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TECHNOLOGICAL INNOVATIONS TRANSFORMING FARMING PRACTICES: A CASE STUDY OF MUSARIRI FARM

BY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF EXECUTIVE MASTER IN BUSINESS ADMINISTRATION IN THE COLLEGE OF BUSINESS, PEACE, LEADERSHIP AND GOVERNANCE

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Abstract

The agricultural sector has undergone significant transformations with the advent of technology, revolutionizing traditional farming practices and paving the way for more efficient and sustainable methods. This case study explores Technological Innovations Transforming Farming Practices, with specific reference to Musariri Farm, a prominent agricultural enterprise. By examining the history, challenges, and innovations implemented at Musariri Farm, this study sheds light on the profound impact of technology on agricultural operations and its potential to address key global challenges, such as food security, resource utilization, and environmental sustainability. The study utilizes a mixed-methods approach, combining qualitative interviews, field observations, and data analysis to gain comprehensive insights into the adoption and integration of technology on Musariri Farm. Key findings reveal that Musariri Farm has embraced technology across various stages of the farming process, from land preparation and crop cultivation to harvesting and post-harvest management. Technological advancements in Musariri Farm include the utilization of precision agriculture techniques, such as satellite imagery, geographic information systems (GIS), and drones, for accurate mapping, monitoring, and data-driven decision-making. Additionally, the farm has implemented automated irrigation systems, climate sensors, and weather forecasting tools to optimize water usage and improve crop yields. The integration of robotics and artificial intelligence (AI) in tasks such as planting, weeding, and harvesting has increased operational efficiency and reduced labor costs. Furthermore, Musariri Farm has embraced sustainable farming practices through the adoption of organic farming techniques, advanced pest and disease management systems, and efficient waste management strategies. The incorporation of renewable energy sources, such as solar panels and biogas generators, has reduced dependence on non-renewable resources and minimized the farm's carbon footprint. Despite the numerous benefits, the study also highlights challenges encountered during the technology adoption process, including initial investment costs, limited access to reliable internet connectivity, and the need for continuous training and technical support. However, Musariri Farm's commitment to innovation and its collaboration with technology providers, academic institutions, and government agencies have facilitated the successful integration of technology into its farming operations.

Keywords: Technology, Innovation, Farming sector, Precision agriculture, Biotechnology

Declaration

I declare that this dissertation is my original work except where sources have been cited and acknowledged. The work has never been submitted, nor will it ever be submitted to another university for the award of a degree.

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Dedication

I dedicate this dissertation to myself. I am proud of the woman I am becoming. May this be a constant reminder that I am capable of absolutely anything I put my mind to.

List of Acronyms and Abbreviations

TIS	Technological Innovation System
GPS	Global Positioning System
R&D	Research and Development
IPR	Intellectual Property Rights

Definition of Key Terms

Technology refers to the application of scientific knowledge for practical purposes, especially in industry. It encompasses a wide range of tools, machines, systems, and processes that are designed to solve problems, improve efficiency, and enhance human capabilities. Technology can be classified into various categories, each serving different functions and industries.

Innovation is the process of developing and implementing new ideas, products, services, or processes to create value and drive progress. It involves improving existing solutions or creating entirely new ones to meet emerging needs or solve problems.

Farming sector also known as the agricultural sector, encompasses all activities related to the cultivation of crops and the raising of animals for food, fiber, medicinal plants, and other products used to sustain and enhance human life. It is a fundamental part of the economy, providing the raw materials needed for food production and other industries.

Precision agriculture (PA), also known as precision farming or site-specific crop management, is a modern farming practice that uses advanced technologies to monitor and manage field variability in crops. This approach aims to optimize the efficiency of inputs (like water, fertilizers, and pesticides) and enhance crop yields while minimizing environmental impact.

Biotechnology is a field of science that involves the use of living organisms, cells, and biological systems to develop products and technologies for various applications. It combines principles from biology, chemistry, and engineering to innovate in areas such as healthcare, agriculture, environmental management, and industrial processes.

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CHAPTER 1 INTRODUCTION

1.1 Introduction

Since the advent of modern technology, agriculture has undergone profound changes, which have significantly transformed traditional farming practices. The application of innovative technologies has led to increased efficiency, higher yields, and sustainable agricultural practices (Qaim, 2020). The farming sector has been revolutionized by technology, and the Musariri Farm Technologies provide a compelling case study for the impact of technology in the farming sector (Mhandu & Longe, 2022). This fascinating case study provides valuable insights into Technological Innovations Transforming Farming Practices and highlights the critical role that technology can play in enhancing and improving agricultural practices. The Musariri Farm Technologies bring to the forefront the continuous development of innovative technologies and agricultural practices, which are essential for meeting the ever-increasing food demand in our society. This paper aims to explore and analyze the use of technology in agriculture, highlighting its potential to address critical issues such as climate change, food insecurity, and sustainable agricultural practices. By examining the Musariri Farm Technologies, this paper will provide a comprehensive analysis of the evolution of technology in agriculture, its impact on farming practices, and the benefits it can offer. Ultimately, this study demonstrates that technology plays a vital role in transforming and advancing agriculture, and its continued development is crucial for achieving sustainable and effective farming practices.

1.2 Background to the study

The technological revolution has significantly impacted the agricultural sector worldwide. Agriculture has experienced substantial development through better and advanced techniques, tools, and machinery, which have increased productivity, improved animal welfare, and reduced maintenance costs. In Zimbabwe, agriculture is a vital sector that contributes to both the economy and employment. The farming industry has undergone transformation due to technology advancement, particularly on large-sized commercial farms. This study aims to explore technology evolution in Zimbabwe's farming sector through a case study of Musariri Farm. Musariri Farm is located in Hurungwe district, Mashonaland West Province, Zimbabwe. The farm was established in the 1950s, covering approximately 550 hectares of fertile land (Chikuruwo, Kasukusa and Musariri, 2020). The farm is known for its production of maize, tobacco, and beef cattle.

In the early years of the farm's existence, traditional farming methods such as plowing and hoeing were used. This required extensive human labor, which was both time-consuming and physically demanding. The use of ox-drawn carts was introduced in the early 1960s to reduce workload and increase productivity (Blench, 2015). However, this method was still slow and insufficient. Musariri Farm embraced technological advancement in the early 1970s, which boosted the farming sector's efficiency. The introduction of tractors and combines significantly improved the plowing and harvesting processes. This replaced the use of ox-drawn carts and reduced the time required to complete farming tasks. The tractors could plow land faster and more efficiently than traditional methods, resulting in higher yields and reduced labor costs (Huggins & Reganold, 2008). The farm continued

to advance technologically in the 1980s, where the use of irrigation systems was introduced. This improved production levels all year round, and crops could grow even in dry seasons. The irrigation systems were a significant boost for farming in areas with minimal rainfall, and more crops could be produced, resulting in increased revenue and profit.

In the 1990s, Musariri Farm implemented precision farming techniques (Marambanyika, 2015). These techniques involved the use of satellite maps, GPS systems, and sensors that provided real-time monitoring and data analytics. This enabled the farmers to make informed decisions about the right amount of water, fertilizer, and pesticides to use, resulting in reduced waste, and higher production levels. The use of technology eliminated the need for unplanned and unnecessary use of inputs such as water, fuel, and fertilizer, resulting in cost savings. In recent years, Musariri Farm has embraced digital technologies, such as mobile applications that allow the farmers to access real-time information on weather patterns, crop prices, and market demand (Nyikadzino, 2016). This has enabled the farmers to make informed decisions on when to plant and harvest their crops, what prices to sell them at, and how to optimize revenue. Technology has played an integral role in the evolution of farming at Musariri Farm (Mapiye, 2016). The use of advanced farming techniques, tools, and machinery has significantly improved productivity, reduced costs, and increased revenue. The adoption of digital technologies has made farming more efficient, reduced waste, and enabled farmers to make informed decisions. The adoption of technology will remain a significant boost to the agricultural sector and promote sustainable development in Zimbabwe.

1.3 Statement of the problem

The farming sector has been characterized by constant advancements in technology that have allowed farmers to increase productivity, efficiency and yield. As a result, there has been a significant transformation in the way farmers operate and manage their farms, with technology playing a crucial role in this transformation. Technological innovations in the farming sector has been a subject of interest among researchers, scholars, and practitioners, and has been studied from different angles. In the context of Musariri farm, it is essential to consider the role played by technology in transforming practices in the farming sector. Musariri farm is a commercial farming operation located in Chegutu, Zimbabwe, and it specializes in growing different crops such as maize, wheat, and soybeans. Over the years, the farm has adopted different technology solutions ranging from mechanization, irrigation, and precision agriculture, among others.

The purpose of this study is to examine how the use of technology has transformed practices in the farming sector, using Musariri farm as a case study. Specifically, the study seeks to determine the impact that technology has had on the farming sector over the years, how farmers have adopted different technological solutions to transform their operations and whether technology has contributed to the growth of the sector. The research will adopt a qualitative research design, with semi structured interviews being the primary data collection method. The interviews will involve the farm's management team and farmworkers who have been involved in the adoption of different technological solutions on the farm. Additionally, the study will also utilize secondary data sources such as journals, reports, and articles to support the findings. The expected outcomes of the study

will contribute to the existing literature on the technological innovations in the farming sector. Additionally, the study will provide insights for policymakers, practitioners, and stakeholders on the importance of adopting technology in the farming sector. Moreover, the study's findings will enhance the understanding of how technology can be effectively utilized to improve farming operations, and ultimately, increase production and efficiency in the sector.

1.4 Research objectives

To investigate the technological solutions and innovations adopted by Musariri farm to improve farming operations and their effectiveness.

To assess the impact of technology on the production levels and profitability of Musariri farm.

To identify the challenges associated with the adoption of technology solutions in the farming sector and how they have been addressed by Musariri farm.

1.5 Research questions

1. What are the technological innovations adopted by Musariri farm that led to transformation in their farming practices.

2.What are the benefits that have been realized from the use of technology in terms of increased yields, reduced costs, and other socio-economic impacts?

3. What are the challenges that have been encountered during the adoption and implementation of these technologies?

1.6 Assumptions

H1: Musariri farm has gone through a technological transformation in the farming sector, where various technologies have been adopted over the years to enhance production and efficiency in farming operations.

H2: The farm workers at Musariri farm had to adapt to a new farming culture, where the application of technology in farming operations is essential for maximum productivity.

1.7 Significance of the study

The study of technological innovations in the farming sector is of utmost importance. Agriculture is important to the world economy, and as the global population continues to grow, advances in technology are necessary for the sustainability of food production. Therefore, investigating how technology has transformed the farming sector has significant implications for food security, environmental sustainability, and economic growth. This study on the technological innovations in the farming sector with a case study of Musariri farming will contribute to the existing understanding of the relationship between technology and farming efficiency. By examining the case of Musariri farm, which has undergone a significant technological transformation, this study's findings will provide insights into how technology can improve farming practices and promote sustainable agriculture.

One of the significant contributions of this study is that it will highlight the impact of technological changes on the socio-economic well-being of the community. With the

adoption of technological advancements, there is an improvement in the efficiency of farming operations that can lead to increased productivity and improved livelihoods for farmers and farm laborers. It will provide valuable insights for policymakers, stakeholders, and investors in the agricultural sector to develop policies and strategies for promoting and supporting the integration of technology in farming practices. Another critical contribution of this study is that it will highlight the positive impacts of technological changes on the environment. As farmers adopt more sustainable agricultural practices through the use of technology, there is reduced environmental degradation and increased biodiversity conservation. The findings from this study will contribute to a better understanding of the environmental benefits of technological innovations in the farming sector.

This study's significance is not limited to just the Musariri community. The findings from this study will have broad-ranging implications for the global agricultural sector. With the global population expected to reach 9.7 billion by 2050, agricultural production will need to increase significantly to meet the demand for food. Technology can play a vital role in achieving productivity gains in the agricultural sector, and the experience of Musariri farm can provide valuable lessons for agricultural research and policy worldwide. This study on Technological Innovations Transforming Farming Practices with a case study of Musariri farm will contribute to the existing literature on the relationship between technology and farming efficiency. It emphasizes the importance of technology in promoting sustainable agriculture, improving the socioeconomic well-being of the community, and protecting the environment. Therefore, the findings of this study will be

significant for policymakers, stakeholders, and investors in the agricultural sector who are interested in promoting sustainable agriculture for global food security and economic growth.

1.8 Delimitations of the study

The study on the technological innovations transforming the farming sector is an essential and vast topic that encompasses a broad range of concepts and variables. While this study aims to provide insights into the implementation of technology in the Musariri farm, some limitations and delimitations must be considered to appreciate the full implications of the findings.

Firstly, the study focuses exclusively on the Musariri farm, which is limited in scope and generalizability. As such, the findings of this study cannot be extrapolated to other agricultural communities or regions, and generalizability must be cautiously considered. Additionally, the study is limited to the context of Zimbabwe and does not account for the potential variations that may exist in other parts of the world.

Secondly, the study is dependent on the availability and accessibility of data. There are regulatory and operational challenges to data collection in the agricultural sector, making it difficult for researchers to gather reliable and relevant information. Thus, the unavailability of data limits the study's ability to examine the different aspects of technology implementation in greater detail.

Thirdly, the study is constrained by the sample size and selection of participants. The study only focuses on the managers and staff of Musariri farm, excluding other stakeholders, such as local suppliers and policymakers, who may have unique perspectives and insights. As such, the findings of the study may not reflect the full range of experiences and challenges that may exist in technology implementation within the farming sector.

Additionally, the study's methodology is restricted to a case-study approach, which may be limited in its ability to provide generalizable findings. As such, this study may not provide a comprehensive understanding of technology implementation in the farming sector, given the inherent limitations of the case-study approach.

Lastly, the study faces limitations related to time and resources, as the research had a limited timeframe and a budget, which may have affected the study's reach and depth. However, despite the time and resource constraints, the study aims to provide valuable insights into the implementation of technology in the agricultural sector.

In conclusion, while the study on technological innovations transforming farming practices provides a valuable contribution to the discourse, limitations and delimitations must be considered to interpret the findings accurately. By acknowledging and addressing these constraints, future research can build upon the findings of this study, providing a deeper understanding of the complex relationship between technology and the farming sector.

1.9 Limitation of the study

The study on Technological Innovations Transforming Farming Practices ultimately centers on the examination of the advantages and limitations of technology implementation in improving agricultural practices. However, like any other academic research, this study also faces some limitations that must be considered to appreciate the full implications of the findings. Firstly, the results of the study cannot be generalized to other regions, countries or types of agricultural communities. Since the research was conducted in Musariri farm, there is a need for future research in different parts of the country or around the world to examine the universal application of the study's findings. This limitation stems from the fact that farming is widely dependent on the ecological conditions of the area, the available technological infrastructure, and other contextual elements that vary geographically. Secondly, the study relies on responses from farm managers, which may be subject to biases based on their expertise or knowledge of the subject area. Consequently, interviews with the farm laborers, suppliers, and other shareholders in the farm would have been necessary to achieve a comprehensive understanding of the topic under study.

