FACTORS INFLUENCING TECHNICAL EFFICIENCY AMONG HORTICULTURAL FARMERS IN LESOTHO: THE CASE STUDY OF TOMATO FARMERS OF LERIBE DISTRICT

BY

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DECLARATION

I, Mapolotso Nkuebele, hereby declare that the work contained in the thesis, entitled **Factors influencing Technical efficiency among horticultural farmers in Lesotho,** the case study of tomato farmers of Leribe district is my own original work and that I have not previously in its entirety or in part submitted it at any university or other higher education institutions for the award of a degree.

____________________________ ____________________________

Mapolotso Nkuebele Date

CERTIFICATION

I the undersigned, certify that the work reported in this thesis was done by Mapolotso Nkuebele under my supervision.

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Dated: ....

DEDICATION

This work is dedicated to my family: my daughter, Sebabatso Veronica Nkuebele, for the horrible times she had to endure as her mother worked to meet an unending string of deadlines; and my fiancé, Mr. Samilton K. Moorosi, for his encouragement, understanding, and support. To Matiisetso Matlalinyane Motalingoane, my sister, who supported me and encouraged me to continue my education. Without the unwavering support and affection of my late parents, Mr. Nkuebele Jacob Nkuebele and Mrs. Malekhetho Florina Nkuebele, I could not have progressed this far in life.

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The secret to success is determination and devotion

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ABSTRACT

The research focused on the factors influencing technical efficiency among tomato farmers in Leribe district. The specific objectives were to evaluate technical efficiency of horticulture farmers in Leribe and to identify factors that influence technical efficiency among horticulture farmers in the study area. Stratified sampling technique was used to select 95 tomato farmers. A combination of primary and secondary data was used to collect data for this study, and these were obtained using a structured questionnaire. Descriptive statistics were used to describe the demographics and socio-economics characteristics of the farmers. Stochastic Frontier Analysis (SFA) was used to measure technical efficiency while Principal Component Analysis (PCA) model was used to identify factors influencing technical efficiency. Data was captured and analysed using Statistical Package for Social Science (SPSS) version 20.0 and National Council of Statistics Software (NCSS) 2024. The SFA results revealed that tomato farmers in Leribe achieved a technical efficiency level of 83.5%, which is above the benchmark of 70%. PCA results showed that factors such as gender with a ($\beta = 0.279$, p = 0.0276), education (β = 0.114, p = 0.0451), seed quality (β = 0.364, p = 0.0009), animal power (β = -0.318, p = 0.0048), farmer experience ($\beta = 0.113$, p = 0.0283), irrigation ($\beta =$ -0.141, p = 0.0385) and off-farm income (β = -0.258 and p-value 0.0279) significantly influenced technical efficiency among tomato farmers in the study area. The study concludes that tomato farmers of Leribe are technically efficient as they achieved way above the acceptable minimum TE score 70%. Furthermore, demographic characteristics and technical factors affect the technical efficiency of tomato production in the Leribe district. To boost technical efficiency among tomato farmers, there is need to promote gender equality in agriculture, efforts should be made to improve access to resources for women by implementing policies that ensure that female farmers have access to land, agricultural inputs, credit, and technology. Moreover, promotion of experience-based learning to develop mentorship and training programs to capacitate the less experienced farmers should be considered by the stakeholders. Learning from the more seasoned professionals will help emerging/inexperienced farmers to gain the skills and knowledge needed to adopt efficient production techniques. Therefore, the situation underscores the multifaceted nature of technical efficiency in horticulture and highlights the importance of addressing these specific factors to improve vegetable farming productivity in the Leribe district of Lesotho.

Key words: Technical efficiency, factors, smallholder, tomato farmers

List of Abbreviations

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
BOS	Bureau of Statistics
COMESA	Common Market for Eastern and Southern Africa
EIF	Enhanced Integrated Framework
ESMF	Environmental and Social Management Framework
EU	European Union
FAO	Food Agricultural Organization
GDP	Gross Domestic Product
GMOs	Generally Modified Organisms
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
LDCs	Least Developed Countries
MAFSN	Ministry of Agriculture Food Security National
MLE	Maximum Likelihood Estimates
NCSS	National Council of Statistics Software
PCA	Principal Component Analysis
SACU	South Africa Customs Union
SADC	Southern African Development Community
SADP	Smallholder Agriculture Development Project
SFA	Stochastic Frontier Analysis
SPSS	Statistical Package Social Science
TE	Technical efficiency

CHAPTER 1

INTRODUCTION

1.1 Background of the study

According to Barrios *et al.,* (2021), agriculture serves as the primary driver of economic growth in Sub-Saharan African countries. However, feeding the growing population in this region has become a significant challenge (Owusu *et al.,* 2022). Diao and Hazell (2022) further emphasize that agriculture is the backbone of economies globally, practiced in various forms across different continents and regions. These discussions focus on the role of industry and agriculture in advancing African development and ensuring inclusive growth that benefits the poor. The prevailing argument, as noted by de Janvry and Sadoulet (2020), is that agriculture is a substantial sector, and enhancing it can lead to increased overall economic growth.

Agriculture has two forms which are crops and livestock farming which makes it the most important economic sector, employing more than half the population on a formal and informal basis and accounting for almost half of GDP and export earnings in Ghana (Kassa - Abrha, 2019). Globally, agricultural practices have witnessed a shift towards intensification and technological advancements, and this includes the adoption of precision farming techniques, the use of genetically modified organisms (GMOs), and increased mechanization to improve productivity and efficiency (Tilman and Clark, 2022).

Agricultural productivity has long been viewed as a critical determinant of rural welfare and an engine for overall economic growth in most African countries (Mugera and Ojede, 2020). According to Odhiambo *et al.* (2021), tomatoes (Solanum lycopersicum) are cultivated worldwide, where China was found to be the largest horticultural producer and consumer in the world with a production volume of over 616 million metric tons, followed by India with approximately 138 million metric tons of fresh vegetables (Shahbaneh, 2024). Considering the volume of vegetables produced worldwide in 2022, tomatoes were the most popular vegetable. Again, Vanloqueren and Baret (2023) stated that the productivity of these two commodities at the international level is crucial for global food security and economic stability in the agricultural sector. Hence, there are productivity factors that horticulture farmers need to take into consideration to better produce tomatoes. These factors include climate as tomatoes require specific climatic conditions for optimal growth. Variations in temperature, humidity, and precipitation can significantly impact tomato productivity (Fanasca *et al.*, 2020). Furthermore, tomatoes farmers need to adhere to cultivation practices by adopting modern agricultural practices, including efficient irrigation, fertilization, and pest control to enhance productivity (Motsara and Roy, 2020).

Moreover, horticultural farmers need to have access to high-yielding varieties through breeding programs and genetic engineering which contributes to increased productivity (Víquez-Zamora *et al*., 2018). Also, for horticulture farmers to remain sustainable, technological advancements such as greenhouse technologies, precision farming techniques, and mechanization are needed to improve productivity (Ricardo *et al.*, 2021). According to Huchet-Bourdon *et al.* (2020), the productivity of tomatoes at the international level is influenced by a complex interplay of factors ranging from climate and cultivation practices to technological advancements and market dynamics. Addressing challenges and leveraging recent trends are essential for sustaining and enhancing productivity to meet the growing demand for these essential vegetables globally.

Productivity levels in tomato farming in the African context have been a subject of concern due to various challenges such as climate variability as the continent experiences unpredictable weather patterns, prolonged droughts, and extreme weather events becoming more frequent. These climatic variations affect crop yields of tomatoes posing significant challenges to farmers (Mohapi and Motumi, 2020). Smallholder farmers often face challenges in accessing quality seeds, fertilizers, pesticides, and irrigation facilities. This limitation hampers their ability to achieve optimal productivity in tomatoes (Lekonyane *et al.*, 2019). In addition, plant pests and diseases are a constant threat to agricultural productivity in Africa and inadequate pest management practices, combined with limited access to effective pesticides and resistant crop varieties, result in substantial crop losses in farming tomatoes (Majara *et al.*, 2021). Moreover, post-harvest losses, poor post-harvest handling, storage, and transportation infrastructure contribute to significant losses of tomatoes, especially during periods of surplus production (Sejanamane *et al.*, 2018). These losses not only affect food security but also reduce farmers' incomes and profitability.

Given the mentioned challenges, understanding and enhancing the productivity of tomato farming in the African context is crucial for sustainable development and poverty alleviation (FAO, 2022). Also, enhancing the productivity of tomatoes in Africa requires a holistic approach to addressing agronomic, socio-economic, and environmental challenges (Mugendi *et al.*, 2020). By addressing challenges and leveraging recent trends, African countries can unlock the full potential of these crops to improve livelihoods and food security across the continent.

1.2 Statement of the problem

The National Strategic Development Plan II of 2018/19-2022/23 indicates that Lesotho's farmers through the Ministry of Agriculture got a financial boost from different fund projects to change their produce and improve productivity (National Strategic Plan, 2022). These are projects like the Smallholder Agriculture Development Project (SADP-II) and Enhanced Integrated Framework (EIF). The purpose of the Smallholder Agriculture Development Project is to empower smallholder farmers to improve their incomes, food security, and livelihoods through sustainable and profitable horticultural production. It supports smallholder farmers through capacity building, access to inputs, infrastructure development, market linkages, value addition, financial support, sustainability, gender, and social inclusion by ensuring the participation and empowerment of women and marginalized groups in horticultural value chains through targeted interventions.

Furthermore, the Enhanced Integrated Framework (EIF) which is a multi-donor program established to support the least developed countries (LDCs) in leveraging trade for their sustainable development has been assisting Lesotho by harnessing the potential of its horticultural sector for sustainable development, poverty reduction, and integration into the global economy. It has been supporting trade-related capacity building, policy reforms, and infrastructure development. The EIF contributes to improving the competitiveness and resilience of horticultural value chains in the country.

Horticulture plays a vital role in the agricultural sector, contributing significantly to food security, income generation, and overall economic development (Alene *et al.*, 2021). According to the Horticulture Statistics Report of 2017/2018, the agriculture sector is one of the main sources of employment in Lesotho (Bureau of Statistics, 2019). The sector is important in curbing the ever-increasing demand for employment in both urban and rural areas, as well as increasing domestic production to boost economic development. However, despite its potential and the different forms of support it is being afforded, the productivity level among horticulture farmers in Lesotho, particularly in Leribe, continues to be low (Lekonyane *et al.*, 2019). This situation has led to the study seeking to identify factors that influence technical efficiency among tomato farmers in the district of Leribe.

1.3 Research Objectives of the study

1.3.1 Main objective of the study

To investigate factors limiting technical efficiency among horticulture farmers in the Leribe district of Lesotho

1.3.2 Specific objectives of the study

i. To identify factors that influence technical efficiency among horticulture farmers in Leribe district.

ii. To evaluate the technical efficiency of horticulture farmers in Leribe

1.4 Research questions

i. What are the factors influencing technical efficiency among horticulture farmers?

ii. Are horticulture farmers in the Leribe district technically efficient?

1.5 Study Hypothesis

H_0 There are no factors affecting productivity in Leribe

H_1 There are factors affecting productivity in Leribe

1.6 Significance of the study

A recent horticulture report of 2019 showed that there is a decline in horticulture products like tomatoes and cabbage in Lesotho (Bureau of Statics, 2019). Considering this, there is a need to solve this problem by policymakers, scholars, and farmers as well. This current study may contribute significantly to factors influencing the productivity of horticulture farmers in different ways. Currently, though there are many studies about horticulture products, most of them do not show clearly the factors influencing productivity in the midst of climate change and new technology in the country. The study is important because it analyses problems that need to be addressed in understanding factors influencing the productivity of horticultural farmers from sustainable agriculture. Through addressing these challenges, the study aims to provide a comprehensive, evidence-based understanding of the factors that impact the productivity of tomato farming in the country. The resulting findings and recommendations may guide policymakers, researchers, and practitioners in the formulation of effective strategies and policies to enhance productivity within the horticulture sector in Leribe.

1.7 Limitations of the study

The effectiveness of the study was compromised by non-contact with resourceful respondents who may be in the fields or are attending agricultural workshops.

1.7.1 Mitigation measures

The researcher ensured that questions were straightforward, unambiguous, and easy to understand for the respondent. Mitigating the risk of non-contact with resourceful respondents, even those who were in the fields or attending agricultural workshops, the researcher made a combination of strategic planning, flexible scheduling, and effective communication. The researcher scheduled multiple attempts to reach respondents at different times and days, including weekends or evenings.

1.8 Delimitation of the study

Although this study analyzed factors influencing horticultural production, the scope was limited to tomatoes. This limitation excludes insights into all commodities produced by the horticultural sector in the district, potentially missing out on the challenges and opportunities unique to other crops and areas. In addition, due to budget constraints, this study did not cover the whole district and the focus was only on the urban areas of Leribe district.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter reviews the relevant literature related to factors that influence technical efficiency among horticultural farmers in Lesotho at Leribe district. The chapter consists of nine themes: definition of horticulture farming, horticulture farming in different contexts, importance of tomatoes in horticulture farming, challenges facing horticulture farming, definition of technical efficiency, technical efficiency among horticultural farmers, definition of productivity and agricultural productivity, factors influencing agricultural productivity and lastly strategies to enhancing agricultural productivity in different contexts.

2.1 Definition of Horticultural Farming

Horticultural farming involves the intensive cultivation of a wide range of crops, including fruits, vegetables, ornamental plants, herbs, and flowers, often on a smaller scale compared to conventional agriculture (Adams and Egel, 2019). It encompasses various production systems, from open-field cultivation to greenhouse and hydroponic production and relies on specialized knowledge and techniques to manage crops efficiently.

2.2 Horticultural farming in different contexts

The global leader in horticultural production and consumption is China, with a staggering production volume exceeding 616 million metric tons. India came in second with about 138 million metric tons of fresh vegetables (Shahbaneh, 2024). Based on the volume of vegetables produced worldwide in 2022, tomatoes were the most popular vegetable. The majority of horticulture products, such as tea, mushrooms, melons, vegetables, flowers, and traditional Chinese herbal medicine, are produced in China (Chen, 2018). One of the most significant agricultural subsectors in China is the horticulture sector. That is the most focal strategy for boosting farmer incomes and decreasing poverty in China. Producing vegetables brought in more than $160 million for Chinese farmers in 2016, which accounted for 10% of the farmers' net revenue per capita (Chen, 2018).

Moreover, India's horticultural output has increased dramatically during the last 20 years, placing it second in the globe only after China (Mitra and Panda, 2020). India's horticultural industry has the ability to produce a variety of revenue streams, which would accelerate the nation's economic expansion (Singh *et al.*, 2017). Horticulture boosts the Indian economy and exports, according to research (Maertens *et al.*, 2012). Furthermore, research by Jha *et al.* (2019) demonstrates that horticulture raised consumer spending power and reduced the market demand for fruits and vegetables in India.

Moreover, horticulture is a common practice in Africa, where a broad variety of fruits, vegetables, ornamental flowers, herbs, and species are grown, used, and preserved. Additionally, horticulture is widely practiced in Africa, where a great variety of fruits, vegetables, ornamental flowers, herbs, and other plants are cultivated, used, and sold both domestically and beyond (Mwangi, 2022). The horticultural industry in Africa has grown significantly in recent years due to advancements in research, the adoption of new technologies, the regulatory framework, and industrial expansion, among other factors. In sub-Saharan Africa, they are produced in the backyard of nearly every homestead for domestic consumption. They are a valuable cash crop for medium-sized commercial farmers as well as smallholders, and they are a major source of vitamins. Also, in a study by Maliwichi *et al.,* (2014) it is stated that tomatoes are grown commercially wherever agronomic conditions permit. Tomato, both for processing and fresh market has become one of the most important crops in agriculture for smallholder farmers in South Africa (Anang *et al.*, 2013).

Horticultural crops have been grown in Kenya for export as well as home markets. The majority of the large-scale, export-focused horticultural farms that grow fruits, flowers, and vegetables were found in the 1980s. Consequently, the agriculture sector's second-largest source of foreign exchange earnings is horticulture production. Therefore, horticultural production is the second most important foreign exchange earner in the agricultural sector in Kenya after tea (Mwangi, 2016). In South Africa, tomatoes are among the most extensively grown horticulture crops, according to Maliwichi *et al.,* (2014).

2.3 Importance of tomatoes in Horticultural Farming

Tomatoes are a cornerstone in horticulture farming, influencing both economic and research landscapes while providing essential nutrition and employment opportunities globally. Horticultural farming plays a pivotal role in global agriculture, contributing significantly to food security, economic development, environmental sustainability, and human well-being (FAO, 2020).

2.3.1 Contribution to Food Security

Horticultural crops, including fruits, vegetables, herbs, and ornamental plants, provide essential nutrients and dietary diversity, addressing malnutrition and improving public health (FAO, 2019). These crops are often high in essential vitamins, minerals, and antioxidants, offering a crucial defence against various diseases (Nuti *et al.,* 2020). Their shorter production cycles allow for quicker responses to changing market demands and climatic conditions, enhancing resilience against food shortages (FAO, 2020).

