DETERMINANTS OF CLIMATE-SMART AGRICULTURAL TECHNOLOGIES ADOPTION BY SMALL HOLDER CROP FARMERS IN QUTHING DISTRICT, LESOTHO.

BY

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2024

DECLARATION

I, Mathebe Josephina Semoko, declare that this research dissertation is my own work, I undertook it, except where otherwise indicated. It is submitted for the degree of Master of Science in Agriculture and Resource Economics (Agri-business management) at the National University of Lesotho. It has not been submitted for any other degree at any University.

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DEDICATION

This research is dedicated to:

- To me, for believing in myself and embarking in this challenging academic journey with determination and perseverance. This dedication reflects personal introspection and celebrates the individual's own journey, acknowledging the challenges overcome and the personal growth achieved throughout the research process.
- To my parent [Matebello Semoko], whose unwavering support and sacrifices have been the foundation of my academic pursuits. This thesis is a tribute to your love and belief in me.
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The Author

ABSTRACT

The agricultural sector in Quthing district is vital for local employment and food security, particularly through smallholder vegetable farming. However, climate change poses challenges such as prolonged droughts, altered rainfall patterns, and increased temperatures, which threaten farmers' livelihoods. These conditions not only reduce crop yields but also exacerbate weed growth, pests, and diseases. In response, Climate Smart Agriculture Technologies (CSAT) have been introduced to improve agricultural productivity. Despite their potential benefits, the adoption of CSAT remains low influenced by various factors shaping farmers' decisions. Therefore, the study aimed to evaluate the factors influencing CSAT adoption among vegetable farmers in rural areas of Quthing district. The specific objectives included evaluating farmers' understanding and awareness of CSAT, identifying adoption patterns, evaluating interventions and support systems towards CSAT adoption, and determining factors influencing CSAT adoption.

A multi-stage sampling technique was employed to select 100 farmers, from whom data was collected through a semi-structured questionnaire. Data analysis utilised descriptive statistics and probit regression model using statistical software (Stata 13). The descriptive statistics revealed that majority of farmers were aware of CSAT benefits: sustaining soil fertility (81%), increasing productivity (92%), reducing pollution (61%) and resource management (90%). Furthermore, the findings revealed varying levels of adoption among farmers: hybrid seed (90%), adjusting planting dates (75%), rainwater harvesting (53%) while agrochemicals is 46%, organic fertilizer (30%), protected farming (28%), irrigation technology (10%) and underground water harvesting (5%). The probit regression model highlights significant factors influencing CSAT adoption among farmers. These factors include farming income (ß= -0.915, P = 0.024), household size (ß=-0.0876, P=0.04), education level (ß= 0.472, P=0.032) farming experience (ß=0.501, P=0.014), access to extension (ß=0.752, P=0.038), membership to associations (ß=0.936, P=0.001) and climate information service (ß=0.936, P=0.064).

Based on these findings, the study concluded that while farmers exhibit awareness and understand of CSAT, adoption rate is hindered significantly by socio-economic, demographic, and institutional factors. To address these constraints, it is recommended that government and financial institutions should develop programs aimed at reducing financial barriers for low-income farmers. Government should invest in rural infrastructure to promote farmers access to services. Priority should be given to enhancing extension services and promoting farmer associations to enhance adoption of CSAT and other innovative technologies.

Key words: CSAT, adoption, smallholder farmers and influence

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LIST OF ACRONOMS AND ABBREVIATIONS

FAO	Food and Agricultural Organization
SADP	Smallholder Agricultural Development Project
NUL	National University of Lesotho
IPCC	Intergovernmental Panel on Climate Change
MANFS	Ministry of Agriculture Nutrition and Food Security
FBOs	Farmer Based Organizations
SSA	Sub-Saharan Africa
GDP	Gross Domestic Product
NGO	Non-Governmental Program
CSAT	Climate Smart Agriculture Technology
CSAIP	Climate Smart Agriculture Investment Plan
CSPM	Climate Smart Pest Management

CHAPTER 1

1 INTRODUCTION

1.1 Background of the study

Agricultural production continues to be the predominant means of supporting livelihoods for most countries in Sub-Saharan Africa (SSA). According to Martey, Etwire and Kuwornu (2020) and Atube (2021), it serves as the primary source of employment and income for over 70% of the employed population in the region. Nevertheless, the sector is severely impacted by impacts of climate change particularly in Southern Africa where production has decreased by 50% making it the lowest contributor in SSA (Lipper *et al*., 2021). Intergovernmental Panel on Climate Change (IPCC) in 2019 report mentioned that this decline has been attributed to effects of climate change effect such as erratic rainfall, heat waves and pests and disease manifestation. As such, it is significant that efforts are made to address agricultural production for food security and rural development.

Agreements and conventions have been ratified by international leaders such as United Nations Framework Convention on Climate Change (UNFCCC) in 2015 as a strategy to adapt and mitigate climate change effects which addresses enhancement of climate change mitigation, adoption and financing and it was signed by 196 countries. These countries then individually drew the legally binding documents within their nations to implement UNFCCC and to encourage adoption such as grants allocation and land tenure reforms (Mutengwa *et al.*, 2023).

The concept of Climate Smart Agricultural Technologies (CSAT) was introduced by the FAO in 2010 as a response to adapting to the challenges posed by climate change (FAO, 2019). According to FAO 2010 (cited in Rosenstock *et al*., 2019), CSAT encompasses a range of technologies designed to enhance agricultural productivity sustainably, build resilience (adaptation), and reduce greenhouse gas emissions (mitigation) despite adverse weather conditions. Examples of CSAT involve drought-resistant or early maturing crop varieties (Martey *et al.,* 2020), protected agriculture methods, and water harvesting techniques (FAO, 2020) among others. The adoption of these technologies is crucial because they enable farmers to maintain or improve their productivity levels despite the effect of climate change. This ensures that farmers can consistently produce sufficient yields to meet food demand, contributing to food security in the face of changing climate conditions.

The adoption of CSAT has been widely acknowledged as a promising and effective strategy to mitigate the impact of climate change hence it has been successful in Mediterranean countries (Yan, 2020). For instance, the evolution of irrigation technology by extensive extraction of ground water increased by 40%, and improved crop production in Europe (Mujeyi, 2021). In the other study by Thilani *et al*. (2020), it was observed that 115 countries have adopted Protected Agriculture (PA) as one of the CSAT measures. Among all, China being the major adopter have been gaining better output which increased agricultural contribution on country's economy from 7.1 in 2019 to 7.7 in 2020 (Yan, 2020).

On the other hand, Branca & Perelli (2020) indicated that despite the known advantages of CSAT for sustainability and economic benefits, its adoption remains low in SSA. This is because SSA countries are dominated by smallholder farmers who are considered less resourceful and family-owned farms (FAO, 2019). Maseko (2021) further mentioned that because CSAT are considered to be costly and not easily accessible, the less resourceful farmers are unable to adopt potential technologies. Again, rights to land tenure system are also observed to hinder adoption in SSA. The adoption is also reported by FAO (2019) to be affected by limited finances and socioeconomic factors.

Agriculture also plays an important role in Lesotho's economy; 8% GDP contribution and more than 60% of Basotho dependency for food and income (Lesotho Meteorological Services, 2017). Given the importance of agriculture and climate change effects to the Local production, the government of lesotho played part to implement ratified UNFCCC agreements. The country has developed a policy agenda for Climate smart Agriculture Investment Plan (CSAIP) that identifies five CSAT investment plans to assure triple win (World Bank Group, 2019). The government is already implementing this plan through agencies concerned about climate change such as Smallholder Agriculture Development Project (SADP II) and through government support (subsidies and incentives). There are several chosen technologies suitable for the country's ecology that are being practiced such as water harvesting and hybrid seeds (Lesotho Country Brief, 2019), but their adoption is significantly low in the country.

Quthing district in particular is highly dependent on rain-fed agriculture which exposes vulnerable smallholder farmers to effects of climatic variations. According to Hunter (2020) and Bureau of Statistics (2021), drought, hail and prolonged cold days are particular concern for the district. This was evident during the 2016 EL. Nino and golf ball sized hailstones that hit the district each year. The World Bank (2019) pointed that despite efforts being made by the government, adoption of CSAT in rural areas is very low.

1.2 Statement of the problem

Lesotho has been identified as one of the countries particularly vulnerable to the negative effects of climate change in the southern Africa (World Bank Group, 2021). Through research, climate smart agricultural technologies (CSAT) have been encouraged as the principal component to address the adverse impact of climate change and acts as a catalytic major for sustainable growth of commercial farming among smallholder crop farmers (FAO, 2010). Matsoari (2015) also believes that accessibility and adoption of this technology can help farmers increase their production hence the country's economy. Although the Government of Lesotho is aligned with the conventions ratified through the formulation of policies that support climate change adaptation measures, CSAT is not intensified (its adoption is still low) and Bureau of Statistics (2019) indicated that agricultural production particularly in the southern part of the country where Quthing is situated has been gradually declining.

The consensus of policy makers, practitioners and researchers is that declining production is because adoption of CSAT is not happening at a desired pace in this part of the country (Khatri-Chhetri, 2017). Before institutional frameworks can be developed and refined, decision makers need to understand the factors that result in poor uptake of CSAT. This situation has led to the study to investigate the factors that influence the adoption of CSAT in the southern part of Lesotho specifically in rural areas of Quthing district.

1.3 Objectives of the study

1.3.1 Overall objective

The main objective is to determine factors that influence CSAT adoption by smallholder crop farmers in Quthing district and to propose practical strategies to influence the uptake of CSAT. Pursuant to this overall objective, the specific objectives are:

1.3.2 Specific objectives

- To evaluate smallholder crop farmers' understanding and awareness of climate smart agriculture technologies.
- To identify CSAT adoption patterns among smallholder crop farmers in Quthing district.
- To identify related interventions and support systems towards CSAT adoption in Quthing.
- To determine factors that influence smallholder crop farmers adoption of climate smart agriculture technology in Quthing.

1.4 Research questions

- What are the CSA technologies adopted by small holder crop farmers in Quthing.?
- What information and knowledge do smallholder crop farmers have on CSAT?
- What interventions and support systems are available to promote CSAT adoption in Quthing?
- What factors are influencing the adoption of CSAT by smallholder crop farmers in Quthing?

1.5 Significance of the study

Smallholder farmers face challenges that hinder their adoption towards climate smart agricultural technology. The study will provide information on constraints that faced by small holder crop farmers towards adoption of CSAT. The findings are expected to assist with a better overview of how farmers can be encouraged and motivated to adopt CSAT. Again, the same study would be important during review and development of strategies used to influence smallholder farmers perception towards CSAT and encourage its adoption.

1.6 Limitations of the study

The research will depend on data from farmers who produce leafy vegetables, and tomatoes exclusively to discover determinants of CSAT adoption while adoption may vary across various commodities.

The possibility of inaccurate and dishonest responses as well as low response rate may limit the study to reach its objectives.

1.7 Delimitation of the study

Due to time constraints and insufficient funds, the study will only be conducted solely in Quthing which is one of the ten districts of Lesotho.

1.8 Hypothesis

1.8.1 Null hypothesis:

H_0: The adoption of CSAT by smallholder crop farmers is not directly influenced by socio-economic, institutional, or demographic factors.

1.8.2 Alternative hypothesis

H_a: Smallholder crop farmers' decision to adopt CSAT is positively correlated with socio-economic, institutional, and demographic factors, indicating a linear relationship among them

1.9 Definition of terms

Smallholder crop farmers: as defined by FAO (2015), smallholder farmers in southern Africa are generally referred to as small scale farms who operate on land holding not more than ten hectares for commercial purposes and normally, they are family-owned farms. Therefore, smallholder crop farmers will be referred here as vegetables producers who operate on a limited scale of up to ten hectares and their farms are family owned.

Climate Smart agricultural technologies: according to FAO (2010) and Mthethwa (2023), it is defined as set of farming strategies and methods approved by the government to increase the resilience and productivity of land affected by climate change.

Rural areas: Geographical area that is located outside town and characterized mainly by agricultural activities. These areas are not defined and declared by the minister under local government but declared by the chief (Land act, 2010).

Adoption: IPCC (2019) and Mujeyi (2021) describe adoption as the act of taking up, following, or employing something. It involves primary plans and measures to reduce the vulnerability against actual or expected stresses.

1.10 Layout of the research

The study is organized into five chapters structured as follows: Chapter One entail the introduction, covering the statement of the problem, objectives, significance of the study, limitations, and delimitations. Chapter Two reviews relevant literature, including past studies and related sources. Chapter Three outlines the adopted research methodology, including the study area description, sampling technique, data collection methods, and data analysis tools. Chapter Four presents the main findings of the study. Finally, Chapter Five provides conclusions based on the findings and offer recommendations for future research or practical applications.

CHAPTER 2

2 LITERATURE REVIEW

2.1 Introduction

This chapter provides a theoretical overview of the study. It is presented in subtitles as follows: overview of agriculture and smallholder farmers, overview of CSAT and its contribution to mitigating the effects of climate change and its role in addressing impacts of climate change, CSAT encouraged in Lesotho and adoption patterns among smallholder crop farmers, the interventions to support farmers toward accelerated CSAT adoption and lastly findings on key influencers on small holder farmers adoption of CSAT across the region as well as strategies that have been employed to promote CSAT in other countries.

2.2 Agriculture and smallholder farmers over-view in SSA and Lesotho

FAO statistics (2016) (cited in Mthethwa, 2022) showed that evident from agricultural share in GDP, the agricultural sector significantly impact the economic growth of many countries in Sub-Saharan Africa. Sabo *et al*. (2017) further mentioned that measured in constant US dollars in 2017, agricultural production increased by 130% in SSA. The crop sector is also found to dominate the total production but differently across regions (Sekariba *et al.*, 2022). Regardless of the increasing agricultural production, Sabo *et al*. (2017) and Mujeyi (2021) proved that southern Africa share has declined by at least 50% and being the lowest agricultural contributor in SSA. Furthermore, drivers of agricultural contribution are found by Dahlin and Rusinamhodzi (2019) to be the smallholder farmers across all regions in Africa.

Sabo *et al*. (2017) mentioned that there is no commonly accepted definition of smallholder farmers. They may be described based on the number of workers, capital invested or amount of land working on. But following FAO (2019) report concept, smallholder farmers are classified by land size of operation and capital invested in the farms. As much as small holder famers are classified by land holding less than 10 hectares, they are significant contributors in agricultural development and food sustainability of developing countries because they are reported by the World Bank Group (2019) to produce 70% of Africa's food supply while also occupying 35% of cultivated land.

Smallholder crop farmers in SSA are faced with declining agricultural productivity that is linked to poor management systems such as low inputs and insufficient control of weeds (Dahlin & Rusinamhodzi, 2019). Sabo *et al*. (2017) and Mthethwa (2023) also included lack of mechanism to overcome climate change effects such as heavy rainfall and extreme temperature stress as major causative effects of low productivity. With more unpredictable weather patterns and events, the resource constrained smallholder farmers are challenged worsening the already declining productivity and suddenly increasing their vulnerability.

Lesotho has an agricultural-based economy, but its contribution seemed to decline in the past five years from 8% in 2018 to 3.5% in 2022 due to changing climate (Lesotho- Country Commercial Guide, 2022). As indicated by Agriculture Finance (2022), agriculture in Lesotho provides more than 40% of economically active employment. Ntloko (2020) further showed that Lesotho's commercial agriculture is also divided in to two main sectors namely, large scale commercial farms and small-scale commercial farms. However, the sector is dominated by small-scale commercial farms (smallholder farmers).

Smallholder farmers are also reported by the World Bank Group (2020) to be the major drivers for Lesotho rural development. Crops are also found to be the dominating agricultural activity while occupying lager portion of agricultural land in the country (Agricultural Finance, 2022). Maize produced by smallholder farmers being the most widely produced crop accounting for 62% and vegetables being lowest at 2% of land cultivated.

Lesotho's Agriculture has been severely affected by climate change effects such as dry spells, El-Nino, and hail stones which have mostly hit southern part of the country where Quthing is situated (FAO, 2021). The country is further explained to experience shift in seasons; extreme hot days followed by prolonged chilly days. According to Policy Brief (2017), the capacity of rain received each year is becoming increasingly uncertain: there has been a decrease in annual rainfall accompanied by consecutive drought occurring within the same season. All this have discouraged unresourceful smallholder crop farmers leaving the major lands fallow while migrating to cities (Help Lesotho, 2022) and this explains the general decline in production. Therefore, the World Bank Group in its 2019 development and climate change report supported FAO intervention indicating that CSAT as a means to address adverse impacts.

2.3 Climate Smart Agricultural Technologies (CSAT)

With the perspective to better enhance agricultural development and aligning with climate-responsiveness which consequently approaches the set sustainable development goals (SDG-1), climate smart agriculture technology (CSAT) was initially integrated by FAO in 2010 to manage the croplands, livestock, and natural lands (FAO, 2019). Climate smart agricultural technologies as defined by FAO (2019) and Mthethwa (2023), is a set of agricultural practices aimed at transforming agricultural development amidst the challenges posed by climate change by adopting green and climate resilient practices with the goal of enhancing agricultural productivity and environmental stability without compromising any of the two while increasing farm income. These technologies include proven practical techniques such as weather forecasting among others (Boto *et al.*, 2017).

