

**THE IMPACT OF FOOD LOSS ON FOOD SECURITY AMONG SMALLHOLDER VEGETABLE
FARMERS IN CAPRICORN DISTRICT OF LIMPOPO PROVINCE, SOUTH AFRICA**

By

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A Dissertation Submitted in Fulfilment of the Requirements

for the

Master of Science Degree in Agriculture in Agricultural Economics (AGMAAE)

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Faculty of Science, Engineering and Agriculture

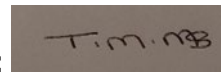
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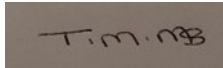
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DECLARATION

I Mmatlou Milicent Thokolo (17017949) hereby declare that this dissertation for Master of Science in Agriculture in Agricultural Economics (AGMAAE) at the University of Venda hereby submitted by me to the Department of Agricultural Economics and Agribusiness, Faculty of Science, Engineering and Agriculture, has not been submitted for a degree at this or any other institution and is my own work in design and in execution and that all reference materials contained herein has been duly acknowledged.



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ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest gratitude to the God of Mount Zion for granting me strength, wisdom and perseverance to complete this study. His grace made it possible for me to successfully complete this dissertation. I would also like to extend my gratitude and appreciation to my supervisor, Prof IB Oluwatayo, for his continuous guidance, support, and constructive feedback throughout the study. His valuable insights and encouragement greatly contributed to the quality and success of the dissertation.

My heartfelt appreciation goes to the smallholder vegetable farmers in Capricorn District Municipality who willingly took part in the study. Thank you so much.

Lastly, I would like to express my gratitude to my family, friends and colleagues for their encouragement, support and patience throughout my academic journey.

DEDICATION

I would like to dedicate this work to my family: my parents, Mr M.W and Mrs M.C Thokolo and my siblings, Innocent and Happy Thokolo.

ABSTRACT

Food loss remains a great threat to global food systems, and food insecurity remains a persistent challenge among households, particularly within developing and emerging economies. Several studies have attempted to unravel the effect that food loss have on food security; however, limited research has focused on how food loss occurring during the early production stage influence food security of primary food producers. The research used a quantitative research design to examine how food loss influence food security outcomes. The study was carried out within the Capricorn District Municipality located in Limpopo Province, South Africa, where a sample of 230 smallholder vegetable farmers were interviewed using a multistage random sampling method. The study made use of descriptive measures to summarize the socioeconomic attributes of the respondents, where the results revealed a slightly higher male gender (54.8%) than their female counterpart (45.2%). The findings indicate that most respondents were adults with age ranging from 36 to 59 years (47.4%). Many of the participants (41.3%) reported earnings below R50 000 per year. To establish how food loss influence food security among the farming households, the Household Food Insecurity Access Scale (HFIAS) tool was employed to ascertain the food security status of the respondents, alongside an Ordered Probit Model (OPM) employed to explore the nexus between food loss and food security. The results of HFIAS show that 70% of the respondents experienced food insecurity, with only 30% being food secure. The results obtained from the OPM indicated that food loss is positively linked to food security status($p \leq 0.000$) with a marginal effect indicating that a rise in the amount of food lost lowers the chances of households remaining food secure by 11.8 percentage points while raising the risk of falling into deeper food insecurity by 8.8 percentage points. The study further found that about 89% of the respondents reported experiencing food loss at the production stage, followed by postharvest (69%) and harvesting (47%). Moreover, poor market access (54.4%), pests and disease infestation (37%), and unfavorable weather conditions (26%) were identified as major causes of food loss among smallholder vegetable farmers. Therefore, improving access to market would enable farmers to sell their produce on time, and adopting Integrated Pest Management (IPM) can reduce losses caused by pests and diseases. Adoption of climate-smart agricultural practices are also essential for addressing losses stemming from extreme climatic conditions. These interventions together can reduce food loss, increase productivity and income and ultimately enhance household food security status of the primary producers.

Keywords: Capricorn district, Food loss, Food security, HFIAS, Smallholder farmers, Vegetable

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LIST OF ABBREVIATIONS AND ACRONYMS

BLM	Blouberg Local Municipality
CDM	Capricorn District Municipality
CSIR	Council for Scientific and Industrial Research
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DAFF	Department of Agriculture, Forestry and Fisheries
DALRRD	Department Agriculture Land Reform and Rural Development
DEFF	Department of Forestry, Fisheries and Environment
DTIC	Department of Trade, Industry and Competition
FAO	Food and Agriculture Organization
FLW	Food Loss and Waste
GDP	Gross Domestic Product
HFIAS	Household Food Insecurity Access Scale
HLPE	High Level Panel of Experts
IDP	Integrated Development Plan
IFAD	International Fund for Agricultural Development
OPM	Ordered Probit Model
SDG	Sustainable Development Goals
SOFI	State of Food Security and Nutrition
SPSS	Statistical Package for Social Sciences
Stats SA	Statistics South Africa
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Funds

USDA	United States Department of Agriculture
WFP	World Food Programme
WHO	World Health Organization
WWF	Worldwide Fund
WWF-UK	Worldwide Fund for Nature- United Kingdom

CHAPTER ONE

INTRODUCTION

1.1. Background to the Study

Food insecurity continues to be an ongoing problem despite the measures implemented by developmental organisations and governments to reduce it. As reported by FAO, IFAD, WFP and WHO (2022), the number of individuals facing hunger and malnutrition rose by 150 million from 2019 and by 46 million from 2020 to 828 million in 2021. In 2022, as indicated by FAO, IFAD, WFP, and WHO (2023), 2.4 million people globally recorded moderate to severe food insecurity conditions, with women and individuals residing in rural areas most affected. Indicating that food insecurity remains a global challenge. The report additionally highlighted that most people suffering from food deprivation and malnutrition in the above-mentioned statistics were found in Asia and Africa, which reflect the inequalities and inefficiencies of the continents' food systems. According to Food and Agriculture Organisation (2002), Food security denotes a state in which individuals can obtain safe, nutrient-rich, and adequate food necessary for good health.