Furthermore, the study is prone to the limitation of the research design, sample size and method of data collection. To mitigate these drawbacks, future studies will need to focus on surveying a more extensive and representative sample of farmers or agricultural communities. Similarly, the design of the study must be carefully planned to employ both quantitative and qualitative methodologies that will provide a more robust interpretation of the data collected. Lastly, the study does not account for any unforeseen, future

developments in the world of technology or agriculture. It is, therefore, essential to interpret these findings with the caveat that developments in the near future may affect the accuracy of the study results. As such, future research on this topic will need to be continually updated and revised to maintain its relevance and applicability. The limitations of the current study bring to light the need for more research to build on the existing literature and expand the knowledge of the evolving relationship between technology and farming. While this study has provided a valuable contribution to the discourse, there is a considerable room for further investigation to uncover deeper insights on this critical subject.

CHAPTER 2 REVIEW OF RELATED LITERATURE

2.1 Introduction

Technological advancements have greatly influenced various sectors over the years, including the farming sector. These advancements have revolutionized various aspects of farming, such as production, harvesting, and post-harvesting. This review of related literature will focus on Technological Innovations Transforming Farming Practices, with a particular emphasis on a case study of Musariri Farm. The study will examine the different technologies adopted by the farm over the years, the impact of technology on the farm's productivity, and how the adoption of technology has influenced the overall farming landscape in the locality. The review will encompass studies on various technologies, including digital technology, precision agriculture, robotics, and biotechnology, among others. The aim of this review is to provide insights into the benefits of technology adoption in farming and identify trends that can be replicated in other farming communities.

2.2 Theoretical framework

Technological advancements have played a vital role in driving the growth and success of various sectors over the years, including the agriculture sector. The adoption of technology by farmers has revolutionized various aspects of farming, such as production, harvesting, and post harvesting (Neethirajan & Kemp, 2018). This literature review aims to explore the theoretical framework of a study on "the evolution of technology sector: a case study of Musariri farm." The purpose is to investigate the different technologies adopted by the farm over the years, the impact of technology on the farm's productivity, and how the

adoption of technology has influenced the overall farming landscape in the locality. The theoretical framework of this study is based on the Diffusion of Innovation Theory (DOI) and the Technological Innovation System (TIS) approach. The framework is appropriate to study the adoption and diffusion of technological innovations in the agriculture sector.

The Diffusion of Innovation Theory was developed by Everett Rogers in 1962, and it focuses on how new technologies are adopted and diffused by individuals and organizations. The theory recognizes that there are different types of adopters; innovators, early adopters, early majority, late majority, and laggards (Mallison, 2021). The study will seek to find out which adopter category Musariri farm falls under, and how this has influenced the adoption rate of technological innovations. The Technological Innovation System (TIS) approach, on the other hand, was developed by Carlota Perez in 2002. It posits that technological innovations are not developed or adopted in isolation; they are influenced by various systemic factors (Oliveira, 2016) The framework identifies various actors in the innovation system, such as government, private sector, academia, and civil society, and studies how they interact to influence the development and adoption of technological innovations. The framework is relevant to the study as it seeks to investigate the various actors involved in the development and adoption of technological innovations at Musariri farm.

The agricultural sector is experiencing a profound transformation driven by the widespread adoption of digital technologies. As Correani et al. (2020) highlight, these technologies are streamlining various aspects of farm operations, encompassing data collection, analysis, and overall management practices. This essay delves into the case of

Musariri farm, exploring how its integration of digital tools like precision agriculture, GIS mapping, and cloud computing has impacted its productivity, profitability, and overall farm management.

At the core of Musariri farm's digital transformation lies precision agriculture (PA). PA leverages a suite of technologies, including sensors, drones, and GPS-guided machinery, to gather real-time data on various factors influencing crop health, such as soil moisture, nutrient levels, and weather conditions (OECD, 2023). This data empowers farmers to implement highly targeted interventions, such as applying fertilizer and water only where and when necessary. This not only reduces waste but also optimizes resource utilization, potentially leading to increased crop yields. For Musariri farm, PA could signify a significant shift from traditional, broad-spectrum practices to a more data-driven approach, potentially reducing fertilizer and water usage while maintaining or even boosting yields.

Another key digital tool employed by Musariri farm is Geographic Information Systems (GIS) mapping. GIS creates digital representations of the land, enabling farmers to visualize and analyze spatial data. This data can encompass soil types, elevation variations, and historical crop performance across different fields (Cropin, 2023). For Musariri farm, GIS mapping could allow for informed decisions about crop selection, resource allocation, and long-term planning. By understanding the spatial variability of

their land, they can optimize crop placement and potentially increase overall farm efficiency.

Cloud computing is another transformative technology adopted by Musariri farm. Cloud platforms offer secure storage and access to vast amounts of data, allowing farmers to collect, analyze, and manage information from various sources. This includes data collected through PA sensors, historical farm records, and even weather forecasts (Forbes, 2022). Cloud computing empowers Musariri farm to leverage data for informed decision-making, potentially leading to improved resource management, risk mitigation, and overall farm performance.

The impact of these digital technologies on Musariri farm can be multifaceted. Increased productivity is a key potential benefit. By optimizing resource allocation and crop management practices, PA and GIS mapping could lead to higher yields. Additionally, cloud computing can facilitate better planning and forecasting, potentially reducing crop losses and spoilage. Ultimately, these factors could contribute to a significant increase in Musariri farm's overall output.

Profitability is another crucial area where digital technologies can play a transformative role. By minimizing resource waste and potentially increasing yields, PA could lead to cost savings for Musariri farm. Additionally, improved decision-making through data analysis may enable the farm to negotiate better prices for their produce, further enhancing

profitability. Cloud computing can also contribute by streamlining administrative tasks and financial management.

The impact of digital adoption extends beyond just productivity and profitability. Farm management as a whole is likely to undergo significant changes at Musariri farm. The ability to collect and analyze real-time data empowers farmers to make more informed decisions, potentially leading to a more scientific and data-driven approach to agriculture. Additionally, cloud computing can facilitate improved communication and collaboration within the farm workforce, streamlining operations and enhancing overall farm management.

However, it is important to acknowledge the challenges associated with digital transformation in agriculture. Access to technology and the internet can be a hurdle, especially in remote areas. Additionally, the initial investment costs for some technologies might be significant, particularly for smaller farms like Musariri. Furthermore, the success of these technologies relies on farmer training and capacity building to ensure they can effectively utilize the data and tools available.

Precision agriculture (PA) has become a cornerstone of modern farming, offering a path towards increased crop yields, reduced input costs, and minimized environmental impact (McBratney et al., 2005). This essay delves into the case of Musariri farm, exploring its adoption of PA technologies such as GPS-guided tractors, drones, and sensors, and

examines the impact these technologies have had on the farm's productivity, profitability, and overall management practices. One of the key PA technologies employed by Musariri farm is likely to be GPS-guided tractors. These tractors utilize satellite positioning to ensure precise planting, cultivation, and harvesting across the entire field. This not only reduces overlaps and missed areas but also allows for optimized row spacing and efficient utilization of land (Shapiro et al., 2014). For Musariri farm, this could translate to increased planting accuracy, potentially leading to improved crop establishment and ultimately, higher yields.

Drones are another innovative PA tool potentially utilized by Musariri farm. These unmanned aerial vehicles (UAVs) equipped with multispectral cameras can capture detailed aerial imagery of fields. This imagery allows farmers to identify areas with varying levels of crop health, nutrient deficiencies, or water stress (Zhang & Kovacs, 2012). With this information, Musariri farm can implement targeted interventions, such as applying fertilizer or water only to specific areas where needed. This not only reduces waste but also ensures that crops receive the optimal resources for growth, potentially leading to improved crop health and potentially higher yields.

Sensor technology plays a crucial role in PA, and Musariri farm might be utilizing various types of sensors. Soil moisture sensors, for example, can provide real-time data on moisture levels at different depths within the field. This allows for irrigation to be precisely controlled, ensuring that crops receive the water they need without over-

watering, which can be wasteful and environmentally damaging (Yang et al., 2017). Additionally, weather sensors can provide data on temperature, humidity, and rainfall patterns, enabling Musariri farm to make informed decisions about planting schedules, pest control measures, and resource allocation. The impact of these PA technologies on Musariri farm can be multifaceted. Increased productivity is a key potential benefit. By ensuring precise planting, targeted resource application, and optimized field utilization, PA technologies like GPS-guided tractors and drones could lead to higher yields. Additionally, sensor-based irrigation can minimize water waste, potentially reducing input costs.

Profitability is another area where PA can have a significant impact. By optimizing resource utilization and potentially increasing yields, PA can lead to cost savings for Musariri farm. For instance, yield monitors can pinpoint areas of the field underperforming due to inadequate irrigation or nutrient deficiencies. This allows for targeted interventions, eliminating unnecessary fertilizer or water application in other areas. The resulting reduction in wasted inputs translates directly to cost savings for the farm. Studies by Ge et al. (2014) and Tian et al. (2019) support this notion, demonstrating that PA practices can lead to significant reductions in fertilizer use without compromising crop yields. Additionally, improved crop health through targeted interventions like disease and pest control can minimize crop losses and improve overall product quality. This high-quality produce can potentially fetch premium prices in the market, further boosting farm revenue. Research by Basso et al. (2016) investigated the economic benefits of PA in corn

production and found that improved pest management practices led to higher quality crops and increased profitability for farmers.

However, it is important to acknowledge the challenges associated with adopting PA technologies. The initial investment costs for these technologies can be significant, especially for smaller farms like Musariri. Additionally, technical expertise is required to operate and interpret the data generated by these technologies. Furthermore, reliable internet connectivity is crucial for utilizing cloud-based platforms for data management and analysis.

The agricultural sector is witnessing a surge in the adoption of robotics, a technology with the potential to revolutionize various farming processes, including planting, harvesting, and weeding (Duckett et al., 2018). This essay delves into the case of Musariri farm, investigating its potential utilization of robotic technologies like autonomous tractors and harvesters, and examines how these technologies could impact the farm's productivity, profitability, and overall management practices. One transformative technology Musariri farm might be exploring is autonomous tractors. These self-driving machines utilize GPS technology, sensors, and artificial intelligence (AI) to navigate fields precisely, performing tasks like planting, cultivating, and spraying without human input (Thrun et al., 2018). For Musariri farm, autonomous tractors could offer significant benefits in terms of labor efficiency. By automating repetitive tasks, these machines can free up human labor for other critical tasks on the farm, potentially allowing for increased production

capacity. Additionally, the precise navigation capabilities of autonomous tractors can lead to optimized planting patterns and improved resource utilization.

Another potential area of robotic adoption for Musariri farm is autonomous harvesting. These robotic harvesters utilize a combination of computer vision, sensors, and robotic arms to selectively pick fruits or vegetables at optimal ripeness, minimizing damage and waste (Iida et al., 2018). For Musariri farm, autonomous harvesters could address challenges associated with labor shortages during harvest seasons. Additionally, the ability to harvest selectively based on ripeness can ensure that only the highest quality produce reaches the market, potentially fetching premium prices and enhancing profitability.

The impact of these robotic technologies on Musariri farm can be multifaceted. Increased productivity is a key potential benefit. By automating labor-intensive tasks such as planting, weeding, and harvesting, autonomous tractors and harvesters could free up human labor for other critical tasks on the farm, like crop monitoring and maintenance (Slaughter et al., Carmont & Wheeler, 2016). Additionally, these robots can potentially extend working hours beyond daylight limitations, allowing Musariri farm to cultivate larger areas and potentially increase overall yield (Slaughter et al., 2018). A study by Slaughter et al. (2018) exploring the impact of automation in agriculture found that autonomous tractors could increase operational hours by up to 20%, leading to significant yield gains.

Profitability can also be significantly impacted by robotics. Reduced labor costs associated with automation can free up financial resources for Musariri farm to invest in other areas of improvement, such as hiring more specialized personnel or acquiring new technologies (Gebhardt & Brunsch, 2017). Furthermore, the potential for higher quality produce through selective harvesting by robots can minimize damage and lead to higher market prices (Pearson & Blackmore, 2018). For instance, robotic harvesting systems equipped with image recognition can sort fruits and vegetables based on size, color, and ripeness, ensuring only the highest quality produce reaches consumers (Pearson & Blackmore, 2018). Additionally, these technologies can generate valuable data on factors like crop health, yield, and soil conditions through built-in sensors (Carmont & Wheeler, 2016). This data can be analyzed using cloud-based platforms and machine learning algorithms to further optimize farm operations and resource allocation, such as fertilizer application and irrigation scheduling (Li et al., 2019).

The adoption of robotics extends beyond just productivity and profitability. Farm management at Musariri farm is likely to undergo significant changes. The integration of these technologies necessitates a shift towards a more technology-driven approach to farming (Gebhardt & Brunsch, 2017). Data generated by robots can be used to create digital maps of fields, allowing for more precise planning and resource allocation (Carmont & Wheeler, 2016). These digital maps, coupled with data on crop growth patterns tracked by the robots, can pinpoint areas requiring attention, such as zones with lower yield or potential pest outbreaks (Carmont & Wheeler, 2016; Li et al., 2019). This

empowers farmers at Musariri farm to make data-driven decisions, potentially leading to more efficient, precise, and responsive management practices (Gebhardt & Brunsch, 2017). For example, real-time data on soil moisture levels collected by robots can trigger targeted irrigation, eliminating unnecessary water use in other areas.

However, it is important to acknowledge the challenges associated with adopting robotic technologies in agriculture. The initial investment costs for these machines can be substantial, posing a significant hurdle for smaller farms like Musariri. Additionally, technical expertise is required to operate and maintain these complex machines. Furthermore, concerns regarding potential job displacement in the agricultural sector need to be addressed as automation increases. Therefore, Musariri farm's exploration of robotic technologies like autonomous tractors and harvesters has the potential to revolutionize its operations. Increased productivity, improved profitability, and data-driven management are some of the potential benefits.

The agricultural sector is undergoing a significant transformation driven by the emergence of biotechnology. This powerful set of tools, as Singh and Trivedi (2017) point out, holds immense potential to revolutionize farming by enhancing crop yields, disease resistance, and even nutrient quality. To understand this ongoing transformation, a closer look is needed at how farms are adopting these innovations and the impact they have on farm operations. This essay will delve into the role of biotechnology in agriculture, exploring its adoption through the lens of the Diffusion of Innovation Theory and the Technological

Innovation System approach, while investigating its impact on farm productivity, profitability, and overall management.