2.3.2 Economic Development

Horticultural farming fosters rural employment and income generation, especially in developing countries, where smallholder farmers dominate production (Akinnifesi *et al.,* 2010). The sector offers diverse opportunities along the value chain, including production, processing, distribution, and marketing, contributing to poverty reduction and livelihood improvement (Shiferaw *et al.,* 2014). High-value horticultural products often fetch premium prices in local and international markets, promoting economic growth and trade (FAO, 2017).

2.3.3 Environmental Sustainability

Compared to traditional monoculture, horticultural farming practices, such as intercropping, crop rotation, and agroforestry, enhance soil fertility, water conservation, and biodiversity (Guzmán *et al.,* 2018). Integration of horticultural crops with livestock and aquaculture systems promotes ecological balance, reduces greenhouse gas emissions, and mitigates climate change impacts (Kumar *et al.,* 2018). The adoption of sustainable production techniques, including organic farming and integrated pest management, minimizes chemical inputs and environmental pollution (Drozdowska *et al.,* 2021).

2.3.4 Human Well-being

Horticultural activities, such as gardening and landscaping, have therapeutic benefits, promoting physical health, mental well-being, and community cohesion (Soga *et al.,* 2017). Access to fresh fruits and vegetables from home gardens or local markets improves dietary habits, reduces chronic diseases, and enhances overall quality of life (Soga *et al.,* 2019). Horticultural therapy programs are increasingly recognized for their positive effects on individuals with disabilities, mental health disorders, and cognitive impairments (Detweiler *et al.,* 2012).

2.4 Challenges facing Horticultural farming

Despite its significance, horticultural farming encounters various challenges that hinder its potential contribution to food security, economic development, environmental sustainability, and human well-being (Frimpong and Bagah, 2019).

2.4.1 Climate Change

Climate unpredictability and environmental conditions including droughts, floods, and degraded soil pose a serious threat to horticultural farming. Increasing temperatures, erratic rainfall patterns, and extreme weather events pose significant risks to horticultural production systems (FAO, 2019). Shifts in climatic conditions affect crop phenology, water availability, and pest, and disease dynamics, leading to yield losses and reduced crop quality (Drozdowska *et al.,* 2021). Vulnerability to climate change impacts varies across regions and crops, worsening inequalities and threatening livelihoods, particularly in low-income countries (Wheeler and von Braun, 2013). Climate-smart agricultural practices and adaptation strategies are necessary to mitigate these risks and enhance resilience (Gassner *et al.*, 2019; Akpan and Zikos, 2023).

2.4.2 Access to Inputs and Resources

Productivity is greatly impacted by the availability of high-quality seeds, fertilizers, insecticides, and other agricultural inputs. Farmers' ability to increase yields may be hampered by the limited availability and cost of these inputs (African Development Bank Group, 2019). Pests, pathogens, and invasive species pose persistent threats to horticultural crops, causing substantial yield losses and economic damage (Gurr *et al.,* 2016). Development of resistance to pesticides, limited availability of effective control measures, and globalization contribute to the spread and emergence of new pests and diseases (Singh *et al.*, 2020; Vrchota *et al.*, 2022). Sustainable pest and disease management strategies, including integrated pest management (IPM) and biocontrol, require interdisciplinary approaches and capacity building (Gupta *et al.*, 2020; Kwon *et al.*, 2021; Malhi *et al.*, 2021; Wang *et al.*, 2021; Khangura *et al.*, 2023).

2.4.3 Market Access and Trade Barriers

Inadequate infrastructure, including poor roads and market facilities, can hinder farmers' access to markets and increase post-harvest losses. Smallholder horticultural farmers often face challenges in accessing markets, including inadequate infrastructure, information asymmetry, and stringent quality standards (Ali *et al.*, 2021; Cao *et al.*, 2023). Limited access to modern farming techniques, inadequate infrastructure, lack of financial resources, and low levels of technological adoption pose significant barriers (Addison *et al.*, 2022; Akpan and Zikos, 2023). Trade barriers, tariffs, quotas, and sanitary and phytosanitary regulations impose added constraints on export-oriented horticultural enterprises, particularly in developing countries (Bhalla and Qiu, 2016; Khan *et al.*, 2021; Rosário *et al.*, 2022).

Improving infrastructure and market linkages is essential for enhancing productivity and profitability (World Bank, 2018; EU, 2021). Strengthening market linkages, enhancing value addition, and promoting fair trade practices are essential for improving market access and competitiveness (Gómez-Limón and Gómez-Ramos, 2014; CGIAR, 2020; Blakeney, 2022).

2.4.4 Land Tenure and Access

For horticulture farming, access to land and secure land tenure are essential. In Lesotho, issues such as insecure land rights and land fragmentation can impede horticulture farming by limiting farmers' ability to invest in their land (FAO, 2016). Competition for land and water resources, urbanization, and land degradation threaten the sustainability of horticultural farming systems (FAO, 2021).

2.4.5 Knowledge, Labor Conditions and Technology Adoption

Access to agricultural extension services and technology adoption is crucial for enhancing productivity in the agricultural sector. Horticultural farming relies heavily on manual labor, often sourced from marginalized communities, migrants, and informal workers (Frimpong and Bagah, 2019). Labor shortages, due to demographic shifts, rural-urban migration, and changing socio-economic dynamics, increase production costs and affect horticulture farm productivity (Martin, 2018). Improving labor conditions, ensuring fair wages, and providing social protection are essential for promoting decent work and inclusive growth in the horticultural sector (Lang, 2017). Farmers' knowledge of modern farming techniques, such as irrigation methods and pest management practices, directly influences their horticulture yields (Makhakhe, 2020).

2.4.6 Policy and Institutional Support

Effective policies and institutional support are crucial for promoting horticultural productivity. Government interventions, including subsidies, credit facilities, and market regulations, can positively influence farmers' access to inputs and markets (Ministry of Agriculture and Food Security, 2017). According to Mathagu (2016), the adoption of policies that are not commodity-based affects horticulture farming.

2.5 Definition of Technical Efficiency

The concept of technical efficiency encompasses the capacity of a firm or production process to generate the highest possible output from a specific set of inputs. It measures the effectiveness with which inputs are converted into outputs without considering the cost of inputs or the output price (Emrouznejad and Yang, 2020).

2.5.1 Aspects of Technical Efficiency in Tomato Farming

Technical efficiency in horticulture farming involves optimizing the use of inputs (e.g., land, water, labor, fertilizers) to achieve maximum output (e.g., fruits, vegetables, flowers).

2.5.1.1 Input Utilization

Efficient use of inputs such as seeds, fertilizers, pesticides, water, and labor are critical. Precision agriculture technologies can help in applying the right amount of inputs at the right time, reducing waste and costs (Zhang and Wang, 2021). Li and Ren (2022) indicated that integrating precision farming techniques can lead to significant improvements in input efficiency in horticulture.

2.5.1.2 Irrigation Management

Effective irrigation strategies are crucial for horticulture, which often involves crops with high water requirements (Pereira and Paredes, 2021). Techniques like drip irrigation and the use of soil moisture sensors can enhance water use efficiency. According to Rodríguez-Díaz and Camacho-Poyato (2021), proper irrigation management can significantly improve crop yield and quality while conserving water resources.

2.5.1.4 Crop Selection and Rotation

When aiming to improve soil health and productivity, it is essential to carefully select appropriate crop varieties and enact crop rotation practices (Smith *et al.*, 2021). This leads to better resistance to pests and diseases and improves long-term soil fertility. Lal (2021) indicated that crop rotation and diversity in horticulture farming can lead to higher yields and reduced input needs.

2.5.1.5 Labor Management

Efficient labor management involves optimizing labor use through training and adopting mechanization where feasible (Chavas and Nauges, 2020). This reduces labor costs and improves productivity. According to Touliatos and Dodd (2020), skilled labor is a key driver of efficiency in horticulture farming.

2.5.1.6 Pest and Disease Control

Integrated Pest Management (IPM) practices that combine biological, cultural, physical, and chemical tools can effectively control pests and diseases, reducing the need for chemical inputs and improving crop health (Kogan and Bajwa, 2021). Also, Ehler (2021) supported this viewpoint by showing that IPM can lead to better crop health and yields, thereby enhancing technical efficiency.

2.5.1.7 Technology Adoption

The adoption of technologies such as greenhouse farming, hydroponics, and vertical farming can significantly enhance the efficiency of resource use in horticulture (Henten and Hemming, 2020). Technological advancements in horticulture have been shown to improve productivity and sustainability.

2.5.1.8 Soil Management

Proper soil management practices, including regular soil testing, appropriate fertilization, and the use of organic amendments, are essential for maintaining soil fertility and structure (Lal, 2021). This researcher indicated that soil management practices directly influence the productivity and efficiency of horticultural crops.

2.6 Technical inefficiency among horticultural farmers

The analysis of technical inefficiency variables is especially important as it provides insight into the significant impact of inefficiency on both production variability and level. Tolesa *et al.* (2019) highlighted that identifying the socio-economic factors contributing to technical inefficiency is as vital as determining the level of efficiency. Total Factor Productivity (TFP) is a measure of efficiency in the use of all inputs (such as labor, land, capital, etc.) in the production process. It reflects how effectively resources are used to generate output. In the context of socioeconomic factors influencing technical inefficiency, TFP can help explain the variations in efficiency across different households. The specific variables like age, education level, farming experience, and family size relate to TFP and technical inefficiencies. The study suggests that various socioeconomic factors, such as the age and education level of the household head, farming experience, family size, among others, influence the degree of technical inefficiency. It is important to note that a negative relationship indicates a decrease in technical inefficiency and, consequently, an increase in overall efficiency.

2.6.1 Age of household head

According to Rahman *et al*. (2019),age can have both positive and negative effects on productivity. Younger farmers might adopt new technologies more readily, increasing TFP through better farming practices. On the other hand, older farmers might have more experience and knowledge, which can also lead to higher productivity, but they may be resistant to innovation, which can limit improvements in TFP. As farmers age, physical ability and adaptability to new techniques may decline, leading to increased inefficiency. However, experience may counterbalance this if older farmers can leverage traditional knowledge effectively. Technical inefficiency tends to decrease with age among farmers, implying that older farmers may be less inefficient than their younger counterparts due to their greater experience and access to resources (Leake *et al.,* 2018). In contrast, Sonny (2020) indicated that older farmers might be less technically proficient than younger ones, possibly because of a reluctance to adopt modern technologies. Despite these conflicting perspectives, the majority of evidence supports the idea that increasing age is generally associated with reduced technical inefficiency.

2.6.2 Level of education

Ali *et al*. (2018) indicated that education generally has a positive effect on TFP, as better-educated farmers are more likely to adopt advanced farming technologies, better management practices, and efficient resource use. They are also better equipped to understand and apply modern agricultural techniques, improving overall productivity. Lower levels of education are associated with higher technical inefficiency because of limited access to information and difficulty in adopting new technologies. On the other hand, educated farmers can reduce inefficiencies by optimizing input use and responding better to market changes. A study by Montle (2016) argues that technical inefficiencies in farming are linked to the level of educational attainment. Their research indicates that farmers with higher education levels tend to adopt more efficient and productive agricultural practices, likely due to their ability to embrace new technologies. Conversely, Mkhabela (2023) presents an opposing view, suggesting that higher education may actually lead to increased technical inefficiency, as more educated farmers often engage in part-time farming and have alternative income sources. This debate highlights the complex and context-dependent nature of the relationship between education and technical inefficiency in agriculture.

2.6.3 Farming experience

Mkhabela (2023) showed that more experienced farmers tend to have a better understanding of the nuances of their land, crops, and environmental conditions, which can enhance productivity. Experience allows farmers to optimize their use of inputs, reduce waste, and apply effective farming techniques learned over time. Lack of experience can lead to inefficient farming practices, as less experienced farmers may not be familiar with the best methods for improving yield or conserving resources. However, too much reliance on traditional methods by experienced farmers without openness to innovation can also contribute to inefficiency. Also, Ogundari *et al.* (2016) found that more seasoned farmers are typically more economical than less seasoned ones, suggesting that experience affects production efficiency by improving the farmers' capacity to gather and analyze data. Chirwa (2023) and Bellouni and Matoussi (2016), on the other hand, discovered that knowledge of farming actually improves technical efficiency. This is because knowledgeable farmers are more likely to accept new technologies, which raises production efficiency while lowering technical inefficiencies.

2.6.4 Family size

Studies by Amos (2017) disclosed that larger family size can increase the availability of labor for farm activities, potentially enhancing productivity, especially in labor-intensive farming systems. More family members can contribute to tasks like planting, weeding, and harvesting, which may help to reduce the need for hired labor and control costs. However, if family labor is not properly trained or managed, larger family sizes may lead to inefficiencies. Over-reliance on family labor without proper organization or investment in labor-saving technologies could result in lower TFP due to poor resource allocation (Mushunje *et al.*, 2023).Maintaining larger family sizes is primarily done to make sure there is a sufficient workforce available during periods of high production, which eventually improves technological efficiency.

On the other hand, Mushunje *et al.* (2015)'s study produced conflicting results about the technical proficiency of cotton farmers in Zimbabwe's Manicaland province. Larger families were linked to higher levels of technical inefficiency for communal area farmers, according to the research, especially for those with big polygamous households that average eight members. Small children in this situation need their mothers' attention, it is difficult for the moms to work full-time in the fields, which lowers their technical efficiency. According to Tijani (2016), larger families may have a detrimental effect on technical efficiency, contingent on the active participation of family members in farming activities. This lends credence to the idea that family size might exacerbate technical inefficiency.

2.6.5 Extension contacts and farmers’ training class

Extension agents play a critical role in facilitating information flow between research institutions, policymakers, and farmers, which is essential for agricultural development and the reduction of technological inefficiencies. In areas including input supply, marketing, and resource sharing, farmers can work together more effectively when extension professionals are involved. Farmers with access to agricultural extension services can improve their productivity by learning about new farming techniques, pest control methods, and market trends. These services help to increase TFP by providing knowledge that optimizes input use and farming practices. Limited access to extension services contributes to higher technical inefficiency because farmers may not be aware of more efficient practices or inputs that could boost their output. Nonetheless, obstacles like unfavorable institutions, insufficient funding, a lack of skills, and low desire frequently restrict the influence of agricultural extension on development (Dunkhorst and Mollel, 2019). According to Mkhabela (2023), there is a lack of extension contacts and farmers' training courses. This suggests that boosting farm visits and training can improve farmers' abilities and acceptance of technology while also reducing inefficiencies. However, the provision of extension services remains a vital component in raising agricultural output.

2.6.6 Credit and off-farm income

Research by Tchale and Sauer (2020) showed that farmers with better access to capital or credit are more likely to invest in modern inputs (such as high-quality seeds, fertilizers, or machinery), which can enhance productivity and improve TFP. Capital allows for more efficient use of inputs and enables the adoption of new technologies that reduce inefficiencies. Access to capital is essential for small-scale farmers to sustain their operations and cover necessary expenses. Kibaara (2018) mentioned that limited access to capital can increase technical inefficiency, as farmers may struggle to afford inputs or tools that would otherwise improve productivity. This can result in suboptimal production methods and resource use, leading to higher inefficiency levels. Due to limited equity capital, these farmers often resort to borrowing, leading to debt accumulation.

In developing countries, most farmers face significant challenges in obtaining loans from traditional financial institutions, such as banks, which typically require substantial collateral and a strong credit history criterion that many small-scale farmers lack. A 2022 study by Mochebelele and Winter-Nelson on migrant labor and farm technical efficiency in Lesotho found that farmers who sent laborers to work in South African mines were more efficient than those who did not. Notably, migrant labor constituted 80% of factor income in Lesotho between 1983 and 1989. Additionally, Tijani (2019) demonstrated that factors related to credit access and off-farm income contributed to reducing technical inefficiency and enhancing technical efficiency among farmers. Consequently, improving access to credit for farmers could be a key strategy for boosting agricultural productivity.

2.6.7 Technological adoption

Technological adoption significantly influences technical efficiency among horticultural farmers by enhancing productivity, reducing input wastage, and improving crop quality and total factor productivity(TFP) (Abdulai, 2022). The adoption of precision agriculture tools, such as GPS-guided equipment, soil sensors, and drones, has been shown to improve efficiency by optimizing input use (water, fertilizers, and pesticides). These technologies allow farmers to make data-driven decisions, resulting in improved resource management and higher yields. Information and Communication Technologies (ICT), such as mobile apps and online platforms, make it easier for farmers to access market information, weather forecasts, and best practices in crop management. This reduces uncertainty and helps farmers to plan and execute their activities more efficiently (Mittal and Mehar, 2016). Adopting greenhouse technology helps in controlling the growing environment, leading to higher and more consistent yields. Greenhouses protect crops from adverse weather conditions and pests, reducing losses and improving resource use efficiency (Vanthof and Glover, 2020).

Using improved crop varieties that are resistant to pests and diseases or that have higher yield potential can significantly enhance technical efficiency (Di Falco and Chavas, 2019) These varieties often require fewer inputs and produce more output, thus improving the overall efficiency of the farming operation. Also, the use of machinery for planting, harvesting, and other farm operations reduces labor costs and increases the speed and precision of these tasks (Adeoti and Oyewole, 2020) Mechanization is associated with higher efficiency due to reduced time and labor input per unit of output.