It is also pointed by FAO (2021) that CSA technologies aim to tackle at least one of the three main objectives that the global community has vowed to achieve, and these are: to sustainably enhance agricultural productivity and income, to adapt and foster resilience against the destructive impacts of climate change, and to reduce or eliminate greenhouse gas emissions wherever feasible. The relative importance of CSAT as mentioned by Khatri-Chhetri (2017) is different across locations and situations. For instance, developing countries depend heavily on agriculture and they are facing food scarcity challenges due to poor production hence the priority is to adapt to climate change (Sekariba *et al.*, 2022). According to Heeb (2019), adaptation to CSAT can manifest in various forms, spanning from individual farm practices such as selecting vegetable varieties, making management decisions regarding fertilization and pesticide application, or investing in capital, to broader landscape-level decisions concerning water resource management.

CSAT has many of the practices of Conservation Agriculture (CA) although CSAT refers to technologies and practices and CA is a specific approach in farming systems, and these involve different elements embedded in local contexts of the user (Mthethwa, 2023). FAO (2019) identified CSAT as a set of events both on-farm and beyond the farm that include expanding evidence base by looking at current and projected climate change effects, policy frameworks that support CSAT adoption, institutions and enhancing financial investment practices towards CSAT. The World Bank Group (2021) further explained that these activities and strategies entail among others; management of agricultural operations (crops, fisheries and livestock) to ensure food security, overseeing land scape management to sustain ecosystem services that are important for adaptation and mitigation, providing climate services to assist farmers and land managers in better management of climate risks, implementing value chain interventions that maximize the benefit of CSAT, and offering financial support to capacitate CSAT adoption.

CSAT is found to offer several climate smart benefits by its pillars. Bouri *et al*. (2023), explained that these set of technologies are found to maintain productive soil by increasing soil organics, support nutrients cycling, resists disease attacks, manage utilization of resources as well as protecting crops against harsh environmental conditions. For example, according to Samuel *et al.* (2019), in agroforestry systems, trees can assist farmers in adapting to hot or windy climates while also contributing to decarbonisation. Conversely, drought-tolerant crop varieties can enhance productivity even during dry spells while also improving the adaptability of farming households. Therefore, IFAD (2018) stated that smallholder farmers' adoption of the technology is important to increase CSA adoption. IFAD (2016) also emphasized that CSAT includes considerations for post-harvest handling of produce throughout the value chain to reduce losses, in addition to promoting sustainable consumption patterns.

In most areas where CSAT has been practiced, it has resulted in substantial benefits for smallholder farms. Agricultural yields generally increased in the long term (after 3-7 years), and very often increased in the short term as well (Adoro, 2023). This has ultimately increased profitability while labour demand usually decreased or became flexible and less arduous. It is also found by Abrham *et al*. (2023) that the technology has been important for women and vulnerable groups since it has reduced amount of time spend in the farm to manage crops. According to Kifle *et al*. (2020CSAT has been acknowledged for its role in enhancing smallholder farmers' capacity to adapt to climate change by reducing vulnerability to drought and improving local resources critical for farm productivity, such as soil. Therefore, CSAT should be prioritized as a preferred approach to agricultural development for smallholder farmers.

With diverse CSA technology, studies such as those by Sova *et al.* (2018) and Samuel *et al*. (2019) have shown that six technology clusters; crop tolerance to stress, water management, crop management, soil and nutrient management, greenhouse reducing, water harvesting, and protected farming contribute about 50% of all CSA technologies across Sub-Saharan Africa (SSA). However, despite this information, CSAT adoption is still very low in the region.

2.4 Smallholder farmers and technology adoption

In the strategic framework for FAO in 2010, 'adoption' is explained as the extent to which farmers implement new innovative methods with thorough knowledge of their uses and benefits. Additionally, CSAT may either complement each other or may be adopted independently. According to FAO (2019), the importance of CSAT can be realized when production increases and they are being widely used. CSAT is widely known across the globe for agricultural production. This is supported by Mujeyi (2021) who found out that in Mediterranean countries, to lessen the impact of changing climate, CSAT has been found to be the remarkable measure. Bernier (2017) further mentioned that the evolution of irrigation technology by smallholder farmers in these countries has increased to 40% which resulted in a 20% increase in production of crops. Nadeesha, Thilani *et al*. (2020) found out that about 115 countries in the world understand and appreciated CSAT technology. Following that, these authors further explained that 90% of smallholder farmers in China are engaged in CSAT which has increased agricultural contribution on country's economy from 7.1% in 2019 to 7.7% in 2022.

In the context of Africa, Cater *et al*. (2016) described CSAT as encompassing multiple dimensions within smallholder agriculture. They highlighted that smallholder agriculture consists of bio-physical and management components, each comprising various distinct elements. Singh (2020) expanded on this, affirming that the bio-physical component includes climate, soil, crops, and associated inputs and outputs. On the other hand, the management component encompasses people, values, goals, resources, and decision-making processes. Therefore, smallholder agriculture represents a complex interplay of these factors, all of which influence the operation and outcomes of farms in the region.

Despite the potential benefits that are evidenced and documented by practitioners, the adoption of CSAT in SSA has seen partial success (FAO, 2020). Kurgat (2022) and the World Bank Group (2019) mentioned that the adoption of CSAT in Sub-Saharan Africa is very low and argued that smallholder farmers in this region still depend on rain fed agriculture which poses their vulnerabilities to consequences of climate variability. Similarly, in the research conducted by Asif, *et al*. (2022) in Malawi and Samuel (2019) in Ghana, the adoption rate of various CSAT is at 46% and 39.5%, respectively. Maseko (2021) discovered that Farmers in developing countries frequently make adoption decisions without complete information regarding the benefits of the technologies. This implies that there is still a need to sensitize smallholder farmers on adoption of CSAT to improve farming output. Musafiri *et al*. (2021)

also discovered that farmers who intensively adopt one of the CSATs see an increase in their output quantity and quality.

In Lesotho, farmers and rural communities are under the greatest threat from climate change. Although these farmers face multiple challenges including poor soil fertility, poor water resources and changing weather patterns, their adoption rate to climatic variation remedy is very limited (Imani, 2021). The same farmers in the southern region of the country, including Quthing district, are also observed to selectively adopt components of the CSAT approach resulting in partial adoption as reported by Lesotho Commercial Guide (2022). This has led to a limited capacity for agricultural climate change adaptation and mitigation strategies in the country and there is a great need for extensive awareness raising to increase smallholder farmers' ability to produce.

2.5 CSAT adoption and vegetables production

Various adaptation measures can mitigate severe to moderate climatic risks in crop production. Agricultural technologies and practices such as hybrid seed use, soil management and conservation, improved irrigation management and residue management are recognised for enhancing yield (Wekesa, 2017). Additionally, Sapkota *et al.* (2015) highlighted that rainwater harvesting, improved seeds and crop insurance are CSAT that have supported smallholder farmers in adapting to climate change variability, leading to a positive change in production.

Smallholder farmers in developing countries practice CSAT to adapt to climate change impact and to improve their livelihoods. Maseko (2021) and FAO (2019) highlight that CSA technologies are designed to establish resilient agricultural systems that ensure food and income security among crop farmers. Ubisi (2016) argues that escalating effects of climate change have necessitated the adoption of strategies to improve agricultural production. Globally, various proven technologies in crop production are integrated across the globe depending on the climatic effects per region. Techniques such as mulching, intercropping, pests and disease management, tillage with recently adapted water harvesting strategies are common in SSA (Wekesa, 2017). Mujeyi (2021) emphasized the necessity of developing new crop varieties that can be adaptable to changing climate and ecological conditions of SSA. Samuel (2019) adds that these new varieties require less intensive use of inputs like fertilizer and pesticides, making them economically viable and better suited to withstand harsh weather conditions.

In Lesotho, the current crop production pathway focuses on expansion of agriculture crop land to keep the pace of food demand (CSAIP, 2017). According to Lesotho Brief (2018), several CSAT interventions have been proposed and implemented through a broad range of models spanning from global to local scales. CSAT tools become a checklist against which CSAT is promoted. The agriculture system in Lesotho has therefore been modified because of climate change (MAFSN, 2017). Farmers could not overcome challenges of extreme weather and climate shocks and as a result, universities, government, and Non-Government Organizations (NGO) had to create room to experiment and study weather and climate challenges in Lesotho. Analysis and recommendations were made on suitable CSAT to be adopted in the context of Lesotho which include soil and water management as CSAT tools and structures among few approved. The table below provides a description of common CSA technologies adopted in the context of SSA.

Table 1 CSAT practices among smallholder vegetable producers in Lesotho

Technology	Strategies to implementation	Expected benefits
Crop management	Intermediate cropping with legumes, enhanced storage, and processing methods, biofortified crop varieties, rotational cropping, diversified crops, cover crop utilization, adjusted planting schedules, and drought-tolerant varieties	Improved dietary variety, increased crop yields, higher incomes, and Improved soil fertility.
Resource degradation management	Intercropping cereal with legumes, implementing Conservation agriculture methods such as gabion blocks, reduced tillage (minimum/no tillage and crop residue management), Contour planting on Terraces and in pits, adopting Innovative irrigation technologies like drip irrigation and irrigation scheduling and using Organic or green manure, composting.	Improved water infiltration, reduced soil erosion, enhanced soil fertility, higher crop yields, Improved water use efficiency, increased storage of carbon and nitrogen and decreased pollution.
Greenhouse Gas emission decreasing technologies.	Agroforestry (e.g., Nitrogen-fixing trees, versatile trees, Integrated Pest Management (IPM), Fodder production.	Intensified removal of CO emissions, organic fertilizer Knowledge Related.
Protected farming	Establishment of green houses, tunnels, and shade nets	Controlled evaporation, less erosion, reduced crop damage and improved yield.
Knowledge Related.	Extension information dissemination concerning weather, weather forecasts, Farmers' e-learning, credit accessibility CSA technologies and remote-control Soil conservation. Smart mobile phones access.	Improved knowledge dissemination intensified financial support, clear planning (when and what variety to plant, what technology to use, fertilizer application rates, when to weed etc.), minimized operational costs, market accessibility and access to meteorological services.

Water harvesting and storage	Ground water harvesting, dams, and tank storages	Water smart practices give opportunities for farmers to mitigate climate-induced water stress and creates water access during scarcity periods

Source: Atwi et al. (2015), Conradt et al. (2015), Carter et al. (2016), CSAIP (2017) and FAO (2022)

2.6 Farmers' understanding of the technology

Ouedraogo (2019) defined understanding as the tendency to act in a certain way. By understanding, a farmer may predict the foreseen impact of the technology. According to Yan (2021), Understanding or perception of farmers towards technology may also be seen as by-product of experience, acquired habits and environmental influence by which they are surrounded.

Farmers' perception of technologies offers a unique perspective on technology adoption, as they directly interact with these innovations and understand them differently compared to researchers and extension agents (Musafiri *et al*., 2021). According to Maseko (2021), farmers' perception is influence by their knowledge and understanding of the innovation, socio-economic context, and their assessment of the performance of CSAT. These factors significantly shape their decision-making process regarding CSAT adoption. Furthermore, Carter *et al*. (2016) suggests that farmers are more inclined to adopt technologies they perceive as meeting their needs, compatible with their environment, or capable of enhancing productivity, viewing such adoption as a positive investment. The adoption decision, therefore, rests on farmers' evaluation of the technology's value. In contrast, Ouedraogo (2019) found that technologies perceived to require new skills and be time-consuming are less likely to be adopted by farmers. Additionally, Mthethwa (2023) observed that farmers prioritize immediate benefits over long-term gains. Ouedraogo (2019) also emphasized that a clear understanding of technology by farmers enhances its adoption likelihood.

Chuang, Wang and Liou (2020) discovered that CSAT strategy focuses on the digital technology to create precisions for farming solutions combined with the application of technical communication and information. According to Singh (2020), while this combined artificial intelligence has been acknowledged for its potential to enhance yield and reduce damage in agricultural production, it has also posed challenges for farms. These challenges have led to complexities in understanding and adoption. Consequently, the integration of new technology remains relatively low compared to the perceived benefits. On the other hand, Ayanlade *et al*. (2017) concluded that farmers understanding, and perception may not alone guarantee the adoption of CSAT as many factors have let to dis-adoption of new technology in Nigeria although farmers seemed to understand the concept of new technologies.

2.7 Interventions to support CSAT adoption among smallholder farmers

As an initiative to support climate change causative reduction, 196 countries participating in United Nations climate change conference (COP21) in Paris agreed to limit the global average temperature increase (The Paris Agreement, 2022). Climate smart agricultural technologies have emerged as a critical strategy to transform agricultural systems towards environmentally suitable and climate resilient practices, prioritized by stakeholders in food security and a safe planet during the conference (UNDP, 2018). According to FAO (2019), to scale up CSAT adoption, many stakeholders have been aligned with the COP21 and United Nations framework on climate change (UNFCC) policies on CSA.

Understanding Poverty (2021) stated that the World Bank adopted the Paris agreement to reduce greenhouse emissions while increasing food production by significantly scaling up its engagement to invest in CSA. In the World Bank (2021-2025) climate change action plan, the World Bank has developed four tools under CSA of which in overall it aims to help countries identify climate impacts on agri-foods and systems such as reduced yield, to give overview of the agricultural challenges and how CSA can help them mitigate this effects by bridging knowledge gaps on CSA and development of CSA investment plan, to mainstream CSA in to national agricultural policies as well as identifying investment areas. Through all this, the World Bank has intervened by providing financial and technical assistance.

On the other side, FAO (2020) shows that as one of the climate change stakeholders, it has prioritized CSAT adoption. It supports countries in creating the required policies with the aim to ensure that implementation practices, policies and investments for CSA are clear. FAO, (2021) has further suggested practices adaptable and sustainable in terms of resource usage such as plant breeding. In its strategic framework 2022-2031, FAO suggested investment in low-income countries by proposing approaches that can support countries fulfil their policy commitments and implement United Nations Framework Convention on Climate Change (UNFCC). It further initiated the monitoring and evaluation of CSA implementations while it is also crucial on usage of natural resources.

In many countries, support systems are brought through the enabling environment to encourage adoption. According to Sulaiman (2017), the enabling environment refers to the framework conditions that facilitate and support adoption of any required technology. Enabling environment as listed by Carter *et al*. (2016) provide the laws, regulations and incentives which clearly spell out the CSA adoption mandate. Climate change scientists, governments, and non-governmental organizations (NGOs) are advocating adaptation and mitigation as sustainable response to the effects of climate change.

Evidenced from Bouri *et al*. (2023), there is a need to transition towards CSAT which can be achieved through establishing and fostering a policy environment conducive for adaptation. African head of states are committed to accelerate agricultural growth and resilience by 2025. To accomplish this goal, the Southern Africa Development Community (SADC) is implementing the initiatives for climate smart agriculture. The World Bank Group (2023) further reported that African governments through African Union commission (AU) advocated for CSAT awareness raising and resource mobilization through funds across stakeholder countries as a means to improve implementation capacity and integration of all potential CSAT across Africa.

In the case study by (Howland, 2018) in Colombia, it was addressed that climate change, agriculture and food security team initiated the implementation of the climate smart village monitoring plan. In this plan, farmers within a village are engaged in participatory action aimed at evaluating options of CSAT that are most suitable across then three CSAT pillars (productivity, adaptation, and mitigation). Constraining adoption factors on potential measures were addressed such as financial restriction at farm level, where farmers were encouraged to join financial cooperatives to assist them in adoption of potential CSAT such as protected agriculture. Ghana like any country has devoted to encouraging CSAT through its friendly policies. Sulaiman (2017) highlighted the development of a national Climate-Smart Agriculture and Food Security Action Plan aimed at operationalizing the national climate policy. This initiative seeks to effectively integrate climate change into food and agriculture development policies.

In the report by United Nations-South Africa (2021), it was emphasized that after identifying the most limiting factor in CSAT adoption, the South African CSA guidelines were developed within CSA practices, CSA value chains and CSA enabling environment. FAO & UN women South Africa (2021) further showed that the government of south Africa developed innovative index-based agriculture insurance packages for agricultural products. Bouri *et al.* (2023) also mentioned that the investment in the Agro-Meteorological infrastructure and enhancing the capacity of micro-finance acts as agent to deliver innovative production packages. According to Ntoyi (2020) in the department of environment in South Africa, upon seeing the gaps in the initiatives, the South African government is also executing programs that will divert from conventional farming mechanization to CSAT mechanization through policy inclusion of provision of cross-sectional coordination of CSA promotion and mainstreaming strategies by availing resources such as CSA funding and market infrastructure.

In the context of Lesotho, creating a conducive environment involves establishing policies, institutional arrangements, stakeholder involvement, infrastructure development, and ensuring access to knowledge. In line with the UNFCCC agreement, Lesotho has submitted and ratified its Nationally Determined Contribution (NDC) to the convention in 2017 affirming its commitment to mitigate greenhouse gas (GHG) emissions. This was supported by establishment of several policies such as pest management policy (PMP) of 2017 that addresses usage of chemicals on agricultural lands and Environmental policy (2017) that focuses on environmental awareness and safeguard on carbon emitting industries among others. The country is also implementing the Comprehensive Africa Agriculture Development Program (CAADP) framework for 2010 which outlines sustainable land and water management for improved agricultural productivity through research, technology adoption and dissemination (Lesotho Agricultural Research Report, 2018). Lesotho has also got support from CAADP in developing national agriculture investment plan (NAIP) which is now in operation.