Globally, while some regions have shown gradual improvement, others, particularly those highly susceptible like sub-Saharan Africa, are experiencing worsening conditions of food insecurity. Many people across the continent are affected by moderate to acute food insecurity, influenced by persistent challenges including conflict, climatic disturbances, and unstable economic conditions, among others. The report by State of Food Security and Nutrition in the World (SOFI) shows a decline in the number of people lacking the financial capacity to acquire sufficient healthy food in various regions during the period 2020–2024 (FAO, IFAD, UNICEF, WFP and WHO, 2025). However, the affordability of a well-balanced diet worsened in Africa, where two in three people reported not affording a nutritionally balanced diet in 2024 (FAO, IFAD, UNICEF, WFP and WHO, 2025). These results were substantiated by the study of Wudil et al. (2022), who noted a rapid increase in access to food and farming productivity over the last 50 years. However, the reverse is the case in sub-Saharan Africa, where statistics show that the challenge of poor food access has continued to rise since 2015, owing to weak economic growth, low crop productivity, and poor infrastructural development, among other factors (Wudil et al., 2022). The study also advised prioritising investment in agricultural facilities and farmer

support programmes, combined with policy measures to boost households' purchasing power, particularly in rural communities, as these factors are crucial for enhancing food availability and access.

With reference to South Africa, despite the country being considered food secure (Stats SA, 2021), the situation of hunger and malnutrition among households persists. This is emphasised by the results released by Stats SA on the General Household Survey, which reported that around 9.34 million families, which accounts for 16% of the individuals surveyed in South Africa, experienced the worst food insecurity in 2020 (Stats SA, 2022). This is corroborated by Ndhleve et al. (2021), who found that food insecurity remains prevalent in South Africa. Findings from the study discovered that in South Africa, 68% of households were severely food insecure. National food security situation masks deep household-level disparities, particularly in rural communities, where studies show that 50% of the households experience moderate to severe food insecurity.

In Limpopo province, Nengovhela, Belete, Hlongwane, and Oluwatayo (2022) noted that the Capricorn and Mopani districts are the regions with the greatest rate of food insecurity in the province. Moreover, Tambe et al. (2023) showed that over half (52%) of households in remote areas in Limpopo Province experienced severe food insecurity. Evidence from the study highlighted that over 66% of the households who participated in the survey faced food insecurity, and 31.8% reported hunger, surpassing the corresponding national and provincial rates of 26.0% and 30.8% respectively. Similarly, Sithole et al. (2023) found that in Limpopo, 54.2% of households were food insecure. These highlight that, despite the province being considered food secure, rural households still suffer from food insecurity.

Meanwhile, food loss and waste (FLW) remain a concerning issue affecting the world, undermining the efforts of researchers, policymakers, and development organisations to improve food security in both high- and low-income countries (Nahman et al., 2013; Tanye, 2016). Food loss and waste have gained significant attention recently due to their widespread impact on food security, the environment, and the economy (FAO, 2013; Oelofse et al., 2021). The major consequences of food loss and waste include loss of resources used throughout the production process (Shamlall, 2024).

Food loss and waste vary across products, supply chain stages, and regions. Food loss according to its definition, is found to be more common within developing regions because of underdeveloped infrastructure and inefficiencies in production at the pre-harvesting stage, harvesting, packaging and storage stages, to before retail, while food waste occurs commonly in

developed countries because of the behavior of consumers which occur at retail and consumption stage (Oelofse et al., 2021). However, the study focuses on food loss that takes place during the initial stage of production.

Moreover, food and energy needs are expected to rise by 35-56% between 2010 – 2050 to supply food to the rising population (van Dijk et al., 2021). Amid the increasing population expected to reach 9,73 billion people by 2050 and the move towards a resilient food system, it is necessary to comprehend the implications of food loss for food security among smallholder farmers (Kotze, 2023). Even though studies show that globally, food production has risen as a result of advancements in technology (FAO, 2022), high levels of food losses undermine the contribution of such an increase to household food security and economic welfare. Minimizing food loss is equally crucial as increasing agricultural production to satisfy the demands of an increasing population and comes with the benefits of improving environmental well-being and enhancing economic sustainability through efficient use of resources. When it comes to addressing the food requirements of a rising population, several studies emphasise increasing production through either increased land size or yield, with limited studies focusing on reducing losses experienced after increasing production.

Across the globe, food loss and waste persist in challenging efforts toward promoting food security and environmentally sustainable practices. Estimates suggest that about one-third of global food production is lost along the food supply chain (HLPE, 2014; Oelofse et al., 2021). According to FAO and Ethiopian statistics (2023), approximately 13.2% of harvested food is lost after harvesting stage. In South Africa, it has been estimated that about 33 percent of the 29 million tons (on average) of food produced each year is lost, with about half of these losses occurring during production, post-harvest handling, and storage stages (WorldWide Fund, 2017; Oelofse et al., 2021). Yet this important aspect of the food system has received limited attention previously. The effects of food loss have wrought enormous havoc on the environment and food security (FAO, 2011). Understanding factors contributing to food loss on farms is critical for informing evidence-based programs and policies to advance sustainable food systems. Hence, addressing food loss should be considered critical and a priority in South Africa to enhance food security (Kotze, 2023). Food loss reduces food availability by removing large quantities of food from the food value chain, particularly in developing countries where high post-harvest losses are influenced by weak infrastructure, inadequate storage, and poor market opportunities. (FAO and Ethiopian statistics, 2023)

In areas such as sub-Saharan Africa, losses after harvest can reach 20–23% for key staples and perishable products (FAO, IFAD, UNICEF, WFP and WHO, 2025). These losses lower farmers' incomes, reduce market supply and increase food prices, thereby limiting accessibility and affordability for low-income consumers (IFAD, 2021). Moreover, the types of food that are mostly wasted include fruits and vegetables, dairy, and fish, which are rich in essential nutrients and can lead to malnutrition and micronutrient deficiencies (Vilarino, Franco and Quarrington, 2017).

In Limpopo province, where agriculture is a predominant activity that contributes to rural economies through employment opportunities and food production (Meliko & Oni, 2010), the issue of food loss is critical. Small-scale farmers in this region play a pivotal role in feeding their communities, yet are characterised by poor productivity, inadequate infrastructure, limited knowledge, and insufficient access to capital and technology (Mpandeli and Maponya, 2014). These factors exacerbate their vulnerability to food loss on their farms and post-harvest (Gustavsson et al., 2011; Ishangulyyev, Kim and Lee, 2019). This presents a significant issue in rural settings, where agriculture serve as the main source of livelihood for most people.

In South Africa, majority of previous research studies have concentrated on food waste at the consumption stage of the food supply chain, leaving a knowledge gap on food loss at primary production. For instance, Dzumbunu (2017) explored determinants of food loss in fast-food supply chains in South Africa, while Ramukhwatho (2016) assessed domestic food wastage in low-income countries focusing on South Africa.

