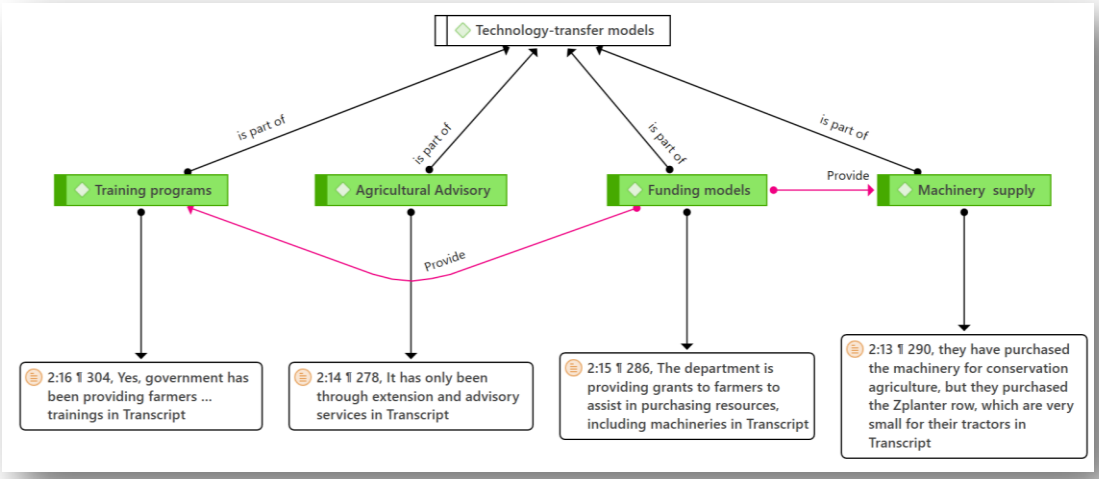
Yes, government has been providing farmers … trainings (P16, Sec .B3-Q2)

Through mentorship and experiential training of both men, women, youth, and people living with disabilities (P3, SecB4-Q1)

Through adopting to new technologies, through attending symposiums, farmers' days, and farm visits (P22, SecB4-Q1)

Funding/in-service training of extension officers (P28, SecB4-Q1)

Figure Technology-transfer models



Source: Created by the researcher in Atlas. ti

RESEARCH QUESTION 5 FINDINGS

RQ5= What is the effectiveness of the technology-transfer models in encouraging farmers to adopt emerging innovation options in their farming practices?

MAIN THEME 5: EFFECTIVENESS OF THE TECHNOLOGY-TRANSFER MODELS IN FARMING PRACTICE	
Effectiveness of technology-transfer models	
5.1 Development	• Technology skill development • Access to funding opportunities • Farmers' co-operatives
5.2 Partnership	• Partnership with research institutions • Private sectors collaboration

5.1. EFFECTIVENESS OF TECHNOLOGY-TRANSFER MODELS (TTMs)

Participants' opinions on the effectiveness of TTMs yielded two themes – development and partnership. Development consists of 4 categories and partnership is grouped into 2

5.1 DEVELOPMENT

5.1.1 TECHNOLOGY SKILL DEVELOPMENT

Issuing of bursaries to advisors. Agriculture is evolving, it only makes sense if advisors enhance their knowledge and then take the knowledge obtained to farmers. In so doing, farmers will develop confidence in adopting new technologies (P17, SecB-Q2)

Through trainings, tours, involvement of other relevant stakeholders (P24, SecB-Q2)

Skills development (P28, SecB-Q2)

5.1.2 ACCESS TO FUNDING OPPORTUNITIES

Grants and rents, sending extension officers abroad on excursions to learn about these technologies (P19, SecB-Q2)

funding (P28, SecB-Q2)

5.1.3 FARMERS' CO-OPERATIVES

Study groups, work as co-operatives, advance training (P8, SecB-Q2)

The model is moving a study group on C.A. and farmers should be encouraged to join(P12, SecB-Q2)

Through farmers' days and information days (P22, SecB-Q2)

Farmers' day, conference, farm visits, and monitoring(P20, SecB-Q2)

Study groups help farmers to learn from one another (P3, SecB-Q3)

Participatory approach (P27, SecB-Q3)

5.2 PARTNERSHIP

Based on the views of participants on the effectiveness of technology-transfer models in farming practice, partnerships with research institutions and Private sector collaboration emerged as subcategories of partnership.