Lesotho's National Strategic Development Plan (NSDP) 2012-2017, which remains operational, has been instrumental in advancing various climate change policies, as noted by Ntloko (2020). This framework has also facilitated the development of the National Adaptation Program of Action (NAPA), aimed at addressing anticipated climatic changes, with a significant focus on agricultural strategies, including Climate-Smart Agriculture Technologies (CSAT), although not explicitly stated. Despite the absence of a specific CSAT policy or strategy, as reported by Lesotho Brief (2019), the government utilizes broad categories such as crop production, cropping systems, and climate change adaptation plans to implement CSAT initiatives. In collaboration with the World Bank, the government has initiated efforts to integrate climate change considerations into the country's agricultural policy agenda through the Climate-Smart Agriculture Investment Plan (CSAIP). The Lesotho CSAIP identifies investments in CSAT that promise multiple benefits, such as enhanced productivity and income. Currently, the government of Lesotho is actively implementing the CSAIP under the second phase of the Smallholder Agricultural Development Project (SADP II), demonstrating a commitment to enhancing agricultural resilience and sustainability in the face of climate change.

World Bank Group (2020) indicated that in 2017, the World Bank approved ten million US Dollars to support the ongoing smallholder agricultural project (SADP) on farmers adaptation to CSAT. So far 55,000 beneficiaries across the country have benefited but just 7% of these beneficiaries are in Quthing district. In response to climatic effects that have been going on in the country, FAO designed an emergency and resilience program to promote CSAT throughout the country in 2016/2017. According to FAO (2020), the program reached 2500 farming households by promoting water harvesting structures and natural resource management. FAO (2020) further reported that less than 11% of farming households consider the water harvesting programs. National budget (2023) also stated that the government of Lesotho initiated subsidy program where farmers pay 20% of inputs costs while the government pays 80%.

2.8 Factors affecting adoption of CSA technology among smallholder vegetable farmers

Farmers' adoption of Climate-Smart Agriculture Technologies (CSAT) is influenced by a diverse array of factors, as identified in previous research highlighting reasons for potential hesitancy. Researchers have investigated both internal (endogenous) and external (exogenous) factors that play roles in technology adoption. Mozzato *et al*. (2018) categorize these factors into four main groups: socio-demographic characteristics, institutional factors, farmers' perceptions of the technology, and socio-economic factors. These factors can be either observable or non-observable, emphasizing the necessity of conducting a thorough examination of all dimensions when studying CSAT adoption.

2.8.1 Socio demographic characteristics

Mthethwa (2023) describes socio demographics as social and personal attributes that describe a population or group of people. Farmers' demographics include among others, age of a farmer, years of engagement in farming, gender of a farmer, education and training, and household size. These characteristics can influence farmers' decision on participation positively or negatively.

Years of engagement in farming

Years of farming can have both positive and negative relationship on technology adoption based on the literature. According to Mthethwa (2023), in South Africa, number of years in farming affected adoption of CSAT positively, the study found that as the duration of farming experience and integration of CSAT on farms. This trend is attributed to the fact that farmers with longer engagement in farming have accumulated capital and have greater access to financial services particularly for technologies that need financial investment such as under-ground water harvesting technology. Kassa and Abdi (2022) also mentioned that farmers who have been engaged in farming for longer period learn from experience on how climatic effects affect their production hence they easily accept new technology better to maximize output. On the other hand, Tran *et al*. (2019) in Zimbabwe concluded that farmers with less years of farming were more likely to adopt CSA because they believe in risk taking than experienced farmers. IFC (2018) further mentioned that farmers who have been engaged in farming for substantial amount of time are found reluctant to adopt new technology since they are comfortable with old technology and not looking up to challenges of new innovations.

Farmers' education and trainings

Farmers' level of education and training is a valued variable that influences technology adoption among smallholder farmers and that builds mental attitude towards acceptance of the technology (FAO, 2019). For instance, Manda *et al.* (2016) and Amadu *et al*. (2020) observed that educated farmers tend to adopt new technologies more readily than their less educated counterparts, as educated farmers are perceived to grasp, comprehend and implement innovations in a short period. Amadu *et al*. (2020) further explained that training also builds farmers' capacity to utilize skills pertinent to technology. Likewise, Kassa and Abdi (2022) found that each additional year of formal education by a farmer increases chances of CSAT understanding and its adoption.

Gender of a farmer

In SSA, women play a significant role in agriculture, but their participation in CSAT adoption is hindered by various factors. Amadu *et al*., 2020 and Martey *et al*. (2020) mentioned that Women constitute minority, with only 35% involved in agricultural enterprises in SSA. They face legal barriers restricting their access to property rights, including land use and ownership (*Amadu et al.,* 2020). Consequently, IFC (2017) supported showing that in SSA, often lack resources and capital necessary to invest in the current farming land and access financial service. Tran *et al.* (2019) highlighted further obstacles for in accessing improved inputs, production technology, land and education which are critical for the deployment of CSAT such as climate smart pest management (CSPM) innovation. Martey *et al*. (2020) further emphasized that Limited of productive capital available to women also impact the proportion of their capacity to cope with adverse climate effects underscoring gender disparity in adopting CSAT. For instance, in Ethiopia, Kassa and Abdi (2022) found that women can restricted access lesser land for an agricultural purpose which renders their adoption of new innovations, again, Amadu *et at.* (2020) also reported Cultural gender discrimination also contributes to lower technology adoption rates among farms headed by women compared to those headed by men.

Household size

Evidenced from FAO (2019), certain technologies require extensive labour for implementation. In small-scale farms, the size of the household is directly related availability of labour. When family members contribute to meeting this labour requirements, the adoption of CSAT tends to exhibit a linear relationship. Researchers like Martey (2020) and Amadu *et al*. (2020) have demonstrated a linear correlation between household size and adoption of labour-intensive CSAT like intercropping. In their studies, the emphasized that larger household sizes play a vital role in farms operations and crop management, thereby influencing the adoption rates of CSAT. This linear relationship is further supported by Kassa and Abdi (2022) who found that in Ethiopia, the lager the family sizes lead to increased engagement in CSAT, thereby enhancing the likelihood of technology adoption and subsequently boosting production and profits.

2.8.2 Socio-economic factors

Socio-economic factors as explained by Cabridge Dictionary and Bernier (2017) are referred to as opportunities and the position of community resources. They include among other but not limited to access to credit and finance, insurance, access to suitable equipment and technological diffusion, infrastructure, benefits from the technology, member of social group.

Farm size

The literature presents conflicting perspectives on the relationship between farm size and technology adoption. Mellisse (2018) conducted research on factors influencing technology adoption and found that farm size negatively impacts the adoption of improved technologies. Specifically, smallholder farmers operating on smaller plots of land tend to adopt innovative technologies more readily than those with larger land holdings. This suggests that technologies such as Conservation Agriculture (CA) are less likely to be adopted on larger farms. Conversely, Nkhoma *et al*. (2017) present a contrasting viewpoint, demonstrating a positive correlation between farm size and technology adoption. They argue that larger farm size is often associated with greater wealth, providing farmers with the capital necessary to invest in various technologies for agricultural improvement. These contrasting findings underscore the complexity of factors influencing technology adoption in agriculture, suggesting that the relationship between farm size and adoption rates can vary depending on local contexts, economic conditions, and specific technologies under consideration.

Farmers' income

Technology adoption requires financial support. According to Bernier (2017), Due to poor production and poor market, Small Holder farmers who depend solely on their farm income discouraged their adoption to improved technology because they are unable to raise required financial support. Kassa and Abdi (2022) observed that farmers with higher incomes are more inclined to adopt technologies compared to those with lower incomes. This finding is supported by Mthethwa (2023), who noted that farmers supplementing their income with off-farm sources are in a better financial position to invest in their farms and adopt technologies that enhance agricultural performance. According to Kifle *et. al* (2022), technologies such as irrigation systems and fertilizers can be relatively costly for smallholder farmers to adopt, necessitating greater financial resources. Consequently, farmers' income levels play a significant role in influencing the adoption of Climate-Smart Agricultural Technologies (CSAT), demonstrating a clear linear relationship where higher income levels facilitate greater adoption rates.

Access to Infrastructure

Access to infrastructure significantly influences the adoption of technology in agriculture, as highlighted by Rasheed (2016). Physical infrastructure such as water supply, transportation, market facilities, and storage infrastructure plays a crucial role in facilitating the adoption of technologies like CSPM, as it enhances the efficiency of the agricultural value chain. Social infrastructure, such as farmer organizations, also positively impacts the adoption of CSAT among smallholder farmers. However, Doss (2018) points out that inadequate infrastructure, both physical and social, limits the adoption of CSAT, especially for smallholder farmers who rely heavily on farm-generated revenues for their investment decisions. Furthermore, the geographical location, topography, and weather conditions of an area can either encourage or discourage the adoption of CSAT. For example, in highland areas with steep landscapes, the adoption of technologies like protected agriculture and irrigation may be hindered due to topographical challenges (Gebre, 2021). These factors collectively underscore the importance of supportive infrastructure and local conditions in facilitating the widespread adoption of CSAT in agricultural practices.

Benefits from the technology

The technology must have outstanding benefits to the farm and household to foster its adoption. According to Musafiri *et al*. (2021), for technology to be widely adopted among smallholder farmers, it must offer substantial ecological, economic, and social benefits to both the farm and household. This comprehensive approach ensures that the technology addresses immediate needs and concerns of farmers, aligning with their priorities for sustainable agricultural practices. For instance, in Sub-Saharan Africa (SSA), technologies that provide significant economic benefits upfront are preferred over those promising future benefits. This preference is due to the immediate food insecurity risks faced by smallholder farmers, as highlighted by Bouri *et al*. (2023). Therefore, technologies that demonstrate clear and tangible benefits in terms of increased income, improved productivity, and enhanced resilience are more likely to be adopted by farmers in SSA. However, Sabo *et al.* (2019) says most effective CSA technologies benefits are seen in the long term such as CSPM and assessing costs and benefits of CSA technologies can be correctly attained in the long run because at first phase they may be seen costly. This is why adoption of the most relevant CSAT investment in the SSA failed.

Ownership of assets

Ownership of equitable assets significantly influences technology adoption among farmers. Factors such as farm profits, household head earnings, and ownership of equipment play crucial roles in this adoption process. Researchers like Maseko (2021) have highlighted that farmers who possess substantial resources and assets are more likely to have the necessary funds and materials to adopt innovative technologies. Additionally, Mthethwa (2023) has emphasized that earnings from non-agricultural activities enable farmers to finance capital expenses associated with innovative technologies.

2.8.3 Institutional factors

Institutional factors may refer to structures in society that guide behaviour and the norms derived from frame works, culture and government agencies (Geber, 2021). The common Institutional factors among smallholder farmers are availability of financial services, insurance services, information dissemination among farmers and belonging to social group.

Access to financial services

Access to financial services is found to influence technology adoption positively. Credit and loans give farmers the opportunity to purchase inputs and investment technology thereby influencing adoption of climate smart technology (Nkhoma *et al.*, 2017). Other research such as USAID (2017) have discovered that promoting credit, influences the adoption of technology through relaxation of liquidity constraints and enhancing household risk bearing ability by creating possibilities to buy inputs, equipment and hiring labour.

Most often these technologies require finances and Kifle *et. al* (2022) further mentioned that smallholder farmers fear to take risks and reinvest their little income because it might threaten their household food security. Farmers are then seen to give up on CSA practices such as climate smart pest management (CSPM) and ground water harvesting as well as hybrid seed in the absence of financial stream support (Gebre, 2021). Lipper *et al.* (2020) further supported that insufficient financial support to obtain investment and inputs hampers adoption rate of CSAT. Martey *et al*. (2020) add that low adoption rates are prevalent in SSA countries, primarily due to discrimination against farmers by credit institutions, which prevents them from financing technologies aimed at increasing yields.

Membership to social group

Social groups can exert both positive and negative influences on technology adoption among farmers. Mujeyi (2021) concluded that membership in social or farmers groups supports social capital, facilitating trust, idea exchange, and information sharing about innovative technologies. Farmers that participate in these community-based organizations are more likely to acquire knowledge about innovative technologies, thereby increasing their propensity to adopt them. This finding resonates with Doss (2018), who observed that farmers belonging to cooperatives were more inclined to adopt Climate-Smart Agriculture Technologies (CSAT) compared to those who were not part of such groups in Zimbabwe.

However, Gebre (2021) found that social groups can also engender negative attitudes towards innovative technologies, particularly in situations where free riding behaviour is prevalent. This suggests that while social groups can be beneficial for technology adoption through knowledge sharing and support, they may also pose challenges if issues like free riding undermine collective efforts towards adoption.

Implementation approach

The literature supports those reducing farmers vulnerability through adaptation strategies is crucial (FAO, 2019). It emphasizes that climate adaptation strategies should not be imposed in a top-down manner. According to Ubisi (2016), South Africa's strategies and policies have seen limited success due to their top-down approach, where government decisions may not align with the actual needs and challenges faced by rural smallholder farmers. According to Lipper *et al*. (2020), argues that the failure of such top-down approaches is rooted in decisions made by the authorities who may lack awareness of local realities and specific needs of smallholder farmers. Sabo *et al.* (2017) further advocate for a participatory approach, where both decision-makers and farmers perspectives and insights are integrated into adaptation strategies, leading to more effective and locally relevant solutions.

Acquisition of information

Adaptive strategies essential for CSA require appropriate practices, equipment, and technological innovations (Lipper *et al.*, 2020). They further stated that extension services play an important role in the implementation and diffusion of new technology and bridge the gap between farmers and new technology. Extension workers do this through farmers' meetings, farm visits and demonstrations (FAO, 2019). This service can also counterbalance the negative effect of lack of formal education (Mwangi and Kariuki, 2015). Access to information by extension service helps farmers make informed decisions and hence a positive relation between extension service access and CSAT adoption. Emmanuel *et al*. (2016) further noted that most farmers access information through extension offices on critical information about innovative technology. Similar findings are also discussed by Khonje *et al*. (2018) that lack of access to extension service denies farmers an exposure to information about innovative technology hence, the adoption becomes poor.

Land tenure system

It is a system of land rights and legally accepted institutions that regulate access to land use (UNFCCC, 2017). Land tenure systems that overlap or vague constraint farmers' investment interests in CSAT. FAO (2019) mentioned that this barrier may result from land access for shorter periods because it is borrowed, inherited, or rented especially for CSA long term investments such as water harvesting, protected agriculture and CSPM. Clear and long-term access to land by individual farm access and proper user rights are found to positively foster CSAT investment and adoption (Lipper *et al*., 2020). This is because the farmer will not be curious about sudden repossession of land. For example, on Mukubu irrigation scheme in Uganda, Ngigi (2021) found that there was withdrawal of development partners from the scheme because of land tenure systems that were insecure. This tenure system also restricts farmers from accessing financial services from development agencies because of undefined land access.

Management, and government structures

Leadership, management, and government structures do influence and guide the legal frameworks that shape the societal institution. Bad governance is found by Gebre (2021) to be an inhibitor of desired developments that can foster community adaptation to CSAT. This is because incompetent management is seen to focus on instant gains and innovation that brings gains in the long run will not be prioritized. Therefore, poorly managed institutions fail to mitigate climate change. Ubisi (2019) in his study reported that in SSA, where there are a proportion of vulnerable smallholder farmers that have inadequate supportive government structures, there is unfair allocation of resources, effective information diffusion and decently implemented policies that protect environment and CSAT implementation. Lipper *et al.* (2020) further stated that encouraging people through forceful implementation of policies and allocation of resources would capacitate them to adopt CSAT. According to Melissa (2018), in SSA, there is a linear relationship between CSAT adoption and good management structure. CAADP also identified lack of adequate policies, lack of policy coherence, lack of technical capacities and insufficient capacities to resource as well as insufficient engagement by private sectors as major challenges to uptake of CSAT by smallholder farmers since they do not have support from relevant stakeholders.

2.8.4 Socio-Cultural

Cultural norms, beliefs and values can bring both barriers and opportunities to acceptance and adoption of CSAT. This is proven by Lipper *et al*. (2020) in his study of two comparable ethic group in Ghana where he found that Adansi group easily accepted diversification in their livelihood approaches to adjust to climate change, the Abidjii people instead found the same approach unacceptable. This proves that certain societal culture can render certain adaptive approaches to climate change impractical even though it has been practiced in another group. Smallholder agriculture in SSA is the main activity for food security within which culture, norms and beliefs are important aspects. However other culture activities such as belonging to social group influences acceptance of innovation through knowledge sharing. According to FAO (2020) some cultures restrict females to have full access to land ownership, hence female headed farming household are discouraged to invest in selected CSATs due to uncertainty of land regulation. Gebre (2021) elaborates that farmers who perceive a symbiotic relationship between humans and the environment are more inclined to adopt farming practices that promote harmony with nature. These farmers are also more likely to consider Conservation Agriculture (CA), which emphasizes sustainable agricultural practices that enhance soil health, biodiversity, and ecosystem services while minimizing disturbance to the soil.

2.8.5 Climate information service

Effective climate services are integral to creating an enabling environment for transition to CSAT (IPCC,2020). Timely and accurate weather information can empower farmers to make informed decisions regarding the adoption of appropriate CSAT thereby enhancing agricultural productivity. It allows for proper planning of a range of climate possibilities. It enables farmers to make decisions on CSAT investment to choose to adapt through risk management and provides more efficient use of CSAT for the forecasted weather. Samuel (2019) found out that farmers without access to climate service are hindered to make timely decisions.