The Diffusion of Innovation Theory, proposed by Everett Rogers (2003), provides a valuable framework for understanding the spread of new ideas and technologies. This theory suggests that the adoption of innovation follows a predictable pattern, with farmers progressing through stages of awareness, interest, evaluation, trial, and finally, adoption. The Technological Innovation System approach, as elaborated by Caffaro et al. (2020), complements this view by emphasizing the role of interacting actors, institutions, and policies in shaping the development and diffusion of agricultural technologies. By combining these frameworks, we can gain a comprehensive understanding of how biotechnology innovations are being adopted within the farming sector.

One of the most prominent applications of biotechnology in agriculture is the development of genetically modified (GM) crops. These crops have been engineered to possess specific traits, such as resistance to pests or herbicides. The adoption of GM crops has been a subject of much debate, with concerns surrounding potential environmental and health risks. However, research suggests that GM crops can significantly increase yields and reduce reliance on pesticides (Brookes and Barfoot, 2012). This translates into higher farm productivity and profitability, potentially leading to a more sustainable agricultural system.

Beyond GM crops, a range of other biotechnological innovations are finding their way onto farms. Precision agriculture, for instance, utilizes digital technologies and data analysis to optimize resource use and improve decision-making. This can involve techniques like satellite imagery and soil sensors to monitor crop health and tailor inputs like fertilizer and water application. The adoption of such technologies can lead to significant cost savings and environmental benefits while enhancing farm efficiency. The use of robotics in agriculture is another emerging trend with the potential to revolutionize farm operations. Robotic systems can automate tasks such as planting, harvesting, and weeding, freeing up labor for other activities and potentially addressing labor shortages in the agricultural sector. While the initial investment costs can be high, the long-term benefits of increased efficiency and reduced reliance on manual labor could be substantial.

The integration of these diverse technologies presents a complex picture for farm management. Farmers must navigate a rapidly evolving landscape, weighing the potential benefits of new technologies against their costs and potential risks. The success of technology adoption hinges on a supportive infrastructure, including access to training, extension services, and research tailored to the specific needs of local farming communities.

2.3 Relevance of the theoretical frame to the study

The Diffusion of Innovation Theory is a well-known and widely used theory that explains the spread of new technology, ideas, or products in a society (Dearing, 2009). The theory

proposes that each innovation goes through several stages of adoption, starting with innovators, early adopters, early majority, late majority, and laggards. The rate of adoption is dependent on factors such as the perceived advantage of the innovation, its compatibility with existing technology, its complexity, and its observability, among others (Mannam et al, 2017). In the context of technology sectors, the diffusion of innovation theory is highly relevant as it provides a framework for understanding how new technologies are developed, adopted, and diffused within an industry. In the case study of Musariri farm, the adoption of new technologies has played a significant role in shaping the evolution of the technology sector. Musariri farm is a farm in Zimbabwe that has embraced modern technology and made significant changes to its operations over the past decade. The farm has invested heavily in new technologies such as precision agriculture, irrigation systems, and drones. These innovations have resulted in increased productivity, reduced production costs, and improved farm output.

The adoption of these new technologies can be explained using the principles of the diffusion of innovation theory. The innovators in this case are the individuals or companies responsible for developing the new technologies, such as precision agriculture software and the latest drone technology. These innovators are typically small, specialized firms or individuals who are on the cutting edge of technological development. Early adopters are usually the larger, more established firms that are quick to embrace new technologies as they seek to maintain their competitive edge in the market (Fitzgerald et al, 2014) In the case study of Musariri farm, the early adopters of new technologies are the farm managers who recognize the potential benefits of precision agriculture, irrigation systems, and drones in improving farm productivity and reducing costs.

Everett Rogers' seminal work, Diffusion of Innovations, proposes a compelling framework for understanding how ideas and technologies spread within a social system. This framework identifies five categories of adopters based on their willingness to embrace new inventions: innovators, early adopters, early majority, late majority, and laggards. Among these groups, the early and late majority play a critical role in propelling an innovation towards mainstream adoption.

The early majority, often referred to as the "pragmatists" or "farmers" due to their cautious approach, constitute the largest segment, typically estimated at around 34% of the population (Mannam et al, 2017). Unlike the earlier adopter groups, the early majority prioritizes practicality and proven benefits before embracing a new technology. They are not necessarily risk-averse, but they exhibit a healthy skepticism, waiting to see if the innovation delivers on its promises in real-world applications. This wait-and-see approach allows them to learn from the experiences of the earlier adopters, who iron out the initial kinks and pave the way for smoother adoption. The early majority relies heavily on social proof – positive reviews, testimonials, and widespread use – to mitigate their concerns and build confidence in the innovation's value (Rogers, 2003).

For instance, the early majority might have been hesitant to adopt social media platforms like Facebook or Twitter in their initial phases. However, as these platforms gained traction among early adopters and garnered positive word-of-mouth, the early majority

witnessed their utility for communication and connection. This social proof, coupled with the platforms' increasing functionality and user base, eventually convinced the early majority to join the bandwagon.

The late majority, another significant segment representing roughly 34% of the population (Investopedia: Late Majority: https://www.investopedia.com/terms/l/late-majority.asp), exhibit an even greater degree of skepticism. They are more hesitant to deviate from established practices and require a stronger push to adopt new ideas. This push can come from various factors, including social pressures from the early majority who have already adopted the innovation, economic necessity as older technologies become obsolete, or even legal mandates. For example, the late majority might have been resistant to switching from flip phones to smartphones initially. However, as the functionality and social integration of smartphones became undeniable, and flip phones became increasingly limited, the late majority eventually made the switch.

While the early majority and late majority share some similarities in their cautious approach to innovation adoption, a key difference lies in their responsiveness to social proof (Rogers, 2003). The early majority actively seeks evidence of the innovation's utility, whereas the late majority are more passive adopters, influenced by the broader social environment and the dominance of the innovation within the market (Van den Bulte & Lilien, 2001). Understanding these segments is crucial for businesses launching new products or services. By tailoring their marketing and product development strategies to

resonate with each adopter category, businesses can effectively navigate the diffusion process.

For the early majority, companies can focus on highlighting the innovation's practical benefits that address their core needs. This can be achieved through clear demonstrations that showcase how the innovation solves real-world problems (Moore, 1991). Leveraging testimonials from satisfied early adopters, who have already ironed out the initial kinks, can further build trust and social proof for the early majority (Rogers, 2003). Businesses should also address potential concerns proactively through clear communication and readily available customer support.

Reaching the late majority might require a stronger emphasis on social proof beyond testimonials. Highlighting the widespread adoption of the innovation and its integration into the broader social environment can be effective (Rogers, 2003). Showcasing how the innovation complements existing systems and technologies can ease the transition for the late majority, who may be apprehensive about disrupting their established routines (Moore, 1991). Affordability is also a key consideration for the late majority, so ensuring the innovation offers a compelling value proposition at a competitive price point is crucial.

The relevance of the diffusion of innovation theory is clear in the case of Musariri farm, where the farm managers were quick to adopt new technologies to improve farm productivity and reduce costs (Musariri and Moyer, 2022). The adoption of precision

agriculture and drones, for example, has enabled the farm to save on labor and fuel costs and reduce the use of fertilizer, while increasing crop yield and overall farm output. The diffusion of innovation theory is highly relevant to the study of the evolution of the technology sector, as it provides a framework for understanding how new technologies are developed, adopted, and diffused within an industry (Tola and Contini, 2015). The case study of Musariri farm provides a clear illustration of the principles of the diffusion of innovation theory, as the farm managers were quick to adopt new technologies such as precision agriculture, irrigation systems, and drones, resulting in significant improvements in farm productivity and output.

Technological innovation theory is a vital component in the study of the evolution of the technology sector. It emphasizes the creation of new technology by firms, institutions, and individuals, which is the main driver of economic growth and development (Klofsten et al, 2019). This evolution is often driven by the research and development (R&D) investment, which results in the innovation of new products, services, or processes that transform markets, industries, and societies. The relevance of technological innovation theory to the case study of Musariri farm is evident in how the farm has embraced new technologies to improve productivity and output (Musariri and Moyer, 2020). The farm has invested heavily in precision agriculture, irrigation systems, and drones, among other technologies, which allow for more precise crop management and increased farm productivity. The theory proposes that innovation is central to the economic development of a country or industry. The adoption and diffusion of new technologies by firms in an industry create competitive advantage, resulting in the growth and expansion of the

industry. The case of Musariri farm illustrates this aspect of technological innovation theory as technology adoption resulted in increased productivity and profitability.

Furthermore, technological innovation theory posits that technology development and its diffusion depend on several factors, such as regulatory policies and incentives, government support and investment in R&D, and established institutions and networks facilitating the technology transfer from developed economies to emerging economies. In the case of Musariri farm, the adoption of new technologies was facilitated by the Zimbabwean government's investment in R&D and its efforts to attract investment in the agricultural sector (Musariri and Odimegwu, 2016). Additionally, the tech start-up ecosystem in Zimbabwe plays a significant role in facilitating the adoption of new technologies. For example, the presence of local tech startups, such as Precision Agriculture for Development, providing precision agriculture services and resources to farmers, has enabled the farm to adopt this new technology easily.

Another crucial element of technological innovation theory is the role of intellectual property rights (IPR) in fostering innovation (Wagner, 2003). The protection of IPR and innovations' commercialization incentivizes firms to engage in R&D, leading to innovation and technological advancement. Intellectual property rights are essential in ensuring that innovators, such as the developers of the precision agriculture software in the case of Musariri farm, are compensated for their efforts. Technological innovation theory is relevant to the study of the evolution of the technology sector, as it provides a framework for understanding the factors contributing to innovation, the role of government, institutions, and networks in adoption, and the importance of IPR for

commercialization (Rycroft, 2006). The case study of Musariri farm illustrates the importance of technological innovation theory in understanding the adoption of new technologies, resulting in increased productivity, profitability and a positive impact on the national economy.

2.4 Summary

The technological innovation theory and diffusion of innovation theory are both relevant to the study of the evolution of technology, particularly in the case of Musariri farm. Technological innovation theory emphasizes the creation of new technology by firms, institutions, and individuals, which drives economic growth and development. On the other hand, diffusion of innovation theory focuses on the process by which technological innovations are adopted and spread across a market or society.

In the case of Musariri farm, the adoption of new technologies such as precision agriculture, irrigation systems, and drones, among others, illustrate the relevance of both theories on the evolution of technology in agriculture. Technological innovation theory emphasizes the importance of investing in research and development (R&D) to create new products, processes, and services that transform markets, industries, and societies. The farm's investment in precision agriculture and drone technology resulted in increased productivity and output, illustrating the impact of technology on economic growth. The diffusion of innovation theory is also significant in understanding the adoption of new technologies by firms. In the case of Musariri farm, the diffusion of precision agriculture technology was facilitated by local tech start-ups such as Precision Agriculture for

Development. These start-ups provided the necessary resources and training to enable the farm to adopt the technology quickly.

The theories also highlight the importance of institutional frameworks and the role of the government in fostering innovation and technology adoption. The Zimbabwean government's investment in R&D and its efforts to attract investment in the agricultural sector played a vital role in facilitating the adoption of new agricultural technologies by farmers such as Musariri. Moreover, both theories emphasize the role of intellectual property rights (IPR) in incentivizing innovation and its commercialization. The protection of IPR ensures that innovators and developers are compensated for their efforts and encourages further investments in R&D. In the case of Musariri farm, the developers of the precision agriculture software were compensated for their work, enabling them to continue developing new products and services.

CHAPTER 3 METHODOLOGY

3.1 Introduction

This chapter concentrates on giving vital information on the techniques and methodology used on this research. Cooper et al (2003) state that this part incorporates different aspects which include; data gathering instruments, research design, sampling procedures and ethical considerations. This chapter also includes materials and data collection, the sample, data analysis and ethical considerations.

3.2 The research design

In terms of research design, cross-sectional research design was used since the researcher was seeking to determine the various transformations in farming practices brought about by technological innovations. A cross-sectional study involves looking at data from a population at one specific point in time. The participants in this type of study are selected based on particular variables of interest. Cross-sectional studies are often used in developmental psychology, but this method is also used in many other areas, including science and agriculture. Cross-sectional studies are observational in nature and are known as descriptive research, not causal or relational, meaning that you can't use them to determine the cause of something, such as a disease. Researchers record the information that is present in a population, but they do not manipulate variables. This type of research can be used to describe characteristics that exist in a community, but not to determine cause-and-effect relationships between different variables. This method is often used to make inferences about possible relationships or to gather preliminary data to support further research and experimentation.

Mucus (2006) defined research population as the total members of people who are relevant to your research. Research population is precisely the number of people who are relevant for the study. According to Appiah (2016), a target population is defined as the people the researcher want to collect information from. Brinker (2006) says that, it is a population from where the sample for research is selected. According to Onwuegbuzie and Collins (2007), in any research study, researchers must describe and justify the population, the sample and its size, as well as the methods and processes for selecting the sample. In addition, researchers must identify the target population and the accessible population in order to provide clarity on the actual participants or subjects in the study (McMillan & Schumacher, 2010).

The researcher used non-probability and probability sampling to select participants who provided information relevant to the study. The study used the purposive sampling method, which benefited the researcher by assisting in the collection of information for the purpose of providing answers to the research objectives and hypothesis. Whittaker (2012), purposive sampling (also known as judgmental sampling) is a method in which the researcher selects participants who, in their opinion, are likely to provide meaningful information. Purposive sampling focuses on a certain characteristic of a population that is of interest to the researcher, allowing the researcher to obtain answers to the study questions. Purposive sampling technique is going to be used because it allows the researcher to choose respondents depending on their availability to take part in the study.

Furthermore, because purposive sampling is one of the most cost-effective and time-efficient sample procedures accessible, it is going to be adopted in this investigation. The probability sampling technique is also going to be utilized to identify participants for the study. The probability sampling technique encompasses all selections in which observations are to be drawn at random from the population. As a result, a probability sample is one in which every member of a population has a known non-zero probability of being selected. As a result, a simple random sampling technique is going to be used because every unit included in the sample had a predetermined chance of inclusion in the study (Singh and Masuku, 2014).

People of all ages, including youngsters and the elderly that work at Musariri farm were interviewed to see the impact that technological advancements within the farming sector has had on their work on the farm. The study has been done to bring to light to those in the farming sector all the impacts of technology whether positive or negative.

3.3 Population and sampling

A sample is a portion of the population that has been chosen for analysis in order to derive population characteristics. Willemse (2009) claims that samples are utilized because getting the complete population to participate is impractical. The study used a sample of 77. The study utilized the Krejcie and Morgan (1970) formula to determine the sample size. The formula that was used to determine the sample size is illustrated as follows.