5.2.1 PARTNERSHIP WITH RESEARCH INSTITUTIONS

Trials conducted by specialists and researchers, especially at the production site (P6, SecB4-Q2).

involvement of other relevant stakeholders (P24, SecB4-Q2)

Local government to engage universities in the development of technologies for better adoption (P25, SecB4-Q2).

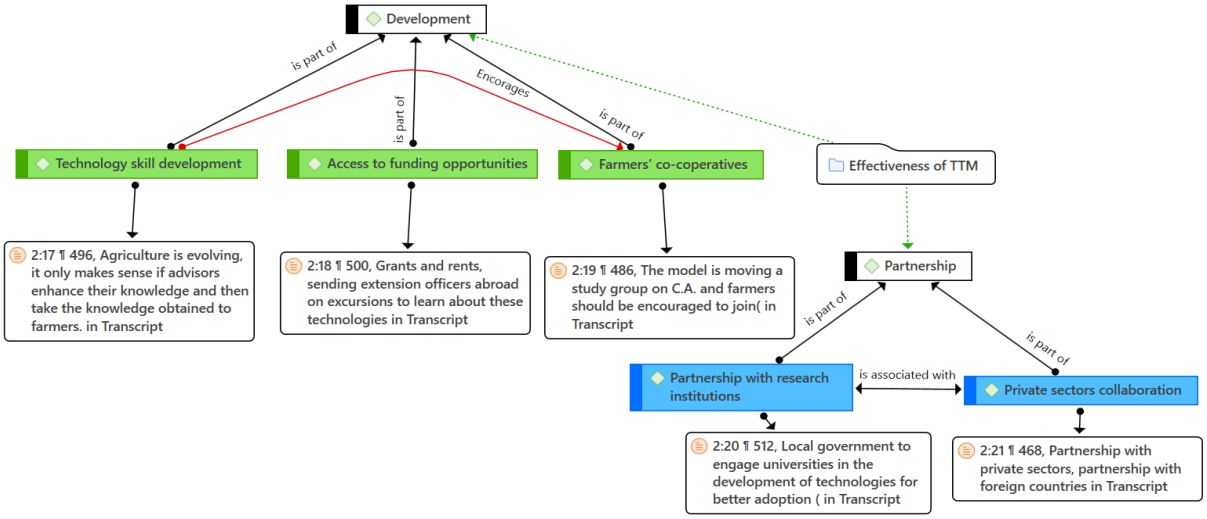
Partnering with universities and institutions, such as ARC, CSIR, etc. (P29, SecB4-Q2).

Skills development, form partnerships with research institutions (P17, SecB4-Q3

5.2.2 PRIVATE SECTORS COLLABORATION

Partnership with private sectors, partnership with foreign countries (P3-SecB4-Q2)

Figure on TECHNOLOGY-TRANSFER MODELS



Source: Created by the researcher in Atlas. ti

note TTM= *technology-transfer models*

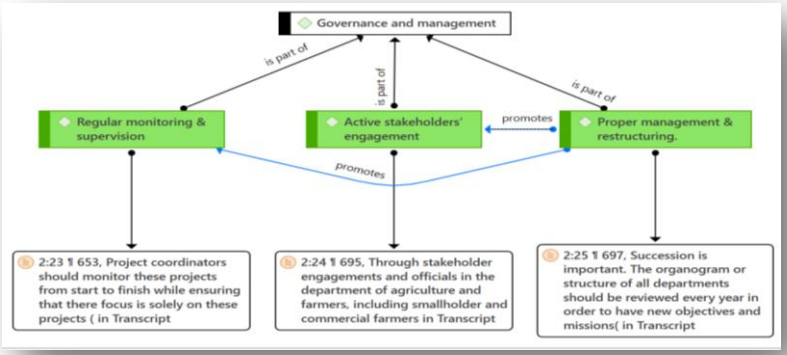
RESEARCH QUESTION 6 FINDINGS

RQ6=What are the recommendations needed to enhance the adoption of emerging technologies and effective governance to improve agricultural practices in the North West province?