Given this background, the research intends to examine the influence of food loss on household food insecurity. The findings of the research will contribute meaningful information for policy formulation, agricultural advisory services, development organisations and researchers working to strengthen food security and economic well-being of small-scale farmers in Limpopo province.

1.2. Problem Statement

Food loss continues to be a serious worldwide issue with significant consequences on economic stability, environmental sustainability, and food security. (Gustavsson et al., 2011; Oelofse et al., 2021). Reports estimate that close to 15.3% of the food produced globally is lost before reaching the market (WWF & Tesco, 2021) due to factors ranging from pests and diseases, extreme weather conditions and lack of proper infrastructure (Ishangulyyev, Kim and Lee, 2019; Oelofse et al., 2021; Fourie et al, 2023).

Within the Capricorn District of Limpopo Province, the problem of food loss is highly concerning due to the role played by smallholder farmers which is fundamental for bettering food security and strengthening rural community's economic well-being through job creation and food supply (Meliko & Oni, 2010). However, this group of farmers face significant obstacles such as deficient infrastructure and constrained access to technology and credit, and poor access to a stable market (Kephe et al., 2022; Chisoro & Padayachie, 2023), which increases their vulnerability to food losses occurring during production and after harvesting (Oelofse et al., 2021). The research by Amjad et al. (2023) noted that smallholder farmers constitute around two-thirds of the losses. This highlights the vulnerability of small-holder farmers to such losses. Moreover, research undertaken by Ramukhwatho et al. (2021) in Limpopo, assessing food losses among smallholder farmers, found that major losses occur at the pre-harvest stage at the farm level.

This situation is concerning, provided that smallholder farmers in Limpopo province primarily depend on fruit and vegetable production for household consumption and income generation (Stats SA, 2021; Baloyi, 2010). Food loss not only reduces their income but also undermines food availability and accessibility in local communities, worsening food insecurity. Additionally, food loss results in the unproductive use of scarce resources such as land, water, and energy (Egwuonwu, 2020) and undermines the effort to achieve Sustainable Development Goal (SDG) 12.3, which seeks to achieve a 50% reduction in food loss and waste by 2030 (FAO, 2011).

Although prior research has evaluated food loss in South Africa, including in Limpopo province, there is limited research on how food loss affects producers' food security status. For example, Ramukhwatho et al. (2021) highlighted the drivers of food loss and the stage at which it occurs but did not explore how these losses affect smallholder farmers' food security status. This leaves an area that remains underexplored to support policymaking and targeted measures to minimize food loss. Understanding the food loss drivers and their implications on food security allows for designing strategies and advising policy on ways to minimize food loss to enhance farmers' resilience and improve food security in the Capricorn district. Hence, this study intends to explore the impact of food loss on access to adequate food for smallholder vegetable farmers across the Capricorn District in Limpopo Province, South Africa

Research Questions

- What are the socioeconomic profiles of smallholder vegetable farmers in the Capricorn district of Limpopo province?

- What are the factors driving and causing food loss among smallholder vegetable farmers?
- What is the household food security status of these farmers?
- What is the relationship between food loss and household food security among smallholder vegetable farmers?
- What possible food loss reduction strategies were utilised to minimize food loss among the smallholder vegetable farmers?

1.3. Aim and objectives

1.3.1. Aim of the study

- To examine the impact of food loss on food security among smallholder vegetable farmers in the Capricorn district of Limpopo Province, South Africa.

1.3.2. Objectives of the study

The specific objectives of the study were to:

- Profile the socioeconomic characteristics of smallholder vegetable farmers in the Capricorn District of the Limpopo Province, South Africa.
- Assess the factors driving food loss among smallholder vegetable farmers.
- Assess the food security status of smallholder vegetable farmers.
- Investigate the link between food loss and household food insecurity among smallholder vegetable farmers.
- Explore strategies to minimize food loss among the smallholder vegetable farmers.

➤ 1.4. Justification for the Study

Food loss has recently gained significant attention as a critical challenge in the agricultural value chain, particularly for perishable commodities such as fruits and vegetables (Gustavsson et al., 2011). This is happening amid ongoing concerns about household food insecurity globally and within the country. Smallholder farming is one of the sectors in agriculture that holds the

capacity to better the state of food security of multiple rural farming households, contribute to job creation and alleviate poverty. Meanwhile, these farmers often face losses ranging from 5 – 50% particularly on fruits and vegetables, due to factors like weather conditions, pests and diseases, inadequate infrastructure and market rejection based on quality standards (Msomi & Zenda, 2024). These losses affect their income and ability to sustain their livelihoods.

However, limited research exists that specifically links food loss to household-level food security among smallholder vegetable farmers. This leaves a knowledge gap that this study seeks to address. Consequently, it was essential to carry out a study to analyze the effect of food loss on food availability and security among vegetable farmers.

Food loss represents mismanagement of scarce economic resources, such as water, land, and energy utilised in production, while also leading to higher greenhouse gas emissions (Shahbazi, Shahbazi, and Zare, 2025). It reduces the profitability of farming operations, making it hard for smallholder farmers to keep up with their household needs and to reinvest in the business. Therefore, addressing food loss among smallholder farmers may improve their business profitability, lead to a more stable and sustainable local economy, and create a community that is also food secure. Losses of food during farming and after harvest significantly threaten food security by lowering the amount of food available and elevating prices. Addressing food loss is more economical and resource-efficient than increasing production. Reducing losses improves resource utilization, economic returns, and supports sustainable agriculture (Shahbazi, Shahbazi and Zare, 2025).

And lastly, vegetables are the cheapest source of vitamins and minerals needed by every household (Atanda et al., 2011) and have the capacity to provide income for those involved in production and improve their dietary diversity (Rajendran et al., 2017; Mlalama et al, 2022).

1.4. Conceptual Framework

Smallholder crop farming is one of the sectors that contributes significantly towards rural employment, food security and improving overall livelihoods of rural communities (Lowder, Scoet and Ranney, 2016). Smallholder farming serves as the mainstay of many rural economies despite several challenges faced by the sector. However, food loss has emerged as one of the challenges faced by fruit and vegetable farmers due to perishable nature of the commodities (Gustavsson, 2011). The study by Amjad et al. (2023) noted that smallholder farmers account for one third of the total food lost along the agricultural value chain.