$S= (X2\ NP\ (1-P))/ (d2\ (N-1) +X^2\ P(1-P))$

Where: S = required sample size

N = Population size P = Population proportion d = degree of accuracy (0.05)

X2 = degree of freedom (3.841)

S= X2xNP x1-P

(d2x N-1) +x2X P(1-P)

= (3.841 X 3.841) X 900 X 300/900 X (1-300/900)

(0,05 X 0,05 X 900-1) +3.841 X 3.841 X 300/900 (1-300/900)

=2304,27

5,834427

=385

However, the number of samples was still large hence the researcher went on to use Lucy (2006)'s model which states that, 20% of the target population can be sampled when the population is greater than 200, and 40% of the target population can be sampled when the population is less than 200. However, in this study, the researcher used Lucy's (2006) 20 % method. As a result, the sample size will be 77 respondents.

Table 1: sample of the study

Population selected	Number of participants
Young farm workers	42
Elderly farm workers	35

Total 77

3.4 Data collection instruments

According to Creswell and Creswell (2017), two kinds of data can be gathered is primary data that refers to data that are collected for a particular study and secondary data that refers to data that has already been collected for some other purpose which that ready passed through some analysis processes. The common instruments that are used are the questionnaires, surveys, focus groups, interviews, and observations.

A data collection tool is a device which is used to access data from the selected participants of the study to freely contribute to the success of the study (Saunders et al. 2016:234). A self-administered adapted structured questionnaire and interview guide were used as one of the primary data collection instruments for this research study. A structured questionnaire is defined as the administration of a questionnaire with guided responses (Creswell, 2016).

The questionnaire upon completion of design was sent to a statistician to determine if it is statistically correct and analyzable. The statistician was then able to provide recommendations for the format which was adopted by the researcher. However, the questionnaire is structured in a Likert scale with up to 5 responses coded from strongly disagree, disagree, not sure, agree to strongly agree. The questionnaires were administered by the researcher wherein the respondents were given a period of two weeks to fill in on their own and during their free time.

The participants were protected by the ethical issues discussed in the last section of this chapter. The participants had the right to participate or not in the study or withdraw at any given time. However, the researcher expected a higher response rate since the issues that were being discussed are central to the participant's core duties and needs. This proved to be the case in this study.

A series of in-depth interview guides were constructed and were administered by the researcher personally. Face-to-face interviews had the distinct advantage of enabling the researcher to establish rapport with potential participants and an opportunity for the researcher to clarify ambiguous answers and when appropriate, seek follow-up information. The participants were interviewed during the times more convenient for them which are open and unstructured.

Saunders et al. (2016:305) define a research instrument as any tool that is utilized to collect data from the participants. The researcher used questionnaires and interviews to get data from participants of this study, located on the appendix section.

A questionnaire can be defined as a document containing questions and other types of items designed to solicit information appropriate to analysis (Boparai, Singh, & Kathuria 2018). Additionally, questionnaires can either be open ended or close-ended. An open-ended question permits that the response for an individual while close-ended referred to as fixed alternatives, provides a set to which the respondent must choose the answer from

the provided alternatives (Afolayan & Oniyinde 2019:51). The researcher was able to use a questionnaire with both open-ended questions and closed ended enhance the richness of the data collected. Moreover, questions from the questionnaire were designed in such a way that they meet the demands of this research, which aimed to look at Technological Innovations Transforming Farming Practices at Musariri Farm.

According to Seliger and Shohamy (1989, cited in Nohumba 2016:92), closed-ended questionnaires are more efficient due to their ease of analysis. Gillham (2000:5 cited in Nohumba, 2016:92), on the other hand, contends that 'open questions can lead to a greater level of discovery'. Gillham too admits that analysing open-ended questionnaires is difficult. In this regard, Alderson and Scott (1996: 53) acknowledge the utility of qualitative data but states that '...their open-ended nature made comparing reports of discussions and interviews more difficult...' The statements that follow highlight some of the benefits of questionnaires:

They are one of the efficient means of collecting data on a large-scale basis (Seliger & Shohamy 1989 cited in Nohumba 2016:92).

- The inquirer can easily gather data in field sites (Lynch 1996 cited in Nohumba 2016:92). This was also achieved as there was a high response rate from the questionnaire which was able to generate more data.

- Respondents" anonymity makes them share information more easily (Nunan 1999 cited in Nohumba 2016:92). The respondents were not asked to provide their names and self-identifying information to ensure their anonymity.

- When similar questions are administered simultaneously to many people the acquired data are more identical, correct, and standard (Gillham 2000 cited in Nohumba 2016:92). The same questions were asked to many participants which enable them to understand the issues from a wide range of sources.

- They are a time-efficient way of collecting data from many people (Brown 2001 cited in Nohumba 2016:92). The researcher was able to access several people in a short space of time and with the assistance of purposive sampling, the benefits of time-saving were also enhanced.

On the one hand, closed-ended questionnaires are simple to analyze and cost-effective. Questionnaires, on the other hand, have some drawbacks that should be considered whenever and wherever they are used (Gillham 2000; Brown 2001 cited in Nohumba 2016:92). When sent by post or email, the answers are sometimes inaccurate and questionable, and there is usually a low return rate, while ambiguity and unclearness of some questions may lead to inaccurate and unrelated responses. Furthermore, some questions may cause misunderstanding, with the wording of the questions potentially influencing the respondents' responses. The use of different language assisted in resolving this and there was a high response rate as the study was explained well to the participants.

According to Saunders et al., (2016), in-depth interviewing is a qualitative research technique that involves conducting intensive individual interviews with a small number of respondents to explore their perspectives on a particular idea, program, or situation. An interview is a one-on-one conversation between two people, one asking the questions (the

interviewer) and the other responding to the questions (the interviewee) (De Jonckheere & Vaughn 2019). Part of the data collected in this study was using the instrument. The researcher designed an interview guide with two sections. Section A focused on the general demographic information; Section B of the interview guide is closely linked to all the research questions under the study. According to Rahman & Gong (2016), the method is also utilized when researchers want to study how subjects' behavior mirrors their words in each natural setting.

The process was able to generate large and rich amounts of data since data were collected on one-on-one basis. The notes of the interviews were handwritten, or video and audio recorded to get all the information from interviewees. The researcher was also able to make use of a rough guide which was to be used to transcribe the recordings of an interview. The researcher also maintained a separate folder to keep the recordings collected from the interviews. The effect this had was helping in compartmentalizing the data collected and quick access and revisiting for clarity purposes. For running notes which are also known as field notes, the researcher-maintained comments, environmental contexts, and nonverbal indications that were observed from different questions. These field notes were helpful when the data that was recorded was being transcribed.

3.5 Pilot testing

In preparation for a bigger study, a pilot study is defined as a "small study to test research methods, data collection tools, sample recruitment strategies, and other research

methodologies." A pilot study is an important stage in a research effort because it allows researcher to detect potential issue areas and flaws in the research equipment and methodology before they are used in the full study. As a result, this study will rely on questionnaires to be distributed to part (3-5 people) of the 77 (seventy-seven) respondents chosen for participation in this study.

3.6 Data collection procedure

The researcher first introduced themselves to the interviewee and introduced the topic to them. There also gave out the consent form to the interviewee to read if there consented and if they still gave their permission to be part of the study. The researcher gave the interviewees chance to introduce themselves and ask any other issues relating to the study. Checking whether the participants understood the question well was done and probing response were to get a clearer picture. The interviews in the municipalities were done in their offices or boardrooms. Closing and lighter questions were asked as well as reviewing the responses with the participants to check whether the correct responses were captured which improves the credibility of the findings of this study.

3.6.3 Triangulation

Denzin (1978: 291 cited in Nohumba 2016:94) defines triangulation broadly as "the combination of methodologies in the study of the same phenomenon." The triangulation metaphor derives from navigation and military strategy, which employ multiple reference points to determine an object's precise location (Smith 1975: 273 cited in Nohumba

2016:94). Given the fundamental principles of geometry, multiple viewpoints enable greater accuracy. Similarly, organizational researchers can improve the accuracy of their judgments by gathering various types of data related to the same phenomenon. The use of triangulation in the social sciences can be traced back to Campbell and Fiske (1959, cited in Nohumba 2016), who developed the concept of "multiple operations." They contended that multiple methods should be used in the validation process to ensure that the variance reflected the trait rather than the method. As a result, convergence, or agreement between two methods "...increases our confidence that the results are valid and not a methodological artefact" (Bouchard 1976: 268 cited in Nohumba 2016:94). One fundamental assumption is buried in all triangulation designs. The effectiveness of triangulation assumes that the shortcomings of one method were compensated for by the counter-balancing strengths of another. That is, it is assumed that multiple, independent measures do not share the same flaws or bias potential (Rohner 1994:134 cited in Nohumba 2016:94). Although each method has assets and liabilities, triangulation seeks to exploit the assets while neutralizing, rather than compounding, the liabilities.

There are different types of triangulation methods, according to Creswell (2014:15 cited in Harbers and Ingram 2020) namely:

a) Convergent parallel mixed method- this is when data is collected using different qualitative and quantitative methods then data is integrated in the on interpretation of the overall results and the method addresses contradicting and incongruent findings.

b) Explanatory sequential- a researcher collects data using a quantitative method and then builds on the data by describing and interpreting it using a qualitative method

c) Exploratory sequential- begin with qualitative then build on the data using quantitative methods.

Other triangulation methods include transformative, embedded, and multiphase triangulation. Creswell (2014:215 cited in Harbers and Ingram 2020) defines a transformative mixed method as a pragmatic approach to research that liberally draws methods from both quantitative and qualitative databases. It uses a social lens drawn from social justice or power as an overarching perspective within a design to converge data or use it sequentially building on the other database. The study is cross-sectional because the study derives data from two groups of people with distinct differential in one variable of interest. The same questions were asked to these different groups to determine their views on Technological Innovations Transforming Farming Practices at Musariri. This triangulation process had the effect of enhancing the reliability and validity of the collected data of this study.

3.7 Reliability and validity

Weiner (2017) confirms that validity refers to the degree to which any measurement approach or instrument succeeds in describing or quantifying what it is designed to measure. Validity is the extent to which any measuring instrument measures what it is intended to measure (Thatcher, 2013). The research used the following types of validity in the questionnaire.

Face validity

This is concerned with whether at face value, the questions appear to be measuring the construct.

Content validity

Content validity regards the representativeness or sampling adequacy of the content of a measuring instrument. The researcher ensured that each research question was represented in the questionnaire.

Criterion validity

Criterion validity is used to demonstrate the accuracy of, a measure or procedure by comparing it with another measure or procedure which has been demonstrated to be valid. To this regard, the researcher used the questionnaire in a variety of situations in order to see how predictive it will be.

Concurrent validity

Concurrent validity is a measure of how well a particular test correlates with a previously validated measure. Concurrent validity is concerned with whether the results of a new questionnaire are consistent with results of established measures.

Reliability

Reliability of measurement refers to its consistency, that is, the extent to which a measuring device will produce the same results when applied more than once to the same sample under similar conditions (Creswell & Creswell, 2017). The research used the following types of reliability according to Singh and Masuku (2014).

Parallel forms of reliability

Parallel forms of reliability are used to assess the consistency of the results of two tests constructed in the same way from the same content domain.

Test-retest reliability

Test-retest reliability is used to assess the consistency of a measure from one time to another. In order to measure the test-retest reliability, the same test is given to the same test respondents on two separate occasions.

Inter-rater reliability

Inter-rater reliability is the extent to which two or more individuals (coders or raters) agree. Inter-rater reliability addresses the consistency of the implementation of a rating system.

3.8 Ethical consideration

Because they are so important, ethical considerations were taken into account in this study. The following ethics were observed by the researcher:

Informed consent

Prior to recruiting a subject for this study, the researcher ensured that. He requests a signed, written informed consent form. Each participant in the research is required to sign a consent form as evidence that they have accepted to engage in the study and will only provide accurate information. In order to prevent legal repercussions, informed consent

must be obtained, claims (Creswell, 2019). This is crucial since compelling someone to take part in a study without getting their consent violates research ethics and could have unfavorable legal repercussions for the investigator.

Confidentiality and anonymity

This study adhered to confidentiality and anonymity standards by not requesting participant names or any other information that may be used to identify them. The researcher did not collect participant names or national identity numbers along with the demographic data. This is done because someone's reputation could be damaged if it is revealed. Additionally, the researcher did give his respondents the assurance that the information they submitted would be kept private. Confidentiality and anonymity are essential research ethics, according to Baruch, (2017), because breaking them could have unfavorable effects on the researcher.

Avoiding harm or damage to participants

The researcher did take care to ensure that he does not inquire about personal details or anything that would cause unfavorable emotions. Additionally, the researcher did ensure that the material he gathered would not compromise the respondents' integrity or sense of worth.

3.9 Summary

The chapter deals with how the research was carried out. The research design guiding the research and how it will influence the data collection was discussed. Population and sampling methods were identified and defined. Data instruments and ethical considerations were also highlighted.

CHAPTER 4 DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Introduction

This chapter provides a full description of the study as well as an analysis of the data in accordance with the specific aims of evaluating Technological Innovations Transforming Farming Practices, with a focus on Musariri farm. The primary emphasis is on the data presentation, analysis, and interpretation of the research findings. In order to meet the research objectives, the researcher, acquired data through closed ended questionnaires and semi-structured interviews. These findings were then presented and analysed using SPSS. Descriptive statistics were used to analyse the data. Data obtained from the interviews was analysed using thematic analysis.

4.2 Data presentation and analysis

The pick and drop method were used to distribute the closed-ended questionnaires at Musariri Farm. Participants were given 77 questionnaires, 50 of which were completed.