2.7 Definition of productivity and agricultural productivity

Productivity in horticulture farming denotes the efficiency of resources used to produce horticultural crops, measured by yield per unit area or input (FAO, 2020). It encompasses factors like crop selection, cultivation techniques, irrigation methods, Pest and disease management, and post-harvest handling (Acquaah, 2019). Campbell *et al.* (2013) defines productivity as the efficiency with which inputs such as labor, water, and capital are utilized to produce horticultural crops. It encompasses the yield and quality of harvested crops per unit area or unit of input. Partial factor productivity is the term for when one input is paired with one or more outputs. Increasing productivity per unit of land area is essential for overcoming barriers to achieving food security, according to Ajibefun (2022), particularly since the majority of cultivable land cannot be extensively converted owing to technological or physical limitations.

Agricultural productivity is a measure of the quantity of agricultural output generated for a given number of inputs (Aminadokiari, 2019). Agricultural productivity is defined as the ratio of agricultural outputs to inputs, and the output is commonly measured as the final market value of the production, omitting intermediate goods (Ibitola *et al.,* 2019; Olajide and Omonona, 2019). Many academics from diverse fields have characterized agricultural production. Different interpretations have been made of it by geographers, economists, agronomists, and agriculturalists. In agricultural geography and economics, agricultural productivity is defined as "output per unit of input" or "output per unit of land area," and the improvement in agricultural productivity is generally considered to result from a more efficient use of the factors of production physical, socioeconomic, institutional, and technological (Onogwu, 2017).

2.8 Factors Influencing Agricultural Productivity

Agricultural productivity plays a critical role in ensuring global food security and economic prosperity, particularly in the face of increasing challenges such as climate change, population growth, and resource scarcity (Jabareen *et al.,* 2021). Understanding the factors influencing agricultural productivity is critical for developing real policies and strategies to sustainably enhance food production while safeguarding natural resources and livelihoods.

2.8.1 Technological innovation

Technological innovations have become a key catalyst in transforming sustainable agriculture worldwide (Khan *et al.,* 2021; Javaid *et al.,* 2022). These advancements include various approaches such as precision agriculture, remote sensing, sensor technologies, digital platforms, and data analytics. They offer significant potential to reshape traditional farming methods, optimize resource utilization, minimize environmental impacts, and enhance overall agricultural sustainability (Triantafyllou *et al.,* 2019; Bayih *et al.,* 2022; Mouratiadou *et al.,* 2023).Therefore, technological advancements have transformed agricultural practices, offering new opportunities to boost productivity. Also, the adoption of precision agriculture, genetically modified organisms (GMOs), and advanced machinery has shown promising results in increasing yields and enhancing resource use (Spielman *et al.,* 2018). However, sustainable agricultural productivity hinges not only on technological innovation but also on soil health and water management. Degraded soils and water scarcity pose substantial constraints on agricultural output, requiring holistic approaches such as conservation agriculture and efficient irrigation systems (Gicheru *et al.,* 2019).

2.8.2 Adoption of improved practices

The adoption of improved practices is essential for enhancing productivity across various sectors. In agriculture, the adoption of improved practices such as precision agriculture, the use of high-yield crop varieties, and efficient irrigation techniques has led to significant increases in productivity (Gollin *et al.,* 2020). For example, the adoption of drought-resistant crop varieties has helped farmers mitigate the impact of climate change and increase yield stability (Lobell *et al.,* 2014). The adoption of sustainable practices not only helps the environment but also enhances productivity in the long run. Practices such as energy efficiency, waste reduction, and recycling not only reduce costs but also improve operational efficiency and brand reputation (Porter & Kramer, 2019). Moreover, pests, diseases, and weeds continue to threaten agricultural productivity, emphasizing the importance of integrated pest management (IPM) strategies and resilient crop varieties (Savary *et al.,* 2019; Srinivasan *et al.,* 2018).

2.8.3 Access to inputs and credit

Access to quality inputs such as improved seeds, fertilizers, and pesticides significantly affects agricultural productivity (Duflo *et al.,* 2018). Farmers with access to high-quality inputs can achieve higher yields, reduce crop losses, and improve income levels. Additionally, access to machinery and irrigation facilities enhances efficiency in farm operations, further boosting productivity (Jin *et al.,* 2020). In the business sector, access to inputs such as raw materials, technology, and skilled labor directly affects productivity levels (McKinsey Global Institute, 2021). Companies that can source quality inputs efficiently and affordably are better positioned to improve production processes, minimize costs, and deliver high-quality products and services.

Access to credit is crucial for both agricultural and non-agricultural sectors, enabling farmers and entrepreneurs to invest in inputs, machinery, technology, and infrastructure (Foltz *et al.,* 2019). Adequate credit helps prompt purchases of inputs and enables expansion and diversification of business activities, ultimately enhancing productivity. Access to inputs and credit is particularly vital for smallholder farmers and microenterprises in low-income countries. Studies show that targeted interventions aimed at improving access to inputs and credit among these groups can lead to substantial increases in productivity and income (Bernard *et al.,* 2020). Government policies and interventions play a key role in enhancing access to input and credit. Initiatives such as subsidy programs, extension services, rural infrastructure development, and financial inclusion schemes can improve accessibility and affordability of inputs and credit, thereby stimulating productivity growth (World Bank, 2021).

2.8.4 Infrastructure development

Infrastructure development plays a critical role in driving economic growth and productivity by supplying essential facilities and services (Fuglie, 2020). Investments in transportation infrastructure, such as roads, railways, ports, and airports, reduce transportation costs, enhance connectivity, and help the movement of goods and people (Bhattacharyya and De, 2019). Improved transportation infrastructure lowers logistics costs, reduces delivery times, and enables businesses to access larger markets, thus boosting productivity. Reliable and affordable energy infrastructure, including electricity generation, transmission, and distribution networks, is vital for powering industrial activities and supporting economic growth (International Energy Agency, 2021). Access to modern energy sources enhances productivity by enabling businesses to use machinery, utilize technology, and meet production demands efficiently.

The development of digital infrastructure, such as broadband networks, internet connectivity, and digital platforms fosters innovation, communication, and collaboration (World Bank, 2020). Access to digital infrastructure enables businesses to use digital technologies, expand market reach, and enhance operations, leading to productivity gains. Investments in water supply and sanitation infrastructure improve public health, enhance quality of life, and support economic activities (World Health Organization, 2021). Access to clean water and sanitation facilities reduces disease burden, increases workforce participation, and enhances productivity in sectors such as agriculture, manufacturing, and services. Social infrastructure, including schools, hospitals, and community centers, plays a crucial role in human capital development and well-being (Organization for Economic Cooperation and Development, 2019). Quality social infrastructure supports education, healthcare, and social services, contributing to a healthy, skilled workforce and higher productivity levels.

2.8.5 Institutional support, and policy environment

Institutional support and a conducive policy environment are critical for fostering productivity growth and economic development (World Bank, 2020). A favorable regulatory environment characterized by clear and transparent regulations, efficient administrative procedures, and regulatory stability promotes business growth and productivity (World Bank, 2021). Streamlined regulations reduce compliance costs, bureaucratic delays, and uncertainty, enabling businesses to use more efficiently and innovate. Institutional support for access to finance, including well-functioning banking systems, capital markets, and financial inclusion initiatives, is essential for entrepreneurship and business expansion (Beck *et al.*, 2019). Access to finance enables firms to invest in technology, machinery, and human capital, leading to productivity improvements and economic growth.

Moreover, investments in institutional capacity building, including public administration reforms, training programs, and governance initiatives, improve the effectiveness and efficiency of public institutions (World Bank, 2020). Strengthened institutional ability enables governments to formulate and implement policies that support productivity-enhancing activities and foster inclusive growth. Institutional support for innovation, research, and development (R&D) funding, technology transfer, and intellectual property protection stimulates productivity growth and competitiveness (European Commission, 2021). Policies that incentivize innovation and technology adoption encourage firms to invest in new technologies, processes, and products, driving productivity gains.

Investments in agricultural research and development (R&D), extension services, education, and rural infrastructure play crucial roles in enhancing agricultural productivity and promoting sustainable agricultural growth (Pardey *et al.*, 2016). Also, policy and governance frameworks shape agricultural productivity outcomes. Government policies, subsidies, and trade regulations significantly influence farmers' decisions and investments in productivity-enhancing measures (Goyal *et al.*, 2020).

2.8.6 Climate variability

Agriculture is highly susceptible to climate variability, with changes in temperature, precipitation patterns, and extreme weather events significantly affecting crop yields and overall productivity

(Lesk *et al.,* 2016). Recent studies highlight the increasing frequency and intensity of climate-related disruptions, emphasizing the urgent need to understand their impact on agricultural systems (IPCC, 2021). Rising temperatures can lead to heat stress in crops, affecting physiological processes such as photosynthesis and respiration, and ultimately reducing yields (Wheeler and von Braun, 2013). Again, recent research by Lobell *et al.* (2020) shows that even small temperature increases can have substantial negative effects on staple crops like wheat and maize.

Studies by Li *et al.*, (2018) show that changes in rainfall patterns worsen water stress in agricultural regions, affecting crop growth and yield stability. Recent events like the heatwave in Europe in 2019 have highlighted the vulnerability of agriculture to extreme heat, resulting in substantial yield losses across various crops (Easterling *et al.,* 2020). Integrated approaches combining climate forecasting, agronomic practices, and policy interventions are crucial for enhancing agricultural resilience in the face of climate change (Ray *et al.,* 2019). Climate variability poses significant challenges to agricultural productivity, with recent research underscoring the urgent need for adaptive strategies and policy interventions to safeguard global food security (IPCC, 2021).

2.9 Strategies enhancing horticultural productivity in different contexts

Horticultural productivity is critical for ensuring food security, improving nutrition, enhancing livelihoods, and promoting sustainable development. Implementing strategies at global, continental, and regional levels can effectively address challenges and maximize opportunities for enhancing horticultural productivity (UNECA, 2019).

International collaboration and partnerships are essential for sharing knowledge, technologies, and best practices to enhance horticultural productivity globally (FAO, 2019). Promoting research and development initiatives, such as the Consultative Group on International Agricultural Research (CGIAR), fosters innovation and technology transfer in horticultural production systems (CGIAR, 2021). Advocating for policies and investments that prioritize horticultural research, extension services, and infrastructure development on the global agenda can catalyze productivity improvements (EU, 2020 and (ASEAN) (2021). Smallholder farmers in Bangladesh have increased horticultural productivity through the adoption of modern technologies such as drip irrigation, greenhouse cultivation, and precision farming (Rana *et al.* (2023). In China, diversification into high-value horticultural crops such as fruits and vegetables has enhanced farm income and reduced vulnerability to market fluctuations (Li and Pramanik (2022).

Regional economic communities such as the African Union (AU) and the European Union (EU), play crucial roles in coordinating horticultural development strategies, harmonizing regulations, and easing trade (UNECA, 2019; European Commission, 2020). Establishing regional centers of excellence, research networks, and capacity-building programs enhances the technical ability and promotes knowledge sharing among countries within the same continent (AU-IBAR, 2016). Implementing regional seed policies, quarantine measures, and phytosanitary standards helps the exchange of high-quality planting materials and reduces the spread of pests and diseases (COMESA, 2015). Also, implementing Integrated Pest Management (IPM) strategies, including biological control, cultural practices, and resistant varieties, has reduced pesticide use and increased yields in Nigerian horticultural systems (Suleiman and Bello, 2023). Arid regions can improve horticultural productivity by adopting sustainable water management practices like rainwater harvesting, mulching, and efficient irrigation techniques (Singh and Singh, 2023).

Sub-regional organizations and alliances, such as ASEAN (Association of Southeast Asian Nations) and SADC (Southern African Development Community), help cooperation, resource sharing, and joint initiatives to improve horticultural productivity (ASEAN, 2021; SADC, 2019). Supporting smallholder farmers through regional value chain development initiatives, access to credit, market linkages, and technology adoption programs strengthens their resilience and productivity (IFAD, 2017). Investing in regional infrastructure, including transportation networks, market facilities, and irrigation systems, improves market access and reduces post-harvest losses, promoting horticultural producers and consumers alike (ADB, 2016). Again, market-led interventions, such as creating producer cooperatives, improving post-harvest handling, and developing market linkages, have enabled access to markets and enhanced horticultural productivity in Ghana (Amoah and Obour, 2023).

In summary, the review of literature on factors influencing technical efficiency among tomato farmers in Leribe, Lesotho, highlights several key determinants, including socioeconomic, institutional, and environmental factors. Education, farming experience, access to extension services and credit, as well as proximity to technological adoption, are key drivers of efficiency. Improving these factors through targeted interventions could enhance productivity and reduce inefficiencies, leading to higher yields and profitability for tomato farmers in Leribe. Tomato farming, a significant horticultural activity in Lesotho, plays a crucial role in both household income generation and food security. However, variations in technical efficiency among farmers affect productivity and profitability.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter aims to detail the methodology used and the data sources relied upon for the study. It covers the main aspects, including the study's geographical location, research design, target population, sampling methods and sample size, data collection procedures and sources, as well as data analysis techniques. Additionally, it outlines the approaches employed to ensure the validity and reliability of the research instruments.

3.2 Selection of the Study Area

3.2.1 Geographical areas of the study

Lesotho is a landlocked country found in Southern Africa, with which it shares its entire land boundary. It is found at geographic coordinates approximately 29.61° S latitude and 28.23° E longitude with an area of approximately 30,355 square kilometers (11,720 square miles), making it one of the smallest countries in Africa (Snyman, 2020).

Lesotho is divided into four agro ecological zones (figure 2), namely, mountains (59%), foothills (15), lowlands (17%) and the senqu river valley (9%). Administratively, the country is divided into ten districts (Butha-Buthe, Leribe, Berea, Maseru, Mafeteng, Mohale`s Hoek, Quthing, Qacha`s Nek, Thaba-Tseka and Mokhotlong) (Mokoena (2021). The districts are further subdivided into 80 constituencies, consisting of 129 local community councils (NSDP Lesotho, 2018).

The total land cover in Lesotho is approximately 30,355 square kilometers (11,720 square miles). This land area includes various types of land cover, such as forests (5-10%), grasslands and rangelands (60-70% of land area), agricultural areas (10-20%), urban areas (likely less than 5%), wetlands and water bodies (estimated to be less than 5%) (FAO, 2020).

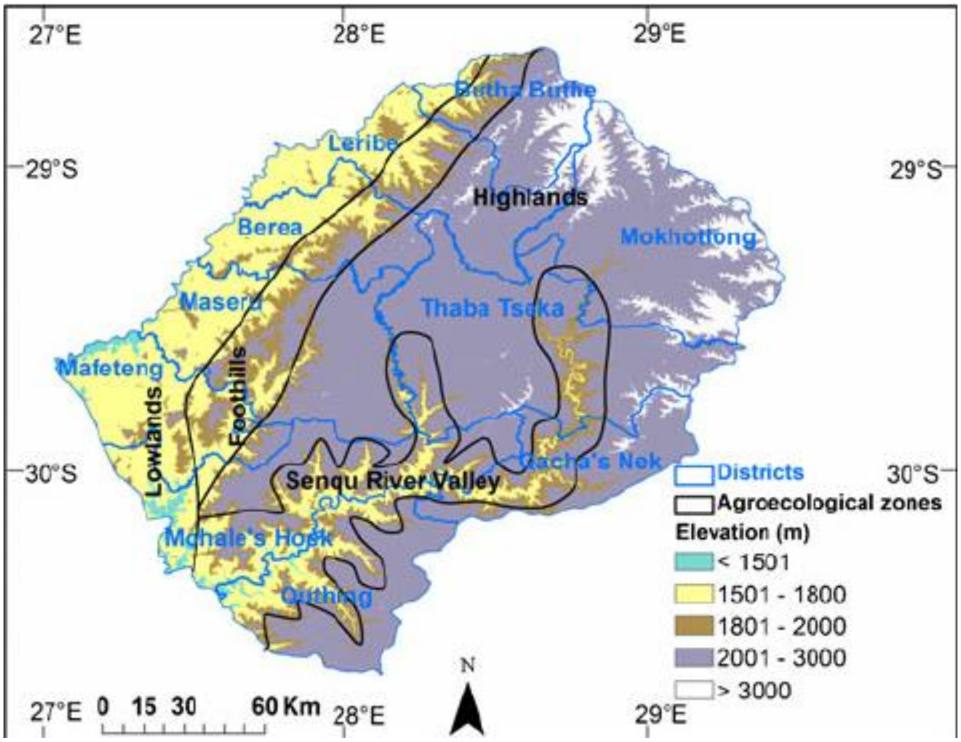

Figure 1: Lesotho map showing four agro ecological zones and ten districts.

Source: Moeletsi, and Walker, S. (2013)

3.2.2 Climate

Lesotho experiences a temperate climate characterized by cool to cold temperatures, influenced by its high elevation. Summers are generally warm, while winters can be extremely cold with snowfall in the higher elevations (Chineke *et al.*, 2019). Rainfall patterns vary across the country, with higher precipitation levels in the east and decreasing amounts towards the west, affecting agricultural practices and water resource management (Mokoena, 2021).