The studies (FAO, 2011 and Gustavsson, 2011) have revealed that about two-thirds of total food produced is lost or wasted along food supply chain. The amount of food lost lead to reduced food available for consumption and sale. The conceptual framework was designed to examine the impact of food loss on household food insecurity among smallholder vegetable farmers. The study conducted by Kotze (2023) have shown that food loss is mainly caused by pests and diseases, extreme weather conditions, damage during harvesting and poor access to markets. This led to reduced income for farmers and reduced food available for consumption, which subsequently lead to farmers experiencing varying levels of food insecurity. Furthermore, socioeconomic factors such as age, gender, income, household size and market access influence both food loss and household food insecurity. The conceptual framework illustrates the relationship between food loss and household food insecurity among smallholder vegetable farmers. The framework further includes food loss reduction strategies such as improved storage, timely harvesting, good pest and disease management which farmers utilise to reduce food loss and improve household food insecurity.

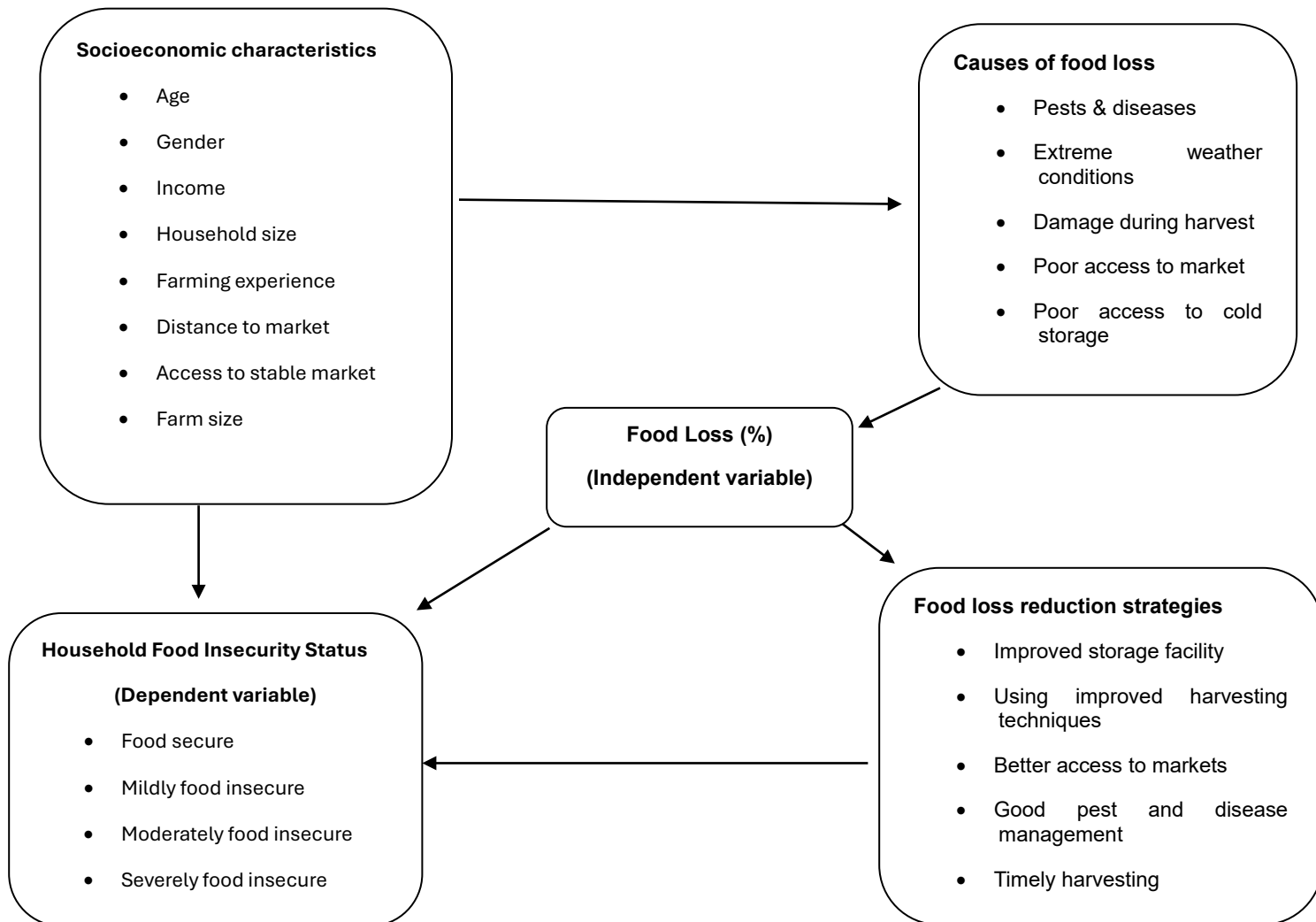


Figure 1: A conceptual framework for analyzing the impact of food loss on household food insecurity among smallholder vegetable farmers in Capricorn district of Limpopo Province, South Africa.

1.5. Operational Definitions of Key Terms

1.5.1. Food loss - is defined as the reduction in the quantity or deterioration in the edibility and nutritional quality of food that never reaches the consumer, occurring during primary production (Gustavsson et al., 2011; Nahman, 2013; FAO, 2019).

1.5.2. Food Security- This condition exists when everyone consistently has physical, social, and affordable access to adequate, safe, and nutrient-rich food that ensures dietary adequacy

for maintaining good health (World Food Summit, 1996; FAO, 2008). The definition of food security comprises four main aspects, viz: Food availability: denotes the sufficient presence of edible and safe food on the farms and in the local markets, which can be either through domestic production or imports. Food accessibility refers to when the available food is within reach of all people; it involves both physical and economic access. The economic access means having the means to buy food or having the ability to purchase it. Food stability means food is always consistently available and within reach for all people. Lastly, food utilization refers to the nutritional aspect of food. People must always get nutritious food that meets their dietary diversity. All the aspect together gives a full meaning of food security as defined by various researchers and scholars (Gibson, 2012).

1.5.3. Smallholder farmers consist of farmers managing production on a relatively small plot of land, typically up to 10 hectares, and rely primarily on family labour to meet production needs and typically retain part of their production for household consumption (FAO,2013). They mainly produce for household consumption and for the market, aiming to obtain food and income to alleviate poverty and improve food security. The definition of smallholder farmers varies and depends on the context and region. A report by the Department of Agriculture, Forestry and Fisheries defines smallholder farmers as those who own small plots of land to grow food for household consumption and rely on family labour (DAFF, 2012). Their main characteristics are that they farm on limited space and rely on family members as labour.