MAIN THEME 6: RECOMMENDATIONS	
6.1 Governance and management	• Regular monitoring & supervision • Active stakeholders' engagement • Proper management & restructuring.
6.2 Training & Development	• Capacitate extension officials and farmers on latest technology • Youth development programs
6.3 Resources	• Adequate provision of agricultural resources • Sufficient provision of latest machinery & technologies • Funding

6.1 GOVERNANCE AND MANAGEMENT (G & M)

FIGURE ON G & M RECOMMENDATION



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6.1.1 REGULAR MONITORING & SUPERVISION

Also managers should consult with advisors from time to time to check on their qualifications and recommend relevant courses (P17,SecB4-Q5)

Project coordinators should monitor these projects from start to finish while ensuring that there focus is solely on these projects (P1, SecB4-Q5)

Should be closely monitored with strong evaluation of each project (P129, SecB4-Q5)

6.1.2 ACTIVE STAKEHOLDERS' ENGAGEMENT

engaging all relevant stakeholders, (P16, SecB4-Q5).

Through stakeholder engagements and officials in the department of agriculture and farmers, including smallholder and commercial farmers(P22, SecB4-Q5).

Private partnerships, (P16, SecB4-Q5)

6.1.3 PROPER MANAGEMENT & RESTRUCTURING.

New technology, improved agricultural practices, Grain South Africa, NWK(P2, SecB4-Q5)

Implementation of projects should be separated from the field of agricultural advice, (P6 SecB4-Q5)

To train extension officers who are the trainers and open the lines of communication between internal and external stakeholders. Do not hold back extension officers when doing their work. Managers are guilty of this. AAs should be the ones choosing their beneficiaries for government support (P10, SecB4-Q5).

If someone is appointed as a crop advisor, it should be kept that way. The situation whereby people change their stream once they are adopted kills the farmer's hope of becoming a commercial farmer someday ((P17, SecB4-Q5).).

showcasing of those emerging technologies, promotion of exercise, start providing drafts(P18, SecB4-Q5)

Ensuring that farmers have the correct skills and that they farm with a specific commodity/breed (P20, SecB4-Q5)

There is no succession in governance, e.g., MEC and HOD have no common interest. After a certain period, the new approaches do not follow-up on the vision and mission of the previous administrators. Succession is important. The organogram or structure of all departments should be reviewed every year in order to have new objectives and missions(P23, SecB4-Q5)

Planning, budgeting (P28, SecB4-Q5) ,

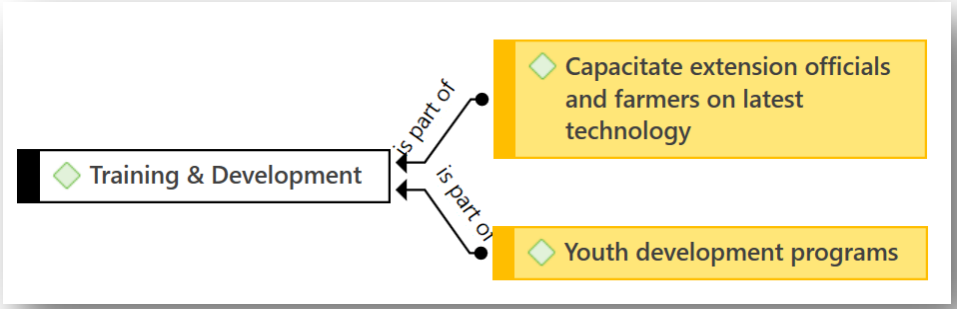
The findings of the study revealed that managers need to ensure that information provided should be communicated in a very simple manner for easy understanding.

Information about the productivity of these technologies. (P1 ,SecB4-Q5)

Simplify information, (P27,SecB4-Q5)

6.2 TRAINING & DEVELOPMENT (T & D)

FIGURE ON T & D RECOMMENDATION



Source: Created by the researcher in Atlas. ti

6.2.1 CAPACITATE EXTENSION OFFICIALS AND FARMERS ON LATEST TECHNOLOGY

Capacitate extension officials and farmers (P4, SecB4-Q4)

To train extension officers who are the trainers (P10, SecB4-Q4))

Training of officers and farmers to equipped with the relevant training institutes, for example, ARC and universities (P6, SecB4-Q5)

Training of farmers on the use of technology should be given a better attention (P7, SecB4-Q5)

Continuous training and workshop, 3. Experienced farmers should be used as demonstrators in farms (P8, SecB4-Q5)