2.9 Strategies to encourage CSAT adoption among smallholder farmers.

Many SSA countries are susceptible to the impact of climate change due to their heavy dependency on agricultural production and limited adaptive capacity (Maseko, 2021). Drawing from the findings in CSA literature across SSA, various recommendations and strategies are proposed to address barriers to the adoption of CSAT and inform programs whose intensions are to scale up CSAT practices to fully realize their potential. According to Att-Aidoo (2022), CSA is more knowledge intensive and concerned stakeholders need to provide long-term tailored support for farmers to adopt CSAT. The following strategies that worked for other countries in SSA can be employed.

2.10 Development of CSA thematic guidelines

Developing initiatives for Climate-Smart Agriculture (CSA) requires a systematic and practical approach, as highlighted by the European Mobility Week (2022). This approach aims to achieve clear and productive outcomes aligned with CSAT goals. Drawing on successful strategies, South Africa has demonstrated effectiveness by implementing guidelines grounded in CSAT practices, focusing on the agricultural value chain, and creating an enabling environment. In South Africa, the Department of Rural Development has pioneered the concept of Agri-parks to foster the inclusion of rural farmers in agro-processing and to reduce post-harvest losses. This initiative, as noted by Mthethwa (2023), has significantly boosted smallholders' participation in commercial farming. One of the notable impacts has been the substantial increase in the adoption of improved agricultural technologies among rural farmers, rising from 32% to 73%. This adoption of technology has played a crucial role in enhancing production efficiency and overall agricultural productivity in rural communities.

Nkhoma *et al.* (2017) further emphasized that the success of the Agri-parks initiative underscores the importance of creating supportive frameworks that enable farmers to access resources, technologies, and markets essential for CSAT adoption. By integrating smallholders into value chains and promoting technological advancements, South Africa has effectively empowered rural communities to embrace sustainable agricultural practices. This holistic approach not only improves livelihoods but also contributes to broader socio-economic development and resilience against climate change impacts.

2.11 CSA funding sources

CSAT needs to be driven by investments in the agricultural sector. It also needs additional financial resources to support the establishment of better technology and trained staff. According to Ngigi and Muange (2022), improving access to resources is critical to encourage adoption of CSAT. This could include interventions and programs that provide farmers with access to credit, increase access to education, extension services and organize tailored training programs. The World Bank Group (2019) also mentioned that there is no doubt that requirements of CSAT are relatively costly and beyond affordability of many farmers. This means that there would be a need to support potential farmers financially and it can be achieved through multiple funding streams. Governments are compelled to fulfil the declaration that states, "African governments should allocate 10% of their spending to agriculture" (AU, 2019). Ngigi and Muange (2022) also pointed that in Ethiopia, as a means to diversify fund streams, enhancement capacity of micro- finance institutions to function as agents for innovation to farmers has helped with famers funding through credit.

2.12 Establishment of co-ordination mechanism to support CSAT

Rasheed (2017) mentioned that effective coordination and networking among various stakeholders are essential for planning and implementing CSAT interventions. This approach ensures that resources, knowledge, and efforts are aligned to maximize impact and sustainability. Governments play a crucial role in facilitating these networks by fostering collaboration among different sectors and agencies involved in agricultural development and climate resilience. Antwin (2020) expands on this by highlighting the mechanisms that facilitate effective coordination. These include interministerial or departmental working groups, policy working groups, and stakeholder platforms. These platforms serve as arenas for dialogue, knowledge sharing, and decision-making among diverse stakeholders, including government bodies, research institutions, non-governmental organizations, farmers' associations, and private sector entities. By bringing together these stakeholders, governments can harness synergies, pool resources, and streamline efforts towards achieving common goals in promoting CSAT.

Ngigi and Muange (2022) provide a practical example from Ghana, where coordinated support systems for Climate-Smart Agriculture have enabled smallholder farmers to make informed decisions about farming systems and land use. This coordination involves linking farmers with various support systems such as extension services, research institutions, agricultural input suppliers, and financial institutions. Through these linkages, farmers gain access to relevant information, technologies, inputs, and financial services that support their adoption of climate-resilient agricultural practices. According to Nkhoma (2017), the coordination of support systems not only enhances the adoption of CSA but also improves the efficiency and effectiveness of interventions by addressing local challenges and opportunities in a holistic manner. It enables tailored approaches that consider specific agroecological conditions, socio-economic contexts, and farmer preferences, thereby increasing the likelihood of sustainable agricultural development.

2.13 Investment in climate information system

As highlighted by Phiri *et al*. (2022), a significant barrier to the adoption of Climate-Smart Agriculture Technology (CSAT) is the lack of access to climate information. Establishing weather stations and forecasting tailored to local agricultural conditions can provide accurate climate information to farmers. The World Meteorological Service, as cited in Musafiri *et al*. (2022), emphasized the critical role of climate information in raising awareness and preparing for future climate scenarios. Timely provision and effective dissemination of climate information are pivotal for promoting CSA among smallholder farmers.

Farmers, as noted by Andati *et al*. (2022), significantly benefit from access to climate information in planning their farming activities including decisions on planting dates, crop varieties, and investments in agricultural technologies aimed at safeguarding their farms against climate risks. Therefore, capacity building programs to enhance farmers' capacity in interpreting and utilizing climate information has been an effective measure. Ngigi and Muange (2022) further highlighted the importance developing advisory services that interpret weather forecast and provide actionable recommendation such as guidance on optimal planting times and crop selection. Investment in infrastructure supporting mobile apps, SMS services, and climate information broadcasting, as recommended by Phiri *et al*. (2022), should be prioritized to enhance access to climate information among smallholder farmers.

2.14 Capacity development for CSAT

Deepening and broadening knowledge about climate-smart agriculture technologies (CSAT) is crucial for enhancing adoption among smallholder farmers. As highlighted by FAO (2021), one effective strategy involves the development of training manuals that cater to all stakeholders involved in CSAT initiatives. This approach ensures that farmers, extension workers, policymakers, and other key actors have access to comprehensive and accessible information about CSAT. In Malawi, for instance, FAO has emphasized the importance of strengthening trainers on CSAT, which plays a pivotal role in disseminating knowledge and building capacity at the grassroots level (FAO, 2021). This initiative aims to empower local extension workers and trainers with the necessary skills and knowledge to effectively communicate and implement CSAT strategies within their communities.

Research by Att-Aidoo *et al*. (2022) and Moroyiwa (2022) highlight a critical barrier to adoption in some regions: inadequate knowledge among extension workers regarding new agricultural technologies. Extension workers serve as frontline implementers who facilitate the transfer of knowledge and technologies from researchers to farmers. Therefore, capacitating these extension workers through targeted training programs is essential. By equipping them with up-to-date information, practical skills, and communication strategies, extension workers can effectively support farmers in adopting and implementing CSAT. Moreover, Musafiri *et al*. (2022) mentioned that enhancing the capacity of extension workers not only improves the adoption rates of CSAT but also fosters sustainable agricultural practices and resilience to climate change among smallholder farmers. This capacity-building approach ensures that extension services are responsive to local contexts and farmer needs, thereby increasing the likelihood of successful technology uptake and implementation.

2.15 Women empowerment:

Shahbaz (2022) underscores the critical importance of empowering women in Climate-Smart Agriculture (CSA) by enabling them to share their experiences, engage in discussions about barriers to technology adoption, and gain access to productive resources. This approach represents a departure from traditional gender mainstreaming efforts, as noted by Khoza (2019), which primarily focused on initiatives like providing land ownership to women-headed households. In Sub-Saharan Africa (SSA), it is imperative for researchers and policymakers to involve female farmers directly in decision-making processes related to CSA, as exemplified by practices in Malawi. Female farmers constitute a significant portion, comprising 38% of smallholder farmers, yet their exclusion from decision-making has impeded progress in CSA adoption rates (Sulaiman, 2017).

According to Doss (2018), Including women in CSAT decision-making is crucial for several reasons. First, it acknowledges their roles and contributions in agricultural production and household food security. Second, it recognizes that women often have distinct knowledge and perspectives on farming practices and climate change adaptation strategies. Third, empowering women in CSAT can lead to more equitable outcomes, as it addresses gender disparities in access to resources, information, and technologies. By involving female farmers in all aspects of CSA decision-making from planning and implementation to monitoring and evaluation, policymakers can ensure that interventions are responsive to the diverse needs and realities of women farmers. This inclusive approach not only enhances the effectiveness and sustainability of CSA initiatives but also contributes to broader goals of gender equality and agricultural development in SSA.

2.16 Information dissemination

In the study conducted by Lopez-Avila (2017), it was suggested that knowledge dissemination approaches such as social networking and peer learning, information, and communication technologies (radios, television, and telephones), group and individual training and demonstration (extension, demonstration fields, field day schools) be incorporated. The demonstration approach helps to eliminate both perceived and actual risks involved in the adoption of CSAT (Rasheed, 2017). Lopez-Avila (2017) further stated that the experience, knowledge, and lessons learned can be transferred to the actual farm over time with less risks and broad knowledge.

In the final report for APPSA report (2019), Institutional commitment and arrangements that include collectivization such as farmer cooperative, contract farming, improved land titling to encourage farmer investment on land of operation and community infrastructure such as construction of dams for irrigation and planting of trees. Abegunde *et al*. (2019) mentioned that there is a need also for more research support to select the most relevant technology to a new and more variable climate for decision on investments. This could also be done through the creation of research fund mechanisms and learning about research results and good practices on CSAT.

2.17 Top-down approach inclusion

In addition to considering different underlying approaches for farmers' inclusion in decision-making interventions, it is crucial to acknowledge the diverse challenges and preferences among smallholder farmers. As highlighted by Ogisi and Begho (2023), many smallholder farmers exhibit risk-averse behaviour, which can significantly influence their adoption of innovative technologies, even when potential benefits are substantial. To effectively address this challenge, employing a top-down approach for the dissemination of knowledge on innovative technologies can be advantageous. According to Shahbaz *et al*. (2022), This approach ensures that essential information reaches farmers efficiently and comprehensively. By leveraging established channels such as agricultural extension services or farmer cooperatives, stakeholders can disseminate information systematically and ensure wide coverage.

Conversely, embracing participatory and community-led development approaches represents another essential strategy. These bottom-up approaches involve farmers directly in the decision-making process, empowering them to contribute their insights and preferences (FAO, 2019). This does not only enhance the relevance and appropriateness of interventions but also fosters ownership and sustainability within the community. The involvement of farmers in the design process, as emphasized by the FAO (2020) and supported by Ogisi and Begho (2023), is paramount. By engaging farmers from the outset, interventions can be tailored to align with their specific needs, local contexts, and aspirations. This collaborative approach not only enhances the effectiveness of interventions but also promotes a sense of ownership and accountability among farmers.

2.18 Conceptual framework

The conceptual framework below illustrates how the dependent, independent, and intervening variables interact with each other to drive the research for achieving meaningful results. In the framework, the socio-economic, socio-demographic, institutional and farmers' understanding of technology influences adoption of CSAT. Farmers' economic status, institutional situation and socio-demographic status are described by variables as follows.

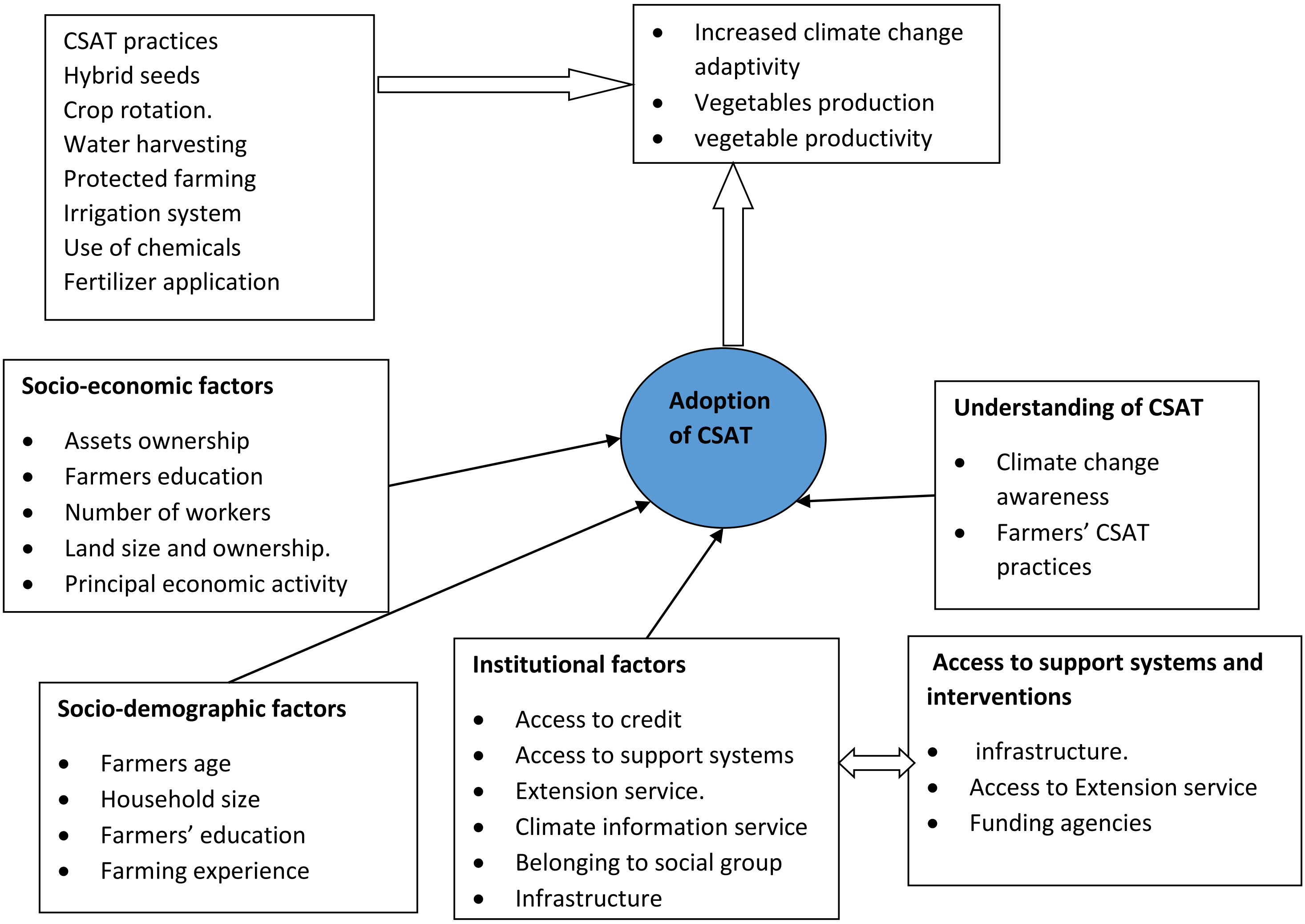

Figure 1: conceptual framework.

Adopted from Mojeyi (2021) and Mthethwa (2022).

CHAPTER 3

3 RESEARCH METHODOLOGY

3.1 Research design

The study was carried out using a cross-sectional approach to collect primary data from smallholder crop farmers. Cross sectional approach was used because it focuses on gathering data on variables at one given point of time across a sample which makes it less costly and timely (Kesmodel, 2018 and Maseko, 2021). Mujeyi (2021) added by saying that cross sectional provides data on multiple variables, which serves the need of this study. It will be carried out through semi-structured questionnaire designed to capture both qualitative to probe smallholder farmers' awareness and quantitative data. Quantitative design will be useful to quantify the problems by way of generating numerical data that can be transformed into usable statistics (Gondwe, 2010).

3.2 Description of Study area

3.2.1 Ecological setting

The study was conducted in Quthing district which is in the south of Lesotho. The district is about 180kilometres from the capital town, Maseru (Letsie, 2015). The district boarders on the Eastern Cape province of South Africa whereas domestically, the district boarders with Mohale's Hoek on the north and Qacha's Nek in the northeast (Lesotho profile, 2016). Quthing elevation is averaged at 1,500 meters above sea level (Singh, 2022). According to Worldometer (2023), the district has a population of 124,048 which is 6.6% of the total country population and possesses a total area of 9.61% of the country.

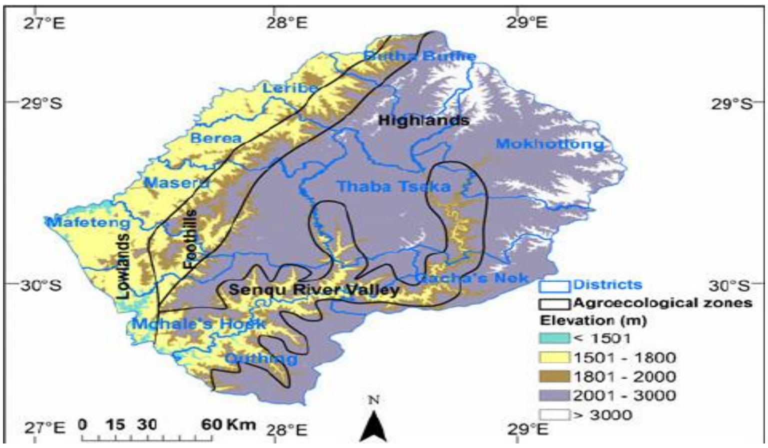

Figure 2: Map showing ecological areas of Lesotho.

The Bureau of statistics (2022) reported that the total land planted formed 1.87% of the total land planted in the country and total production accounted 2.35% of the country's output. Although the district is dominated by rural areas that depend heavily on agricultural production, deforestation, overgrazing, and soil erosion are reported among the environmental challenges facing the region, affecting biodiversity and ecosystem health (Agriculture research, 2019).