1.5.4. Vegetables- edible parts of plants that are consumed by humans as food, including leaves, stems, roots, tubers, bulbs, and flowers (Belitz, Grosch and Scheiber, 2008). It is a plant grown for food, with leaves, roots, stems, or even tubers.

1.5.5. Ordered Probit Model – is a statistical model that estimates the link between a categorical dependent variable and a set of independent variables. It is only used when the dependent variable is ordinal in nature, such as ‘food secure’, ‘moderately food insecure’, and ‘severely food insecure’ (Jackman, 2000).

1.6. Limitations and Delimitations

Acknowledgement of the study’s limitations is necessary. Firstly, the study scope was limited to smallholder vegetable farmers in the Capricorn district, Blouberg and Mole-mole local municipalities of Limpopo Province, South Africa. Secondly, the research focused on the primary production stage of the food supply chain. Thirdly, the research was limited to smallholder farmers, which means the findings may not reflect the experiences of commercial farmers or other players within the value chain.

1.7. Layout of Research Study

The research examining how food loss affects food security among smallholder vegetable farmers in the Capricorn District is organised into five chapters:

- **Chapter One** offers an overview of the study. It outlines the background, the problem under investigation, the research questions, the aim and specific objectives, the rationale for conducting the study, definitions of key concepts, and the study's limitations, delimitations, and overall structure.
- **Chapter Two** examines the theoretical framework and presents a review of the existing literature on food loss and food security.
- **Chapter Three** explains the methodology employed in the study, including details on the study area, research design, target population and sampling strategy, techniques of collecting data, methods of analysis, and ethical protocols.
- **Chapter Four** reports on the findings obtained from the research, followed by the discussion and analysis of the study results.
- **Chapter Five** provides a summary of the key findings, along with the conclusions reached in the study and the recommendations proposed.

CHAPTER TWO

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1. Theoretical Framework

This section provides definitions of core terms and indicates how they are interrelated. It gives direction and understanding of the study. This study adopts the Theory of Production, Agricultural Household Model and the Food Security framework, which are applicable to the study. According to Kerlinger (1979) in Creswell (2009), theory is an arrangement of interrelated variables and definitions that provides a structured perspective on a given phenomenon. It helps in specifying how and why the variables are interrelated.

2.1.1. The Theory of Production

This theory involves the process of transforming resources into outputs. It involves understanding how production resources, including land, labor, capital and technology, are brought together to produce goods and services. The decisions primarily concern which goods to produce, the quantities to be produced, and the methods of production (Coulman & Young, 2010). However, lack or limited access to such resources can result in food/crop loss, leading to food insecurity. For instance, skills and knowledge of labor determine production. If there are limited training and education of farmers and farm workers on modern farming practices, it can result in crop loss. Furthermore, seasonal labor shortages or reliance on unskilled labor can lead to delays in harvesting and improper handling of produce, causing deterioration and loss of product (FAO, 2011 and Fourie et al., 2023).

Capital involves access to financial resources such as credit. It refers to funds used to purchase items used in the production process (Ellis, 2000). So, lack of credit and financing restricts the capacity of smallholder farmers to make investments in harvest and post-harvest technologies and storage facilities, leading to higher losses due to spoilage and improper handling by farmers or farm workers.

This theory helps understand the causes of food loss, which in turn informs the design of intervention strategies. It emphasises the role of addressing inefficiencies throughout production and external constraints to minimise food loss and improve overall productivity and sustainability of smallholder farming systems, thus improving food availability.

The study further incorporated Agricultural Household Model which explains how farm households make decisions about production, consumption and labour allocation simultaneously (Singh et al., 20). This model recognizes smallholder farmers as both producers and consumers. Smallholder farmers produce crops for both household and sale, while at the same time relying on income generated from farming activities to purchase other food and meet households needs. Therefore, production outcomes and household welfare are jointly determined.

The model assumes that households rely on farm production and income to meet their food needs and often operate under imperfect or missing markets, such as limited access to credit, storage facilities and markets. In this context, food losses reduce the quantity of vegetables available for household consumption and sale, resulting in lower income and reduced food availability. Consequently, food losses increase the likelihood of household food insecurity among smallholder vegetable farmers.

Furthermore, the study adopted a food security framework to explain how food loss directly and indirectly affects food security. Food loss that results from inefficiencies of the production process influences four aspects of food security. Firstly, it influences food availability, which is a critical aspect of food security. If food is lost at the production stage, this means less food will be available for consumption, making it harder for the population to meet its dietary needs. Secondly, production inefficiencies can raise food prices, making it less accessible to low-income households. When a substantial quantity of food is lost along the early phase of the production process, this causes a low supply in the market, driving up food prices. Higher prices affect poor people, reducing their purchasing power (Machete, 2004; HLPE, 2014) and limiting their access to nutritious food, thus exacerbating food insecurity. Another third aspect of food security affected is stability. This aspect can be affected over time. Food losses from inefficiencies in production can cause fluctuations in food supply over time, leading to a period of scarcity and instability in the food supply chain. These fluctuations make food inaccessible year-round. Lastly, the utilisation aspect is also affected. Low-quality crops may also indicate poor nutrition availability.

2.2. Literature Review

This section synthesises existing knowledge examining food loss and its impacts on food security. It explores food loss from the global and South African perspectives. The section further explores the factors contributing to food loss and reduction strategies utilised in primary production and provides a review of food security in the country.

2.2.1. Vegetable industry in South Africa

The vegetable industry is a vital sub-sector of the horticultural industry within the broader agricultural sector across the country. It consists of large commercial farmers together with a substantial number of small-scale farmers. This is among the rapidly growing agricultural sub-sectors, contributing 0.1% to the overall economic output of the country (GDP) in the second quarter of 2023. More broadly, horticulture accounts for about 27–30% of total agricultural sales, with a gross value estimated at R108 billion in 2022, making it the third-largest contributor to South Africa's agricultural sector (Nyakabawo, 2024). The sector's growth is also reflected in gross income trends: by early 2025, horticulture generated approximately R33 billion, with vegetables being the second-largest contributor. However, this contribution is largely driven by commercial producers, as most smallholder farmers mainly supply the informal market and produce for local consumption (Southern Africa Food Lab, 2015).