Table 1: Key Climatic Characteristics for the Four Regions

DESCRIPTION	LOWLAND	SENQU RIVER VALLEY	FOOTHILLS	MOUNTAINS
Annual rainfall (mm)	600 - 900	450 - 600	900 – 1,000	1,000 – 1,300
Temperature (^{0}C)	-11 - 38	-5 - 36	-8 - 30	-8 - 30
Average Temperature (^{0}C)	17	16	14	13

Table 2: Agro-Ecological Characteristics, and Production Opportunities

Description	Lowlands	Foothills	Mountains	Senqu river valley
CHARACTERISTICS				
Area - sq. km.*1	5,200 (17%)	4,588 (15%)	18,047 (59%)	2753 (9%)
Altitude range (m)	< 1,800	1,800-2,000	2,000-3,250	1,000-2,000
Topography	Flat to gentle rolling	Steeply rolling	Very steep bare rock, outcrops, and gently rolling valleys	Steeply sloping
Soils	North: Sandy, textured, red to brown South: Clayey	Rich, alluvial along valleys, thin and thick rock on slopes	Fragile, thin horizon of rich black loam except in valley bottoms.	Calcareous clayey, red soils with poor penetration by rainfall.
Climate	North: Moist South: Moderately dry	Moist, sheltered	Cold & moist	Higher rainfall Dry
Risks	Parching sun; strong winter winds; hail; droughts; High soil erodibility.	Flooding. high soil erodibility	Long periods of frost, snow, hail, high soil erodibility.	Severe drought, moderate soil erodibility.
Vegetation	Crop stubble, reforestation on some hills fruit trees near homesteads.	Poplar and willow trees along streams and gullies, crop stubble fruit trees near the homestead.	Denuded grassland, indigenous shrubs in some river valleys, and stunted peach trees near homesteads.	Denuded & dry, shrubs, brush, and a few fruit trees in valleys.

Source: Lesotho - PSLP –Environmental and Social Management Framework (ESMF), (2022)

3.2.3 Population

Lesotho, a landlocked country with a high altitude and a population of 2.1 million people, is completely surrounded by South Africa. The latest population census (2016) indicates that females make up 51 percent of the population, while males make up 49 percent. The population density is relatively low at 66 persons per square kilometer. However, when considering arable land, the population density increases to 349.8 people per square kilometer. The majority of the population (58 percent) resides in the rural areas of the country, where they largely rely on subsistence farming for their livelihoods (FAO, 2022). The largest districts, Maseru, Leribe, Berea, and Mafeteng together account for 65 percent of Lesotho's population (Census, 2016).

3.2.4 Economy

The economy of Lesotho experienced a growth of 1.8% in 2022, with the key drivers being construction, mining, manufacturing, business services, and public administration. The positive contribution of agriculture was notable, attributed to favorable seasonal rainfalls and input subsidies (World, 2023). The economic performance of Lesotho is heavily reliant on agriculture, livestock, manufacturing, and mining, with agriculture contributing approximately 7.4% to GDP, industry 34.5%, and services 58.2%. The country boasts significant natural resources such as diamonds and water, with agriculture remaining the primary source of employment, particularly within rural areas, where approximately 70% of the population resides. Despite only a small fraction of the land being suitable for farming, crop production serves as the primary source of income for rural residents, mainly through traditional low-input-low-output rainfed cereal production and extensive animal grazing. It is worth mentioning, however, that Lesotho does not produce enough food to sustain its growing population (Imani, 2017).

In terms of inflation, the rate was recorded at 8.3% in 2022, marking an increase from the 6% seen in 2021. In July 2022, inflation peaked at 9.8%, but has since moderated to 4.5% as of July 2023, primarily due to declines in fuel and food prices. The current account deficit widened from 1.4% of GDP in 2021 to 2.4% in 2022, driven by increased imports of capital goods and services pertaining to the Lesotho Highlands Water Project and limited export growth (African Economic Outlook, 2024)

The fiscal situation exhibited a deterioration, evidenced by an overall deficit of 7.6% of GDP in 2022, up from 4.2% in 2021. This was attributed to rises in both recurrent expenses and capital spending, alongside a decline in revenue resulting from reduced South Africa Customs Union (SACU) receipts. Lesotho's public debt stock in 2022 stood at 59% of GDP, primarily due to the redemption of 7-year and 10-year Treasury Bonds, with the bulk of the public debt sourced externally, constituting 72.7% of the total debt. In terms of their shares to GDP, external and domestic debt represented 44.8% and 16.9% of GDP in 2022, respectively. Although Lesotho's risk of external and overall debt distress remains moderate, risks to debt sustainability have escalated since the previous Debt Sustainability Analysis in 2021 (AEO, 2024).

3.2.5 Agriculture

Agriculture is the main economic activity and source of livelihood for most Basotho men and women, especially in rural areas, and is dominated by small-scale subsistence agriculture mostly low input, low output, rain-fed cereal production, and livestock rearing (Bureau of Statistics, 2019) Small livestock offers meat, wool, and mohair, which are essentially the mainstay of the economy of rural communities and make up a larger share of the agricultural contribution to GDP.

Lesotho's agricultural sector presents a fundamental paradox. Despite the country's limited land resources, with only 10% of its area suitable for crop farming and a mere 0.4% classified as good land, there is a concerning trend of increasing land lying fallow. The sector is dominated by smallholder farmers with about 90 percent being small-holders and just 10% classified as commercial farmers (Prifti *et al.*, 2020). According to Mbago-bhuna (2020), smallholder farmers work on less than one (1) hectare of land.

The arable land suitable for agricultural production is below 10% of the total land (Prifti *et al.*, 2020). Most socio-economic activities in Lesotho are restricted to the lowlands, the foothills, and the Senqu River valley, leaving the mostly infertile and rocky mountain region used primarily for rangelands (Banka, 2021). In the 2021/22 summer cropping season, the total land area used to plant major crops (maize, wheat, sorghum, beans, and peas) was 219,678 hectares (BOS, 2023), while the total land area used to plant vegetables in 2017/18 was 17,543 hectares (Horticulture Statistics Report, 2019b).

The rest of the land is composed of grassland suitable for livestock grazing. Livestock farming is very important for farmers in Lesotho, and it consists mainly of raising sheep and goats for wool and mohair production. Wool contributes about an average of 55 percent of the total agricultural exports (Prifti *et al.*, 2020). Lesotho is second in the world in terms of production of wool and mohair (Growth and Crea, 2022).

3.3 Locality of the Study Area

3.3.1 Geography

The study was conducted in the Leribe district, located in the northeastern part of the country. Covering an area of 2,828 square kilometers, Leribe is situated between latitude 28.87° S and longitude 28.05° E (Phakoe, 2016). The district's elevation ranges from approximately 1,400 to 3,500 meters above sea level. Leribe shares borders with four districts: Butha-Buthe to the north, Mokhotlong to the east, and Berea and Thaba-Tseka to the south. Its western boundary adjoins South Africa (Muroyiwa and Ts'elisang, 2021). The district has two official border posts with South Africa: Ficksburg Bridge and Peka Bridge. Hlotse, the capital town of Leribe, is the second-largest district in the country after Maseru (Mofolo and Rethabile, 2021).

According to the District Profile (2022), Leribe is divided into 13 constituencies, 13 community councils, and 3 administrative zones. For agricultural management, the district is served by seven resource centers. Leribe spans a total land area of 282,559 hectares, accounting for 9.32% of the country's total area, with 83,711 hectares dedicated to agriculture (FAO, 2022). The district's topography is characterized by three agro-ecological zones: the lowlands, covering 42% of the area (below 1,800 meters), the foothills, accounting for 28% (between 1,800 and 2,300 meters), and the mountainous regions, making up 30% (above 2,300 meters) (Muroyiwa and Ts'elisang, 2021).

Leribe has a temperate climate, characterized by cold winters and mild summers, with an average altitude of 1,800 meters above sea level (ESMF, 2022). The warm season lasts from November to March, with temperatures reaching up to 35°C. The region receives moderate to high rainfall, which varies according to altitude (Ministry of Agriculture, 2019). In Leribe, horticulture farming is primarily rain-fed, with a small number of farmers engaging in irrigated crop production (Mofolo and Rethabile, 2021). Water scarcity remains a significant challenge for farmers in the area, contributing to low production levels, particularly during El Niño seasons (Morahanye, 2020).

3.3.2 Population

In 2016, the population of the Leribe district was 337,500, with the majority of residents relying on agriculture for their livelihoods, as most villagers are involved in crop and livestock production, while only a small proportion are engaged in full-time formal employment (NSDP Lesotho, 2018). The district's population largely consists of very poor and poor individuals, who make up approximately 49 percent of the total population (Morahanye, 2020). According to recent data from the Leribe District Agricultural Office (2023), horticulture accounts for over 60% of agricultural output in the region, highlighting its economic significance. It is a crucial sector in

Leribe District's economy, contributing significantly to employment, income generation, and food security. Understanding the factors influencing productivity among horticulture farmers is essential for ensuring food security in Leribe District. With a growing population and increasing urbanization, there is a greater demand for fresh fruits and vegetables, which are predominantly produced by horticulture farmers (WFP, 2022).

3.3.3 Agriculture

Agriculture remains a fundamental pillar of the local economy in Leribe, sustaining a large portion of the population (FAO, 2021). The district boasts a diverse agricultural landscape that significantly contributes to the regional economy and livelihoods, with most farming being rainfed, though some semi-commercial farmers engage in irrigated crop production. Farmers cultivate a variety of crops, including cereals such as maize, sorghum, and wheat; legumes like beans and peas; and a broad range of vegetables, including rape, spinach, cabbage, green peppers, carrots, beetroot, tomatoes, potatoes, radishes, pumpkins, and onions, along with other traditional crops (Mofolo and Rethabile, 2021). According to the Ministry of Agriculture and Food Security (2023), the estimated production figures for Leribe's major crops are: maize (20,000 to 30,000 tons), wheat (5,000 to 10,000 tons), sorghum (5,000 to 8,000 tons), beans (3,000 to 5,000 tons), and potatoes (2,000 to 4,000 tons). During the 2017/2018 agricultural year, total vegetable production reached 68,709 metric tons (Horticulture Statistics Report, 2019b).

Horticultural crops grown in Leribe include vegetables, fruits, and flowers. The horticulture report (2019) revealed the agriculture sector as one of the main sources of employment in Leribe and its significance in decreasing the ever-increasing demand for employment in both urban and rural areas, as well as increasing domestic production to boost economic development. Therefore, BOS (2019) shows tomatoes and cabbage as the commodities in the horticulture report which seem to perform better in their production, however, the country still depends heavily on imports which means most of the landholdings are fragmented and often yield low produce (Rantso and Seboka, 2019).

Again, Leribe is one of the pilot districts in Lesotho for the government-sponsored block farming program (Rantso and Seboka, 2019). The government of Lesotho has implemented various agricultural programs and policies aimed at promoting sustainable farming practices and improving the livelihoods of farmers in Leribe (MAFSN, 2019). For example, two projects SADP and EIF have been implemented in the study area. Furthermore, sustainable horticulture practices are essential for preserving the natural environment and mitigating climate change impacts in Leribe (Mokhele and Makara, 2021).

3.4 Research design

Research design provides a systematic framework for the collection and analysis of data (Tashakkori, 2020). It outlines the procedures for gathering the necessary data, specifies the methods for data collection, and details how these methods will address the research questions (Creswell and Plano Clark, 2019).

Research design can be categorized into three main types: quantitative, qualitative, and mixed methods (Poth and Munce, 2020). It can also be classified based on its primary purpose: descriptive, explanatory, or exploratory. Descriptive research aims to provide a detailed account of a situation, person, or event, and to illustrate relationships between variables (Creswell and Plano Clark, 2018). Explanatory research seeks to elucidate and account for the descriptive data (Grey, 2014). In contrast, exploratory research is used when there is limited understanding of a situation or an ill-defined problem (Boru, 2018). This study utilizes a descriptive design and adopts a quantitative approach.

Corrigan and Onwuegbuzie (2020) describe quantitative research as a formal, objective, systematic approach used to describe test relationships and to explore cause-and-effect interactions among variables. Surveys can serve descriptive, explanatory, and exploratory research purposes. This study employed a descriptive survey design. Surveys are designed to collect original data for describing populations that are too large to assess directly (Creswell and Plano Clark, 2018). They gather information from a sample through self-reported responses to questions posed by the researcher (Syaifudin, 2019). Asenahabi (2020) notes that surveys are an effective method for gathering substantial amounts of data, typically in statistical form, from many individuals within a short timeframe using closed-ended questions. In this study, data will be collected using a questionnaire, which will be personally distributed to respondents by the researcher.

3.5 Population and Sampling

The study was conducted in the Leribe district of Lesotho, focusing on smallholder vegetable farmers who use tunnel farming systems. Situated in the northern part of Lesotho, Leribe district has considerable potential for crop production (NSDP Lesotho, 2018). The target group includes smallholder vegetable farmers operating under tunnels, supported by two initiatives: the Smallholder Agricultural Development Project (SADP), which assists 90 farmers, and the Enhanced Integrated Framework (EIF), which supports 22 farmers. In total, the study involves 112 farmers from these funded projects.

A stratified random sampling technique was employed because the population consists of two heterogeneous projects. Stratified sampling ensures that the sample includes specific attributes identified by the researcher (Creswell and Guetterman, 2019). Subsequently, simple random sampling was used to select samples from each stratum.

To ensure that every unit in the population had an equal chance of being selected, simple random sampling was utilized to draw samples from each stratum. According to Creswell and Guetterman (2019), simple random sampling ensures that all elements in the study population have an equal probability of being included in the sample. To determine the sample size from each stratum, the formula provided by Taherdoost (2018) was applied.

Slovin`s formular (1960)

$$n = \frac{N}{(1 + Ne^2)}$$

Where:

n = sample size

N = population size

e = degree of precision (95%) (Alpha level of 0.05)

3.5.1 Sampling

EIF_ Stratum 1

$$n = \frac{22}{1 + 22(0.05^2)}$$

SADP_ Stratum 2

$$n = \frac{90}{1 + 90(0.05^2)}$$

$n = 21$ $n = 74$

3.6 Data collection

In a study by Muhammad and Kabir (2019), data collection is defined as the systematic process of gathering information on relevant variables to address research questions, test hypotheses, and evaluate outcomes. The study utilized both primary and secondary data sources. Primary data were collected using a structured questionnaire specifically designed for the research, which was distributed to the target audience through phone calls and hand-delivered by the researcher's assistant. Secondary data were gathered from a variety of sources, including government and international organizations, academic journals and publications, industry reports, library databases, and national and regional economic reports. These sources provided extensive data, statistical reports, and economic analyses that were valuable for the research and informed decision-making.

3.7 Instrumentation

Given the nature of the study, a questionnaire was deemed appropriate for data collection. A questionnaire is composed of a series of open-ended or closed-ended questions, or a combination of both, to which respondents provide answers (Muhammad and Kabir, 2019). This tool helps researchers collect data for quantitative analysis. A structured questionnaire was chosen because it facilitates rapid coding, data entry, and analysis; simplifies the response process for participants; and reduces the need for advanced communication skills among respondents (Hyman and Sierra, 2020).The questionnaire contained the following themes:

- Part 1: General Information
- Part 2: Demographic Characteristics
- Part 3: Farm Characteristics
- Part 4: Institutional factors
- Part 5: Factors influencing technical efficiency
- Part 6: Technical efficiency

3.8 Validity and Reliability

3.8.1 Validity

The concept of validity pertains to whether an indicator accurately measures the intended concept. Validity encompasses two main components: internal validity (credibility) and external validity (transferability). According to Moses and Yamat (2021), validity can be further divided into four types: content validity, face validity, construct validity, and criterion-related validity. In this study, content validity and face validity were employed to validate the research instrument.

Sürücü and Maslakçi (2020) define content validity as a qualitative evaluation of whether the items in a measuring instrument accurately represent the intended phenomenon. Content validity is particularly important during the development of a new instrument, as advised by Taherdoost (2016). Conversely, face validity involves a subjective assessment based on researchers' perceptions, feelings, and intuition regarding the functionality of the measuring instrument (Sürücü and Maslakçi, 2020). In this study, to ensure the instrument's validity, the researcher consulted with a supervisor and a panel of expert judges chosen for their expertise in horticulture farming.

After completing the consultation, the researcher integrated the feedback and recommendations from the panel. This included rephrasing certain questions to resolve ambiguity and adding more appropriate options to closed-ended questions to enhance the quality of the data collected for analysis.