3.2.2 Climate and water resources of Quthing

The climate and water resource play a critical role in shaping socio-economic activities and livelihoods. Water resources in Quthing are primarily rivers and springs. This is supported by Lesotho Meteorological service which stated that the Senqu River is one of the major rivers in Lesotho that passes through Quthing district which serves as a crucial water source for irrigation, livestock, and domestic use. Furthermore, the district has several springs scattered across its landscape, providing natural water sources. Despite the presence of these water sources, Quthing, like many other regions, faces challenges related to water scarcity, particularly during drought periods.

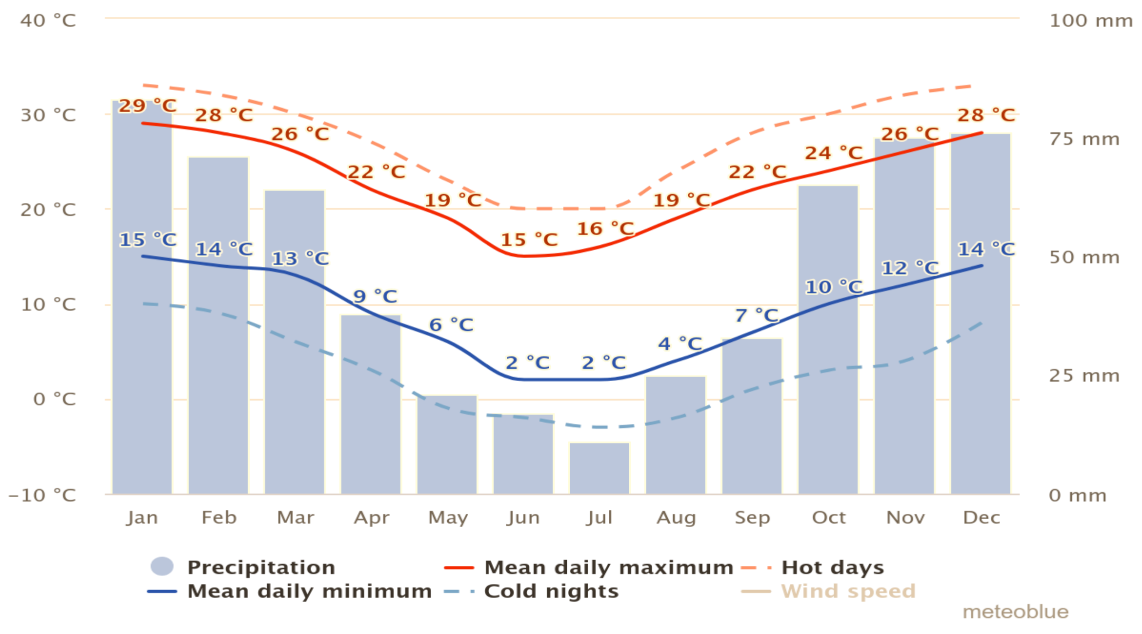

Figure 3 monthly rainfall and temperature variation in Quthing

Hunter (2020) indicated that Quthing, like any other district, experiences a temperate climate with two distinct seasons, namely summer and winter, and transitional ones (autumn and spring). Summers are characterized by warm to hot days and occasional rainfall, whereas winter, which is characterized by cold days and frequent frost, snow is rare but can be scattered in mountainous areas of Quthing (Figure 3).

The district has annual average rainfall which is indicated in figure 4 below. It has declined from 1034.51mm in 2011 to 879.83mm in 2022 (FEWS NET, 2023 and World-Weather online, 2024) most of which is received during rainy seasons in October to April (Figure 3).

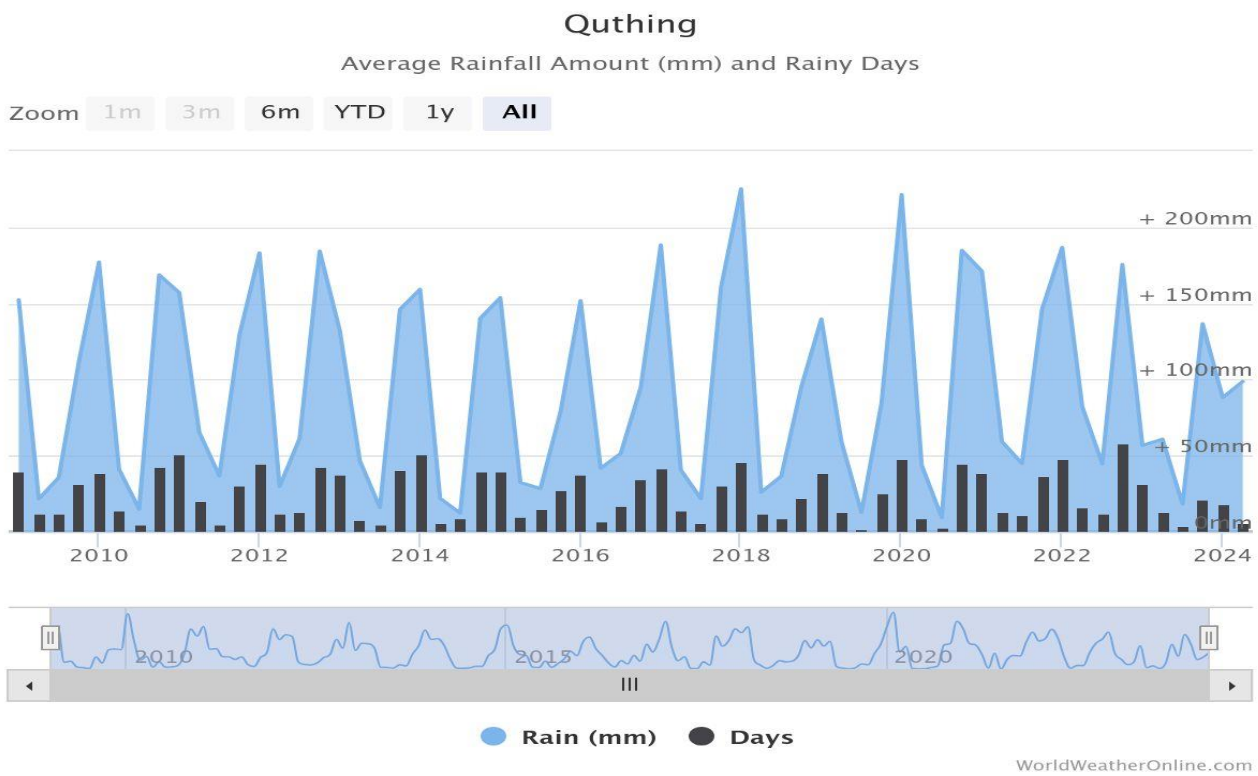

Figure 4: Annual average rainfall for Quthing. (World-Weather online)

Quthing is chosen based on its extreme climatic condition effects, the fact that it is dominated by rural areas and smallholder farmers with land holding averaged at 3.42 hectares as reported by Bureau of statistics (2019) and disaster Authority (2020). These smallholder farmers depend heavily on crop production for livelihood, like any other district, CSAT has been promoted in the district, but the technology uptake is exceptionally low.

3.3 Target population and sample size

To determine factors affecting the smallholder crop farmers adoption to CSAT, the target population for this research were smallholder horticultural farmers producing vegetables for commercial purposes, which are living in the rural areas of Quthing. According to Agricultural research (2019) and APPSA (2020), there are 1488 commercial small scale crop farmers and only 607 smallholder crop farmers who produce vegetables for commercial purposes in Quthing. To calculate the sample size, 607 vegetables farmers were inserted in the automatic Rao software sample size calculator which is adopted from Mujeyi (2021). In this software, the margin error was estimated at 5% and confidence interval at 95% which resulted in a sample of 236 farmers to be interviewed.

However, a sample of one hundred farmers was interviewed instead of 236. This resulted from limited time and financial resources. Katz (2018) also supports this sample size (one hundred) in that even one hundred respondents can represent the entire population of the study because it is an accepted number to run the model while this sample size also minimizes costs.

3.4 Sampling procedure

The multi-stage probability sampling technique was employed to select one hundred respondents of smallholder crop farmers representatives for data collection. It started by systematic identification of three resource centres out of six in the district (Tele, Koali and Makoae). Secondly, three villages in each resource Centre were randomly selected from a provided list of villages as presented on table 2. Lastly, smallholder farmers were randomly selected from a list provided by the area extension office per selected villages. Probability sampling was adopted to give every item the equal opportunity of being included in the sample without biasness (Alvi, 2016). Sample size (one hundred) respondents were then evenly distributed among resource centres.

Table 2. sample size selection.

RESOURCE CENTER	VILLAGE	SAMPLE SIZE
MAKAOE	Makoae	13
	Ntemere	11
	Pulane	9
TELE	Matebeleng	11
	Tele	11
	Nokeng	12
KOALI	Letlapeng	7
	Mantsoepa	12
	Moeling	13

3.5 Instrumentation

A semi-structured questionnaire was designed following a thorough review of related literature and objectives of the study. This instrument was employed to gather both qualitative and quantitative data from target population. The questionnaire was organised into several sections designed to capture demographic information, information on CSAT practices, information on access on related services, farmers perspectives on CSAT adoption and finally information pertaining to interventions aimed at promoting CSAT uptake.

3.5.1 Instrument testing.

Validity: To verify if the instrument measures its intended constructs, the developed questionnaire was reviewed by three experts from the Department of Agricultural Economics and Extension within the Faculty of Agriculture. Their feedback was considered during the final preparation of the research questionnaire.

Reliability: To verify the instrument's consistency, a test-retest approach was employed in a pilot study involving fifteen farmers not included in the main study. The results were analysed using Cronbach's Alpha (ά) to determine reliability, yielding a coefficient of 0.81. This result was deemed acceptable as per Frost (2022) who states that α typically ranges from 0 to 1 and can occasionally be negative in extreme cases. A coefficient within the range of 0.7 to 1 suggests strong correlation, indicating the instrument's reliability and suitability for use.

3.6 Data collection

To determine factors affecting smallholder crop farmers to adopt Climate Smart Agricultural Technologies, primary data was collected from selected farmers through the semi-structured questionnaire on a period of two weeks while secondary data was gathered from the government policies and reports, as well as publications.

3.7 Ethical considerations

Permission to collect data was granted by the Faculty of Agriculture at National University of Lesotho through the department of Agricultural economics, and the authorization was granted by the Ministry of Agriculture in Quthing district. A self-introduction to area extension officer and smallholder farmers was done by the researcher. Before the interview, the researcher had a discussion of the instrument with the farmers to ensure their full participation. The smallholder farmers were provided consent letters before the beginning of session which pledged the anonymity, voluntary participation, and confidentiality of provided information.

3.8 Data analysis

This section describes the methodologies and techniques utilized to derive results for presenting and discussing the study findings aligned with the research objectives. Responses from closed-ended questions were systematically coded and analysed using a variety of analytical tools.

3.8.1 Adoption patterns among smallholder crop farmers

After classifying farmers into homogenous variables, analysis of the number and type of technology adopted by each cluster was done using descriptive statistics that entail usage of frequencies and percentage as statistical indicators.

3.8.2 Evaluate of smallholder crop farmers' understanding and awareness of CSAT

In determining the level of understanding of CSAT among smallholder farmers, descriptive methods using statistical analysis such as percentages is used.

3.8.3 Identification of related interventions and support systems towards CSAT adoption

Both content analysis that involves examining textual data (secondary data) and descriptive analysis through frequencies and ranges was used to depict available interventions and support systems that support CSAT adoption.

3.8.4 To identify factors that influence smallholder farmers' adoption of CSAT

To identify factors that influence adoption of CSAT among smallholder farmers, the study adopted the Probit model which was used by Mthethwa (2023). This model assumes that the respondents make two decisions, for instance, decision concerning adoption and not to adopt. In this model according to Mujeyi (2021) each decision is modelled as a dichotomous variable taking the value of 1 if the farmer chooses to adopt and 0 if they do not.

The model is chosen because it is a binary and nonlinear model (Gujarati, 2020), which is suitable for this study because farmers may choose to adopt CSAT or not to adopt and their decision is nonlinear. The model will be executed in the econometric software package SATA 13.

3.8.5 Model specification

The decision equation will be simplified and modelled as binary using a Probit model as:

Probit model: $Y_i = \acute{\alpha}_0 + \acute{\alpha}_1 w_i + \ldots w_n + u_i$

Simplified as: ***CSAT adoption decision model:*** $D_{i\,(1,0)} = ß_0 + ß_1 X_i + \ldots ß_n X_n + u_i$

D_i =dichotomous variable that takes value 1 if a farmer participant in CSAT and 0 other wise $ß_0$ = constant parameter, $ß_1 \ldots ß_n$ = ***parameters to be estimated,*** $X_i \ldots X_n$= independent variables (farmers experience, access to credit, farmers' training, age, off farm income, land access…..), u_i= error term estimated at zero.

Table 3: variable description

Variable categories	*Variable name*	*Nature of variable*	*Expected relation*
Dependent variable			
CSAT adoption	Adoption	Dummy yes = 1 no = 0	-
Independent variables			
Socio-demographics			
Gender of a farmer	Gender	Dummy (0=female 1= male)	+/-
Age	Age	Continuous	-
Marital status	Marital stat	Categorical	+/-
Level of formal education	Edu.level	Continuous	+
Household size	HH size	Continuous	+
Farm size (in hectares)	Land size	Continuous	+/-
Farming experience	Experience	Continuous	+
Socio economic factors			
Principal economic activity	Main income	Dummy (farming = 1 off-farm income= 0)	+/-
Access to credit	Credit	Dummy (0=access 1= no access)	+
Assets ownership	Assets		+
Institutional factors			
Land tenure system	L/ownership	Categorical	+/-
Access to Extension service	Extension	Dummy (yes=1 no = 0)	-
Member of association	Mem of ass.	Dummy (yes = 1 no = 0)	+/-
Climate information service	Climate info	Continuous	+/-

CHAPTER 4

4 FINDINGS AND DISCUSSION

4.1 Introduction

The chapter presents the findings from the study and discusses the factors hypothesized to influence the adoption of CSAT. The chapter presents detailed information and analysis on socio-demographic characteristics and farmers’ familiarity with technology among smallholder farmers in the study area. Furthermore, it includes descriptive statistics regarding the adoption of various technologies and interventions available in the study area. Moreover, the chapter discusses the results of econometric analysis aimed at identifying the determinants influencing the choice to adopt and offers an in-depth discussion on these findings.

4.2 Description of farmers socio-demographic variables in vegetable production

4.2.1 Gender

The findings revealed that 68% of respondents engaged in vegetable production in rural areas of Quthing were men, while 32% were women (Table 4). These findings indicate that vegetable production in rural areas of Quthing is dominated by males. The dominancy of male could be attributed to traditional gender roles where men are often seen as the primary providers and custodians of families, while women may be engaged in household chores, particularly in married and male-headed households. These results are consistent with Mujeyi (2021) findings when assessing the impact of CSAT in integrated crop-livestock farming who also highlighted lower involvement of women in farming activities. Similarly, Chhetri and Sherpa (2017) noted that although climate change policies aim to involve women, their participation in agricultural production remains limited.

4.2.2 Farmers’ age

At least 47% of the total respondents of the vegetable farmers in the study area were between 46 and 55 years constitute of age. The second largest group comprises farmers aged 36 to 45 years, accounting for 26%, followed by farmers aged 18 to 35 years at 20%. Farmers aged 56 years and above formed the smallest segment, making up 7% of vegetable farmers. These results underscore that vegetable farming in the study area is predominantly carried out by adults aged between 46 and 55 years. One possible reason for this demographic pattern could be that young adults in Lesotho migrate to South Africa in search of employment opportunities, while others are still pursuing education, which limits their involvement in agricultural activities. This observation is consistent with the findings by Ubisi (2020), who noted that older farmers are more actively engaged in agricultural activities compared to youth.

4.2.1 Marital status

The results revealed that 58% of the total respondents were married, 22% were single and 11% were widowed whereas 9% were divorced (Table 4). These findings suggest that married farmers dominated vegetable farming. This phenomenon may be attributed to the responsibilities associated with marriage, such as increased financial obligations, which often motivate individuals to engage in agribusiness as a means of generating income and providing for their families. This observation is supported by studies conducted by Neway *et al*. (2022) and Sabo *et al*. (2017), both of which also noted a predominance of married individuals among participants who are engaged in commercial farming.

4.2.1 Farmers' education level

The data presented in Table 4 indicated that 46% of farmers had primary education, 29% had no formal education, 9% had secondary education, 12% had completed high school, and 4% had tertiary education. This distribution of education levels indicate that majority of farmers have attained primary education. The higher prevalence of primary education among farmers can be influenced by the country's provision of free primary education, which has expanded access to basic education across a broader segment of the population. Majority of farmers with basic education may also be attributed to limited opportunities for formal employment for individuals with lower educational attainment which they can often choose farming as their main source of income. These Findings are consistent with Gaya *et al*. (2017) who observed that farmers with higher educational attainment were less inclined to directly engage in agricultural activities, possibly because they have access to other career opportunities.