In terms of trade, the horticultural industry has recorded strong export growth. Between 2013 and 2022, fresh fruit and vegetable exports increased by 88%, with vegetables making up a significant share of this growth (Nyakabawo, 2024). Even though the sector shows growth at the national level, smallholder farmers continue to face various structural and production constraints, including poor access to credit, inadequate irrigation, and insufficient infrastructure, along with high post-harvest losses (Mdoda et al., 2024).

Consumption wise, vegetables have a considerable impact on enhancing food security, improving micronutrient intake, and supporting rural livelihoods. However, evidence from the General Household Survey highlights that household food budgets and variable access to fresh produce constrain consumption, particularly among low-income households (Stats SA, 2023). Some studies further show that many households consume fewer vegetables than recommended, with access largely shaped by affordability, proximity to markets, and household production capacity (Chakona & Shackleton, 2018; Du Toit et al., 2022). Consequently, affordability and access barriers continue to limit regular vegetable consumption for a significant portion of South Africans (Stats SA, 2023; Chakona & Shackleton, 2018). Research also shows that greater availability and consumption of vegetables are positively associated with more diverse household food consumption patterns and improved nutrition outcomes (Gareake & Shackleton, 2020).

2.2.2. Overview of Food Security in South Africa

The issue of food insecurity has persisted as a cause for concern for so many years locally and globally. One may wonder why it is still a challenge even today, despite so many efforts by public and private institutions to reduce it? Food security goes beyond mere availability of food in stores, but also about the ability to afford such available food, and it is essential that food is safe and provides proper nutrition. This complex definition of food security limits the capacity for it to be achieved and requires collaborative efforts to reduce food insecurity. Achieving food security may also be difficult due to several interrelated factors, including poverty, climate change, economic inequality, inadequate policies amid limited resources, and a rapidly rising population. To achieve food security, there should be a multifaceted approach, addressing the major hotspots of food insecurity.

In South Africa, many studies confirmed and emphasised that despite national-level food sufficiency, individual households continue to face food access difficulties (FAO, 2008; Dube, 2013; Stats SA, 2023; Simelane and Oosthuizen, 2023). This argument was initiated by the FAO in 2008 and has since been supported by several subsequent studies. This may be partly due to the prominent level of inequality in the country because South Africa has enough food through production and imports, but the majority of households, particularly those in rural settings, cannot access and afford it due to rising food prices and food being available in towns far from them (Stats SA, 2019). Many South Africans dwell in rural settings, which then makes the state of food insecurity worse at the household level (Stats SA, 2023). This means that policies should address food supply and its economic accessibility for rural and poor households to bridge the gap between national and household food security status.

The issue of food security gained significant attention in South Africa after the country became democratic in 1994. The Department of Agriculture was then given a mandate to provide opportunities to meet basic food needs in the country, with one of its major roles being to motivate South Africans to partake in agricultural activities as a means of alleviating food insecurity (DAFF, 2013). Since 2017, South Africa has experienced rising levels of food insecurity, attributed to extreme climatic conditions, economic pressures, and social disruptions. With a report projecting that in 2025, half of South Africa's population will face food insecurity. However, Stats SA (2019) noted that between 2011 and 2016, South Africa recorded a 6,1% decline in households involved in agricultural production. The study further highlighted a downward trend in the number of households reporting hunger and limited access to sufficient food in South Africa, albeit slowly and on a small scale.

Stats SA recently reported that moderate to severe food insecurity was more common among households engaged in agricultural activities (25.5%) than among non-agricultural households at 18.5% (Stats SA, 2025). This highlights inefficiencies in smallholder agriculture and challenges experienced by this group of farmers. In 2023, among agricultural households, 27.8% cultivated crops to complement other food items, 24.7% cultivated crops to generate additional income, and 23.6% households primarily secured their food from agricultural production. This emphasises the role farming plays in supporting household economic conditions. Hence, it is important to address inefficiencies in smallholder agriculture (Stats SA, 2025). In the Stats SA survey (2021), a higher share of households with insufficient or severe access to food are rural households. It is challenging for rural households to access and afford food in towns; therefore, it is better if there is sufficient local production by smallholder farmers to reduce the high food prices in towns.

South Africa's government view food security as one of its strategic priorities that deserves more attention. Hence, the government implemented and developed various strategies, policies, and programmes to ensure adequate food security. These policies include the National Food Security and Nutrition Plan, Fetsa Tlala (End Hunger) Food Production Intervention and the National Development Plan (DAFF, 2013). Despite these efforts, food insecurity remains persistent among rural households in the country. This may be due to poor implementation of the policies and programmes that result from poor coordination among government departments and inefficiencies in the execution. Furthermore, some factors influencing food insecurity are far beyond the control of these policies and programmes, such as climate change, rising food prices and economic and income inequality.

The literature shows that the government and private sectors are trying to reduce food insecurity, but still, households, especially those involved in agricultural production, face moderate to severe food insecurity. While smallholder agriculture is widely recognized as having the potential to address food insecurity. This highlights an existing gap in smallholder agriculture amongst those that prevent improved food security for households, especially those involved in production.

2.2.3. The Role of Smallholder Farmers in Enhancing Food Security

Small-scale farmers cultivate relatively small plots, typically 1 to 20 hectares. They are often considered family farmers, as they frequently depend on family labor to satisfy production requirements while retaining part of the harvest for household consumption (FAO, 2013; Knight, 2022). Globally, there are more than 500 million smallholder farmers, most of whom reside in

Asia and sub-Saharan Africa (Lowder et al., 2014). These groups of farmers account for 65 to 70% of the workers in Africa's agricultural industry and produce 80% of the continent's food (Lowder, Scoet and Ranney, 2016; Lowder, Scoet and Singh, 2014). This reflects the potential of the sector within the workforce worldwide and its ultimate influence on world food security. Gomez et al. (2020) highlighted in their study that smallholder farmers often contribute more to food production than official statistical records.

The contribution of smallholder farming is vital for maintaining food security in many areas across the world, especially in developing economies through employment opportunities, reduced food prices, and higher farm earnings (FAO, 2013; Oluwatayo, Modika and Marutha, 2017; Oluwatayo, 2019). In sub-Saharan Africa, 80% of farming is done by smallholder farmers, contributing 23% to the regional GDP. As such, food availability and affordability depend primarily on smallholder farming in developing countries. As most rural populations are involved in agriculture (Stats SA, 2021), strengthening this sector could help mitigate food insecurity and hunger in rural communities. Studies show that roughly 92% of rural households in sub-Saharan Africa engage in farming, which provides about 75% of their income (Davis et al., 2017). Furthermore, DeCock et al (2013) noted that more than half of rural households in Limpopo province faced severe food insecurity in 2013.