3.8.2 Reliability

Reliability refers to the stability and consistency of a measurement (Bandalos and Finney, 2020). To evaluate reliability, the tool was pre-tested in the Leribe district with 20 farmers who were not part of the targeted population but were from the same area. These farmers were excluded from the main study. According to Kubai (2019), reliability is defined as the degree to which an instrument consistently measures the attributes it is intended to measure across different conditions or with alternative instruments assessing the same construct. Reliable instruments should yield consistent results when used repeatedly over different timeframes (Moses and Yamat, 2021). In quantitative research, reliability encompasses the consistency, stability, and repeatability of results. An outcome is considered reliable if it remains consistent under identical conditions but across various circumstances (Mohajan, 2017). Common methods for testing reliability include test-retest, equivalent forms, internal consistency, and reliability statistics (Moses and Yamat, 2021). In this study, Cronbach's Alpha was used to assess the instrument's internal consistency. According to Heale and Twycross (2019), Cronbach's Alpha produces a value between 0 and 1, with a score of 0.7 indicating acceptable reliability for quality research.

3.9 Data Analysis

A structured questionnaire was utilized to collect primary data, which was subsequently processed and presented in a format accessible to users. Data analysis was conducted using Microsoft Excel and the Statistical Package for the Social Sciences (SPSS). Prior to performing Stochastic Frontier Analysis (SFA), data anomalies were addressed using the National Council of Statistics Software (NCSS) 2024. Outliers were identified through scatter plots and NCSS data screening.

Using FRONTIER version 4.1(c) (Coelli, 1996), the Maximum Likelihood Estimates (MLE) for both the technical inefficiency model specified by Equation 5 and the linear stochastic frontier production function outlined in Equation 1 were computed simultaneously. To address multicollinearity issues before integrating the technical inefficiency variables into the SFA model, Principal Component Analysis (PCA) was employed. PCA was utilized as a strategy to assess and mitigate the effects of multicollinearity in the regression data. The following data analysis methods were applied to address each of the study's objectives.

Objective 1: To identify factors that influence technical efficiency among horticulture farmers in the Leribe district.

The relationship between a single dependent variable and multiple independent variables affecting the technical efficiency of horticulture farmers in the Leribe district was analyzed using Principal Component Analysis (PCA). PCA is employed to address multicollinearity in regression data by reducing the dimensionality of the variables in the inefficiency model to a smaller set of uncorrelated principal components (PCs). This technique integrates linear regression with PCA within the Stochastic Frontier Analysis (SFA) framework. The PCA process involves several key steps, starting with the reduction of the original variables to uncorrelated principal components.

The five principal components (PCs) were used in the Stochastic Frontier Analysis (SFA) to assess their impact on technical inefficiency. The SFA model incorporated two equations: one for technical inefficiency and one for efficiency. The analysis revealed that only two PCs were significant. The importance of various variables within these significant PCs was then evaluated. To assess their effect on the level of technical inefficiency, the estimated coefficients, standard errors, t-ratios, and probabilities for each individual variable were computed.

To identify the variables affecting productivity differences among horticulture farmers in the study area, the technical inefficiency model will be utilized. Specifically, the model will be estimated as follows:

$$u_i = \delta_0 + \sum_{n-1}^{13} \delta_n Z_i + \omega_i \quad \text{.........(5)}$$

Where:

Z_i = vector explanatory variables associated with technical inefficiency effects,

δ=vector of unknown parameters to be estimated, ω_i = unobservable random variables, which is assumed to be identically distributed, obtained by truncation of the normal distribution with mean zero and unknown δ^2, such that u_j is non-negative. The inefficiency of production u_j will be modeled in terms of the factors that are assumed to affect the technical efficiency of farmers. Such factors are related to the socioeconomic variables of the farmers.

Since the use of the linear production function frontier model is not conventional, generalized likelihood-ratio (LR) tests will be conducted to ensure that technical inefficiency effects are present and that they are not stochastic. The LR test statistic,λ, is defined by:

$\lambda = -2 [L(H0) - L(H1)]$ .... (6)

Where $L(H_0)$ is the log-likelihood value of the unrestricted model and $L(H_1)$ is the log-likelihood value under the restricted model (Coelli, 1995). The test statistic is usually assumed to be asymptotically distributed as a chi-square or as a mixture of chi-squares with degrees of freedom equal to the number of restrictions involved (Baten and Kamil, 2010). The null hypothesis is rejected if the test statistic is greater than the critical value but accepted if the test statistic is smaller than the critical value.

The model justification

Since the PCA model is thought to be the most appropriate method for analyzing regression data affected by multicollinearity, it was chosen (Johansson, 2023). Principal component analysis (PCA) was used to reduce the dimensionality of the variables in the inefficiency model to a small number of uncorrelated principal components (PCs). However, given the fundamental distinctions between both approaches and the potential for differing results, selecting between PCA and SFA methodologies is a contentious decision that requires careful thought (Sarafidis, 2021). Moreover, it appears that the policy implications arising from the research are influenced by both methodologies, given their respective strengths and notable limits (Wang *et al.,* 2022; Mulwa, 2021). The technique to be used is determined by the goals of the investigation.

Objective 2: To evaluate technical efficiency among horticulture farmers in Leribe.

Stochastic Frontier analysis (SFA) was used to evaluate technical efficiency among horticulture farmers.

The relationship between independent factors and the dependent variable (productivity output) was examined using the Stochastic Frontier Analysis (SFA) model. This model also identified which farm enterprises in the study area exhibited technical inefficiencies. The stochastic frontier model developed by Battese and Coelli (1995) allows for technological inefficiencies to be represented as a function of explanatory factors combined with a random error (Adkin, 2003; Coelli, 1996). This model underpins the specification of the frontier model. The evaluation of the sample farmers was carried out by estimating the frontier model of the linear stochastic production function, which is implicitly defined as follows:

$$Y_i = \alpha + \sum_{j}^{n=5} \beta_j X_j + \varepsilon_j \quad \text{.........} \quad (1)$$

In which, Y will be the productivity output of the i^{th} farmer (i=1, 2, 3……. N), j refers to the j^{th} input of the commodities producer i in the firm, β is the vector parameter to be estimated, ε_j implies a stochastic disturbance. The error term ε_j consists of two components $_j$ and u_j. The two components of the composed error term are assumed to be independent of each other. v_j is the normally distributed random error, v- $N(0,\sigma^2_v)$ which captures variations in output due to factors outside the control of the farmer like fluctuations in input prices, the effect of weather, luck, and any other factor outside the control of the farmer. u_j is a non-negative random variable that accounts for technical inefficiency and is assumed to be independently distributed as truncations at zero of the $N(m_j \sigma_u^2)$, where $m_j = z_{ij}\delta$, δ is a vector of parameters to be estimated and z_{ij} is a vector of variables that may influence the efficiency of the decision maker.

The variance parameters are $\sigma^2 = \sigma_v^2 + \sigma_u^2$ .... (2)

and $\gamma = \sigma_u^2 / \sigma^2$ ....(3)

So that $0 \leq \gamma \leq 1$.

Given the specification of the stochastic frontier model in Equation (1), the technical efficiency of production of the *ith* farmer given the level of inputs is defined as:

$TE_i = \exp(-u_i)$ .... (4)

So that $0 \leq TE_i \leq 1$ and are inversely related to technical inefficiency (Khairo and Battese, 2005).

The model justification

Stochastic frontiers, as noted by Mushunje (2005) and Maseatile (2011), are often more suitable for agricultural contexts than Data Envelopment Analysis (DEA), particularly in developing countries where data can be significantly influenced by factors such as measurement error, weather conditions, variations in input quality, and disease. The SFA model enables the simultaneous integration of production functions and technical inefficiency equations. A key advantage of SFA is its ability to account for the possibility that an economic unit may operate below its production frontier due to pure errors and uncontrollable circumstances, thereby providing a more accurate measure of technical efficiency (Margono, 2023).

The stochastic frontier model is advantageous because its error term includes a one-sided component that captures inefficiency relative to the stochastic frontier, along with two additive symmetric components representing pure random elements. The SFA model estimates factors affecting technical efficiency by distinguishing between error and inefficiency components. It also accounts for the influence of random shocks, which are beyond the control of producers, on output.

The Principal Component Analysis (PCA) and Stochastic Frontier Analysis (SFA) models were conducted with a list of the production function and technical inefficiency variables that affect production factors, together with their predicted sign.

Table 3: Production and Explanatory variables and their expected signs

Variable	**Measurement**	**Expected sign**
Y_i =Productivity	The quantity of tomatoes produced per farm (ton/ha)	
Production function X_1=Land (L) Rais	Land area planted per farm(1rai=0.16 acres)	+
X_2 =Labour(Ld) man days	Amount of total labor use from family and hired labor per farm	+
X_3 =Fertiliser (Kg)	The quantity of chemical fertilizer used per farm	+
X_4 = Seeds quantity(kg)	The quantity of seeds used per farm	+
X_5 =Education(skills)	Special qualification in farming	+
X 6 = Weather	quantify the relationships between weather variables and agricultural productivity	+/-

Inefficiency Model		
Z_1Age	Age of farmers	-
Z_2Gender	Dummy=1 if the farmer is male, 0=if female	-
Z_3HH-size	Number of people in a household	+/-
Z_4Cattle Power	Dummy=1 if the used cattle power is only for land preparation 0=Otherwise	-
Z_5Tractor power	Dummy= 1 if the farmer used tractor power only for land preparation, 0=otherwise	-
Z_6Farm size	Dummy variable with a value of 1 if the planted area has been more than two and = 0 otherwise	+/-
Z_7Off-farm income	1=yes, 0=no	-
Z_8 =Primary Education	Dummy=1 if the farmer has a primary education, 0=otherwise	+/ -
Z_9 Farming experience	Producer's years of cultivation experience	+/ -
Z_{10} Seed Quality	Dummy=1 if the farmer used vegetables hybrid seed, 0=if Indigenous seeds	-
Z_{11}Extension visits	1=yes, 0=no	-
Z_{12} Credit Access	Dummy=1 access to formal credit 0,= access to informal credit	-
Z_{13}Technological adoption	Dummy = 1 farm has adopted modern technologies and practices in its production process 0,= no modern technologies	-
Z_{14} =Farm training	1=yes, 0=no	-

3.10 Ethical consideration

The researcher took into account ethical considerations in order to uphold and respect the privacy of the participants, minimize potential destruction, and promote ethical conduct (Abrar and Sidik, 2019). Additionally, Fleming and Zegwaard (2018) underscore the importance of ethical expectations such as obtaining informed consent, minimizing risk of harm, ensuring anonymity and confidentiality, and addressing conflicts of interest. The participants were fully informed about the study to guarantee their complete contribution and their right to privacy was safeguarded by treating the evidence provided by the participants with the utmost confidentiality. To maintain ethical standards in this study, the researcher made every effort to avoid plagiarism. Furthermore, the literature was meticulously reviewed to ensure the production of high-quality research.

In summary, the methodology for analyzing factors influencing technical efficiency among tomato farmers in Leribe, Lesotho, involves several key steps. This includes selecting an appropriate sampling technique, data collection methods, and analytical tools to measure and analyze efficiency and its determinants.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and findings of the study, including an overview of the descriptive statistics of the respondents' demographics, the estimation of technical efficiency using the Stochastic Production Frontier (SFA) model for evaluating technical efficiency among horticultural farmers and the identification of factors influencing technical efficiency among horticultural farmers in Leribe through the Principal Component Analysis (PCA) model. The descriptive statistics provide insights into the study population, setting the foundation for further analysis. The SFA model assesses the degree to which farmers operate at their production frontier, with Maximum Likelihood Estimates (MLE) offering quantitative measures of technical efficiency. The PCA was employed to create composite indices, enabling a comprehensive analysis of the factors impacting efficiency.

4.2 Socio-economic and demographic of smallholder vegetable farmers

This section discusses the socio-economic characteristics of 95 smallholder vegetable farmers. According to Mazibuko (2019), these characteristics are crucial because the primary household activities are managed by the household head, whose decisions are often shaped by their demographic profile.

4.2.1 Gender and age

The results in Table 4 revealed that female respondents accounted for about 35% while male accounted for 65%. This shows that males dominate tomato production in the study area. According to Ng'Atigwa *et al.* (2020), men predominantly dominate land as they often inherit land and have better access to financial resources, such as credit and farming equipment. These are more likely to make them adopt precision farming technologies that may lead them being to more technically efficient and they often better in farming technologies while females are denied access to resources with limited decision-making power within the household because of the gender-based segregate in African community culture.

The results in Table 4 showed that 42.26% of the respondents were aged between 31 and 40 years, 24.21% were aged between 41 and 50 years, 16.84% were aged between 51 and 60 years and older farmers aged 61 years and above accounted for 13.69% of the respondent population. The situation indicates that farmers who are aged 31 and 40 years are participating more than older farmers. They are likely to be more progressive and more willing to adapt to new technological practices, with the potential to enhance technical efficiencies in tomato production. According to Ng'Atigwa *et al.,* (2022), young farmers are more innovative and are more likely to implement advanced farming techniques and utilize modern agricultural inputs, which can lead to higher output.

Table 4: Percentage distribution of farmers by their demographic characteristics

Variables	**Frequency**	**Percentage %**
Gender		
Female Male	33 62	35 65
Total	**95**	**100%**

Variables	**Frequency**	**Percentage %**
Age		
Between 31 and 40 years	43	42.26
Between 41 and 50 years	23	24.21
Between 51 and 60 years	16	16.84
Above 61 years	13	13.69
Total	**95**	**100%**

4.2.2 Source of income and farming experience

The respondents had several alternative sources of income and the results in Table 5 showed that the respondents' main source of income was from vegetable production at 36%, followed by other farming practices at 23%, off-farm employment at 20%, other alternative sources at 18% and pension at 3 %. The situation shows that most of the respondents were engaged in agriculture hence, their main source of income. Sekoai and Rantlo (2016) also found out that most population in Lesotho is dependent on agriculture for livelihood purposes. Further, the results in Table 8 indicate that 45.3% of the respondents were farmers, 18 % of the respondents were self-employed, and 15.8% were civil servants, while 10.5% were engaged in other sectors. Muroyiwa *et al. (*2020) showed that the main occupation of farmers in Lesotho is either crop or livestock farming.

The results in Table 5 further revealed that most farmers (95.79%) had experience in vegetable production and marketing, while a small proportion of 4.21%, lack farming experience in either production or marketing. Farmers who are more experienced in farming are likely to adopt progressive farming techniques and technologies. Farming experience improves the rate of adoption of improved techniques which means effective utilization of inputs, which is likely to increase the technical efficiency of the farming operation (Saiyut *et al.*, 2019).

Table 5: Percentage distribution of farmers by their socio-economics characteristics

Variables	**Frequency**	**Percentage %**
Main Source of Income		
Vegetable Production	34	36
Other farming Practices	22	23
Off farm employment	19	20
Pension	3	3
Other	17	18
Total	**95**	**100%**
Variables	**Frequency**	**Percentage %**
Main Occupation		
Farmer	43	45.3
Self employed	17	18
Civil servant	15	15.8
Other sectors	10	10.5
Unemployed	7	7.4
Private Sector	3	3
Total	**95**	**100%**
Variable	**Frequency**	**Percentage %**
Farming experience		
Yes	91	95.79
No	4	4.21
Total	**95**	**100%**

4.2.3 Educational level

Results on the level of education of the respondents Table 6 showed that 64.21% of the farmers in the study area acquired tertiary education, followed by secondary education at 22.11%, whereas 8.42% of the respondents attained primary, and only 5.26% were illiterate. The situation indicates the potential knowledge of farmers who are likely to be innovative in producing tomatoes using advanced technological farming equipment than illiterate farmers. Islam *et al*. (2023) showed that farmers with formal schooling tend to be more efficient in production, due to their enhanced ability to acquire technical knowledge, which makes them move close to the frontier output. According to Kiprop *et al.* (2020), education level of the household head is one of the considerable determinants of farmers ‘technical efficiency among horticulture farmers.

Table 6: Percentage distribution of farmers by their level of education

Educational level	Frequency	Percentage %
Tertiary education	61	64.21
Secondary education	21	22.11
Primary education	8	8.42
Illiterate	5	5.26
Total	**95**	**100%**

4.2.4 Farm size and land tenure system

The farm size in the study area ranges from less than one acre to 5 acres. Results in Table 7 showed that majority (68.42%) of the respondents in the study area farmed on an area less than 1 acre. Farmers with areas between 1.1 acres and 2.0 acres accounted for 16.84%, farms between 2.1 areas and 3 areas constituted 7.36%, and those between 3.1 acres and 4.0 acres accounted for 3.16%. Farmers with land size areas of 4.1 acres and 5.0 acres, and those at 5.1 acres, and above occupy 2.11% each respectively. The situation indicates that most farmers in the study area were smallholder farmers with an area of less than 1 acre. In Lesotho, the average land holding per family is about 1.0 acres per family (World Bank, 2019).

The results in Table 7 further revealed that majority (66.32%) of the land was privately owned, 22.11% leased, 7.36% was for rented land, and 4.21% communally owned. The results showed that most farmers in the study area own land privately, which can be used as collateral for smallholder farmers to acquire loans to improve their production efficiency to be able to access lucrative formal markets. According to Nkadimeng *et al.* (2021), the type of land ownership system has influence on agricultural development and the type and size of investment made.