To train agricultural advisors, training farmers (P11, SecB4-Q5)

The recommendation needed is to empower extension officers so as to impact knowledge to the farmers(P12, SecB4-Q5)

Proper training for both local farmers and agricultural advisors(P13, SecB4-Q5)

ensuring skills transfer to farmers (P16, SecB4-Q5)

Training extension officers so that they can transfer the technologies to farmers through agri-shows, (P18, SecB4-Q5)

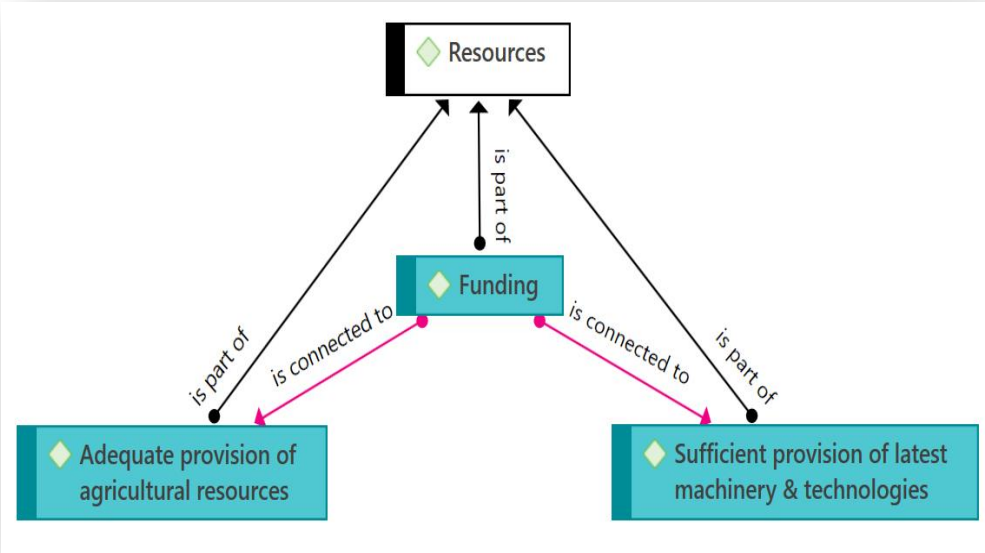
training of both extension officers and farmers (P28, SecB4-Q5) ,

6.2.2 YOUTH DEVELOPMENT PROGRAMS

involve children (farmers' children) (P24, SecB4-Q5)

6.3 RESOURCES

FIGURE OB RESOURCES RECOMMENDATION



Source: Created by the researcher in Atlas. ti

6.3.1 ADEQUATE PROVISION OF AGRICULTURAL RESOURCES

Provision of resources, water for livestock, fences, handling facilities, (P8, SecB4-Q4)

6.3.2 SUFFICIENT PROVISION OF LATEST MACHINERY & TECHNOLOGIES

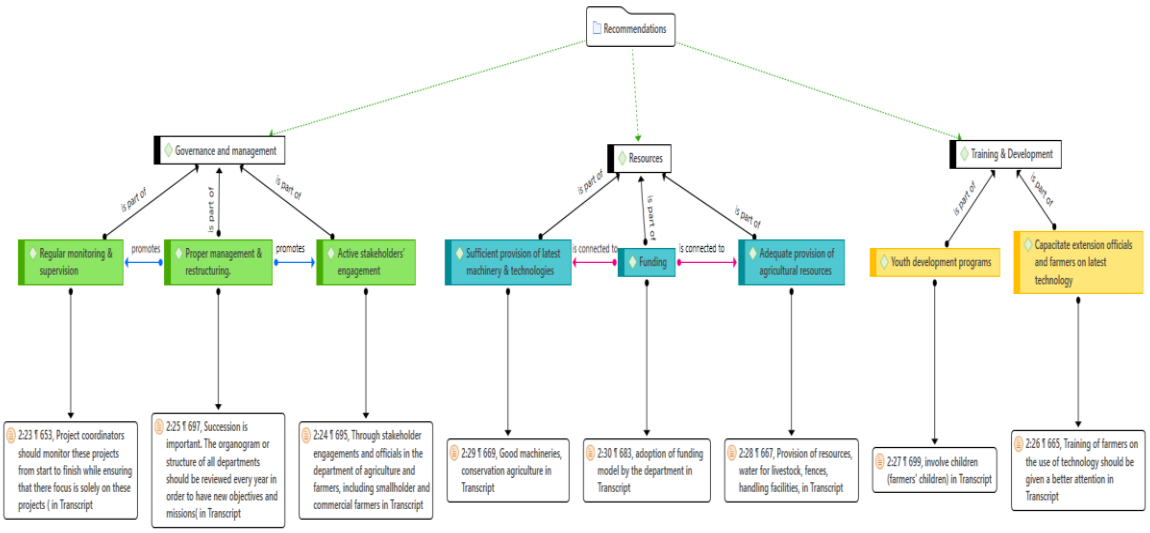
Good machineries, conservation agriculture(P9, SecB4-Q4)