Smallholder farmers are primary producers of a broad range of food, including staple crops and vegetables, fruits, and livestock. This group of farmers contribute significantly towards food supplies in local markets. They supply most retail stores and supermarkets in rural villages, as well as national and international markets, ensuring food availability in the area. Additionally, this contribution to local markets reduces dependence on food imports. Production of vegetables by smallholder farmers in rural communities allows local people, especially low-income households, to access vegetables at an affordable price. Selling these vegetables locally also reduces transportation and storage costs and market agents' fees, thereby lowering overall food prices and improving farmers' incomes.

This group of farmers have the capacity to increase earnings, thereby improving the purchasing power of farmers and farm workers, allowing them to access other food items not produced on their farms to improve nutrition and dietary diversity (Kapari et al, 2023). This is emphasized by Oluwatayo (2019), in his study "Towards Assuring Food Security in South Africa: Smallholder Farmers as Drivers," who noted that smallholder farmers can enhance the utilization component of food security. Food utilization, according to FAO (2002), refers to individuals obtaining sufficient energy and nutrients through appropriate dietary habits and food preparation methods.

In other words, food utilization is about diverse nutrient intake to support a healthy and active lifestyle. Attaining food security involves more than just ensuring food availability and also encompasses the ability to obtain food that is safe and nutritionally adequate. FAO (2015) also noted that only those countries that improved agricultural productivity reduced undernourishment. Therefore, it is important to improve productivity among smallholders, especially in vulnerable communities.

According to Kapari et al. (2023), smallholder farmers grow vegetables, which are important for maintaining good health. The research by Sithole et al. (2023) discovered that fruits and vegetables are vital for meeting the need for adequate, nutritious food. In addition, the study emphasized that producing nutrient-dense foods, such as fruits and vegetables, is acknowledged as a key strategy to promote food and nutrition security. Enhancing access to, affordability of, and intake of nutrient-rich vegetables can significantly contribute to combating malnutrition and supporting good health (Tadesse, 2023). Food security extends beyond the presence of food to include proper nutritional quality and food safety. Smallholder farmers, through their diverse crops and vegetable production, ensure that all nutrients are available to support the dietary diversity of local people, thus combating malnutrition, obesity, and diet-related diseases. Smallholder farmers often produce organic, fresh produce that is minimally processed, helping ensure safe food for a healthy lifestyle.

Smallholder agriculture can also ensure stability in food security through a constant supply of food. Food stability refers to consistency and reliability in food supply, thereby balancing and stabilizing food prices. This is supported by Oluwatayo (2019), who noted that these farmers act as a buffer against price volatility and other market shocks. And they have the potential of mitigating fluctuations in food supply, especially because they produce and store surplus for future consumption. Smallholder farmers often produce a variety of crops all year round as most of them do not specialize. This production ensures that food is available all year round and stabilizes the food supply. The availability of vegetables also leads to reduced food prices and reduced dependence on imports, thereby stabilizing food prices in the country.

Even with the challenges smallholder farmers face, ranging from climate change and gender disparities and discrimination to financial exclusion, the role these farmers play in food security cannot be underestimated. From the literature, there is no doubt that smallholder farming holds potential in enhancing food security. However, despite the important contribution of these farmers to both local and global food security, they remain neglected by development policy (Gomez, Riesgo and Louhichi, 2020).

2.2.4. Description of Food Loss and Waste

Multiple studies grappled with defining and analysing food loss and food waste in various ways, and there is no exact definition of food loss agreed upon. The features that characterize “Food loss” and “food waste” vary from individual to individual according to the researcher’s intended objectives.

Food loss denotes a reduction in the volume or quality of food destined for human consumption that fails to reach consumers, occurring at the levels of primary production, processing, and post-harvest handling across the food supply chain (FAO, 2013; Breewood, 2019; DEFF and CSIR, 2021). Most losses occur during on-farm activities, across all stages of the food supply chain but prior to the retail and consumption stage. Food loss often occurs as a result of the actions of supply chain actors (excluding retailers and consumers), or to unintentional loss resulting from factors such as poor infrastructure and extreme weather conditions (FAO, 2011). Furthermore, Buzby & Hyman (2012) explain food loss as an unintentional loss in the volume of food meant for human intake because of spoilage and inefficiencies in supply chain practices.

For human consumption, food loss is broader and includes the diversion of food that is no longer good or nutritionally adequate for human consumption. It typically occurs during retail and at the household consumption level.

Although what constitutes food loss and food waste vary across researchers, many studies agree that food loss occur at primary production while food waste occur at the retail outlets and among final consumers (FAO, 2019; Gustavsson et al, 2011; Parfitt et al., 2010; Hodges et al, 2022; Lipinski et al, 2013 and Buzby & Hyman, 2012). Food losses are mainly driven by poor infrastructure, lack of technology, oversupply, and insufficient skills, while food waste is often due to spoilage and individual consumer behaviour.

Understanding the definitions of food loss and food waste is crucial for developing and informing proper policy interventions and priorities (Chamari, 2023). In the study, food loss refers to the decrease in either the quality or quantity of food for human diets. (FAO, 2013; World Resources Institute, 2019) in primary production/farm level. The study’s definition excludes food losses associated with crops intended for alternative uses, such as animal feed or biofuel.

2.2.5. Global Perspective of Food Loss

Food loss is becoming a serious global concern and a great challenge that impedes the efforts of making agricultural food systems efficient and sustainable. Estimates suggest that about a

third of all food meant for human intake globally did not reach consumers, leading to a yearly financial loss of \$940 billion (Gustavsson et al., 2011). Similarly, the Food Loss Index from the FAO in 2016 reported that 14% of food produced is lost before entering the retail supply chain, amounting to a financial loss of 400 billion dollars (FAO, 2020). Beyond economic implications, food loss contributes significantly to environmental degradation. This level of food loss accounts for approximately 38% of the total energy consumption in the entire food system and contributes 10% of global GHG emissions (FAO, 2020). Moreover, this loss does not only harm the environment and economy, but also wasted resources such as water, land, energy and time invested in producing that food. Emphasised by Shukla (2022), who noted that around 4.4 million square kilometers of farmland are lost due to inefficiencies in food production.

In addition, the increasing demand for food, coupled with unsustainable production practices, exacerbates land degradation. FAO (2013) projects that if current trends persist, around 120 million more hectares of land will be required for producing crops in developing countries, while developed nations may see a reduction of 50 million hectares due to environmental degradation from soil erosion and desertification.