Table 4. Socio-demographic characteristics

Variable description	*Categories*	*Frequency*	*%*
Gender	Male	68	68
	Female	32	32
Age	18-35	20	20
	36-45	26	26
	46-55	47	47
	56≤ above	7	7
Marital status	Single	22	22
	Married	58	58
	Widowed	11	11
	Divorced	9	9
Level of education	No formal education	29	29
	Primary	46	46
	Secondary	9	9
	Highschool	12	12
	Tertiary	4	4
Land ownership	Borrowed	34	34
	Rented	6	6
	Own land	60	60
Land size (hectares)	0.1-0.99	83	83
	1-3	10	10
	4-6	3	3
	7-9	0	0
	10≤ above	0	0
Farming experience (years)	years<1	10	10
	2-3	17	17
	4-5	40	40
	6 or more	33	33
Principal economic activity	Farming	60	60
	Off-farm self-employed	27	27
	Formal employment	13	13

N=100, source: own survey 2024

4.2.2 Principal economic activity

The results in Table 4 illustrated that 60% of the respondents rely mainly on agricultural production for income, whereas 40% supplement their income through off-farm sources. This indicates that most farmers in the study area derive their primary income from agriculture. This trend could be attributed to the viewpoint that agricultural production acts as a fundamental economic activity and a vital livelihood strategy in rural settings. These results align with the Lesotho country profile (2021) and FAO (2021) which affirmed agriculture vital role in the rural economy as the backbone of the rural economy in the country. The finding is further supported by Sabo *et al*. (2017) indicating that the sector does not only provide significant employment opportunities but also ensures food security for a substantial majority (over 70%) of rural residents in SSA..

4.2.3 Farmers' experience

The results on farming experience in vegetable production indicate that 40% of vegetable farmers have accumulated between 4 and 5 years of farming experience. Additionally, 33% of farmers reported having 6 or more years of farming experience, while 17% had between 2 and 3 years of farming experience. The smallest group, comprising 10% of respondents, indicated they had less than a year of farming experience (Table 4). The results indicate that most farmers are experienced in vegetable production. The high proportion of smallholder farmers with farming experience could imply greater awareness on extensive farming background, they are well informed about local climate variability and may understand the advantages of agricultural technologies such as CSAT. These farmers might be more open to adapt CSAT if they perceive it as a feasible alternative to their current farming methods. These findings are in line with Ouedraugo's (2019) findings, which also demonstrated that more experienced smallholder farmers were actively engaged in practices related to innovative farming. This was linked to their thorough knowledge of agricultural practices including benefits of sustainable technologies which makes it easier to comprehend the advantages of CSAT.

4.2.4 Land ownership

The results in Table 4 indicate that 60% of the respondents own land for farming, 34% produce on borrowed land, and only 6% use rented land. This suggests that majority of farmers in the study area own land to support their agricultural activities. The higher percentage of farmers who own land can be attributed to the ease of access to land in rural areas where land allocation is typically managed locally by chiefs, without extensive ministerial processes for obtaining formal title deeds. This local allocation system facilitates farmers' access to land, encouraging higher rates of land ownership among agricultural producers, hence promoting agricultural commercialization. These findings resonate with research by Mthethwa (2023), which similarly observed that in rural areas of Mpumalanga, majority of smallholder farmers owned land allocated by local leadership.

4.2.5 Land size

The majority (80%) of the respondents in the study area operated on land sizes ranging between 0.1 and 0.9 hectares (Table 4). The second largest category is those who operated on land sizes between 1 and 3 hectares, accounting for 10%, while the smallest category is land sizes between 4 and 6 hectares, at 3%. This indicates that respondents in the study area operated on small land size. This situation can be attributed to environmental degradation impacts such as land degradation and poor soil quality that limit the productive potential of available land, making it less feasible for cultivating lager land size, and economic constraints limiting access to financial resources for farmers to expand or consolidate landholdings or leasing larger land. This forces farmers to cultivate on smaller land size. Another probable reason can be explained by the small size and mountainous terrain of the country which limits the availability of arable land suitable for agricultural production. The land available tend to be fragmented and small due to natural constraints, forcing farmers to operate on small land size. These findings are consistent with a report by FAO (2021), which similarly noted that most of smallholder farmers in Lesotho farm on land parcels smaller than one hectare due to limited arable land because of land degradation and fragmentation. Hunter (2020) additionally pointed out that the ability to Acquire large land holding in Lesotho is hindered by insufficient financial resources for purchasing and leasing land.

4.3 Evaluation of smallholder crop farmers' understanding and awareness of CSAT

To find whether farmers understand and are aware of CSAT, participants were initially sensitized on their perspective on climate impact affecting their areas and crop production. Subsequently, they were interviewed about their CSAT, including its benefits and functionalities.

4.3.1 Smallholder vegetable farmers' view on climate variability effects

As presented in Figure 5, the majority of respondents have observed various climatic condition that had an impact on agricultural output. Specifically, 92% of the farmers have noted an increase in temperature, 61% experienced extended chilly days, and 87% observed decrease in annual rainfall. These findings suggest that changes in temperature, prolonged cold periods, and reduced rainfall are the primary climate variables affecting vegetable farmers in the study area.

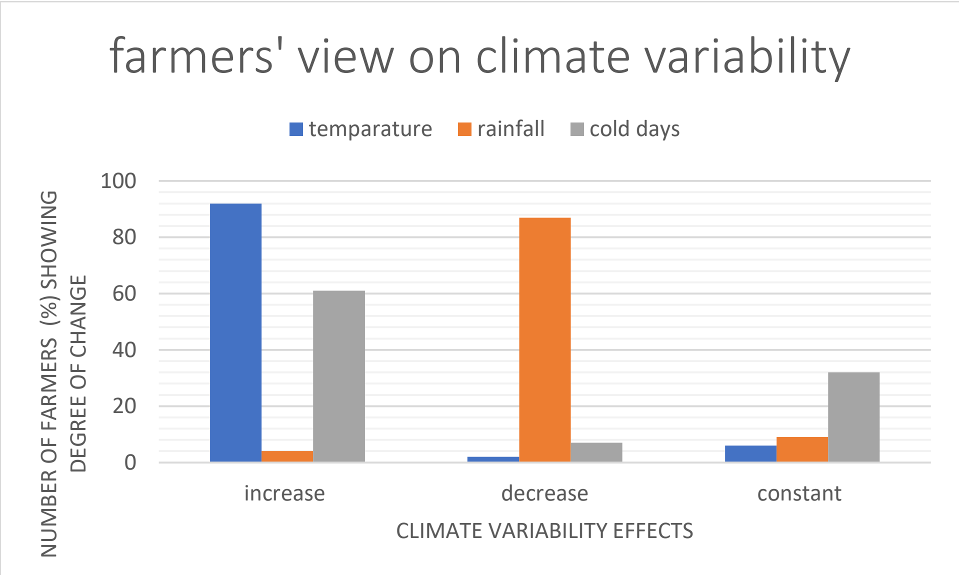

Figure 5: Farmers' view on climate variability effects**.**

According to the respondents, altered rainfall patterns and rising temperatures have led to water scarcity, impacting agricultural irrigation and exacerbating pest and disease infestation, which in turn results in economic loses in agriculture. These observations are consistent with Intergovernmental Panel on Climate Change (2021) which documented a decline in precipitation since 2015 in SSA which has led to unsustainable water sources that is crucial for irrigation in the region. Omer (2019) and Kahsay *et al*. (2019) also highlighted that significant temperature fluctuations and reduced rainfall amounts in SSA have accelerated the incidence of pests and diseases in agricultural practices.

4.3.2 Climate variability impact on vegetable production

On assessing the impact of major climate variability on vegetable production in the study area, majority of respondents (75%) indicated that climate variability has caused a decrease in vegetable harvest, while 19% reported no noticeable impact, and 6% noted an increase in vegetable output as presented in Figure 6. These findings suggest that fluctuations in temperature and precipitation are adversely affecting vegetable production, leading to reduced agricultural yields.

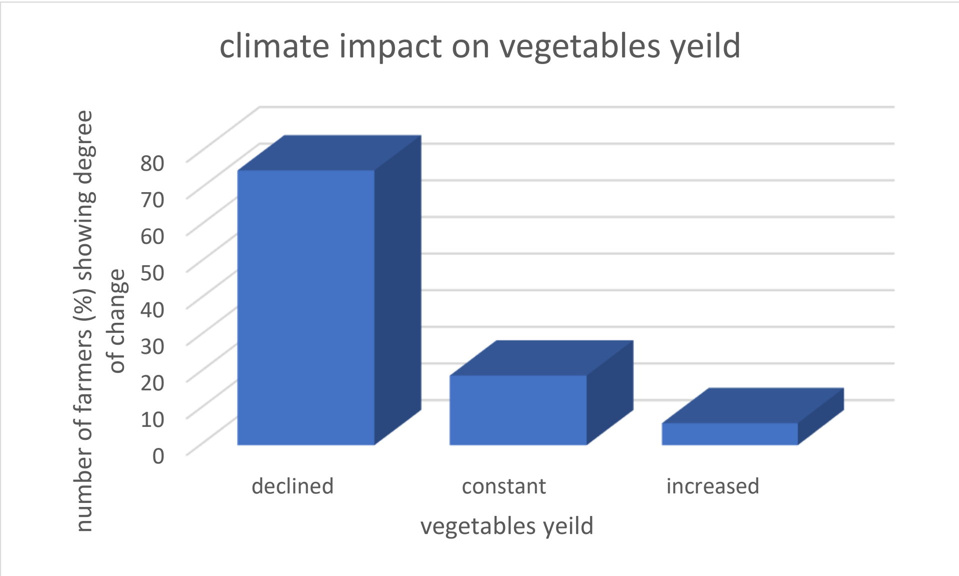

Figure 6: Climate impact on vegetable yield.

The likely explanation is that smallholder farmers typically depend on open field for farming. These makes them susceptible to climate change effects such as frost, hail, reduced or heavy rainfall and unfavourable temperatures that result in rapid loss of moisture leading to poor production. Moreover, climate fluctuations can disturb natural ecosystem processes and the nutrients cycling, ultimately reducing agricultural output, and causing lower yields. These findings align with Bernier (2017) discovery that decreased rainfall led to reduced crop yields condition which resulted in late maturity and wilting, consequently lower net revenue.

4.3.3 Smallholder crop farmers' understanding and awareness of CSAT

Farmers were further interviewed on the significant roles that they believe CSAT plays in mitigating climatic effects they encounter. The responses were categorised on a continuous scale (fully aware, aware, and not aware). Results in Figure 7 revealed that majority of respondents highlighted the following views: 81% of farmers are fully aware and understand that CSAT can help to sustain soil fertility, 72% perceived that CSAT helps to withstand drought effects, 92% indicated that CSAT enhances productivity, 61% showing CSAT helps in reduction of pollution in farms and 90% suggested that CSAT helps reduce resource wastage in farming. These findings indicate that most farmers are well informed about CSAT and recognize its potential impacts in maximizing agricultural production.

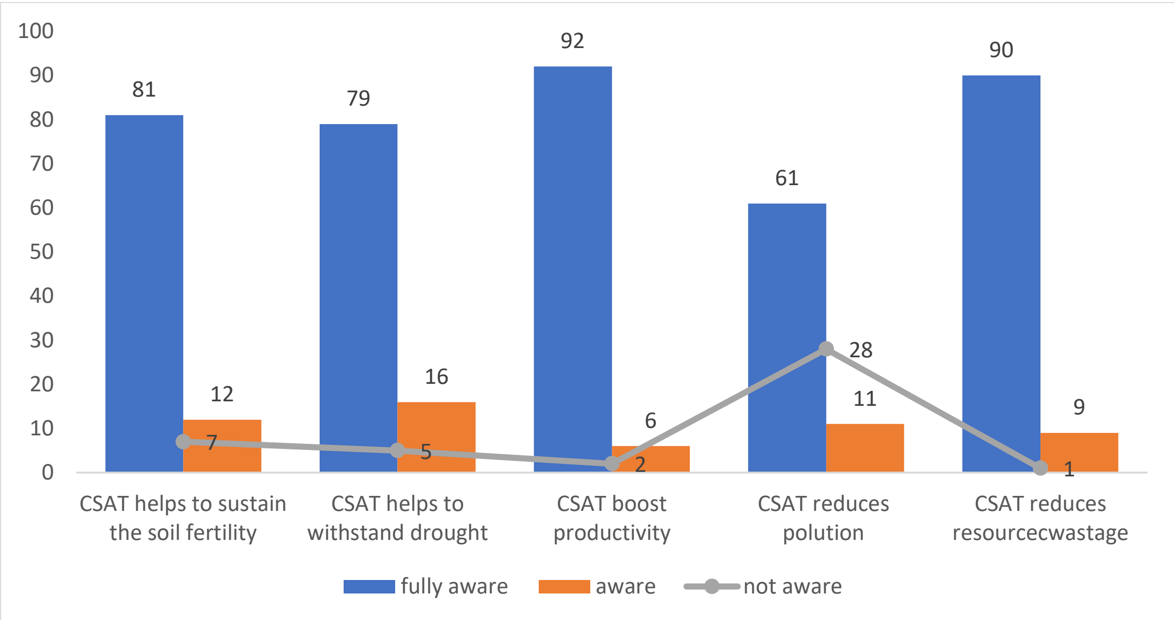

Figure 7: Farmers' understanding and awareness on CSAT.

Farmers' awareness of Climate-Smart Agriculture Technologies (CSAT) benefits can be attributed to several factors identified during interviews, and respondents mentioned that certain CSAT benefits, such as drought resilience and resource management, are well-known for their benefits through traditional farming practices like mulching and agroforestry systems, which are also integral components of CSAT. Additionally, farmers' understanding and awareness of CSAT may stem from attending training sessions, receiving information from extension services, and engaging in peer-to-peer discussions. These findings align with research by Quisumbing *et al*. (2021), who similarly observed high awareness of Climate-Smart Agriculture practices benefits among smallholder farmers because of the developed supportive policy frameworks and non-governmental initiatives through capacity building activities that focused on promoting CSAT. This has fostered awareness and adoption of CSAT. Similarly, Omer (2019) documented positive perceptions among farmers in eastern Ethiopia regarding various CSAT practices such as erosion control and resource management techniques which resulted from the training programs and capacity building initiatives aimed to equip smallholder farmers with skills needed to adopt CSAT.

4.4 CSAT adoption patterns among smallholder crop farmers in Quthing

The findings of the study revealed that smallholder farmers in the study area adopted some CSAT as coping mechanism against adverse weather conditions. Furthermore, figure 4 below shows the most of common CSA technologies that have been approved as means to adapt to adverse weather and are being used by vegetable farmers in Quthing district. Generally, the results have shown that all interviewed farmers use various CSAT in vegetable production.

4.4.1 Hybrid seed

Approximately 90% of farmers have chosen to use hybrid seeds to improve their production and productivity (Figure 8). This demonstrates that majority of vegetable farmers in the study area have access to and adopted hybrid seeds. The widespread adoption of hybrid seeds can be attributed to their cost-effectiveness and breeding characteristics, particularly traits like increased yield potential and better adaptation to local growing conditions. Masiza *et al*. (2021) similarly noted that smallholder farmers are increasingly embracing hybrid seeds due to financial benefits stemming from potential higher yields and improved produce quality.

4.4.2 Adjustment of planting dates

In the study area, another widely adopted climate-smart agricultural practice is altering planting dates, utilized by 75% of farmers (Figure 8). This shows that most farmers choose to modify their planting schedules to reduce risks linked to severe weather events such as droughts, extreme heat, and cold spells. This approach is probably popular because adjusting planting dates draws upon local knowledge and does not typically require substantial financial investment to implement. Heeb *et al*. (2019) support this finding by highlighting that farmers are increasingly advised to shift their planting dates in response to shifting weather patterns, thereby enhancing crop growth, and maintaining resilience in agricultural methods.

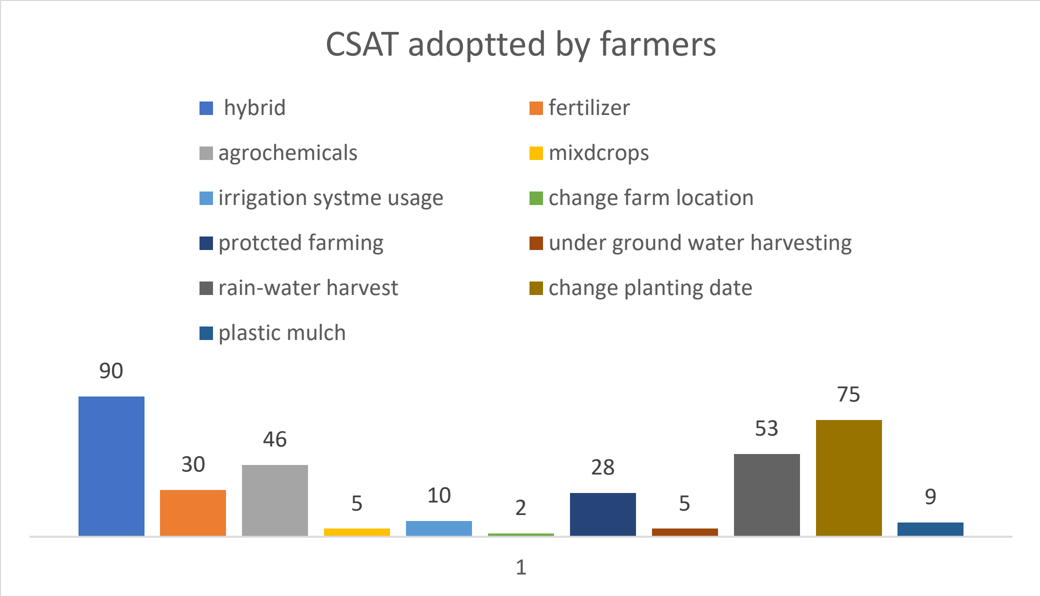

Figure 8: CSAT adopted by farmers in the study Quthing district.