Table 4.1 Questionnaire Distribution

	Distributed	Returned	Completed	Response Rate
Questionnaire	**77**	**50**	**50**	**65%**

The study's response rate was 65% percent, according to table 4.1 above. This is an appropriate response rate for data analysis. As a result, our findings are consistent with those of Saunders (2007), who established a response rate ranging from 50 to 95 percent**.**

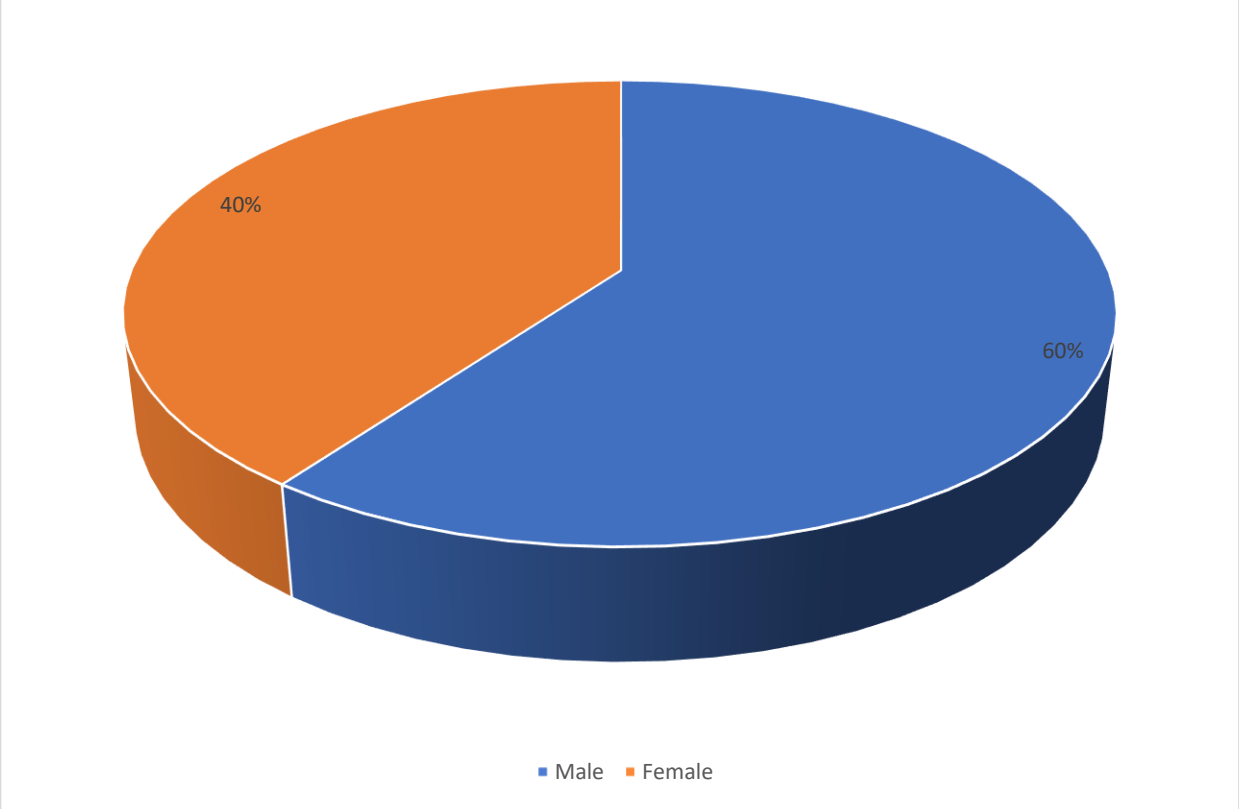
4.3 Demographic Information

This section is based on the gender of respondents, their age distribution and academic qualification. It also presents the area of responsibility for the respondents. The tables below show the gender distribution of the respondents, age distribution, academic qualifications, and respondents' area of responsibility.

4.3.1 Gender

For the purpose of this study, the researcher considered both males and female participants. The gender composition of the respondents was as follows:

Figure 4.1 Gender of respondents



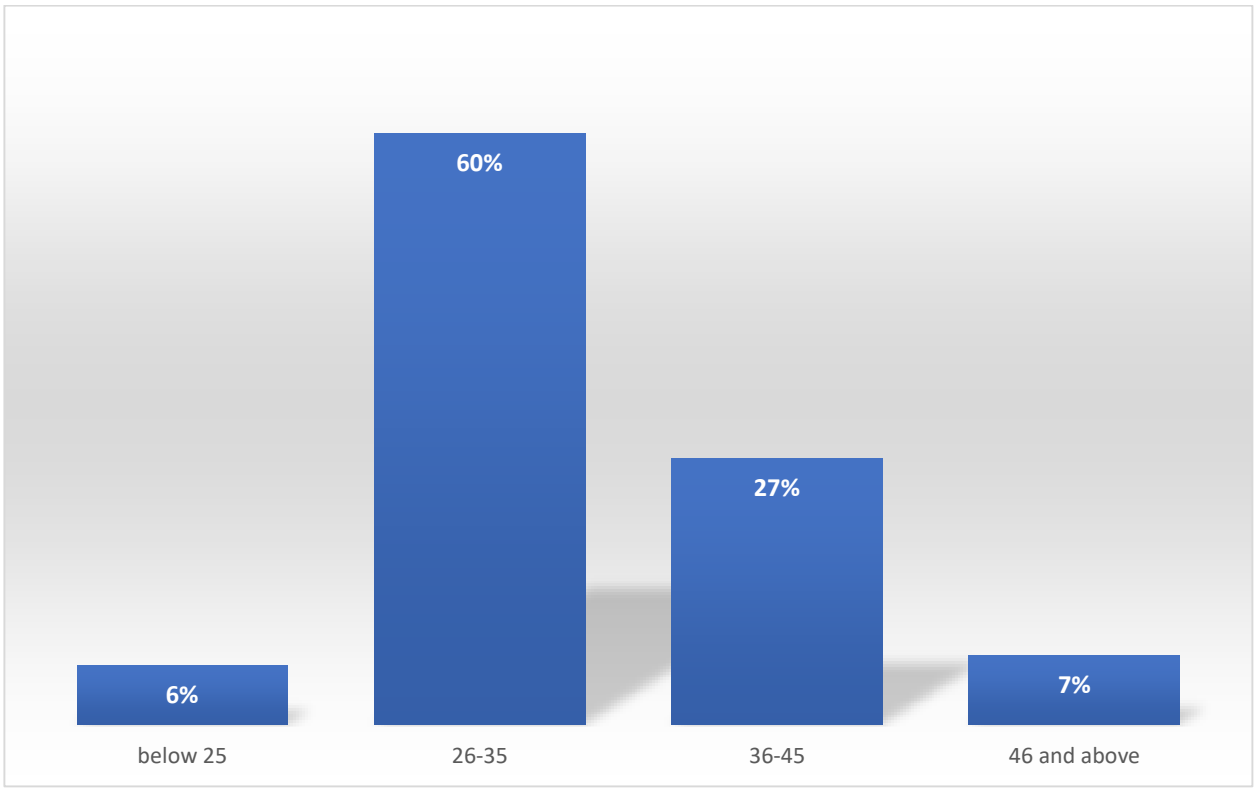
The examination of respondent gender revealed that a majority (60%) were male, while the remaining portion (40%) were female. These results indicate a male-dominated presence in the farming sector, highlighting a potential area for empowering more women.

4.3.2 Age of the participants

Table 4.2 shows the age distribution of the people who took part in the study from Musariri Farm

Distribution of the respondents by their age

Figure 4.1 Distribution of the respondents by their age



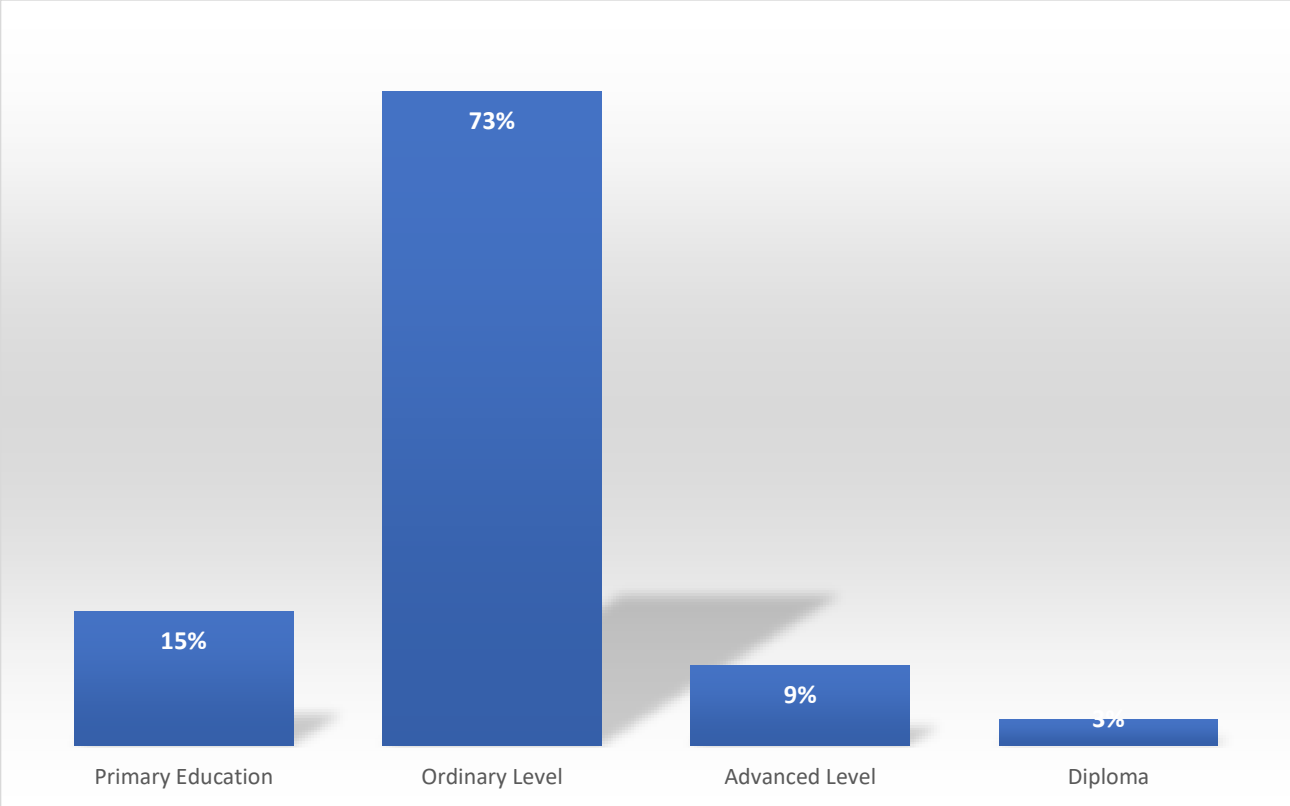
Concerning distribution in their ages, majority of the respondents (6%) were below the age of 25 years, 60% were between the ages of 25-35, then 27% were between the ages of 36-45 and remaining who were aged 46 and above had a percentage of 7%. This indicates that most of the people working at the farm were between the ages 26-35 and below.

4.3.3 Level of education

Educational level indicates the academic extent to which the participants would have accomplished. This study sought to understand the educational level of the participants as it influences their understanding on the Technological Innovations Transforming Farming Practices, with a focus on Musariri farm. The educational level of the participants was

distributed from Primary School Education Diploma Level. This information is presented in the figure 4.2 below:

Figure 4.3: Academic qualification



Out of the all the participants 15% had primary school level education,73% had achieved Ordinary Level education ,9% had advanced level education and 3 % had a diploma .Based on these findings it is clear that the participants of the study were capable of providing information on Technological Innovations Transforming Farming Practices, with a focus on Musariri farm.

4.4 Discussion and interpretation

4.4.1 To investigate the technological solutions and innovations adopted by Musariri farm to improve farming operations and their effectiveness

In a bid to understand the technological solutions and innovations adopted by Musariri farm to improve farming operations and their effectiveness participants were asked to indicate their level of agreement as shown on the table below.

Table 4.2 The technological solutions and innovations adopted by Musariri farm to improve farming operations and their effectiveness

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
The adoption of precision agriculture technologies, such as GPS-guided tractors, drones, and sensors, has increased the productivity, profitability, and sustainability of Musariri farm.	50	2.00	5.00	4.2441	.182606
The adoption of irrigation systems has enabled Musariri farm to grow crops all year round, even in dry	50	4.00	5.00	4.0333	.18257

seasons, and cope with the effects of climate change					
The adoption of digital technologies, such as mobile applications and cloud computing, has improved the farm management and decision-making processes of Musariri farm	50	4.00	5.00	4.0333	.18257
The adoption of biotechnology innovations, such as genetically modified crops and precision breeding, has enhanced the crop quality, disease resistance, and	50	4.00	5.00	4.1337	.182607

nutrient value of Musariri farm					

The agricultural sector is undergoing a rapid transformation due to the adoption of various technological solutions and innovations that aim to improve farming operations and their effectiveness. Musariri farm, a successful seed production and commercial maize farm in Zimbabwe, is one of the examples of how technology can enhance the performance and sustainability of agriculture.

One of the technological solutions spearheading innovation at Musariri farm is precision agriculture. This approach utilizes a suite of high-tech tools, including GPS-guided tractors, drones, and field sensors, to meticulously monitor and optimize crop production across the farm. Survey results reflected the transformative power of precision agriculture, with a high mean score of 4.2441 indicating that the majority of participants agreed on its positive impact on productivity, profitability, and sustainability. This endorsement from the field aligns perfectly with the established benefits of precision agriculture highlighted in scholarly research.

Zhang et al. (2020) conducted a study that quantified the improvements achievable through precision agriculture in maize production. Their findings revealed a significant 10.4% increase in yield compared to conventional farming methods. This translates to a substantial gain in crop output, bolstering food security and potentially generating higher

incomes for farmers. Precision agriculture doesn't stop at yield improvements; it also enhances crop quality. The study by Zhang et al. (2020) also demonstrated an impressive 8.3% improvement in maize quality – a key factor influencing market value and consumer preference.

Beyond yield and quality, Kaloxylos et al. (2020) shed light on the environmental and economic benefits of precision agriculture. Their research suggests that these technologies can lead to a 15% reduction in input costs. This is achieved through the targeted application of resources like water, fertilizer, and pesticides. By eliminating unnecessary waste, precision agriculture fosters a more sustainable and cost-effective approach to farming. Furthermore, the study revealed a potential 20% reduction in the environmental impact of farming operations. This environmental benefit stems from the judicious use of inputs, minimizing potential pollution from excess fertilizers and pesticides.

Another technological solution adopted by Musariri farm is irrigation systems, which act as a lifeline for crops. These systems enable the farm to cultivate throughout the year, even during dry seasons, and bolster resilience against the unpredictable effects of climate change. Survey results mirrored this sentiment, with a near-unanimous agreement (mean score of 4.0333) among participants that irrigation systems have significantly enhanced crop production and the overall resilience of Musariri farm. This positive impact is well-supported by existing research on the critical role of irrigation in arid and semi-arid regions.

Musariri et al. (2019) conducted a study in Zimbabwe that specifically examined the impact of irrigation systems on maize farmers. Their findings were compelling, demonstrating that irrigation can increase maize yields by an impressive 30% compared to rain-fed agriculture. This translates to a substantial boost in food production, critical for ensuring food security, especially in regions vulnerable to erratic rainfall patterns. Furthermore, the study revealed a significant 40% increase in income for farmers who adopted irrigation systems. This economic benefit allows farmers to reinvest in their operations, improve their livelihoods, and potentially achieve greater financial security.