Table 7: Percentage distribution of farmers by their farm characteristics

Farm Size		
Size of the farm in acres	**Frequency**	**Percentage (%)**
Less than 1 acre	65	68.42
Between 1.1 and 2.0 acres	16	16.84
Between 2.1 and 3.0 acres	7	7.36
Between 3.1 and 4.0 acres	3	3.16
Between 4.1 and 5.0 acres	2	2.11
Above 5.1 acres	2	2.11
Total	**95**	**100%**
Land Tenure System		
Communal	4	4.21
Leased	21	22.11
Private Owned	63	66.32
Others	7	7.36
Total	**95**	**100%**

4.2.5 Access to extension service

The results in Table 8 showed that the majority (85%) of the farmers had access to extension services while 15% of the farmers indicated that they had no access to extension services during recent cropping seasons. The key role of extension agents is to transfer knowledge and marketing information to the farmers to have the best farming practices and improve their efficiency. Abate *et al*. (2019) reported that access to extension services has a positive influence on the technical efficiency and productivity of pepper farmers in north Ethiopia.

Table 8: Frequency distribution of access to extension service

Extension service	**Count**	**Percent**
Access to extension services	81	85 %

No access to extension services	14	15 %

4.2.6 Labour engaged in the farm

Table 9 illustrates the type of labour engaged in the respondents' farms. Labour was divided into three categories: permanent, casual, and family labour. The majority of the respondents (55%) used family labour, followed by casual labour at 38.95% and lastly permanent hired labour at 6.05%. The situation indicates that the study area is dominated by farmers who are resource poor and forced to engage their families in vegetable production to reduce production costs. Mukarumbwa *et al.*(2018), indicating that the availability of adequate family labour boosted productivity and increased technical efficiency.

Table 9: Frequency distribution of labour engaged in the farm

Labour in the farm	Count	Percent
Family labour	52	55%
Casual labour	37	38.95%
Permanent labour	6	6.05%

4.3 Tomato production in Leribe

4.3.1 Fertilizers used in the farm

The significance of the fertilizer variable derives from the fact that fertilizer is a major land fertilizing input and improves the productivity of existing land by increasing crop yields per acre. The results in Table 10 revealed that most farmers 74.7% used inorganic fertilizers at a rate of 5 bags of 50kg capacity per acre during the recent growing season, while about 25.3% of the farmers revealed that they use organic fertilizers during recent cropping seasons at a rate of 10 bags with a capacity of 50kg per acre. This situation shows that inorganic fertilizers are predominant in the study area, and inorganic fertilizers are deemed to provide immediate nutrient availability that contributes to sustained crop yields by maintaining and improving soil health over the long term and increase technical efficiency among farmers (Schnitkey *et al.*, 2023).

Table 10: Frequency distribution of fertilizer used in the farm

Fertilizer	Bags used/kg	Count	Percent
Inorganic	5-10 (50kg)	71	74.7%
Organic	10-15(50kg)	24	25.3%

4.3.2 Quality of seeds

The results in Figure 2 revealed that the types of seeds used by the farmers in tomato production were hybrid and indigenous seeds. The results showed that the majority (80.25%) of the farmers used hybrid seeds such as Monica, Roma VF and Moneymaker because of their resistance to different types of diseases, while 21.25% of the farmers used indigenous seeds such as Oxheart, Heirloom Varieties and Local heirloom cherry tomatoes. The situation indicates that most farmers use superior seeds that have the potential for higher production levels and are likely to increase their technical efficiency. Hayati *et al.* (2024) contended that hybrid seeds lead to increased yields and resistance to diseases, especially when used in the aggregation of all farming inputs including pesticides and fertilizers.

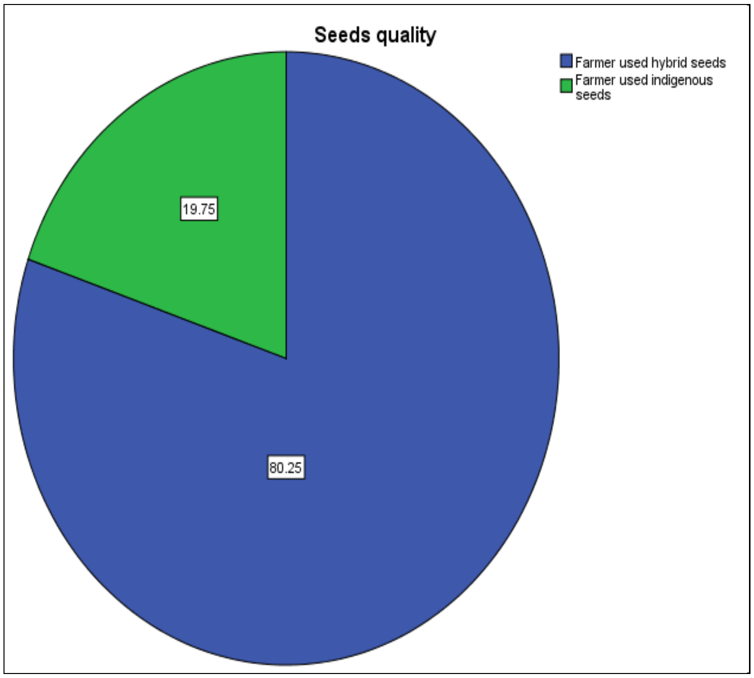

Figure 2: Distribution of seed quality among farmers

4.3.3 Pest and Disease Control

The results in Figure 3 show that chemical methods of pest and disease control are most frequently employed at 54.32%, followed by manual hand methods at 27.16% and mechanical methods at 18.52% % for controlling pests and diseases in tomatoes. The use of chemical control measures by farmers in Leribe is predominant and Ahmad *et al.* (2022) indicate that chemical control measures can considerably lower crop losses and increase yields because they frequently work quickly and broadly against a variety of pests and diseases hence, potential for increased technical efficiency.

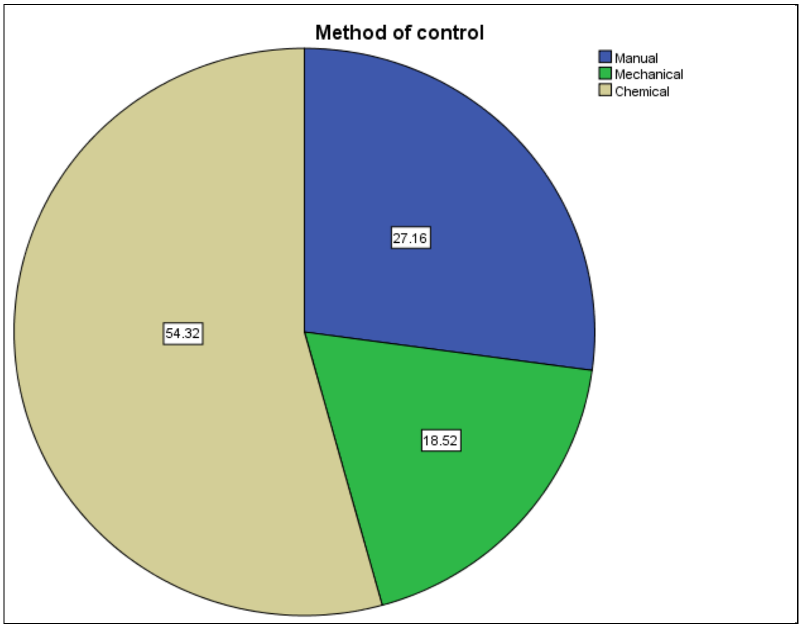

Figure 3: Distribution of disease and pest mitigations among farmers

4.3.4 Irrigation and Sources of power used in cultivation

As seen in Table 11, the majority of farmers (81.05%) have access to irrigation water while the remaining 18.95% have no access to irrigation water. This signifies the possibility for increased agricultural performance even during dry seasons as irrigation increases productivity and yields among farmers. According to Kumar and Patel (2023), smallholder farmers with access to irrigation are more likely to extend the growing season, allowing them to produce tomatoes even during dry periods, which can significantly increase total yield.

Table 11: Distribution of access to irrigation and sources of power used in cultivation

Access to Irrigation	Count	Percent	Source of power used in cultivation	Count	Percent
Access	77	81.05%	Cattle	60	63.16%
No access	18	18.95%	Tractor	35	36.84%

The results in Table 11 further indicate that 63.16% of the farmers used animal traction while 36.84% used tractors during their cultivation-related operations. This indicates that a substantial proportion of farmers still rely on animal power, which is a more affordable alternative to agricultural machinery that is financially out of reach for many small-scale farmers (Mosotho and Thulo, 2022).

4.3.5 Output produced by farmers per acre

The results in Table12 revealed that 38.3% of the farmers produce between 200 and 300 boxes of tomato per acre, each with a 10 kg capacity, 30.9% of the farmers produce between 300 and 400 boxes of 10 kg each, while 24.70% produce more than 400 boxes of the same size and 4.9% of the farmers produce between 100 and 200. Lastly, 1.2% of the farmers produce fewer than 100 boxes, with each bag having a capacity of 10 kg.

Table 12: Frequency distribution of output produced per acre among farmers

Output	Count	Percent
< 100 boxes	1	1.2%
100 - 200 boxes	5	4.9%
200 -300 boxes	36	38.3%
300 - 400 boxes	29	30.9%
> 400 boxes	24	24.7%

This situation indicates a considerable variation of output levels among tomato producers in Leribe, and this may be attributable to range factors including access to resources, extension services, and production methods that have a bearing on production and productivity levels. Thabane and Makoae (2022) showed that limitations in terms of resources, extension services, and production methods have the potential to radically reduce productivity and technical efficiency.

4.4 Maximum Likelihood Estimates (MLE) frontier parameters

Table 13 presents the Maximum Likelihood Estimates (MLE) for the parameters of the linear production function and the results of related statistical tests derived from the stochastic frontier production function analysis. The estimated parameters reveal that land, fertilizers, seeds, and weather significantly impact tomato production, while labor and educational attainment were found to have no significant effect.

Table 13: MLE of linear stochastic production frontier for 95 tomatoes farmers

Variable	Parameter	Coefficient	Std-error	t-ratio	Probability
Production functions					
Productivity(Constant)	β_0	0.0000	0.8005	2.410	0.0185***
Fertilizers	β_1	0.0445	0.2113	-0.965	0.0378***
Labour (Ld.)	β_2	-0.0167	0.1937	-0.213	0.8316
Land(L)	β_3	0.6691	0.1573	8.400	0.0000***
Seeds	β_4	0.0010	0.1937	0.012	0.0301***
Education skills	β_5	0.1086	0.1787	1.345	0.1827
Weather(C^0)	β_6	-0.2069	0.1892	-2.576	0.0120***
Diagnostic statistics					
Sigma-square ($\sigma^2 = {}^{\sigma}u2 + {}^{\sigma}v2$)	σ2	0.465	0.0781	8.0810	0.0000***
Gamma ($\gamma = {}^{\sigma}u2 / \sigma^2$)	γ	0.645	0.0095	2.2728	0.0181***
Ln (Likelihood)	-126.76				
LR test	25.296				
Mean technical efficiency	0.835				
Number of observations	95				

Significance level ***0.05(5%) *** 0.01 (1%)

Using the gamma (γ) value, estimated using the generalized log-likelihood ratio test, the study also measured technical inefficiency in tomato production. Gamma (γ) has a value of 0.645, which shows that out of the total disparity in tomato production, 64.5% was due to technical inefficiency, while the remaining 35.5% was due to expected noise, especially in agriculture where uncertainty is greater. The diagnostic statistics of the inefficiency component reveal that the sigma square (σ^2) is statistically significant which indicates goodness of fit.

Fertilizers (β_1): the results revealed that fertilisers are significant at 5% and positively influenced technical efficiency with a correlation coefficient of 0.0445 and a p-value of 0.0378. This connotes that a unit increase in fertilisers use increased to 0.0445 units of technical efficiency of tomato farming. The possible explanation for this scenario is that fertilizers are thought to provide immediate nutrient availability that contributes to sustained crop yields by maintaining and improving soil health over the long term and increasing technical efficiency among farmers. This agrees with Smith (2023) who indicated that the use of fertilizers promotes the growth and expansion of output and also enhances tomato production.

Land (β_3): this variable recorded a coefficient of 0.6691 and a p-value of 0.0000 which indicates that size of the farming land positively and significant at 1% that influenced technical efficiency in tomato production. Specifically, for each unit increase in land size, productivity increases by 0.6691 units. The larger land areas might allow for more efficient farming practices, economies of scale, or better resource management that require more sophisticated resource management practices to ensure consistent tomato production. This concurs with the findings of Bayav (2023) who indicated that larger land sizes can lead to higher technical efficiency in agricultural production hence, farmers with larger landholdings often benefit from more efficient use of technology and inputs, resulting in higher overall efficiency.

Seeds (β_4): the quality of seeds had a positive and statistically significant influence on technical efficiency among horticulture farmers with a coefficient of 0.0010 and p-value of 0.0301. These results imply a significant at 5% that a unit increase in the quality of seeds input led to an increase of 0.0010 units of technical efficiency among tomato farmers. The probable reason is that high-quality seeds with better germination rates and disease resistance yield optimum tomato production. These results concur with Hayati *et al.* (2024) who highlighted that hybrid seeds lead to increased yields and resistance to diseases, especially when used in aggregation of all farming inputs including pesticides and fertilizers.

Weather (β_6): the results showed that weather negatively influenced technical efficiency among horticultural farmers with a coefficient of -0.2069 and a p-value of 0.0120. This negative coefficient suggests that weather conditions are associated with a decrease in technical efficiency among tomato farmers. Specifically, for each unit increase in unfavorable weather conditions, technical efficiency decreases by 0.2069 units. The possible explanation for this situation is that unfavorable weather conditions significantly hinder the efficiency of tomato farming operations at 5%. This is supported by Cavicchi and Palmieri (2023) indicating that extreme heat and drought conditions, driven by climate change, have led to significant reductions in tomato production efficiency in key regions such as California and Italy.

4.5 Hypothesis testing

To test the presence of technically inefficiency effects, a statistical test of the inefficiency hypothesis using the generalized log likelihood-ratio (LR) tests and the gamma estimates as indicated in Chapter 4 was used. Table 14 gives the generalized LR tests for the presence of technical inefficiency effects.

Table 14: Generalized likelihood ratio (LR) tests

Null Hypothesis	LR value	Test statistic	Critical value	Decision
$H_0 : \gamma = \delta_0 = \delta_1 \ldots \delta_5 = 0$	-126.76	25.296	14.22	Reject H_0
$H_0 : \gamma = 0$	-133.597	12.17	5	Reject H_0

To test the hypothesis of the technical inefficiency effects the restriction was imposed as:

$H_0 : \gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$.. (18)

The chi-square computed was 25.296 while the critical value, χ^2 (0.05) was 14.22.

The null hypothesis of no inefficiency effects in tomatoes production was strongly rejected. The null hypothesis was rejected in favor of the alternative hypothesis because the estimated test statistics of 25.296 were larger than the critical value of 14.22.

The null hypotheses specify that technical inefficiency effects are not stochastic and are tested by enforcing the following restriction:

$H_0 = \gamma = 0$ .... (19)

The null hypothesis was also rejected because the estimated test statistic of 12.17 is greater than the critical value range 5 to 7.08, implying that technical inefficiency effects are random.

It can, therefore, be concluded that technical inefficiency effects are present in the model, making the use of the stochastic production function appropriate.

The presence of technically inefficiency effects was confirmed by a statistical test of the inefficiency hypothesis using the generalized ratio tests. The zero hypothesis of no inefficiency effects in tomatoes production was strongly rejected, which indicates that the production frontier estimated is stochastic. The estimated sigma-square was highly statistically significant at a one percent level indicating a good fit and the correctness of the specified distributional assumptions. Although significant, the 0.645 value for the variance gamma (γ) parameter in this study is far from one, suggesting that all of the residual variations are not due to the inefficiency effects, but to random shocks. Therefore, it can be concluded that the technical inefficiency effects associated with the production of tomatoes by the sampled farmers are very small. Nevertheless, the gamma which is statistically significant suggests that the traditional (OLS) function is not an adequate presentation.

Though the results of the inefficiency model are of particular interest in this study, there were 20% technical inefficiency effects, thereby establishing that low levels of technical inefficiency exist. The implication is that the overall decline in tomatoes productivity is due to about 80% random shocks emerging from factors beyond farmers' control. The study raises an important concern that the success of techniques to improve tomato production and yield stability depend on the good management of the production factors which are most limiting to its yield over time.

Hence, the major concern towards improving the capacity of tomato horticultural farmers to increase the current technical efficiency level should be based on quantifying such random shocks. The three major factors beyond farmers' control arising from this study are attributed to the effect of climate change, poor pests' control and poor management of water resources.

Lesotho is highly vulnerable to climate change because many socio-economic activities depend on climate, especially rainfall. The impact of rainfall changes on tomato cultivation significantly depends on the timing with respect to the crop growth cycle. Changes in rainfall patterns affect tomato cropping, planting dates, dry spell length, frequency of dry days, rainfall intensity and total rainfall during critical stages of the tomato growth cycle.