4.4.3 Rainwater harvesting

Figure 8 illustrates that 53% of the respondents have integrated rainwater harvesting into their farming practices. This adoption rate suggests that a portion of farmers in the study area have embraced this technique. One reason for its popularity could be its alignment with traditional water management practices and its cost-effectiveness, which facilitates easier adoption by farming communities. Mburu *et al*. (2015) supports this finding when indicating that majority of farmers adopted rainwater harvesting to adapt to changing climate.

4.4.4 Agrochemical use

According to Figure 8, only 46% of respondents reported the use of agrochemicals in their farming practices. This indicates a relatively low prevalence of farmers utilizing agrochemicals such as pesticides, herbicides, or fungicides to improve crop productivity or manage pests and diseases. The limited adoption of this technology can be attributed to the fact that many rural farmers are hesitant to adopt innovative technologies, particularly when they perceive uncertainty associated with health issues. Additionally, the limited availability of agricultural inputs like chemical fertilizers, is attributed to their distributions centre located in towns. This discourages farmers from travelling to distribution centres due to the associated costs. Heeb *et al*. (2019) discovered that smallholder farmers exhibit reluctance towards adopting agrochemicals in their farming practices probably due to influence by cultural norms and beliefs that shape their agricultural practices. Additionally, Atube *et al*. (2021) mentioned that financial constraints deter the smallholder farmers from using agrochemicals.

4.4.5 Organic Fertilizer usage

Approximately 30% of respondents reported the use of organic fertilizers in their vegetable farms (Table 8). This suggests that organic fertilizer application is not widespread among vegetable farmers in the study area. Lower adoption of organic fertilizers can be attributed to several factors like scarcity of organic material like animal dung in rural areas. This is because during interviews, farmers mentioned that the decline in organic fertilizer use is linked to prolonged drought conditions that have affected number of livestock kept in households, leading to a scarcity of dung available for agricultural purposes. Bernier (2017) supports these observations by noting that smallholder farmers refrain from using any form of organic fertilizer because farmers with limited labour resources prefer easier and quicker alternative whereas organic fertilizer require more time and labour to prepare and apply them.

4.4.6 Protected farming, irrigation technology, underground water harvesting technologies

Based on Figure 8, adoption rates for various agricultural technologies are as follows: protected farming stands at 28%, irrigation technology at 10%, plastic mulch adoption at 9%, and underground water harvesting at 5%. This implies a relatively low adoption rate of some climate-smart technologies. It suggests that farmers in the study area may be cautious about adopting technologies that require substantial investments. One primary reason for this caution could be the high initial costs associated with acquiring new equipment, requiring specialized installation skills and labour, and the need for training on its usage. Smallholder farmers may perceive these financial commitments as burdensome, especially without guaranteed short-term returns. These findings are consistent with observations by Ubisi (2016) and Maseko (2021), who noted that farmers tend to favour technologies that do not demand significant financial investment or intensive labour for adoption.

4.5 Related interventions and support systems to adopt CSAT

Supporting the adoption of CSAT in Lesotho has become the stakeholders' concern and priority in order to enhance agricultural productivity, resilience, and food security. FAO in collaboration with the ministry has brought forth the awareness and training initiative by conducting campaigns and training programs to educate farmers, extension workers and other stakeholders about the benefits of CSAT (FAO, 2021). According to SADP report (2023), the organization has established demonstration farms (with successful beneficiary projects) where farmers can observe CSAT practices in action, learn from successful implementation and gain experience under the guidance of agricultural experts. The government of Lesotho, through its budget allocation of the fiscal year 2024/25 has allocated funding to the Ministry of Agriculture, Food Security and Nutrition to ensure availability and affordability of CSATs such as drought resistance seeds, climate-smart fertilizers, and input supply chains which is done through subsidies.

4.5.1 CSAT intervention by trainings

Table 5 displays results showing that across all selected villages of the study area, about 63% of the farmers reported that they did not have access to any training on improved CSAT, while 37% stated they had received trainings. These results imply that majority of farmers have not been trained on CSAT. One potential explanation for this situation could be that rural area often lack adequate infrastructure needed to for effective training, such as access to technology and trainings facilities. Again, poor roads networks and limited transportation can make it difficult for trainers to reach remote area and for farmers to attend trainings sessions. This situation can hinder the logistic involved in conducting training sessions for these farmers. These findings align with previous research by Anuga *et al*. (2019) which emphasized that smallholder farmers in rural areas of Ghana often do not have sufficient exposure to modern farming techniques due to inadequate training sessions due to limited transportation option making it difficult for trainers to reach remote areas.

Table 5: overview of interventions and support systems on CSAT

CSAT interventions	frequency (n= 100)	percentage (%)
CSAT intervention by training		
Trained farmers	37	37
Never been trained	63	63
Access to area extension office		
Yes	47	47
No	53	53
Source of Climate service info		
Radio	80	80
Tv	30	30
Newspaper	8	8
Weather stations	14	14

4.5.2 Access to area extension office

In the study area, 53% of respondents stated they do not have access to area extension offices in their villages, while 47% reported having access to such support (Table 5). This highlights a gap in farmers' access to extension services to support farming communities. Limited access to extension service can be attributed to several factors. Firstly, rural, and remote areas often lack adequate infrastructure such as roads and extension offices, making it challenging for extension agents to reach farmers effectively. Furthermore, limitations in human resource within government agency can lead to a shortage of trained extension workers or agricultural advisors available to serve rural communities. This scarcity can hinder the support needed to enhance the adoption of agricultural innovations like CSAT among farmers. As mentioned by Mujeyi (2021) many farmers lack access to extension services due to an imbalanced ratio of farmers to extension agents which results from limited financial resources to employ more extension service agents. Kurgat (2020) further mentioned that due to logistical challenges associated with delivering extension services in rural areas, majority of these regions do not have access to extension agents.

4.5.3 Source of climate information

Based on Table 5, 80% of the respondents use radios to access climate information, 30% rely on television, 14% utilize weather stations and 8% rely on newspapers. This indicates that farmers in the study area consider radio as a dependable source of climate information. This preference can be attributed to the widespread availability and reliability of radios even in remote rural areas where other communication technologies may be scarce. Unlike digital devices that require electricity, radios can operate using batteries or solar power, enhancing their reliability in areas with intermittent electricity supply. These findings are consistent with Mthethwa (2023) research which discovered radios as the preferred and effective means of climate information dissemination in rural areas of Mpumalanga.

4.6 Factors that determine smallholder vegetable farmers adoption of CSAT

To assess the factors that influence adoption of CSAT by smallholder vegetable farmers, the study employed the probit regression model and Table 6 presents the results. The independent (control) variables are described by their coefficient to determine their relationship with the dependent variable. The empirical estimations are presented with the model significant at 1%, 5% and 10%. The results of the Chi square test indicated that the likelihood ratio statistics is significant with a p-value of 0.00104 indicating that the model exhibits strong explanatory power. Pseudo-R value of 0.697 suggests that the variables included in the model explain approximately 70% of the variation in the decision to adopt CSAT.

The empirical results of the probit econometric model showed that off-farm income, household size, education level, experience in farming, extension service, membership to farmers association and access to climate service significantly influenced adoption of CSAT in the study area. The main source of income and household size have negative coefficients, indicating that as these factors increase, other things being equal, the outcome variable decreases. On the other hand, education level, land ownership, farmers' experience, membership in farmers' associations, access to extension services, and climate information services have positive coefficients, suggesting that an increase in these factors is associated with an increase in the outcome variable, assuming all other variables are held constant.

4.6.1 Principal source of income

Principal source of income recorded correlation coefficient of -0.915 and p-value of 0.024. this finding suggests a that there is a significant and inverse relationship between farm income and the adoption of CSAT. This result means that a unit increase in income derived primarily from farming decreases the likelihood of adopting CSAT by 0.915 units. The situation can be attributed to the expenses involved in investing on technology adoption. Smallholder farmers who are reliant on farming income often lack enough funds to make such investments like irrigation systems as this can be financially prohibitive for farmers who are already financially constraint. This result is consistent with the findings by Ubisi (2016) who noted that farmers whose primary income came solely from farming were hesitant to invest in their farms due to the high costs involved in adopting innovative technologies. Mthethwa (2023) also indicated that farmers with non-farm income increased likelihood of adopting innovative technologies due to increased household income and better opportunities on access to credit to finance their farms.

4.6.2 Household size

The household size exhibited a correlation coefficient of -0.876 with a p-value of 0.040. This finding suggests a statistically significant inverse relationship between household size and CSAT adoption. The findings mean that a unit increase in household size decreases the likelihood of farmers adopting CSAT by 0.876 units. In simpler terms, larger households tend to adopt CSAT less frequently compared to smaller households. This situation is likely influenced by factors associated with household size, such as greater financial constraints stemming from higher consumption needs. This is because the allocation of financial resources between family necessities and agricultural investments impedes the adoption of innovative technologies. The observation aligns with the findings by Bernier (2017) and Shahbaz *et al*. (2022) who noted that farmers with large household size are responsible for supporting more dependents. These farmers face greater financial obligations within their households which limit their capacity to invest in CSAT due to the expenses associated with adopting innovative technologies.

Table 6: Probit regression of determinants of CSAT adoption by vegetable farmers

Variables	*Coef.*	*Std. Err.*	*Z*	*P>/z/*
Farming income	-0.915	0.112	-2.34	0.024**
Credit access	0.275	0.234	-2.04	0.058
Gender (male)	0.874	0.482	1.81	0.070
Marital stat, (married)	-0.331	0.257	1.14	0.110
Age	-0.489	0.483	-1.40	0.066
Household size	-0.0876	0.153	-2.30	0.040**
Edu. Level	0.472	0.238	-0.16	0.032**
land ownership	0.645	0.547	-1.39	0.058
Land size	-2.38	1.001	-2,36	0.057
Experience	0.501	0.356	1.87	0.014**
Extension	0.752	0.461	-2.40	0.038**
Member ass.	0.913	0.495	1.64	0.001*
Climate info	0.936	0.768	-0.67	0.064**
Constant	-1.25	0.22	2.42	0.036

Number of observations = 100   Pseudo R2 = 0.6970

LR chi2(10)   =   24.61   Log likelihood = -25.190401   Prob > chi2 = 0.00104

****, **, * means statistically significant at 10%, 5%, 1%. Source: survey 2024*

4.6.3 Farmers' level of education

Farmers' level of education exerted a positive and statistically significant influence on adoption of CSAT, as indicated by a coefficient of 0.47 and a p-value of 0.032. This suggests that a unit increase in farmer's level of education led to a 0.47 unit increase in CSAT adoption. One possible explanation is that education equips farmers with the skills to understand complex information, enabling them to make informed decisions about production and technology adoption. Another possible reason is that highly educated farmers may have better employment opportunities, which can provide the financial means to invest in farming technologies like CSAT. These results align with the findings of Makamane *et al*. (2023), who concluded that farmers with higher levels of education play a crucial role in the adoption of technology. Omer (2019) further indicated that educated farmers are more adept at foreseeing the risks associated with farming, interpreting complex information necessary for making innovative decisions on their farms. This ability fosters a propensity towards innovation and the adoption of innovative technologies among educated farmers.

4.6.4 Farmers' experience in farming

There was a significant and linear relationship between farmers' experience and CSAT adoption exhibiting correlation coefficient of 0.501 and p-value of 0.014 (Table 6). The results mean that for a unit increase in the number of years in farming, there is 0.501 unit increase in CSAT adoption by farmers. The results agree with the study's prior expectation that experienced farmers are likely to adopt CSAT. This situation may stem from several reasons including that farmers with greater experience often have established financial stability or have access to resources that facilitate the adoption of technology, potentially enabling them to invest in CSAT. Adedoyin (2016) supports this observation by indicating that prolonged engagement in agriculture provides farmers with better access to resources like capital and enhance farmers' recognition of the CSAT long-term benefits. This promotes the adoption of innovative technologies, since becoming familiar with one technology often fosters a willingness to adopt some of the technologies.

4.6.5 Access to extension service

The results revealed that access to extension services positively and significantly influenced CSAT adoption among farmers with a correlation coefficient of 0.752 and p-value of 0.038. This suggests that a unit increase in access to extension services increased adoption of CSAT by vegetable farmers by 0.752 units. The possible explanation for this situation lies in the crucial role played by extension services in disseminating information. They educate farmers about the benefits and practices of agricultural technologies and provide technical assistance on adopting appropriate technologies. The finding is consistent with Mujeyi (2021) observation that extension workers with enhanced skills are trusted by farmers, facilitating the adoption of new and improved technologies. Additionally, Musafiri *et al*. (2022) highlighted that extension services in Western Kenya fostered networks through workshops and trainings among farmers, creating opportunities for knowledge sharing and peer learning that further encouraged CSAT adoption.

4.6.6 Farmers' engagement in associations

The findings on table 6 revealed a significant and positive influence of farmers' engagement in farming association on CSAT adoption. The variable recorded correlation coefficient of 0.913 and p-value of 0.001. The result means that a unit increase in the degree of participation in farmers' associations results in an increase of 0.913 in the adoption of CSAT by vegetable farmers in the study area. This is possible because farmer associations often provide their members (farmers) information, funding opportunities, training workshops and demonstrations on farming technology such as CSAT. Farmer associations also cultivate a culture of peer learning, enhancing awareness and understanding of various agricultural practices and technologies which in turn encourages farmers to adopt CSAT. This finding is supported by Branca and Perelli (2020) who noted that farmer associations are common drivers of smallholder producers' adoption of innovative technology, offering its members opportunities to access grants and financial incentives. Similarly, Rakotsoane *et al*. (2023) found that active participation in social organizations encouraged farmer to farmer information sharing which increased farmers' likelihood of adopting innovative technologies by maize producers at Mt.Moorosi.

4.6.7 Access to climate information service

The results revealed a significant and positive relationship between climate service information and CSAT adoption. The variable recorded correlation coefficient of 0.936 and p-value of 0.064, as detailed in table 6. This indicates that a unit increase in access to climate information by farmers increases adoption of CSAT by 0.936 units. The possible explanation for this situation is that climate information may provide insights into long-term climate trends and farmers can strategically utilize this information for decision-making such as selecting and investing in appropriate technologies. This finding is consistent with Ngigi and Muange (2022) who found that access to reliable climate service technology consistently increased the adoption of improved agricultural technologies among crop farmers because farmers who had access to climate service technology stayed informed about current and predicted climate variations, enabling them to adjust their farming practices proactively in response to forecasted conditions.

CHAPTER 5

5 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter synthesizes the study's findings, draws conclusions and implications based on the results discussed in the preceding chapter. The research specifically determines the factors influencing the adoption of CSAT among vegetable farmers. Each objective's findings are utilized to derive conclusions in relation to existing literature along with recommendations aimed at assisting implementers and policymakers in understanding the determinants of CSAT adoption. Additionally, the chapter identifies areas for future research.

5.2 Summary of the study

The study aimed to determine factors influencing the adoption of CSAT among smallholder vegetable farmers in rural areas of Quthing District. It had four specific objectives: to assess farmers' understanding and awareness of climate-smart agriculture technologies, identify patterns of CSAT adoption, examine related interventions and support systems, and determine factors influencing adoption of CSAT. Data was collected from 100 randomly selected vegetable farmers across nine villages within three resource centres out of six using a semi-structured questionnaire. Frequencies and percentages were employed to describe demographic characteristics, adoption patterns and awareness as well as support systems and interventions. Econometric model, specifically the probit model, was utilized to analyse factors influencing CSAT adoption.

The socio-demographic characteristics in the study area are as follows; there is a predominance of male farmers (68%) in the study area, indicating a significant gender imbalance in vegetable production. A notable proportion of farmers (47%) were aged between 46 and 55 years, highlighting the involvement of older individuals in vegetable farming. Married farmers constituted the majority (58%), underscoring the impact of family units on agricultural practices. Additionally, majority of farmers operated on land sizes less than 1 hectare (83%), with 60% of farmers owning land. This underscores the prevalence of small-scale farming and land ownership among farmers. Moreover, majority of farmers had basic education at 46% while 60% relied primarily on farming income, emphasizing agricultural production importance as a livelihood source.