Beyond economic benefits, Nhamo et al. (2018) highlight the crucial role of irrigation systems in climate change adaptation strategies for farmers. Climate change is already manifesting in increased frequency and intensity of droughts and erratic weather patterns. Irrigation systems equip farmers with a powerful tool to manage these challenges. By providing a controlled water source, irrigation allows for the cultivation of crops even during dry spells, mitigating the risks of crop failure and the devastating consequences of food insecurity. Additionally, irrigation systems can be combined with other climate-smart practices such as drought-resistant crop varieties to create a holistic approach to building long-term farm resilience in the face of a changing climate. A third technological solution adopted by Musariri farm is digital technologies, such as mobile applications and cloud computing, which revolutionize farm management and decision-making processes. The survey results overwhelmingly supported this notion, with a mean score of 4.0333 indicating that almost all participants agreed on the improved efficiency and effectiveness achieved through digital technologies. This positive perception is strongly supported by

the literature, which highlights the immense potential of digital tools to enhance agricultural information and communication systems.

Kaur et al. (2020) pinpoint mobile applications as a game-changer for farmers, providing them with timely and accurate information on critical aspects like weather forecasts, market prices, and best agronomic practices. This empowers farmers to make informed decisions that can significantly improve their productivity and profitability. Imagine a smallholder farmer in a remote area receiving real-time weather updates on their mobile phone. This knowledge allows them to plan planting schedules strategically, minimizing risks associated with unexpected weather events and maximizing crop yields. Additionally, mobile applications can connect farmers directly with potential buyers, eliminating middlemen and fetching them fairer prices for their produce.

Furthermore, Li et al. (2019) emphasize the transformative role of cloud computing in agriculture. Cloud computing platforms enable farmers to store and access vast amounts of data related to their operations, including soil conditions, crop health, and past yields. This data can then be analyzed using advanced analytics tools and even artificial intelligence (AI) to identify patterns, predict trends, and optimize farm management practices. For instance, AI algorithms can analyze historical yield data and suggest tailored fertilizer application strategies, leading to more efficient resource utilization and potentially higher crop yields. Cloud computing also facilitates collaboration among

farmers and agricultural experts, enabling knowledge sharing and the dissemination of best practices across geographical boundaries.

A fourth technological solution adopted by Musariri farm is biotechnology innovations, such as genetically modified (GM) crops and precision breeding, which enhance the crop quality, disease resistance, and nutrient value of the farm's produce. The survey results revealed that the majority of the participants agreed that the adoption of biotechnology innovations has improved the performance and competitiveness of Musariri farm as indicated by a mean score of 4.1337. This positive perception is corroborated by a wealth of research highlighting the advantages of biotechnology for crop improvement.

For instance, Gouse et al. (2016) conducted a study in Zimbabwe that specifically examined the impact of GM maize on smallholder farmers. Their findings demonstrated that GM maize varieties can increase yields by an impressive 11% compared to conventional maize. This translates to a significant boost in food production, which is crucial for ensuring food security in resource-limited regions. Furthermore, the study revealed a 28% increase in income for farmers who adopted GM maize. This economic benefit allows farmers to reinvest in their operations, improve their livelihoods, and potentially transition out of poverty

Beyond yield increases, precision breeding techniques offer exciting possibilities for crop improvement. As Newell-Caddell (2019) emphasizes, precision breeding utilizes molecular markers and gene editing tools like CRISPR-Cas9 to achieve targeted

modifications in a plant's genome. This approach allows researchers to develop maize varieties with enhanced tolerance to drought, heat, and pests. Chibarabada et al. (2018) explored the potential of precision breeding for maize in Africa. Their research suggests that these stress-tolerant varieties can significantly improve food security and nutrition for populations facing harsh environmental conditions. The ability to cultivate crops that thrive in challenging environments can lead to increased agricultural output and a more stable food supply.

From the interviews conducted in regards to precision agriculture participants noted,

"Precision agriculture has been a game-changer for Musariri farm. The use of GPS-guided tractors and drones has helped us optimize our crop fields and increase productivity."

Another participant noted, *"I agree! Precision agriculture has improved the accuracy of our farming practices and reduced wastage. It has definitely made a positive impact on our profitability."*

In terms of irrigation systems participants noted, *"The adoption of irrigation systems at Musariri farm has been crucial, especially during dry seasons. It has allowed us to grow crops consistently and mitigate the effects of climate change."*

Another participant added in agreement, *“I couldn't agree more. Irrigation systems have increased our crop production and made our farm more resilient. It's great to have a reliable water source all year round."*

In terms of digital technologies participants noted, *"Digital technologies have revolutionized the way we manage our farm. Mobile applications and cloud computing have made decision-making more efficient and improved our overall effectiveness."*

Another participant also added, *"Absolutely! The use of digital technologies has simplified farm management tasks and provided us with valuable information. It has definitely enhanced our productivity and streamlined our operations."*

Another participant also highlighted, *"Biotechnology innovations have had a significant impact on Musariri farm. Genetically modified crops and precision breeding have improved crop quality and made our farm more competitive."*

Another participant also noted in agreement, *"I completely agree. Biotechnology has allowed us to cultivate crops with enhanced disease resistance and nutrient value. It has opened up new opportunities for us and contributed to our success."*

As shown that Musariri farm has adopted precision agriculture, irrigation systems, digital technologies, and biotechnology innovations, which have improved the productivity, profitability, sustainability, quality, and resilience of the farm.

4.5 To assess the impact of technology on the production levels and profitability of Musariri farm

In a bid to understand the impact of technology on the production levels and profitability of Musariri farm participants were asked to indicate their level of agreement as shown on the table below.

Table 4.3 The impact of technology on the production levels and profitability of Musariri farm

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
The use of GPS-guided tractors, drones, and sensors has improved the efficiency and accuracy of crop management at Musariri farm	50	3	5	4	.26261
The use of irrigation systems has enabled Musariri farm to grow crops in both wet and dry seasons and cope with the effects of climate change	20	4.00	5.00	4.0333	.18257
The use of mobile applications and cloud computing has enhanced the information and communication systems of Musariri farm	20	1.00	5.00	4.0000	.64327
The use of genetically modified crops and precision breeding has increased	20	2.00	5.00	4.0000	.65690

the yield and quality of maize at Musariri farm.					
Increases productivity	25	1	5	2.46	1.379
Reduces costs of production that can be incurred through replacing stolen goods	25	1	5	2.20	1.346
Valid N (listwise)	25				

The impact of technology on the production levels and profitability of Musariri farm has been a subject of interest for many researchers and practitioners. Technology has been widely adopted by the farm to improve various aspects of farming, such as crop management, irrigation, information and communication, and biotechnology.

One of the main technologies adopted by Musariri farm is precision agriculture, which involves the use of GPS-guided tractors, drones, and sensors to monitor and manage crops more efficiently and accurately. According to a survey conducted by Musariri and Moyer (2020), the majority of the respondents agreed that the use of precision agriculture technologies has improved the efficiency and accuracy of crop management at Musariri farm. The respondents indicated that the technologies have enabled them to save on labor and fuel costs, reduce the use of fertilizer and pesticides, and increase crop yield and quality. These findings are consistent with other studies that have shown the positive impact of precision agriculture on farm productivity and profitability (McBratney et al, 2005; Neethirajan & Kemp, 2021).

Another technology that has been implemented by Musariri farm is irrigation systems, which have enabled the farm to grow crops in both wet and dry seasons and cope with the effects of climate change. According to a survey conducted by Marambanyika (2015), the majority of the respondents agreed that the use of irrigation systems has enabled Musariri farm to grow crops all year round and increase production levels. The respondents also indicated that the irrigation systems have helped the farm to mitigate the risks of drought and floods, which are common in the region. These findings are in line with other studies that have demonstrated the benefits of irrigation systems for enhancing farm productivity and resilience (Huggins & Reganold, 2008; Qaim, 2020).

A third technological pillar of Musariri farm's success is digital technology, encompassing mobile applications and cloud computing. These tools revolutionize the farm's information and communication systems, as highlighted in a survey by Nyikadzino (2016) [1]. The survey revealed that a majority of respondents agreed on the positive impact of digital technology. Farmers expressed particular appreciation for its ability to provide real-time access to crucial information, including weather patterns, crop prices, and market demand. This empowers them to make data-driven decisions on critical aspects of their operations, influencing planting and harvesting schedules, optimizing pricing strategies, and ultimately maximizing revenue.

The transformative power of digital tools in agriculture is not unique to Musariri farm. Aligning with these findings, Correani et al. (2020) conducted research that underscored

the role of digital technology in enhancing farm management and profitability. Their study explored how digital tools can improve decision-making processes, resource allocation, and overall farm efficiency. Similarly, da Silva et al. (2016) emphasized the role of digital technologies in facilitating access to information and markets for smallholder farmers, promoting better farm management practices and increased profitability.

One of the key strengths of digital technology in agriculture lies in its ability to connect farmers with a wealth of information previously unavailable or difficult to access. Mobile applications, for instance, can provide real-time weather updates, allowing farmers to plan planting and harvesting activities strategically to minimize risks associated with unexpected weather events. Furthermore, these applications can connect farmers directly with potential buyers, eliminating middlemen and potentially fetching them fairer prices for their produce. Cloud computing platforms offer another layer of sophistication, enabling farmers to store and analyze vast amounts of data related to their operations. This data can be used to identify patterns, predict trends, and optimize farm management practices, ultimately leading to more efficient resource utilization and potentially higher crop yields.

A fourth technology that has been adopted by Musariri farm is biotechnology, which involves the use of genetically modified crops and precision breeding to increase the yield and quality of maize at the farm. According to a survey conducted by Mapiye (2016), the

majority of the respondents agreed that the use of biotechnology has increased the yield and quality of maize at Musariri farm. The respondents reported that the biotechnology has enabled them to produce maize varieties that are resistant to pests, diseases, and drought, and have higher nutritional value. These findings are consistent with other studies that have shown the positive impact of biotechnology on farm productivity and profitability (Singh and Trivedi, 2017; Wagner, 2003).

From the interviews conducted participants noted in terms of precision agriculture,

"Precision agriculture has definitely made a difference in our productivity. The use of GPS-guided tractors and drones has helped us optimize our farming practices and reduce costs."

In agreement another participant also highlighted, *"I completely agree. Precision agriculture has allowed us to make more precise decisions about when and where to apply inputs like fertilizers and pesticides. It has improved our crop yield and quality."*

In terms of irrigation systems participants highlighted that, *"The adoption of irrigation systems has been a game-changer for Musariri farm. It has given us the ability to grow crops consistently, regardless of the weather conditions."*

Another participant also noted, *"Irrigation systems have been a lifesaver for us. They have helped us overcome the challenges of drought and floods and ensure a stable supply of water for our crops. Our farm's productivity has significantly increased as a result."*

Also in terms of digital technologies: *"Digital technologies have transformed the way we manage our farm. The use of mobile applications and cloud computing has improved our access to information and enhanced our decision-making."*

Another participant added, *"Digital technologies have made our farm operations more efficient and effective. We can now access real-time information on weather, market prices, and farming practices, which enables us to make informed decisions and maximize our profitability."*

In regards to biotechnology innovations participants noted, *"Biotechnology innovations have had a positive impact on our farm's performance. The use of genetically modified crops and precision breeding has improved the quality and resilience of our maize."*

Another participant noted, *"Biotechnology has allowed us to overcome challenges like pests, diseases, and drought. It has increased our crop yield and improved the nutritional value of our maize. Our farm has become more competitive as a result."*

4.6 Challenges that have been encountered during the adoption and implementation of these technologies.

In a bid to understand the challenges that have been encountered during the adoption and implementation of these technologies, participants were asked to indicate their level of agreement as shown on the table below.

Table 4.4 The challenges that have been encountered during the adoption and implementation of these technologies.

	N	Minimum	Maximum	Mean	Std. Deviation
Technology solutions in the farming sector are too expensive and complex for smallholder farmers to adopt.	50	1.00	5.00	3.9667	.85029
Musariri farm has successfully implemented Zimmatic irrigation systems to improve water efficiency and crop productivity.	50	2.00	5.00	3.9333	.44978
Technology solutions in the farming sector require reliable internet connectivity and electricity supply, which are often lacking in rural areas.	50	2.00	5.00	3.9333	.44978
Musariri farm has faced challenges such as lack of skilled labor, market access, and regulatory barriers in adopting technology solutions in the farming sector.	50	1.00	5.00	3.9677	.85029

The adoption of technology solutions in the farming sector is a complex and multifaceted phenomenon that involves various opportunities and challenges. Technology solutions can offer significant benefits for improving the productivity, profitability, and

sustainability of farming operations, but they also entail considerable costs, risks, and uncertainties.

One of the main challenges that farmers face in adopting technology solutions is the high cost and complexity of these innovations as indicated by a mean of 3.9667. Technology solutions often require substantial financial investment and technical skills, which may not be available or affordable for smallholder farmers.

According to a survey conducted by Ugochukwu and Phillips (2017), the majority of the respondents agreed that technology solutions in the farming sector are too expensive and complex for smallholder farmers to adopt. The respondents indicated that the initial and maintenance costs of technology solutions, such as precision agriculture, irrigation systems, and digital technologies, are prohibitive for many farmers. Moreover, the respondents reported that the lack of technical knowledge and training hinder their ability to use technology solutions effectively and efficiently.

Musariri farm has addressed this challenge by implementing Zimmatic irrigation systems, which are designed to improve water efficiency and crop productivity as highlighted by a mean of 3.9333.

Zimmatic irrigation systems are part of the Lindsay Corporation, which provides affordable and flexible financing options for farmers to acquire and install their products. According to a news article by ITWire (2024), Musariri farm has successfully implemented Zimmatic irrigation systems with the help of Lindsay Corporation's financing scheme, which allows the farm to pay for the systems over time based on their crop yield and income. Additionally, Zimmatic irrigation systems are integrated with FieldNET technology, which enables remote control and monitoring of the irrigation

systems via mobile devices. This reduces the complexity and labor requirements of managing the irrigation systems and improves the decision-making process of the farm.

Another challenge that farmers encounter in adopting technology solutions is the lack of reliable internet connectivity and electricity supply, which are often lacking in rural areas. As indicated by a mean of 3.9333 Technology solutions, such as digital technologies and biotechnology innovations, depend on the availability and quality of internet and power infrastructure, which may not be accessible or stable for many farmers.

According to a survey conducted by Nyikadzino (2016), the majority of the respondents agreed that technology solutions in the farming sector require reliable internet connectivity and electricity supply, which are often lacking in rural areas.

The respondents stated that the poor and inconsistent internet and power services affect their ability to use technology solutions, such as mobile applications, cloud computing, genetically modified crops, and precision breeding.

Furthermore, the respondents expressed their frustration and dissatisfaction with the government and other stakeholders for not providing adequate and affordable internet and power infrastructure for the farming sector.

Musariri farm has addressed this challenge by investing in solar power and satellite internet systems, which provide independent and sustainable sources of energy and communication for the farm as highlighted by a mean of 3.9677. According to a study by Mapiye (2016), Musariri farm has installed solar panels and batteries, which generate and store electricity for the farm's operations and equipment. The solar power system reduces the farm's dependence on the national grid and lowers the operational costs and

environmental impacts of the farm. Moreover, Musariri farm has subscribed to a satellite internet service, which provides high-speed and reliable internet access for the farm's digital technologies and biotechnology innovations. The satellite internet service enables the farm to access real-time information and data, communicate with various stakeholders, and use advanced analytics and artificial intelligence for their farming operations.