6.3.3 FUNDING

Those who are willing to teach should be empowered with financial assistance for these technologies (P1, SecB4-Q5)

adoption of funding model by the department(P16, SecB4-Q5)

Figure on recommendation overview



Source: Created by the researcher in Atlas. ti

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APPENDIX 3 QUESTIONNAIRE

EMERGING TECHNOLOGIES AND EFFECTIVE GOVERNANCE FOR AGRICULTURAL SUSTAINABILITY IN THE NORTH WEST PROVINCE

QUESTIONNAIRE FOR FARMERS IN THE NORTH WEST PROVINCE

The main aim of this study is twofold, firstly; to peruse if the application of emerging technologies and good governance would enhance achieving agricultural sustainability in the North West province. Secondly; the study is aimed at proposing a framework to enhance technology adoption and effective governance to enhance agricultural sustainability in the North West province.

Please mark with an '**X**' in this box □ if you agree to participate in the study.

SECTION A: DEMOGRAPHIC INFORMATION

Answer each question presented below in the demographic section. The demographic information is needed in order to understand whether the research participants are a representative sample of the target population for the study.

Please mark the number that best characterizes your response with an '**X**'. Your honest responses and complete participation are important to the ultimate success of this study. Thank you, in advance, for your participation.

				Mark with X	V1
Q1	Gender	1	Female		V2
		2	Male		V3
Q2	Age Group	1	Less than 20 years		V4
		2	21 – 30 years		V5
		3	31 – 40 years		V6
		4	41 – 50 years		
		5	51 – 60 years		
		6	Above 60 years		
Q3	Nationality	1	South African		
		2	Other		
Q4	Ethnicity	1	Black African		
		2	Indian		
		3	Coloured		
		4	White		
		5	Other		
Q5	Can you read and write? **Not necessary**	1	Yes		
		2	No		
Q6	Please state your highest educational qualification		Never been to school		
			Primary schooling		
		1	High school		
		2	Diploma/Certificate		
		3	Undergraduate Degree		
		4	Postgraduate Degree		
		5	Other		
Q7	Are you the owner of the farm?	1	Yes		
		2	No		
Q8	Please indicate the local municipality where the farm is situated	1	Mahikeng		
		2	Ratlou		
		3	Ramotshere		
		4	Moiloa		
		5	Ditsobotla		

		6	Tswaing		

	Farming system(s)				
FS1	Do you have a paid employment besides farming?	1	Yes		
			Partly		
		2	No		
FS2	What is your main farming activity?	1	Farming (grain)		
		2	Horticulture		
		3	Livestock		
		4	Mixed farming		
FS3	What is the total size of your farm (cultivated and uncultivated)?	1	less than 1 hectare		
		2	1 to 5 hectares		
		3	6 to 10 hectares		
		4	more than 10 hectares		
FS4	How many crops (example: maize, sunflower, lettuce) do you usually cultivate in a year?	1	1		
		2	2		
		3	3		
		4	4		
Agricultural Extension Services					
AES1	Have you invested in new farming technology in the past 5 years?	1	Yes		
			Partly		
		2	No		
AES2	Are you a member of any farmer group?	1	Yes		
		2	No		
AES3	For how many years have you been a member the group?	1	less than 1 year		
		2	1 to 3 years		
		3	4 to 6 years		
		4	more than 6 years		
AES4	Do you receive any additional agricultural extension service?	1	Yes		
			Partly		
		2	No		
AES5	How frequent did you receive advices from agricultural extensions' agents?	1	Never		
		2	every 3 days		
		3	Weekly		
		4	Monthly		
		5	Bi-monthly		
		6	Once every 6 months		
AES6	Which are your main sources of information to get agricultural (agronomic) information and advices?	1	Extension agents		
		2	Organisations		
		3	Direct communications with neighbours		
		4	Meetings & Events		