Some agricultural practices in Lesotho destroy soil structure, result in soil erosion and take away topsoil which has a lot of humus and essential nutrients required for plant growth. The situation suggests that it is therefore important to employ conservation agricultural practices that will improve the prevailing tomato productivity under a range of soil and rainfall conditions. Water is the limiting factor for rain-fed tomato production in the dry land regions. Rain-fed tomato production is required when rainfall is limited or irregularly distributed, especially during the main cropping season. Better management of water and rainwater harvesting will be useful for tomato production. The availability of water will be useful for the uptake of nutrient elements like fertilizers, which appeared to be negative and significantly correlated to tomato output.

4.6 Estimated Technical Efficiency (TE) Scores of farmers of tomato production and its distribution

This section aims to present and discuss the frequency distribution of the technical efficiency estimates obtained from the stochastic frontier model. Table 15 presents summary statistics of the technical efficiency scores at which the farm households operate.

The mean Technical Efficiency of approximately (0.835) indicates that on average, the farmers achieve around 83.5% of their potential output at the current level of inputs, these results indicate a wide range of TE between tomato producers. This suggests a reasonably efficient use of resources but also leaves room for improvement. The mean TE of sample farmers was 0.835 with a minimum level of 1 and the maximum of 2. This means that if the average farmers in the sample was to achieve the technical efficient level of its most efficient counterpart, then the average farmers could fulfil 16.5% derived from (1-0.835/1)*100 increase in output by improving technical efficiency with existing inputs and technology. On the other hand, this value means that on average, in the short-term, there is a potential for tomato producers to increase their efficiency by 16.5%, utilizing existing farm resources better and adopting improved technology and techniques if they use inputs efficiently. Omotayo *et al.* (2023) indicated that farmers above 80% efficiency levels are technically efficient.

Table 15: Distribution of technical efficiency scores of farmers of tomato production

District	Mean	Stdev	Minimum	Maximum
Leribe (N = 95)	0.835	0.18	1	2

4.7 Factors influencing technical efficiency among horticultural farmers in tomato production

The results presented in Table 16 show both positive and negative signs for the estimated parameters. The negative sign on estimated parameters in the technical inefficiency model signifies that a related variable diminishes inefficiency, leading to a positive effect on technical efficiency and subsequently increasing productivity levels. The estimated coefficient signs of the variables from the inefficiency model regarding gender, education level, seed quality, animal power, farming experience, irrigation, and off-farm income are statistically significant at the 0.05% level. This implies that these variables reduce technical inefficiency, thereby enhancing technical efficiency. Although the coefficient signs for household, tractor power, extension visits, and access to credit are negative, they are statistically insignificant, indicating that their effect on the level of technical efficiency in tomato production in Leribe has not been conclusively established. The remaining variables, including technological adoption and age, have positive signs, suggesting that these variables have resulted in a reduction in technical efficiency among farmers in the study area.

Table 16: Technical efficiency factors in tomato production

Variables	Parameter	Coefficient	Std error	T-stat	Probability
Constant	δ_0	0.0000	0.5917	3.257	0.0018***
Gender	δ_1	0.2790	0.1091	2.254	0.0276***
Age (years)	δ_2	0.0201	0.1976	0.1987	0.8521
HH-size	δ_3	-0.0783	0.0749	-0.687	0.4945
Education level	δ_4	0.1140	0.1197	0.912	0.0451***
Seed Quality	δ_5	0.3638	-0.0974	3.491	0.0009***
Animal Power	δ_6	-0.3184	0.0956	-2.924	0.0048***
Tractor Power	δ_7	-0.0651	0.1266	-0.586	0.5598
Farmer experience	δ_8	0.1131	0.0967	1.093	0.0283 ***
Extension Visits	δ_9	-0.0812	0.1515	-0.701	0.4859
Irrigation	δ_{10}	-0.1411	0.1186	-0.190	0.0385***
Technological adoption	δ_{11}	0.0445	0.1037	0.397	0.6925
Credit Access	δ_{12}	-0.0804	0.1268	-0.552	0.5831
Off-farm income	δ_{13}	-0.2579	0.1029	-2.246	0.0279***

Significance level ***0.05(5%)***0.01(1%)

Gender: The findings of this study show that gender positively affects technical efficiency and significant at 5% of the smallholder farmers in tomato production as it recorded a correlation coefficient of 0.2790 and a p-value of 0.0276. This result connotes that a unit being male leads to a 0.2790 unit increase in technical efficiency among tomato farmers in Leribe. A possible explanation for this scenario is that gender plays a significant role in farming, influencing various aspects such as access to resources, decision-making, productivity, and the adoption of agricultural technologies. This agrees with the findings of World Bank (2019) who highlighted the critical role of gender in farming and underscores the need for gender-sensitive policies and interventions to ensure equitable access to resources, opportunities, and benefits in agriculture that enhance farmer's efficiency.

Educational level: the results indicated that educational level positively and statistically significant influences technical efficiency with a coefficient of 0.1140 and ap-value of 0.0451. These results imply significant of 5% that a unit increase in the level of education led to an increase of 0.1140 units in the technical efficiency of the tomato farmers in Leribe. The possible explanation for this situation is that higher educational attainment enhances farmer's better use of information and new technology to boost their farming productivity. Kiprop *et al.* (2020) indicated that the education level of the household head is one of the considerable determinants of farmers 'technical efficiency among horticulture farmers.

Seed quality: the use of hybrid seeds had a positive and statistically significant relationship with the technical efficiency of tomato farmers as it recorded a correlation coefficient of 0.3638 and a p-value of 0.0009. This implies a significant of 1% that a unit increase in the use of hybrid seed leads to a 0.3638 unit increase in technical efficiency. The possible explanation is that farmers using hybrid seeds greatly produce relatively high production of tomatoes as these seeds enhance the efficiency of other resources. The finding is consistent with the study of Jagesh Kumar Tiwari *et al.* (2022) who found that high-quality seeds lead to more productive and efficient tomato farming because they are often genetically consistent, disease-resistant, and have ideal growth quality. Other studies, Chirwa (2023) and Oyewo *et al*. (2023), found that use of hybrid seed improved the output of tomato produced.

Animal power: this variable recorded a coefficient of -0.3184 and a p value of 0.0048, indicating a negative and statistically significant influence of animal traction during cultivation on the technical efficiency of tomato farmers. This result implies a significant of 1% that a unit increase in the use of animal traction resulted in an increase of 0.3184 unit in technical efficiency of tomato farmers**.** The probable explanation is that animal traction allows farmers to manage larger areas of land more efficiently compared to manual labor in regions where mechanized equipment is either too expensive or unsuitable due to terrain. This is in consistent with FAO (2022) report in Uganda which showed that the use of animal traction enabled smallholder farmers to increase their land productivity by allowing them to open larger acreages in a shorter amount of time, which subsequently leads to increased yields and improved income.

Farming experience: the results revealed that farming experience positively and statistically influenced technical efficiency with a correlation coefficient of 0.1131 and p-value of 0.0283 in the study area. This implies a significant of 5% that a unit increase in the experience in farming led to 0.1131 increase in the production efficiency of tomato. The results agree with the study of Rantlo and Bohloa (2022) who indicated that experienced farmers have extensive contacts and knowledge of the sector and are more likely to opt for the effective and efficient approaches in production. Also experienced farmers are more likely to adopt precision farming with better knowledge in enhancing productivity and efficiency. The results are also supported by Omonona *et al.* (2017) who found that a unit increase in farming experience leads to a better assessment of the importance and complexities of good farming decision-making, including efficient use of inputs.

Irrigation: This variable was found to be negatively and statistically significant at 5% in influencing technical inefficiency of tomato farmers in the study area as it recorded a correlation coefficient of -0.1411 and p-value of 0.0385. The result implies that a unit increase in irrigation led to a decrease of 0.1411 in the technical inefficiency among tomato farmers. The possible explanation is that irrigation plays a vital role in boosting technical efficiency in tomato production by improving water management, which in turn enhances yield, fruit quality, and overall farm productivity. The results agree with Koye *et al.* (2022) who indicated that in tomato production, water is a critical input, and efficient irrigation ensures that the plants receive the precise amount of water they need, minimizing water stress and enhancing growth conditions which leads to higher yields and better fruit quality, that are essential for increasing overall productivity.

Off-farm income: the variable recorded a correlation coefficient of -0.2579 and a p-value of 0.0279 which reflect a negative and statistically significant at 5% relationship between it and technical inefficiency among tomato farmers. The results connotes that a unit increase in off-farm income led to an increase of 0.2579 in technical efficiency. This could be attributed to the fact that off-farm income might be a proxy for agricultural credit and this off-farm income may facilitate the purchase of more farm inputs to intensify production and improve performance of tomato farmers in the study area, thus they become closer to the frontier. The finding is consistent with Winters *et al.* (2020) who indicated that off-farm income allows households to invest in their agricultural activities help them purchase better inputs like seeds, fertilizers, and machinery, as well as adopt new technologies that improve productivity.

In summary, the study on factors influencing technical efficiency among tomato farmers in Leribe, Lesotho, involved detailed data collection and analysis to understand efficiency levels and their determinants. The findings are presented through descriptive statistics, efficiency scores, and principal component analysis, and Stochastic Frontier analysis results.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECCOMMENDATIONS

This chapter summarizes the findings of the study and draws up relevant conclusions in relation to the research findings and objectives. Also, it emphasizes some recommendations for further action, based on the research findings, and establishes recommendations and suggestions for further research.

5.1 Purpose of the study

The purpose of this study was to investigate factors limiting technical efficiency among horticulture farmers in the Leribe district of Lesotho.

5.2 Specific objectives of the study

i. To identify factors that influence technical efficiency among horticulture farmers in Leribe district.
ii. To evaluate technical efficiency of horticulture farmers in Leribe

5.3 Methodology

This study was conducted with a rigorous and comprehensive research design. A descriptive quantitative research design was chosen, and survey-based research was used to gather facts and opinions about the factors influencing technical efficiency among horticultural farmers in Leribe. The study employed stratified sampling technique, and a simple random sampling was used to draw sampling units from each stratum.

The target population was a group of smallholder farmers producing under tunnels funded by the two projects Small-holder Agricultural Development Project (SADP) and Enhanced Integrated Framework (EIF). A total of 95 participants were involved in this survey, and a questionnaire was used to collect data. Data was analysed using descriptive statistics to describe the respondent's demographics and, the Stochastic Production Frontier (SFA) model was used for evaluating technical efficiency among horticultural farmers in Leribe, while the Principal Component Analysis (PCA) model was used to identify factors that influence technical efficiency among horticultural farmers with the use of Statistical Package for Social Sciences (SPSS) and National Council of Statistics Software (NCSS) version 2024.

5.4 Summary of the Empirical Findings

The study aimed to define the demographics and socioeconomic characteristics of farmers as they have effect on the technical efficiency among tomato farmers in Leribe to gain a clear understanding of the distribution of respondents based on factors such as gender, education level, age, labour engaged in the farm, farm size, income, and farming experience.

The study findings revealed that males were predominant as they accounted for 65% of smallholder farmers, with 63.75% of the farmers in the study area having acquired tertiary education which makes them more likely to be innovative in producing tomato using advanced technological farming equipment. The study also revealed that 42.26% of the respondents were aged between 31 and 40 years that are likely to be more progressive and, more willing to adapt new technological practices, with a potential to enhance technical efficiencies in tomato production in the study area. Moreover, 95.79% of farmers revealed that had experience in vegetable production and marketing, which augers well for technical efficiency prospects in the area.

The empirical findings from the study revealed that there was a disparity in tomato production efficiency the variables such as gender, seed quality, educational level, animal power, farming experience, irrigation and off farm income influenced technical efficiency and, 64.5% was due to technical inefficiency, while the remaining 35.5% was due to expected noise, especially in agriculture where uncertainty is greater. Also, the mean technical efficiency of 83.5% was recorded indicates that on average there is a 16.5% allowance of efficiency improvement by addressing important constraints that affect farmers' levels of technical efficiency and productivity in the study area.

The findings from the SFA and PCA model identified several significant factors that influence technical efficiency among horticulture farmers in the Leribe district. Gender plays a significant role in influencing technical efficiency in agriculture, including tomato farming. Societal norms, access to resources, decision-making power, and agricultural knowledge can all vary based on gender, impacting how efficiently men and women farmers manage resources. Gender was identified as a significant enhancer, with male farmers showing higher likelihood to realise high technical efficiency levels. This disparity suggests potential gender-related barriers or unequal access to resources such as land, agricultural equipment, and lack of collateral, tenure security and opportunities in vegetable farming. Secondly, irrigation positively impacted the technical inefficiency among tomato farmers. The availability of irrigation leads to a range of positive impacts, including increased soil fertility, reduced disease pressure, water conservation, and environmental conservation hence, high technical efficiency.

Additionally, income levels negatively affected technical inefficiency among tomato farmers. Financial capability enables farmers to invest in production inputs and/or intensification of production and improve performance of tomato farmers. Furthermore, education was identified as the most significant enhancer in acquiring knowledge about precision agriculture and better farming techniques that will enhance technical efficiency among farmers. Lastly, prior experience in tomato production was revealed as a factor indicating familiarity with production techniques and methods that enhance farmers' productivity levels.

5.5 Conclusions

Based on the findings of this study, the following conclusions are drawn as per two objectives of this study. The study conclusions enabled the researchers to later come up with the recommendations for this study.

The tomato farm sector is characterized by gender disparities that prevent the sector to fulfil its full economic potential in the study area. Nevertheless, the predominance of the young in this sector renders the environment conducive for improved technical efficiency among tomato producers. Furthermore, the positive situation is augmented by high educational attainment among tomato farmers which augers well for technical information gathering and interpretation as well as technology adoption that all enhance technical efficiency. Moreover, tomato farming is characterized by vastly experienced farmers which augers well for technical efficiency prospects in the area.

The tomato production attained an average technical efficiency of 83.5% which implies that tomato farmers are technically efficient as they surpassed the acceptable minimum TE score of 70%. Nonetheless, the notable 16.5% deficiency indicates need for improvement in terms of resource use efficiency at farm level.

The results identified several key factors that significantly influence technical efficiency among horticulture farmers in the Leribe district. Gender emerged as a critical factor, with male farmers having greater opportunities in achieving high efficiency due to high access to resources and opportunities. Educational attainment reduced technical inefficiency by equipping tomato farmers with the knowledge, skills, and tools necessary to make better decisions, optimize resource use, adopt new technologies, and manage financial and environmental risks. The use of hybrid seeds has also rendered the environment suitable for increasing technical efficiency among tomato farmers as these are high yielding, disease-resistant and drought-tolerant, which all lead to increased technical efficiency among tomato farmers.

Additionally, proper irrigation has improved the efficiency of other inputs like fertilizers and pesticides by ensuring they are absorbed effectively by the plants. This leads to better crop performance and reduced wastage of inputs, contributing to higher technical efficiency. Moreover, experienced farmers were often better at evaluating and adopting new technologies that fit their specific needs and conditions. This includes precision agriculture tools, improved irrigation systems, or pest control methods, all of which enhance efficiency. Lastly, the off-farm income was regarded as a proxy for agricultural credit and it facilitated the purchase of more farm inputs to strengthen production and improve performance of tomato farmers. The situation underscores the multifaceted nature of technical efficiency in horticulture and highlights the importance of addressing these specific factors to improve vegetable farming productivity in the Leribe district of Lesotho.

5.6 Recommendations

Based on the conclusions derived from the empirical findings, the following recommendations are proposed to enhance technical efficiency among horticultural farmers in the Leribe district

a) To promote gender equality in agriculture, efforts should be made to improve access to resources for women by implementing policies that ensure that female farmers have equal access to land, agricultural inputs, credit, and technology. This could include gender-sensitive agricultural programs and initiatives to reduce barriers that women face in farming.

b) To improve irrigation practices, the government and other relevant stakeholders should consider the provision of technical and financial support for irrigation upgrades through subsidies or financial incentives for farmers to invest in modern, water-efficient irrigation systems. If this is clearly articulated, this can help in addressing the issues of soil degradation and water wastage, leading to better technical efficiency.

c) Furthermore, promotion of experience-based learning to develop mentorship and training programs to capacitate the less experienced farmers should be considered by the stakeholders. Learning from the more seasoned professionals will help emerging/inexperienced farmers to gain the skills and knowledge needed to adopt efficient production techniques.

5.7 Recommendations for Further Research

This section defines recommendations for future research and these suggestions aim to explore new dimensions and address remaining questions, providing opportunities for further advancement in the field. The suggestions for further research are as follows.

This study was only conducted in Leribe district with 95 respondents. Therefore, it is imperative to conduct comprehensive case studies in all districts to determine whether the situation is the same or different from the current study as this may lead to development and adoption of more comprehensive programs and policies that may effectively address factors influencing technical efficiency among the horticultural farmers in Lesotho.

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APPENDICES

QUESTIONNAIRE

FACTORS INFLUENCING TECHNICAL EFFICIENCY AMONG HORTICULTURE FARMERS IN LERIBE DISTRICT

Questionnaire Number

The objective of this study to investigate factors limiting technical efficiency among horticulture farmers in the Leribe district of Lesotho.