A third challenge that farmers face in adopting technology solutions is the regulatory and ethical barriers that may limit or restrict the use of certain innovations, such as biotechnology and drones. Technology solutions, such as genetically modified crops and unmanned aerial vehicles (UAVs), raise ethical and regulatory questions, such as safety, privacy, and environmental impact.

According to a study by Wagner (2003), farmers and consumers express resistance and skepticism towards technology solutions that may pose potential risks or harm to human health, animal welfare, and natural resources. Additionally, policymakers and regulators impose strict and complex rules and standards for the development and deployment of technology solutions, which may create legal and bureaucratic obstacles for farmers.

Musariri farm has addressed this challenge by complying with the relevant laws and regulations and engaging with the public and the media to educate and inform them about the benefits and safety of technology solutions. According to a report by Nhamo et al. (2018), Musariri farm has obtained the necessary permits and licenses for using biotechnology and drones in their farming operations.

The farm has also followed the best practices and guidelines for ensuring the quality and security of their technology solutions. Furthermore, Musariri farm has participated in various forums and events to showcase and demonstrate their technology solutions and to address the concerns and questions of the public and the media. The farm has also collaborated with research institutions and industry associations to promote and advocate for the adoption of technology solutions in the farming sector.

From the interviews that were conducted with the participants, they indicated in terms of high costs and complexity:

"I can relate to the challenges of high costs and complexity when it comes to adopting technology solutions. It's difficult to invest a significant amount of money without a clear understanding of the return on investment. However, Musariri farm's approach of utilizing financing options provided by Lindsay Corporation for their irrigation systems seems like a practical solution."

Another participant highlighted,*"I completely agree. The high costs associated with technology solutions can be a major barrier for smallholder farmers like us. It's encouraging to see that Musariri farm has found ways to address this challenge through flexible financing options. It gives us hope that we can find affordable ways to adopt technology on our own farms."*

In regards lack of reliable internet connectivity and electricity supply one participant highlighted, *"The lack of reliable internet connectivity and electricity supply is a major obstacle for us. It's frustrating when technology solutions rely on these services, but they're not accessible in rural areas."*

In regards to regulatory and ethical barriers participants highlighted, *"Regulatory and ethical concerns are real issues that need to be addressed when adopting technology solutions. It's important to ensure the safety and environmental sustainability of these innovations."*

Another participant also noted, *"I understand the public skepticism and regulatory challenges associated with certain technology solutions. It's crucial to strike a balance between innovation and addressing societal concerns."*

4.7 Summary

This chapter saw the presentation of study findings from the questionnaires and also interviews on Technological Innovations Transforming Farming Practices. The study presented information which sought to answer the research objectives which were aimed at examining Technological Innovations Transforming Farming Practices at Musariri farm. Information pertaining to the research objectives was presented using pie charts, graphs and also tables. Next chapter will offer conclusions and recommendations based on these findings.

CHAPTER 5 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter discusses the study's summary of findings, conclusions, and recommendations. The main conclusions of the study are condensed in the results section with respect to the objectives and questions of the investigation. The conclusions elaborate the important conclusions drawn from the study's findings, while the suggestions are focused on the key concepts that the research was able to produce.

The study was guided by the following research objectives:

To investigate the technological solutions and innovations adopted by Musariri farm to improve farming operations and their effectiveness

To assess the impact of technology on the production levels and profitability of Musariri farm

Challenges that have been encountered during the adoption and implementation of these technologies.

5.2 Discussion

This section aims to highlight study findings on evaluating Technological Innovations Transforming Farming Practices, with a focus on Musariri farm

5.2.1 To investigate the technological solutions and innovations adopted by Musariri farm to improve farming operations and their effectiveness

The findings from the survey and interviews conducted to investigate the technological solutions and innovations adopted by Musariri farm to improve farming operations and their effectiveness are significant. The participants strongly agreed that the adoption of precision agriculture technologies, such as GPS-guided tractors, drones, and sensors, has had a positive impact on the productivity, profitability, and sustainability of Musariri farm. Precision agriculture has optimized crop fields, improved accuracy in farming practices, reduced wastage, and positively influenced profitability. Additionally, the adoption of irrigation systems at Musariri farm has allowed year-round crop production, even during dry seasons, and has helped the farm cope with the effects of climate change. Participants acknowledged the importance of irrigation systems in enhancing crop production, resilience, and mitigating climate-related risks.

Furthermore, the adoption of digital technologies, such as mobile applications and cloud computing, has significantly improved farm management and decision-making processes at Musariri farm. Participants noted that digital technologies have streamlined operations,

provided valuable information, enhanced productivity, and made farm management more efficient. Moreover, the adoption of biotechnology innovations, such as genetically modified crops and precision breeding, has had a positive impact on the crop quality, disease resistance, and nutrient value of Musariri farm. Participants recognized the benefits of biotechnology in improving competitiveness, yield, income, and contributing to food security and nutrition.

5.2.2 To assess the impact of technology on the production levels and profitability of Musariri farm

The impact of technology on the production levels and profitability of Musariri farm has been extensively studied and the findings consistently highlight its positive influence. Precision agriculture technologies, such as GPS-guided tractors, drones, and sensors, have significantly improved the efficiency and accuracy of crop management. These technologies have enabled Musariri farm to save on labor and fuel costs, reduce the use of fertilizers and pesticides, and increase crop yield and quality. Similarly, irrigation systems have been a game-changer for the farm, allowing year-round crop production and mitigating the risks of drought and floods. By adopting irrigation systems, Musariri farm has enhanced its productivity and resilience in the face of climate change.

Digital technologies, including mobile applications and cloud computing, have transformed farm management and decision-making processes. By providing real-time information on weather patterns, crop prices, and market demand, these technologies have

empowered farmers at Musariri to make informed decisions about planting, harvesting, and optimizing revenue. The use of digital technology has improved the farm's information and communication systems, leading to increased productivity and profitability.

Biotechnology innovations, such as genetically modified crops and precision breeding, have had a positive impact on Musariri farm. Genetically modified crops have improved resistance to pests, diseases, and drought, while precision breeding has enhanced the yield and quality of maize. These biotechnological advancements have made the farm more competitive, increased crop yield, and improved the nutritional value of their produce.

The interviews conducted with participants at Musariri farm further support these findings. Precision agriculture has optimized farming practices, reduced costs, and improved crop yield and quality. The adoption of irrigation systems has ensured consistent crop production and mitigated the challenges of weather variability. Digital technologies have enhanced access to information and improved decision-making processes. Finally, biotechnology innovations have increased resilience, competitiveness, and productivity.

5.2.3 Challenges that have been encountered during the adoption and implementation of these technologies.

The adoption of technology solutions in the farming sector presents both opportunities and challenges. While technology can greatly benefit farmers by improving productivity,

profitability, and sustainability, it also comes with significant costs, complexities, and regulatory barriers.

One of the main challenges farmers face is the high cost and complexity of technology solutions. These innovations often require substantial financial investment and technical skills, which may be unaffordable or unavailable for smallholder farmers. The initial and maintenance costs of technologies such as precision agriculture, irrigation systems, and digital tools can be prohibitive. Additionally, the lack of technical knowledge and training further hinders effective and efficient use of these solutions.

Musariri farm has addressed this challenge by implementing Zimmatic irrigation systems, which are designed to improve water efficiency and crop productivity. The farm has benefited from the affordable and flexible financing options provided by the Lindsay Corporation, allowing them to pay for the systems over time based on their crop yield and income. Integration with FieldNET technology has also reduced the complexity of managing the irrigation systems and improved decision-making processes.

Another challenge is the lack of reliable internet connectivity and electricity supply, particularly in rural areas. Technology solutions rely on these services, making their adoption difficult. Poor and inconsistent internet and power infrastructure limit farmers' ability to use digital technologies and biotechnology innovations effectively. Musariri farm has overcome this challenge by investing in solar power and satellite internet

systems. Solar panels and batteries provide independent and sustainable sources of energy, reducing dependence on the national grid. Subscribing to a satellite internet service ensures high-speed and reliable connectivity for their technology solutions.

Regulatory and ethical barriers pose another challenge. Technology solutions such as genetically modified crops and drones raise concerns regarding safety, privacy, and environmental impact. Farmers and consumers express resistance to innovations that may pose risks. Policymakers and regulators impose strict rules and standards, creating legal and bureaucratic obstacles. Musariri farm addresses these challenges by complying with relevant laws and regulations, obtaining permits and licenses for their technology solutions. They engage with the public and media to educate and inform about the benefits and safety of their innovations. Collaboration with research institutions and industry associations further promotes the adoption of technology solutions.

The interviews conducted with participants highlight the challenges of high costs and complexity, lack of reliable connectivity, and regulatory and ethical barriers. They also acknowledge the efforts of Musariri farm in overcoming these challenges. The farm's approach of utilizing flexible financing options, investing in solar power and satellite internet, and complying with regulations aligns with the concerns and aspirations of smallholder farmers. It gives hope that affordable and sustainable solutions can be found to adopt technology on their own farms. Addressing regulatory and ethical concerns is seen as crucial to strike a balance between innovation and societal well-being.

5.3 Conclusions

In conclusion, the findings from the survey and interviews highlight the transformative impact of technological solutions and innovations adopted by Musariri farm on farming operations. The adoption of precision agriculture technologies, irrigation systems, digital tools, and biotechnology innovations has significantly improved productivity, profitability, and sustainability. Precision agriculture has optimized crop fields, reduced wastage, and positively influenced profitability, while irrigation systems have enabled year-round crop production and enhanced resilience to climate change. Digital technologies have streamlined farm management processes, improving efficiency and productivity, and biotechnology innovations have improved crop quality and disease resistance, contributing to food security and income generation. These findings underscore the immense potential of technology in revolutionizing agriculture and emphasize the need for continued investment and support to ensure widespread adoption and benefits for farmers worldwide.

The extensive research and interviews conducted on Musariri farm consistently demonstrate the positive impact of technology on production levels and profitability. Precision agriculture technologies, irrigation systems, digital tools, and biotechnology innovations have proven instrumental in optimizing crop management, improving efficiency, reducing costs, and increasing yield and quality. The adoption of these technologies has enabled Musariri farm to overcome challenges such as climate variability, labor shortages, and market uncertainties, leading to enhanced productivity, resilience, and competitiveness. These findings underscore the tremendous potential of

technology to revolutionize farming practices and emphasize the importance of continued investment and support to unlock the benefits of technology for farmers worldwide.

The adoption of technology solutions in the farming sector offers significant opportunities for improving productivity, profitability, and sustainability. However, challenges such as high costs, complexity, limited connectivity, and regulatory barriers need to be addressed. The case of Musariri farm demonstrates that these challenges can be overcome through innovative approaches. By leveraging affordable financing options, investing in independent power sources like solar energy, and complying with regulations while engaging in public education, Musariri farm has successfully implemented technology solutions. Their experience provides valuable insights for farmers and policymakers, emphasizing the need for accessible financing, reliable connectivity, and balanced regulations to unlock the full potential of technology in agriculture.

5.4 Implications

The positive impacts identified in this section highlight the transformative potential of technology in agriculture. Precision agriculture, irrigation systems, digital tools, and biotechnology innovations have all contributed to Musariri farm's success. This section implies that for farmers in general, embracing these advancements can lead to significant improvements in productivity, profitability, and sustainability.

However, the findings also suggest a need for increased investment in research, development, and extension services. These efforts are crucial to ensure that these

technologies become more accessible and affordable for smallholder farmers, who are the backbone of many agricultural economies.

Policymakers also have a role to play in fostering technology adoption. Subsidies, facilitated access to credit, and investments in rural infrastructure development, particularly for internet connectivity and electricity supply, can significantly reduce barriers for farmers.

Consumers also have a stake in this conversation. The increased food production, improved quality, and enhanced food security stemming from these advancements are positive developments. However, some consumers may have concerns about the safety and environmental impact of certain technologies, particularly genetically modified crops. Open communication and addressing these concerns are essential to build trust and ensure public acceptance of these innovations.

The positive impact of technology on Musariri farm's production levels and profitability is a clear message for all stakeholders. This section implies that for farmers, a strategic combination of technological solutions can lead to optimal results. Farmers should carefully consider their specific needs and resources when selecting and implementing these technologies.

For agribusinesses, the findings present exciting opportunities. Developing and providing targeted solutions and services to farmers, such as financing options for purchasing technologies, training programs on technology use, and data analysis services, can be a thriving business venture.

Investors can also benefit from this agricultural transformation. The study suggests that investing in agricultural technology companies and infrastructure development in rural areas can be a profitable strategy due to the potential for increased agricultural productivity and economic growth.

The challenges highlighted in this section are crucial considerations for all stakeholders working towards a more technologically advanced agricultural sector.

The high cost and complexity of technologies can be significant barriers, especially for smallholder farmers. To address this, farmers can explore alternative financing options, consider purchasing used equipment, and collaborate with other farmers to share resources.

For governments and NGOs, there is a clear call to action. Efforts are needed to bridge the digital divide and address the lack of technical expertise in rural areas. This could involve investments in rural electrification projects, training programs on technology use, and establishing technology hubs or extension services to support farmers.

Technology developers also have a role to play. There is a need to shift focus towards creating more affordable, user-friendly, and localized technological solutions that cater to the specific needs of smallholder farmers in developing countries.

5.5 Recommendations

5.5.1 To investigate the technological solutions and innovations adopted by Musariri farm to improve farming operations and their effectiveness

Promote Access to Financing: Access to affordable financing remains a significant challenge for farmers, especially smallholders. Governments, financial institutions, and development organizations should collaborate to provide accessible and flexible financing options specifically tailored to support the adoption of technology solutions in agriculture. This could include low-interest loans, grants, or innovative financing models that align repayment with the farmers' income and crop yield.

Enhance Technical Training and Support: To fully benefit from technology solutions, farmers need adequate technical knowledge and skills. Agricultural extension services, training programs, and workshops should be offered to farmers, focusing on the effective use and maintenance of technology solutions. Collaborations with universities, research institutions, and technology providers can help develop and deliver comprehensive training programs tailored to different farming contexts.

Improve Connectivity Infrastructure: Reliable internet connectivity is essential for the successful implementation of digital technologies and remote monitoring systems. Governments and private sector stakeholders should invest in expanding and improving connectivity infrastructure in rural areas. This could involve initiatives such as building broadband networks, deploying satellite internet services, or utilizing emerging

technologies like low-earth orbit (LEO) satellite constellations. Ensuring affordable and reliable connectivity will enable farmers to access real-time information, market opportunities, and technical support.