		5	TV/Radio/Newspaper		
		6	Social media		
		7	Mobile phone based (SMS, WhatsApp groups)		
		8	Internet (websites)		
AES7	Do you normally follow the advice you receive?	1	Yes		
			Partly		
		2	No		
AES8	If No, which will be the reasons for not following the advices provided by your main sources?	1	Not specific to my location		
		2	Inappropriate availability of quality inputs (seed, pesticides and fertilizers)		
		3	Poor or no access to soil and/or water testing		
		4	Poor access to markets		
		5	Financial constraints		
		6	Other issues		
AES9	From the following list of information on agriculture, what information do you find most useful? (max 3)	1	Weather		
		2	Input use in general (fertilizers, seeds, agro-chemicals)		
		3	Yields prediction		
		4	Income and costs from nearby farms		
		5	Advise to manage pest, diseases and weeds		
		6	Prices forecasting		

Section B

In responding to the items below, please mark the number that best characterizes your response with an '**X**'. **1=Strongly disagree, 2=Disagree, 3=Agree, 4=Strongly agree**

	Behavioral Intention (BI)	Strongly disagree	disagree	Uncertain	agree	strongly agree	
BI 1	In the future, I intend to use or continue using emerging						

	technologies that increase my farm yield.							
BI 2	I will always try to use emerging technologies that provide me higher farm yield.							
BI 3	I plan to use or continue using emerging technologies that enhance farm productivity.							
	Performance expectancy (PE)							
PE 1	I find agronomic advices relating to emerging technologies, useful in my daily life.							
PE 2	Using emerging technologies help me to increase my productivity.							
PE 3	Using emerging technologies help me to accomplish things faster on my farm.							
PE 4	Using emerging technologies increases my possibilities of achieving higher crop yields.							

	Effort expectancy (EE)							
EE 1	Learning how to use emerging technologies is easy for me.							
EE 2	My interaction with emerging technologies is clear and comprehensive.							
EE 3	I find emerging technologies easy to use.							
EE 4	It is easy for me to become skillful at using emerging technologies.							
	Social influence (SI)							
SI 1	People whose opinions I value, prefer that I adopt emerging technologies.							
SI 2	People who influences how I behave think I should adopt emerging technologies.							
SI 3	People who are important to me think that I should use emerging technologies.							
SI 4	People who are important to me would use emerging technologies themselves.							

	Facilitating conditions (FC)							
FC 1	I have the necessary resources to use emerging technologies.							
FC 2	I have the necessary knowledge to use emerging technologies.							
FC 3	The emerging technologies are compatible with other technologies I use.							
FC 4	I can get help from others when I have difficulties using emerging technologies.							
	Trust (TR)							
TR 1	The extension services provider is very concerned about my crop(s) production.							
TR 2	My needs and desires are very important to the extension services provider.							
TR 3	The extension services provider would not knowingly do anything to hurt me.							
TR 4	The extension services provider really							

	looks out for what is important to me.							
TR 5	The extension services provider will go out of its way to help me.							
	Mastery-approach goals (MAG)							
MAG 1	I want to learn as much as possible about emerging farming technologies.							
MAG 2	It is important for me to completely understand the advantages and disadvantages of emerging farming technologies.							
MAG 3	I desire to completely master the use of emerging farming technologies.							
	Innovativeness (IN)							
IN 1	If I heard about a new technology, I would look for ways to experiment with it.							
IN 2	Among my peers, I am usually the first to explore new gadgets and technologies.							

IN 3	I like to experiment with new technologies.						

THANK YOU FOR YOUR TIME.