Findings of the study in respect to the objectives are as follows:

1. The empirical results of this study revealed that majority of participants demonstrated knowledge of CSAT's multifaceted benefits: 81% acknowledged its role in sustaining soil fertility, 79% recognized its effectiveness in enhancing drought resilience, and 92% believed it contributed to increased productivity. Furthermore, 61% of respondents noted CSAT's impact on reducing pollution, underscoring its environmental benefits, while 90% emphasized its crucial role in efficient resource management. High awareness is likely because some of the practices stem from traditional farming, peer learning and training offered. These findings highlight CSAT potential for sustainable agricultural practices.
2. The study found that among vegetable farmers in rural areas of Quthing District, the most widely adopted CSAT were hybrid seeds (90%), adjusting planting dates (75%), and rainwater harvesting (53%). These technologies were favoured due to their perceived immediate returns and lower initial costs. Conversely, adoption rates were lower for other CSAT such as agrochemicals (46%), organic fertilizers (30%), protected farming (28%), irrigation technology (10%), and underground water harvesting (5%). This discrepancy was primarily attributed to perceived barriers such as high initial investments, transaction costs, and specialized skills needed for implementation of these technologies.
3. The study's findings regarding intervention and support systems for CSAT adoption revealed that a minority of farmers (37%) received CSAT training, while the majority (63%) did not. This disparity was primarily attributed to financial constraints faced by governments and stakeholders. Access to extension services was reported by 47% of farmers, with the remaining 53% lacking such access, citing shortages in staff, financial resources, and inadequate infrastructure as key barriers. Additionally, climate information services were found to be scarce in the study area, with 80% of farmers relying on radio broadcasts due to insufficient infrastructure supporting the use of alternative devices and information sources.
4. Furthermore, the findings from the probit regression model highlight key factors influencing CSAT adoption among vegetable farmers in rural areas of Quthing. Specifically, household income source and size were identified as negatively impacting CSAT adoption, indicating that farmers relying more on off-farm income or with larger households encountered barriers to adopting new agricultural technologies. Conversely,

higher levels of education, farmer experience, membership in farmer associations, and access to extension and climate information services were positively associated with CSAT adoption. These results suggest that farmers with better education, more experience, and access to support services are more inclined to adopt and integrate sustainable agricultural practices into their farming operations.

5.3 Conclusions of the study

Based on the findings derived from four specific objectives of the study, the following conclusions are reached respectively:

1. Based on the results on assessment of farmers' awareness and understanding of CSAT findings, the study concluded that majority of smallholder vegetable farmers in the study area demonstrated a strong awareness and understating regarding CSAT. Most participants recognized and appreciated the diverse benefits of CSAT, including its roles in sustaining soil fertility, enhancing draught resilience, increasing productivity, reducing pollution, and managing resources efficiently. This highlights the potential of CSAT to encourage sustainable farming practices among smallholder farmers. Therefore, this is a strong basis for promoting CSAT adoption, and efforts aimed at promoting CSAT can build upon this existing awareness and understanding.
2. Based on the findings from the adoption patterns, it is evident that certain CSAT have been more widely adopted than others among vegetable farmers in rural areas of Quthing. The study concludes that technologies exhibiting immediate productivity gains, minimal initial investment costs and are relatively straight forward to implement such as hybrid seeds, adjusting planting dates, and rainwater harvest are the embraced technologies. Conversely, technologies such as agrochemicals, protected farming, irrigation technology and underground water harvesting face lower adoption. These technologies are perceived to involve higher upfront investment costs, transaction expenses and need for specialized skills. This highlights the crucial importance of financial support in promoting the adoption of CSAT among farmers in the region.

3. Based on the findings from interventions and support systems, it is evident that critical challenges exist in the interventions and support systems for promoting the adoption of CSAT among vegetable farmers in the study area. The findings lead to the conclusion that current efforts and initiatives to support CSAT adoption among rural farmers are inadequate and highlight a gap in initiatives and support system deliverance. This inadequacy is rooted in limited training opportunities for farmers due to limited financial resources, constrained access to extension services because of inadequate infrastructure and shortage of staff. Again, climate information service is lacking due to absence of infrastructure to support more advanced technologies hence farmers rely heavily on radios broadcast for climate information. This limit farmers' ability to make informed decision based on timely and accurate weather forecast and climate information.
4. Based on the probit regression results, the study concludes that socio-economic, demographic, and institutional factors influence CSAT adoption in the study area. Factors such as reliance on farm income and larger household sizes constitute unfavourable conditions hindering the adoption of CSAT. These factors typically limit financial resources available for investing in CSAT due to family obligations and lower income levels. Conversely, higher levels of education and increased farming experience are found to have positively influenced CSAT adoption. Education not only enhances farmers' economic opportunities through better prospects for off-farm employment but also enables better comprehension and evaluation of CSAT concepts. Additionally, greater farming experience is associated with higher farming skills and financial resources accumulated over time. This means that more experienced farmers are likely to have lower uncertainty regarding new technologies, making them more inclined to adopt CSAT. This highlights the importance of knowledge and skills in adoption decisions.

   Furthermore, access to extension services, membership in farmer associations, and climate information services are identified as significant factors that augment CSAT adoption. These services provide essential training that helps farmers effectively assimilate technology information. They also offer tailored opportunities to accelerate CSAT adoption and provide technical assistance, thereby empowering farmers with the knowledge and support needed to adopt and sustain CSAT practices. This means promoting adoption requires addressing a range of factors including socio-economic conditions, institutional support, and demographic characteristics.

5.4 Recommendation for action

Based on the conclusions drawn from results gathered during this study, the following recommendations are distilled. It is assumed that improving on some factors will reduce or remove some hindering factors in adopting the new CSAT resulting in higher output and economic growth.

1. Based on the findings indicating higher awareness and appreciation of CSAT among smallholder farmers, several recommendations can be proposed. These include leveraging existing awareness to further educate farmers about CSAT practices. Efforts to promote CSAT adoption should prioritize improving access to CSAT technologies, offering training and technical support, and cultivating partnerships that facilitate CSAT integration into local farming practices. Highlighting the diverse benefits of CSATs can additionally boost adoption rates and enhance livelihoods.
2. Based on the findings on analysis of adoption patterns of CSAT, it is recommended that the government and financial service institutes prioritize interventions aimed at reducing financial barriers among smallholder farmers to offset the initial investment costs associated with other technologies such as protected farming. This will encourage widespread adoption of improved agricultural technologies thereby promoting sustainable agricultural production. It is crucial to promote agricultural financial instruments and programs that specifically benefit farmers, particularly those reliant on agriculture for income. Strategies could include offering technology subsidies and facilitating access to credit facilities tailored to the needs of agricultural investments or implementing technology leasing and rental program.

   Furthermore, farmers could be Provided with capacity building initiatives that focus on equipping farmers with necessary skills to effectively implement practices that require specialised skills like underground water harvesting. The capacity building program should also focus on educating farmers about the long-term benefits and promotion of low-costs technologies that offer immediate productivity with minimal financial investments. Stakeholders should also highlight success stories where such technologies are adopted.

3. Based on the identified gaps in the initiatives and support systems to encourage CSAT adoption, several recommendations can be made to address this issue, government should prioritize investment in infrastructure development, particularly in improving rural roads, access to electricity and communication networks. Improving infrastructure will facilitate the effective delivery of extension services to facilitate CSAT trainings and access to diverse climate information service options. These investments are critical for bridging education, knowledge, and service gaps among farmers, improving access CSAT and available support systems, and encouraging their adoption. Enhanced accessibility will enable farmers in remote and rural areas to receive timely and relevant agricultural information, thereby supporting informed decision-making and sustainable agricultural practices. Moreover, it is recommended that government and other stakeholders should prioritize substantial investments in agricultural extension services. These investments should focus on expanding the reach and enhancing effectiveness of extension programs within rural farming communities. This can be achieved by allocating sufficient financial resources to cover the capacity and outreach of agricultural extension services. Key measures may include increasing number of extension officers, ensuring ongoing training opportunities, and equipping them adequately to deliver quality services.
4. Based on the findings and conclusions of the study regarding determinants of CSAT adoption among vegetable farmers in rural areas of Quthing, the following recommendations are proposed to enhance CSAT adoption: stakeholders should prioritize promoting farmer-based associations (FBAs) which can facilitate peer learning, knowledge-sharing, collective bargaining power and access to resource markets, thereby fostering a supportive environment for CSAT adoption. Farmers should be encouraged to join FBAs by educating them about the advantages of membership. Additionally, stakeholders should invest in educational programs and training aimed at enhancing farmers' knowledge and skills, focusing on improving agricultural literacy and technical expertise. These programs should be hands-on, participatory, involving collaboration with local educational institutions and NGOs to expand farmers education and experience. This can empower farmers to make informed decisions and overcome barriers associated with lower education attainment and CSAT adoption. Moreover, the introduction of subsidies and low-interest loans designed for CSAT adoption should be considered as they can help mitigate the financial barriers faced by farmers, particularly those with limited income sources or larger households.

5.4.1 Recommendations for further research

This study examined CSAT adoption and its determinants among vegetable farmers in rural areas of Quthing. Future research could explore comparative studies between areas or regions within the districts and between districts, or between different agricultural practices. Such studies could reveal variations influenced by content specific factors.

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APPENDIX

QUESTIONNAIRE FOR VEGETABLE FARMERS SURVEY

DETERMINANTS OF CLIMATE-SMART AGRICULTURAL TECHNOLOGY BY SMALLHOLDER CROP FARMERS IN QUTHING DISTRICT, LESOTHO

Self-introduction

I am Mathebe Semoko a student at the National University of Lesotho. I am doing research entitled **"Determinants of Climate Smart Agricultural Technology among small holder crop farmers in Quthing district."** I have randomly selected 100 household farms in rural areas of Quthing within current resource centres regarding the influencing factors towards adoption or Dis-adoption of CSAT.

The information provided during this study will only be used for the intendent purpose and therefore will be kept confidential without giving names and personal information. For the purpose of records and consent, I request we sign the declaration before we commerce.

I …………………………………………(name and surname) hereby declare that I understand the purpose of the interview and give permission for it to be conducted with me as a respondent.

Date : …………………………… .

District:…………………..........

Resource centre: …………………….

Village name:…………………..

Signature:…………………………

SECTION 1: FARMER'S SOCIO-DEMOGRAPHIC CHARECTERISTICS (tick appropriate answer)					
#	**questions**	**codes**			
1	Gender of a farmer.	0=male		1= female	
3	Age of a farmer	0= (18-35)	1= (36=45)	2= (46-55)	3= (56- <)

2	Farmers' marital status	0=married	1=widowed	2=divorced	3=single	
4	Number of family members	0= (1-3)	1= (4-6)	2=(7-9)	3= 10 0r more	
5	Number of family members who provide labour on part-time basis	0= (0-1)	1= (2-4)	2= (5-7)	3= 8 0r more	
6	Number of family members who provide labour permanently	0= (0-1)	1= (2-4)	2=(5-7)	3= 8 0r more	
7	Total number of workers in a farm	0= (0-1)	1= (2-4)	2=(5-7)	3= 8 0r more	
8	Level of formal Education completed	0=Primary	1= secondary	2=high school	3= tertiary	
9	Type of farmer	0= full time		1=part time farmer		
10	Farming experience (in years)	0= >1	1= (2-3)	2= 4-5)	3= 6 or more	
11	Do you belong to any social network platform?	0=WhatsApp	1= face book	2= linked	3= other specify	
12	How far is your house from the farm in KM?	0= >1km	1= (2-3)	2= (4=5)	3= 6<	
13	Farmers' specialty in agricultural training or education	0=certificate				
		1=degree				
		2= Master Farmer training				
		3= 1-5 days course/training				
		4= 1-2 months training				
		5= more than 2 days training				
		6 =none				
14	The main type of horticulture crop in the farm (choose one most grown crop)	0= leafy vegetables	1=fruits	2=tubers	3= other specify	
15	Who mainly influences your crop selection to plant?	0=extension officers				
		1= farmer to farmer advise				
		2= NGOs advice				
		3= own choice				
		4=indigenous knowledge				
		5=other specify				
SECTION B: SOCIO-ECONOMIC FACTORS						
16	What is the size of your farmland (in hectors)?	0=Land <1	1= (1-3)	2= (4-6)	3= (7-9)	4= up to 10
17	What is the total land size usually cultivated ?	0=Land <1	1= (1-3)	2= (4-6)	3= (7-9)	4= up to 10
18	If not all land size is cultivated, why?					
19	Principal economic activity	0=farming	1=off farm self-employed	2=formal employment		
20	Which assets do you own?	0= Car	1= tractors	2= land	3= buildings	
21	Among all, which is your primary market?	0= Community members 1=local shops 2= other retailers 3= other specify				
22	On average, how have been your production in the past five years?	0= increased	1= decreased	2= constant		
23	On average, how much income did you make per year from sale of output?	0= 2019	1=2020	2= 2021	3= 2022	4= 2023
24	How do you reach to the market?	0= public transport	1= cart	2=own car	3= hired car	

25	What is the condition of the road to your market?				
26	Do you have network facility in your area to communicate with customers?	0= yes		1=no	
27	Do you have access to appropriate storage to keep your products ?	0= yes		1=no	
28	If yes, who owns the storage	0=government		1= own storage	2= hired
29	What is the portion of produce is consumed by family members or donated to others?	0=less than quarter of the produce			
		1= quarter of the produce			
		2=half of the produce			
		3= all the produce			
30	What is the state of your output in the past production season	0= Increasing		1=Decreasing	2= Constant
31	Explain variation in your income if any				
SECTION C: INSTITUTIONAL FACTORS					
32	Means of land ownership	0 = inherited	1=borrowed	2= rental	3= bought
33	Are there any credit facilities available to you?	0 = YES		1= NO	
34	Are there formal credit facilities you have access to,? mention available facilities				
35	Have you had loan from formal financial services?	0 = YES		1= NO	
36	If yes, what was the purpose of loan?				
37	If no, explain reasons not to				
38	Do you have any insurance protection of your crops against climatic effects?	0 = YES		1= NO	
39	If you do not have any insurance against your crops how do you usually cope?				
40	Do you belong to any social group? If yes, Name them	0 = YES		1 =NO	
41	Which support systems have you used to cope with the challenge and who provides them?				
42	Do you have any access to donor funding agricultural agencies related to crop production in the community you live in?	0 = YES		1 = NO	
43	Have you had opportunity to benefit?	0= YES		1 = NO	
44	What was the purpose?				
45	If you have never benefited, what are the reasons?				

46	please list the support they provide for any that is available in your community.	0=extension office……………………………		
		1= farmer organization………………………		
		2= social group……………………………		
		3= NGOs……………………………………		
		5= media……………………………………		
		6= other specify……………………………...		
47	Do you have access to extension service?	0= YES	1 = NO	
48	Extension officers are knowledgeable about climate change support interventions	0=strongly agree		
		1=agree		
		2=neutral		
		3=disagree		
		4= strongly disagree		
49	The information you get from extension office about CSAT interventions makes difference in your production	0=strongly agree		
		1=agree		
		2=neutral		
		3=disagree		
		4= strongly disagree		
50	Do you have easy access to inputs market?	0= YES	1 = NO	
SECTION D: CLIMATE INFORMATION SERVICE				
51	Do you have any access to weather related information?	0= YES	1 = NO	
52	If yes, what is the source of information?	0=radio		
		1=television		
		2= online publication		
		3=info centre		
		4= other specify………………		
53	The information from weather service is reliable	0=strongly agree		
		1=agree		
		2=neutral		
		3=disagree		
		4= strongly disagree		
54	Do you participate in field days?	0= YES	1 = NO	
SECTION E: CLIMATE VARIABLES AVAILABLE IN THE AREA				
55	Have you observed any climate change variability over the past 5 years?	0= yes	1= no	2= no idea
56	If yes, how has the variability in climate manifested in your observation?	0= prolonged drought []		
		1= temperature variability [ ]		
		2= Heavy rainfall [ ]		
		3 =extended cold days [ ]		
		4= invasive pests		
		5= Other…………		

SECTION F: FARMERS UNDERSTANDING ON CSAT						
57	Do you know anything about CSAT?	0= YES			1 = NO	
58	What informed you?	0=radio	1= newspaper	2= extension	3= internet	4= social group
59	How do you perceive CSAT to be?					
60	Which of the CSAT do you know?					
61	Which one do you practice?					
62	What is your most reliable source of information on climate CSAT?	0=radio	1=internet	2= TV	3= farmer to farmer	4= extension office
63	Do you think CSAT practices is happening at a rate that is significantly impacting crops? explain					
Adaptation to climate variability impact						
64	Which of the following on-farm adaptation options do you adopt in the event of crop failure due to the changing climate? (0= yes, 1= no)	1.Crop hybrid seeds	Yes	No		
		2. Use of agrochemicals	Yes	No		
		3. Mixed cropping	Yes	No		
		4. Changing crop varieties	Yes	No		
		5. Irrigation system farming	Yes	No		
		6. Changes in farm location	Yes	No		
		7. practice protected farming	Yes	No		
		8.underground water harvesting	Yes	No		
		9. rainwater harvesting	Yes	No		
		10. changing dates of planting	Yes	No		
		11. build water harvest schemes	Yes	No		
		12. use mulching (plastic/ cover mash)	Yes	No		
65	For measures you did not adapt, what made you not to?	0=lack of information				
		1=lack of inputs				
		2=water shortage				
		3= did not see need				
		4= poor health				
		5= lack of resources				
		6= lack of skills				
66	What necessitate the selection of adaptation? Choice, you did not adopt?	0. Community-based governance system[ ]				
		1. Age [ ]				
		2. Availability of resources e.g. finance [ ]				
		3. Land tenure status [ ]				
		4. Experience [ ]				
		5. Extension services [ ]				
		6.Others, specify…………………				

67	Which CSAT do you perceive to be most effective in the type of farming you are practicing?	
68	If you are not practicing these technologies, why?	0= lack of knowledge
		1= financial constraints
		2= land tenure
		3= physical power
69	What is the degree of effectiveness of the various adaptation technologies you employ?	1= Very effective
		2.=Moderately effective
		3= Not effective
70	What is your source of water for irrigation?	0=rain fed
		1=tank storage
		2=tap
		3=rain harvest (dams and tanks)
		4=river
		5=underground harvesting
71	Why did you choose current source over others?	

***We have come to the end of the interview, thank you for your time*.**