You are therefore requested to spare some of your time to respond to the questions that follow. The researcher undertakes to keep the information private and confidential. The National University of Lesotho has a policy which requires researchers dealing with human subjects to adhere to ethical conduct and to protect the respondents by respecting their freedom. The analysis will use personal identification numbers that the researcher will assign each respondent. This will protect respondents by making the responses anonymous.

Please, you are kindly requested to respond to this questionnaire.
Your cooperation on the above is highly appreciated.
Thank you in advance for your participation and cooperation in this project!!!

PART A: GENERAL INFORMATION

Study Profile

Date of the Interview (dd/mm/yyyy)	
Interviewed by:	
Code of the respondent:	
Village:	
Resource Centre:	
Phone number:	

PART B: DEMOGRAPHIC CHARACTERISTICS

Characteristics	**Coding**	**Response**
Age	1 = <30	
	2 = 31-40	
	3 = 41-50	
	4 = 51-60	
	5 = >61	
Gender	1= Female	
	2= Male	

Marital Status	1 = single	
	2 = married	
	3 = divorced	
	4 = widowed	
	5 = other	
Education Level	1 = Illiterate	
	2 = primary	
	3 = secondary	
	4 = tertiary	
Main Occupation	1 = farmer	
	2 = civil servant	
	3 = Unemployed	
	4 = Private Sector	
	5 = Self employed	
	6 = Other	
Main source of income	1 = vegetable production	
	2 = Other farming practices	
	3 = off- farm employment	
	4 = Pension	
	5 = Other	
Farming Experience	1 = Yes	
	2 = No	
Household size at the time of interview (include absentees)	1-3	
	4-6	
	7-9	
	10-12	
	≥ 13	
If yes, how many years have you been planting vegetables	1 = <10	
	2 = 11 – 20	
	3 = 21 – 30	
	4 = 31 – 40	
	5 = <41	
Please specify skills	Production Experience	
	Marketing Experience	

PART C: FARM CHARACTERISTICS

1. General farm information

Characteristics	**Coding (Acres)**	**Response**
Farm Size	1 = <1.0	
	2 = 1.1 - 2.0	

	3 = 2.1 - 3.0	
	4 = 3.1 – 4.0	
	5 = 4.1 – 5.0	
	6 = >5.1	
Land tenure system	1 = Communal	
	2 = Rented	
	3 = Leased	
	4 = Private Owned	
	5 = Others	
Land preparation methods	Manual	
	Ox-drawn	
	Machinery(tractor)	

2. Did you grow tomatoes last season?

Crop	**Area (acres) / m^2**	**Total production (kg)/head/bundles**

PART D: FACTORS INFLUENCING TECHNICAL EFFICIENCY

1.INSTITUTIONAL FACTORS

Agricultural extension service

a. Did you receive agricultural extension services related to vegetables production last season?

☐ Yes

☐ No

b. If yes, how many times were you visited by one of the extension officers in the last growing season season (2022/23)?			
	Government extension officers	**NGO extension officers**	**Research officers**
1. Daily	1	1	1
2. Weekly	2	2	2
3. Monthly	3	3	3
4. Quarterly	4	4	4
5. Once in a while	5	5	5
6. Never	6	6	6
7. Other (specify)	7	7	7

c. Do you think the extension officers provided you with enough knowledge needed for production of horticulture crops?	
Yes	1
No	2

d) What kind of extension service did you receive last season?

- [ ] Finance
- [ ] , fertilizers and irrigation equipment's
- [ ] ntion of pests and diseases
- [ ] ultural trainings
- [ ] s

e) Type of labour

What type of labour is engaged in the vegetable farm?

- [ ] Permanent labour
- [ ] Casual labour
- [ ] Family labour

3. CLIMATE SERVICE AWARENESS

a) Are you aware of climate services (weather forecasts, climate predictions, early warning systems)?

- [ ]
- [ ]

b) How often do you use climate services?

- [ ] Daily
- [ ] Weekly
- [ ] Monthly
- [ ] Rarely

c) Which climate services do you use most frequently? (Select all that apply)

- [ ] Weather forecasts
- [ ] Seasonal climate predictions
- [ ] Early warning systems
- [ ] Agricultural advisories

d) How do you access climate services? (Select all that apply)

- [ ] Television
- [ ] Radio

☐ Internet

☐ Mobile apps

☐ Community meetings

e) How would you rate the reliability of the climate services you use?

☐ Very reliable

☐ Reliable

☐ Neutral

☐ Unreliable

4. CLIMATE ADAPTATION PRACTICES

a) Have you implemented any practices to adapt to climate change?

☐ Yes

☐ No

b) If yes, which of the following adaptation practices have you implemented? (Select all that apply)

☐ Changing planting dates

☐ Using drought-resistant crop varieties

☐ Diversifying crops

☐ Water conservation techniques

☐ Building flood defences

☐ Relocating to safer areas

☐ Other (please specify)

c) What challenges do you face in adapting to climate change? (Select all that apply)

☐ Lack of information

☐ Financial constraints

☐ Technical knowledge

☐ Social or cultural barriers

☐ Government support

☐ Other (please specify)

d) How effective have these adaptation practices been in mitigating climate impacts?

☐ Very effective

☐ Effective

☐ Neutral

☐ Ineffective

5. SUPPORT AND IMPROVEMENTS

a) What kind of support would help you better adapt to climate change? (Select all that apply)

☐ Financial assistance

☐ Training and education

☐ Access to reliable climate information

☐ Community support programs

☐ Government policies and programs

☐ Other (please specify)

b) How can climate services be improved to better meet your needs?

☐ More accurate forecasts

☐ Better communication channels

☐ Tailored advice for specific sectors

☐ Timelier information

☐ Increased community engagement

☐ Other(please specify)

6.CROP MANAGEMENT PRACTICES

a) Types of crops cultivated:

☐ s

☐ tables

☐ s

☐

☐ ers

☐ other crops

b) Plant Spacing

a) Do you use a specific spacing distance for planting each type of crop?

☐ Yes
☐ No

b) How do you determine the plant spacing for your crops?

☐ Extension advice
☐ Farmer experience
☐ Neighbouring farms
☐ Agricultural research

☐ Other

c) Have you noticed an impact of plant spacing on crop yield?

☐ Yes

☐ No

d) Do you think the current plant spacing is optimal for your crops?

☐ Yes

☐ No

7. OPERATIONS AND THEIR LEVEL AND TIMING (E.G. .WEEDING, WATERING)

a) Weeding practices; How often do you weed your crops?

☐ Weekly

☐ Bi-weekly

☐ .Monthly

☐ Other

b) What method do you primarily use for weeding?

☐ Manual weeding

☐ Chemical weeding (herbicides)

☐ Mechanical weeding

c) Do you weed at a specific stage of crop growth?

☐ Yes

☐ No

d) Have you faced challenges with weeding?

☐ Yes

☐ No

e) If yes, what challenges do you face? (Select all that apply)

☐ Labour shortage

☐ High cost of herbicides

☐ Weather conditions

☐ Other

8. WATERING PRACTICES

a. **Was your commodity irrigated?**		
Yes		1
No		2

b) How often do you water your crops?

☐ Daily

☐ Weekly

☐ Bi-weekly

☐ Monthly

c. If yes, which methods of irrigation used

☐ rrigation
☐ kler irrigation
☐ Surface irrigation
☐ Subsurface irrigation
☐ Flood irrigation
☐ Furrow irrigation
☐ Manual irrigation
☐ Other irrigation methods

d) Do you water at a specific time of day?
☐ Yes
☐ No

e) Do you monitor soil moisture levels before watering?
☐ Yes

☐ No

f) Have you faced challenges with watering?

☐ Yes

☐ No

g) If yes, what challenges do you face? (Select all that apply

☐ Water scarcity

☐ High cost of water

☐ Irrigation system breakdowns

☐ Other

9.GENERAL OPERATIONAL PRACTICES

a) Do you use any specific scheduling tools or techniques for managing your farm operations?

☐ s

☐ No

b) How do you manage labour for your farm operations?

☐ Family labour

☐ Hired labour

☐ Cooperative labour

☐ Other

c) What are the main challenges you face in managing farm operations? (Select all that apply)

☐ Labour shortage

☐ High input costs

☐ Lack of access to credit

☐ Poor market access

☐ Other

10. WEEDS,PESTS AND DISEASE CONTROL

a) Please indicate type of weeds that commonly affect tomatoes in your area.	
Weeds commonly affecting Tomatoes	
Nutgrass(Cyperus rotundas)	
Nightshade(Solanum spp.)	
Field Bindweed(Convolvulus arvensis)	
Morning Glory(Ipomoea spp.)	
Johnson Grass(Sorghum halepense)	

b) Please indicate type of pests that commonly affect tomatoes in your area.	
Pests commonly affecting tomatoes	
Spider Mites (Tetranychidae family)	
Tomato Hornworm (Manduca quinquemaculata)	
Aphids (Aphididae family)	
Whiteflies (Aleyrodidae family)	
Tomato Fruitworm (Helicoverpa zea	

c) Please indicate type of diseases that commonly affect tomatoes in your area.	
Common Diseases Affecting Tomatoes:	
Early Blight (Alternaria solani)	
Late Blight (Phytophthora infestans)	
Fusarium Wilt (Fusarium oxysporum f. sp. lycopersici)	
Tomato Spotted Wilt Virus (TSWV)	
Bacterial Spot (Xanthomonas campestris pv. vesicatoria)	
Verticillium Wilt (Verticillium dahliae)	

d) Which method of weeds, pests and disease control did you use in 2022/23 growing season?					
Activity	**Method of Control**				
	Hand	**Cultural**	**Mechanical**	**Chemical**	**Other (specify)**
Weeds	1	2	3	4	5
Pests	1	2	3	4	5
Diseases	1	2	3	4	5

e) What was the cost of each of the following inputs in 2022/23 growing season?		
Input	**Cost**	
Herbicides (specify)		1
Pesticides (specify)		2
Disease chemical (specify)		3

f) How much of the following did you apply in 2022/23 growing season?		
Input	**L/acre**	
Herbicides		1
Pesticides		2

Disease chemical		3

g) Please indicate the source of power used for the following activities in 2022/23.				
Activity	Manual	Cattle	Tractor	Other (specify)
1. Ploughing	1	2	3	4
2. Harrowing	1	2	3	4
3. Sowing	1	2	3	4
4. Applying Fertilizer	1	2	3	4
5. Applying Herbicides	1	2	3	4
6. Applying Pesticides	1	2	3	4

☐

11.CROP ROTATION PRACTICES:

a) Types of crops included in rotations:

☐ fruits in botany(tomatoes)
☐ Brassicas (e.g., cabbage etc.)
☐ Root crops (e.g., carrots, potatoes)
☐ Leafy greens (e.g., lettuce, spinach)
☐ Legumes
☐ Other:

b) Rotation schedule:

☐ al rotation
☐ ial rotation
☐ Tercentenary rotation
☐ Irregular rotation (please specify)

c) Reasons for implementing crop rotation:

☐ Soil fertility improvement
☐ Pest and disease management
☐ Weed suppression
☐ Break crop-specific pest cycles
☐ Diversification of income sources

d) Management practices between rotated crops:

☐ Cover cropping
☐ Green manure incorporation
☐ Fallow periods
☐ Intercropping

e) Challenges or concerns related to crop rotation:
☐ Limited crop options for rotation
☐ Constraints due to factors influencing productivity
☐ Increased management complexity
☐ Time and labor requirements

f) Perceived benefits of crop rotation:

☐ Improved soil structure and fertility
☐ Reduced pest and disease pressure
☐ Enhanced water retention
☐ Diversified income streams

12. YIELD AND STORAGE OF TOMATOES

a) In what form did you use your tomatoes 2022/23 growing season?	
Fresh	1
Processed	2
Both	3

b) When did you harvest your tomatoes in 2022/23 growing season?			
Commodity		**Tomatoes**	
January			1
February			2
March			3
April			4

c) How much tomatoes did you consume in 2022/23 growing season?	**Tomatoes (Kg)**
Commodity	

d) Please indicate method used to harvest tomatoes in 2022/23 growing season	
Commodity	

			Tomatoes
Handpicking			1
Mechanical			2

e) On what basis do you have access to the machinery used for harvesting	
Own	1
Rent	2
Other (specify)	3

f) How many bags (kg) of tomatoes were harvested in 2022/223 growing season?	kg/acre
Tomatoes	

g) Please indicate the amount of tomatoes used for the following				
Produce			**Amount (kg)**	
Consumption				1
Sold				2
Stored				3

13. MARKETING MANAGEMENT

a) Do you sometimes produce surplus?	
Yes	1
No	2

b) Please indicate type of market you have access to for your tomatoes produce			
Commodity			
Formal Market			1
Informal Market			2
Both Formal and Informal Market			3
None			3

c) If formal, please indicate your marketplace		
Shoprite Lesotho	1	

Pick'n Pay	2	
Cooperatives (Street vendors)	3	
School /Shops	4	
Other (Specify)	5	
d)How did you sell your produce in 2022/23?		**Tomatoes**
Cash	1	
Credit	2	
Exchange with Animals	3	
Other (specify)	4	

	Quantity (kg)	**Selling price(M)**		**Tomatoes**
Nearby villages (kg)			1	
Shoprite Lesotho (kg)			2	
Pick 'n Pay(kg)			3	
Cooperatives (Street vendors (kg)			4	
Schools/Shops			5	
Other (Specify)			6	

e) Is there any produce that you could not sell in 2022/23 growing season?	
Yes	1
No	2

f) If yes to above, what was the reason?	
Not profitable enough	1
Not enough buyers	2
Market too far away	3
Did not know where to sell	4
Could not meet required tomatoes and cabbage quality	5
Shoprite market closed	6
LMC prices were too low (determined by SUFFEX)	7
Other	8

14.CREDIT ACCESS AND OFF-FARM INCOME

a)Did you make use of external capital for tomatoes production in 2022/23 growing season?	
Yes	1
No	2
b) If yes to above name the source of external capital	
Formal Sources (SADP,EIF and ministry of agriculture, etc.)	1
Informal Sources (credit unions, farmer's associations, stokvels, etc.)	2

c) Do you need credit for your tomatoes enterprise?	
Yes	1
No	2

d) Is credit available to you as small-scale farmers?	
Yes	1
No	2

e) If no to above what is the reason?	
Do not need extra money to buy inputs	1
The interest rate is too high	2
Bank doesn't lend money to individual farmer due to insufficient security(e.g., land)	3
Poor repayment ability of the farm	4
Do not know how to organize credit	5
Other (specify)	6

15. OFF-FARM INCOME

a) Do you have any occupation other than farming?	
Yes	1
No	2

b)If yes to above please state that other occupation

c)Please state income you receive from this	M

d)Does anyone in the household have any other form of income which is also used for farming operations?

Yes	1
No	2

a) If yes to above please state income received	M

16. ACCESS TO RESOURCES

a) Availability of water resources:

☐ Yes
☐ No

b) Access to quality seeds and planting materials:

☐ Yes
☐ No

c) Availability of skilled labour:

☐ Yes
☐ No

17.INPUTS

a) Did you get any subsidies for tomatoes and cabbage cultivation in 2022/23?

☐ Yes
☐ No

b) If yes to (1) above in, what form did you get subsidies in 2022/23 growing season?

Cash / Chegue	1
Inputs (seeds, fertilizers, herbicides and pesticides)	2
Land preparation	3
Harvesting	4
Other (specify)	5

c) Did you make use of any of the following inputs on your farm in 2022/23 growing season?

	Yes	**No**
1. Fertilizer	1	2
2. Herbicides	1	2
3. Pesticides	1	2

18. ENVIRONMENTAL FACTORS

a) Climate conditions during harvesting:

☐ Normal

☐ Moderate
☐ Bad
☐ Extreme

b) Pest and disease pressure during production:

☐ Normal
☐ Moderate
☐ Bad
☐ Extreme

c) Soil quality and fertility during production:
☐ Excellent
☐ Good
☐ Poor
☐ Horrible

19.TRAINING AND EDUCATION
a) Participation in training programs related to horticulture farming:

☐ Yes
☐ No

b) Access to agricultural extension services:

☐ Yes
☐ No

c) Knowledge of best agricultural practices:

☐ Yes
☐ No

20. FEEDBACK AND SUGGESTIONS

a) Do you have suggestions for improving technical efficiency on your farm?

☐ Yes

☐ No

b) If yes, to above how important is improving technical efficiency to increasing your farm's productivity?

☐ Very important

☐ Important

☐ Moderately important

☐ Slightly important

☐ Not important

c) Are there any additional comments or insights you would like to share about your horticultural practices?

☐ Yes

☐ No

d) If yes, to above write your comments below

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

21. CHALLENGES AND CONSTRAINTS

a) Major challenges faced in horticulture farming:

☐ licable
☐ al
☐ rate
☐ me

22. OPPORTUNITIES FOR IMPROVEMENT

a) Suggestions for improving productivity:

☐ Irrelevant
☐ Moderate
☐ Highly needed

b) Areas where support is needed:

☐ Training and extension services
☐ Financial assistance
☐ Technology adoption
☐ Access to agricultural inputs
☐ Irrigation methods
☐ Policy advocacy and representation

THANK YOU VERY MUCH FOR YOUR COOPERATION