APPENDIX 4 ETHICS CERTIFICATE

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ETHICS APPROVAL LETTER OF STUDY

Based on approval by the **Faculty of Natural and Agricultural Sciences Ethics Committee (FNAS-REC)**, the Faculty of Natural and Agricultural Sciences Ethics Committee hereby **approves** your study as indicated below. This implies that the North-West University Senate Committee for Research Ethics (NWU-SCRE) grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Emerging Technologies in the North West Province
Study Leader/Supervisor: Prof SS Letsoalo
Student: SFD Mohono

Ethics number: N W U - 0 1 4 5 8 - 2 2 - A 9
Institution Study Number Year Status

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application type: Single **Risk Category:** **Minimal**

Commencement date: 29/09/2022
Expiry date: 31/12/2023

Approval of the study is initially provided for a year, after which continuation of the study is dependent on receipt and review of the annual (or as otherwise stipulated) monitoring report and the concomitant issuing of a letter of continuation.

Special in process conditions of the research for approval (if applicable):

- The following documentation are archived by FNASREC and should be complete and kept up to date:
  - Research proposal
  - Signed approval from the scientific committee indicating the proposed risk category
- All researchers involved in the study should submit signed NWU code of conduct statements annually.
- All researchers of low risk studies should submit proof of relevant ethics training every two years.
- All researchers that take part in activities that pose a safety and security threat to the researchers or the environment should submit a risk assessment form annually.
- All research involving human interaction should follow best ethical practise and keep documents as proof. This includes informed consent, questionnaires, incorporation of risk-benefit, and responsible data management.
- Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the FNASREC. Ethics approval is required BEFORE approval can be obtained from these authorities.

Special conditions:
The best practices with regards to interviews should be implemented, including proper negotiation of access to participants; representative sampling; documented informed consent that includes the important elements; alignment of information collected with research questions; anonymization of collected information, ensuring the integrity and security of all data collected. If personal information is collected as part of the study, it will change the risk level of the project.

General conditions:
While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, the following general terms and conditions will apply:

- *The study leader/supervisor (principle investigator)/researcher must report in the prescribed format to the FNASREC:*
  - *annually (or as otherwise requested) on the monitoring of the study, whereby a letter of continuation will be provided, and upon completion of the study; and*
  - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*
- *The approval applies strictly to the proposal as stipulated in the application form. Should any amendments to the proposal be deemed necessary during the course of the study, the study leader/researcher must apply for approval of these amendments at the FNASREC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*
- *Annually a number of studies may be randomly selected for an external audit.*
- *The date of approval indicates the first date that the study may be started.*
- *In the interest of ethical responsibility, the NWU-SCRE and FNASREC reserves the right to:*
  - *request access to any information or data at any time during the course or after completion of the study;*
  - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process;*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the study are revealed or suspected;*
    - *it becomes apparent that any relevant information was withheld from the FNASREC or that information has been false or misrepresented;*
    - *submission of the annual (or otherwise stipulated) monitoring report, the required amendments, or reporting of adverse events or incidents was not done in a timely manner and accurately; and / or*
    - *new institutional rules, national legislation or international conventions deem it.*
- *FNAS-REC can be contacted for further information or any report templates via Roelof.Burger@nwu.ac.za 018 299 4269*

The FNASREC would like to remain at your service as scientist and researcher, and wishes you well with your study. Please do not hesitate to contact the FNASREC or the NWU-SCRE for any further enquiries or requests for assistance.

Yours sincerely,

Prof Roelof Burger
Chairperson Faculty of Natural and Agricultural Sciences Ethics Committee (FNASREC)

APPENDIX 5 LANGUAGE EDDITING

NORTH-WEST UNIVERSITY
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FACULTY OF EDUCATION

Cell: 0729116600

Date: 26th November, 2023

TO WHOM IT MAY CONCERN

CERTIFICATE OF EDITING

I, Muchativugwa Liberty Hove, confirm and certify that I have read and edited the entire dissertation in article format, **EMERGING TECHNOLOGIES AND EFFECTIVE GOVERNANCE FOR AGRICULTURAL SUSTAINABILITY IN THE NORTHWEST PROVINCE**, submitted by **S.F.D. MOHONO**, student number **21486360**

S.F.D. MOHONO was supervised by **Professor SS LETSOALO** and co-supervised by **Dr. CHRISTIAN** and **Mr. LUVHENGO.**

I hold a PhD in English Language and Literature in English and am qualified to edit such a dissertation for grammatical correctness, cohesion and coherence. The views expressed herein, however, remain those of the researcher/s.

Yours sincerely

Professor M.L. Hove (PhD, MA, PGDE, PGCE, BA Honours – English)

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