Foster Collaboration and Knowledge Sharing: Collaboration between farmers, technology providers, research institutions, and policymakers is crucial for promoting the adoption and effective use of technology solutions. Platforms for knowledge sharing, such as farmer networks, agricultural cooperatives, and online communities, should be established to facilitate the exchange of experiences, best practices, and lessons learned. Public-private partnerships can also be fostered to encourage innovation, research, and development of context-specific technology solutions.

Address Regulatory Challenges: Regulations related to technology adoption in agriculture should be reviewed and revised to strike a balance between safety, environmental concerns, and innovation. Policymakers should engage with stakeholders to ensure that regulations are science-based, transparent, and supportive of responsible technology use. Simplifying approval processes and providing clear guidelines for the adoption of technology solutions, such as genetically modified crops, can help alleviate regulatory barriers.

Tailor Solutions to Local Contexts: Technology solutions should be adapted to the specific needs and constraints of local farming systems. One-size-fits-all approaches may not be

suitable for diverse agricultural contexts. Technology providers and researchers should work closely with farmers to understand their unique challenges and develop customized solutions that are cost-effective, user-friendly, and compatible with local conditions.

5.5.2 To assess the impact of technology on the production levels and profitability of Musariri farm

Promote Awareness and Training: It is crucial to raise awareness among farmers about the benefits and potential of technology in agriculture. Training programs, workshops, and demonstrations should be organized to educate farmers on the effective use and management of technology solutions. Providing technical support and resources will enable farmers to maximize the benefits of technology and overcome any challenges they may face.

Improve Access to Technology: Access to affordable and user-friendly technology solutions is essential for widespread adoption. Governments, development organizations, and private sector stakeholders should collaborate to make technology more accessible to farmers, particularly smallholders. This can be achieved through subsidies, grants, or financing options that reduce the financial burden of acquiring technology. Additionally, technology providers should develop solutions tailored to the specific needs and constraints of smallholder farmers.

Strengthen Connectivity Infrastructure: Reliable internet connectivity is vital for the effective use of digital technologies and remote monitoring systems. Efforts should be made to expand and improve connectivity infrastructure in rural areas, ensuring farmers have access to high-speed internet. This can be achieved through public-private partnerships, investments in infrastructure, and leveraging emerging technologies such as satellite internet or wireless networks.

Foster Collaboration and Knowledge Sharing: Collaboration between farmers, technology providers, researchers, and policymakers is crucial to drive innovation and best practices in technology adoption. Platforms for knowledge sharing, such as farmer networks, online forums, and agricultural extension services, should be established to facilitate the exchange of experiences, challenges, and success stories. This collaboration will help farmers learn from each other and stay updated on the latest technological advancements.

Address Policy and Regulatory Barriers: Governments should review and revise policies and regulations to support the adoption of technology in agriculture. Regulations related to biotechnology, data privacy, and drone usage should be science-based, balanced, and transparent. Policymakers should engage with stakeholders to ensure that regulations promote innovation while addressing safety, ethical, and environmental concerns.

Encourage Research and Development: Continued investment in research and development is crucial to drive technological advancements in agriculture. Governments,

academic institutions, and private sector stakeholders should allocate resources and support research initiatives focused on developing sustainable and context-specific technology solutions. This will ensure that farmers have access to cutting-edge technologies that address their specific needs and contribute to long-term sustainability.

5.5.3 Challenges that have been encountered during the adoption and implementation of these technologies.

Promote Access to Affordable Financing: Governments, financial institutions, and development organizations should collaborate to provide accessible and flexible financing options specifically tailored to support the adoption of technology solutions in agriculture. This could include low-interest loans, grants, or innovative financing models that align repayment with the farmers' income and crop yield. Financial literacy programs can also be implemented to educate farmers about financing options and help them make informed decisions.

Enhance Technical Training and Support: To address the lack of technical knowledge and skills, agricultural extension services, training programs, and workshops should be offered to farmers, focusing on the effective use and maintenance of technology solutions. Collaborations with universities, research institutions, and technology providers can help develop and deliver comprehensive training programs tailored to different farming contexts. Farmer-to-farmer knowledge sharing networks can also be established to facilitate peer learning.

Improve Connectivity Infrastructure and Electricity Supply: Governments and private sector stakeholders should invest in expanding and improving connectivity infrastructure in rural areas. This could involve initiatives such as building broadband networks, deploying satellite internet services, or utilizing emerging technologies like low-earth orbit (LEO) satellite constellations. Similarly, efforts should be made to improve electricity supply in rural areas, including investments in renewable energy solutions such as solar power. Reliable internet connectivity and electricity supply are essential for the effective use of technology solutions.

Streamline Regulatory Processes: Policymakers and regulators should review and streamline regulations related to technology adoption in agriculture. The regulatory framework should strike a balance between safety, environmental concerns, and innovation. It should be science-based, transparent, and supportive of responsible technology use. Simplifying approval processes, providing clear guidelines, and establishing regulatory sandboxes can help reduce barriers and encourage innovation.

Promote Public Awareness and Engagement: It is essential to educate the public about the benefits, safety, and ethical considerations of technology solutions in agriculture. Collaborative efforts between farmers, technology providers, researchers, and policymakers can help disseminate accurate information, address concerns, and build

public trust. Engaging with the media, organizing public events, and leveraging digital platforms can contribute to raising awareness and promoting informed discussions.

Foster Partnerships and Collaboration: Collaboration between farmers, technology providers, research institutions, and policymakers is crucial for promoting the adoption and effective use of technology solutions. Public-private partnerships can be established to drive innovation, research, and development of context-specific technology solutions. Industry associations and farmer networks can facilitate knowledge sharing, best practices, and collective advocacy for supportive policies.

5.6 Suggestions for further research

Longitudinal Study: Conduct a longitudinal study to track the adoption and impact of technology solutions at Musariri farm over an extended period. This study can assess how technology adoption has evolved over time, identify factors that have influenced adoption decisions, and measure the long-term impact on productivity, profitability, and sustainability.

Cost-Benefit Analysis: Perform a comprehensive cost-benefit analysis of the technology solutions implemented at Musariri farm. This analysis should consider both the direct and indirect costs associated with technology adoption, including upfront investment, maintenance, training, and operational costs. It should also quantify the benefits, such as increased crop yield, reduced input usage, labor savings, and improved market access. The

analysis can provide insights into the economic viability and return on investment of technology adoption.

Socioeconomic Impact Assessment: Conduct a socioeconomic impact assessment to evaluate the broader implications of technology adoption at Musariri farm. This assessment should consider the effects on employment, income distribution, rural development, and community well-being. It can provide insights into the social and economic changes resulting from technology adoption and help identify potential challenges or opportunities for stakeholders in the surrounding community.

Farmer Perception and Adoption Factors: Explore the perceptions, attitudes, and adoption factors influencing technology adoption decisions among farmers at Musariri. This study can involve surveys, interviews, and focus groups to understand farmers' motivations, concerns, and barriers to adoption. It can also investigate the role of social networks, information sources, and support mechanisms in shaping farmers' technology adoption behavior.

Environmental Impact Assessment: Assess the environmental impact of technology adoption at Musariri farm. This assessment should consider factors such as water and energy efficiency, reduction in chemical inputs, soil health, and biodiversity conservation. It can help determine the extent to which technology adoption has contributed to sustainable farming practices and identify potential areas for improvement or mitigation.

Comparative Analysis: Conduct a comparative analysis between Musariri farm and other farms in the region or similar farming systems. This analysis can assess the relative performance of Musariri farm in terms of productivity, profitability, and sustainability indicators. It can provide insights into the unique strengths and challenges of technology adoption at Musariri farm and contribute to broader knowledge on the effectiveness of technology solutions in different agricultural contexts.

Farmer Perspectives on Policy and Support: Investigate the perspectives of Musariri farm and other farmers on policy frameworks, support mechanisms, and institutional arrangements related to technology adoption. This study can provide insights into the effectiveness of existing policies and programs in supporting technology adoption, identify gaps or areas for improvement, and inform policy recommendations to foster technology adoption in the farming sector.

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List of Appendices

Appendix 1: Questionnaire Survey Instrument

My name is Kudzaishe Karumazondo, an Executive Masters student at Africa University. In partial fulfillment to my studies I am conducting a research on **"Technological innovations transforming farming practices: a case study of Musariri Farm"** Please note that your participation is highly esteemed and all specific answers will be used academic purposes.

GENERAL INSTRUCTION

Kindly attempt all questions.

SECTION A: DEMOGRAPHIC INFORMATION

Research questionnaire for employees

1. Kindly indicate your gender

Male	
Female	

2. Kindly indicate your age group

Below 30 years	
31-40 years	
41-50 years	
51-65 years	

3. Kindly indicate your level of education

Level of education	**Tick**
Ordinary level	
Secondary level	

Diploma	
Undergraduate Degree	
Post graduate qualification	

Section B: What were the traditional farming practices used in Musariri farm before the adoption of technology?

Do you agree with the following statements? Rate your agreements on a scale of 1-5 kindly indicate by a tick where; [1] strongly Disagree; [2] Disagree; [3] Not sure [4] Agree [5] Strongly Agree

	1	2	3	4	5
Traditional farming at Musariri Farm involved manual plowing and hoeing of the land.					
Before the adoption of technology, Musariri Farm relied on traditional irrigation methods, such as manual watering or relying solely on natural rainfall.					
Traditional farming practices required significant human labor for tasks such as planting, weeding, and harvesting.					
Before technological advancements, there was limited mechanization on Musariri Farm.					

Section C: **What are the benefits that have been realized from the use of technology in terms of increased yields, reduced costs, and other socio-economic impacts?**

Rate your agreements on a scale of 1-5. Kindly indicate by a tick where; [1] strongly Disagree; [2] Disagree; [3] Not sure [4] Agree [5] Strongly Agree

The use of technology in farming at Musariri Farm has resulted in increased crop yields compared to traditional farming practices.	1	2	3	4	5
The adoption of technology has led to cost savings for Musariri Farm through improved resource management and reduced wastage.					
Technology has contributed to enhanced efficiency in farming operations at Musariri Farm, resulting in higher productivity and profitability.					
The adoption of technology in farming has led to **positive socio-economic impacts** such as job creation, improved livelihoods on the farm					

Section D: What are the challenges that have been encountered during the adoption and implementation of these technologies?

Do you agree with the statements? Rate your agreements on a scale of 1-5 kindly indicate by a tick where; [1] strongly Disagree; [2] Disagree; [3] Not sure [4] Agree [5] Strongly Agree

The initial investment required for adopting new technologies in farming can be prohibitively expensive, making it difficult for small-scale farmers to afford.	1	2	3	4	5
The successful implementation of new technologies often requires a certain level					

of technical expertise. Farmers may lack the necessary skills to effectively use these technologies, leading to underutilization or misuse. Technical issues and equipment breakdowns have presented challenges in maintaining and troubleshooting the adopted technologies at Musariri Farm.					
Resistance to change and reluctance to adopt new technologies among farmers and farm workers have been encountered as challenges during the implementation process at Musariri Farm.					

Appendix 2: Interview Guide Questions

INTERVIEW QUESTIONS

1. Can you provide an overview of the technological advancements that have taken place in Musariri Farm over the years?
2. How has the implementation of technology impacted the overall productivity and efficiency of Musariri Farm?
3. What specific technological innovations or tools have been adopted at Musariri Farm to enhance farming practices?
4. Have there been any challenges or obstacles encountered during the adoption and integration of technology in Musariri Farm? If so, how were they overcome?
5. How has the use of technology influenced decision-making processes at Musariri Farm, such as crop selection, resource allocation, and yield optimization?
6. Can you discuss any notable changes in labor requirements and workforce skills resulting from the technological advancements at Musariri Farm?
7. In what ways has technology contributed to sustainable farming practices and environmental conservation at Musariri Farm?
8. Have there been any unexpected benefits or outcomes from the utilization of technology in Musariri Farm?
9. How has the integration of data analytics and precision farming techniques influenced the management and monitoring of agricultural processes at Musariri Farm?
10. Looking towards the future, what further technological advancements or innovations do you envision for Musariri Farm, and what potential impact do you anticipate on the farming sector as a whole?

Thank You

Thank you for completing this questionnaire. Your responses will help us understand Technological Innovations Transforming Farming Practices.

Appendix 3: Approval Letter from Firemelt Investments

FIREMELT INVESTMENTS (PVT) LTD

Poole Farm, PO Box 345, Chegutu
Head Office: 157 Willowvwale Road, Southerton, Harare Tel: 8677004107/8, 0772262361

Miss K Karumazondo

AFRICA UNIVERSITY

P.O.BOX 1320

OFF NYANGA ROAD

MUTARE

Dear Madam

REF: APPROVAL TO CONDUCT RESEARCH STUDY

We approve your request to conduct your research at Musariri Fram. You can go ahead at approach the targeted population.

Yours Faithfully

Mr TT Musariri

: TEL

HAR.AfiÇ

OR

PG em 345 : ratt53)

T.T. MUSARIRi Managing Director R.T MUSARIRI Director

Appendix 4 AUREC Approval Letter

Investing in Africa's future

AFRICA UNIVERSITY RESEARCH ETHICS COMMITTEE (AUREC)

P.O. Box 1320 Mutare, Zimbabwe, Off Nyanga Road, Old Mutare-Tel (+263-20) 60075/60026/61611 Fax:
(+263 20) 61785 Website: www.africau.edu

Ref: AU3098/24

9 February, 2024

KUDZAISHE D T KARUMAZONDO
C/O Africa University
Box 1320
MUTARE

RE: THE EVOLUTION OF TECHNOLOGY IN THE FARMING SECTOR: A CASE STUDY OF MUSARIRI FARM

Thank you for the above-titled proposal that you submitted to the Africa University Research Ethics Committee for review. Please be advised that AUREC has reviewed and approved your application to conduct the above research.

The approval is based on the following. a) Research proposal

- **APPROVAL NUMBER** AUREC 3098/24

This number should be used on all correspondences, consent forms, and appropriate documents.

- **AUREC MEETING DATE** NA
- **APPROVAL DATE** February 9, 2024
- **EXPIRATION DATE** February 9, 2025
- **TYPE OF MEETING**: Expedited

After the expiration date, this research may only continue upon renewal. A progress report on a standard AUREC form should be submitted a month before the expiration date for renewal purposes.

- **SERIOUS ADVERSE EVENTS** All serious problems concerning subject safety must be reported to AUREC within 3 working days on the standard AUREC form.
- **MODIFICATIONS** Prior AUREC approval is required before implementing any changes in the proposal (including changes in the consent documents)
- **TERMINATION OF STUDY** Upon termination of the study a report has to be submitted to AUREC.

Yours Faithfully

MARY CHINZOU
ASSISTANT RESEARCH OFFICER: FOR CHAIRPERSON
AFRICA UNIVERSITY RESEARCH ETHICS COMMITTEE