A report by WWK-UK and Tesco in 2021 showed that food losses on farms worldwide amount to 1.2 billion tonnes per year, which is about 15,3% of total global food production. This translates into an economic loss of approximately USD\$370 million on farms (WWK-UK and Tesco, 2021). This loss occurs before food can even reach retail, which suggests inefficiencies during harvesting and production. In the USA, food loss at the farm level accounts for 16% of the total food loss. In 2022, agricultural production resulted in 14.9 million tons of surplus produce, of which the majority (over 80%) remained unharvested in the fields. (Shukla, 2018). This highlights two major concerns, firstly, this suggests market-driven losses whereby farmers may not harvest crops if market prices are too low, making it economically unviable and secondly, labour challenges whereby a shortage of labour can lead to farmers leaving produce on the field. Even more concerning, only 1.6% of the surplus produce was donated for hunger relief, highlighting a missed opportunity to address food insecurity and inefficiencies at the farming level. A research project undertaken in the United Kingdom found that out of 12.8 million tons of food loss in primary production, 3.3 million tons is lost on farms, accounting for 10% of UK agricultural emissions valued at £1.8 billion (WWF, 2022). The environmental consequences of this loss are alarming, as the carbon footprint associated with producing food that is never consumed is substantial.

Food loss and waste vary greatly across regions, and different actions need to be prioritised to mitigate and prevent them. Studies have shown that food loss takes place during production, before retail, mostly in developing nations, while food waste take place at the retail and consumption level, mostly in developed nations (Oelofse, 2021; FAO, 2013; Gustavsson et al., 2011). This trend is clearly illustrated and confirmed by the insights obtained from Gustavsson et al. (2011) in Syam et al. (2022) illustrated in figure 1, where regions like Sub-Saharan Africa, South and Southeast Asia and Latin America exhibit the highest percentages of losses during production and handling stages while regions such as North America, Oceania, and Europe which are industrialized nations, show a concentration of food waste occurring at the consumer level.

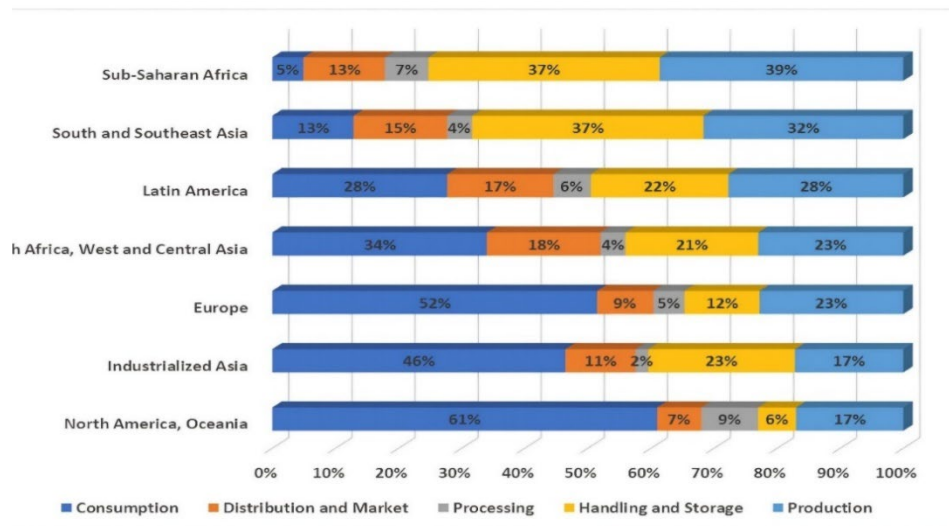


Figure 2: Global patterns of Food loss and waste across low-, middle-, and high-income regions.
Retrieved from Syam et al. (2022)

In industrialized countries, such losses are shaped by both consumer and retailer attitudes. For example, in Europe and North America, research has shown that the practices and attitudes of both food retailers and consumers contribute to poor planning and unsustainable consumption patterns. (FAO, 2013). In Africa and Asia, food loss arises from managerial and financial limitations, inadequate infrastructure, including insufficient technology and transportation, and poor farming practices (Gustavsson et al., 2011; FAO, 2013). As a result, research and interventions in developing nations should prioritise food loss, particularly at earlier stages (Harvesting, storage, and production) food value chain. In line with this, various studies conducted within emerging economies such as Ghana, Rwanda, and Nigeria have examined the food loss obstacles confronting smallholder farmers, particularly during the production and

post-harvest stages. However, there remains a considerable gap in similar research within the South African context. Addressing this gap is crucial for implementing targeted solutions.

The region of Sub-Saharan Africa experiences the highest levels of food loss, which calls for urgent attention, as most of the households in the region rely on agriculture for their economic well-being. Focusing on reducing food loss from production through to before reaching retail markets can help reverse nutritional deficiencies and food insecurity among vulnerable households.

The significance of addressing food loss and waste globally is underscored by the United Nations Sustainable Development Goal 12.3, targeting a 50% reduction of food waste in retail and household consumption while minimizing food losses throughout production and the supply chain. This goal necessitates joint efforts among the public, the private sector, and research and development.

To highlight the issue of food loss and waste and encourage global collaboration toward achieving Sustainable Development Goal 12.3, “the United Nations General Assembly declared 29 September as the International Day for Awareness of Food Loss and Waste”. The 2023 theme was “Reducing food loss and waste: Taking Action to Transform Food Systems” which provided an opportunity for private and public sectors and motivated them to prioritise actions through innovative approaches intended to minimize food loss and waste, thereby contributing to the restoration and strengthening of resilient and sustainable food systems (FAO & UNEP, 2020).

2.2.6. Food Loss in South Africa

As a developing country, South Africa has sufficient food to meet the nutritional needs of its population. Yet the country still faces significant levels of food insecurity and poverty. This may be because poor functionality and an unstable South African food system, which calls for urgent attention. According to Oelofse et al. (2021), South Africa discards and loses approximately 10.3 million tons of food suitable for consumption annually (averaged over 2014–2018), representing 34% of domestic food production or 45% of the country’s total food supply including imports (Kotze, 2023). According to WWF (2017), throughout the food value chain, half of the food is lost during production, a quarter during processing, one-fifth during distribution and retail, and 5% at the point of consumption. Of the wasted or lost food in South Africa, the most wasted categories are seeds and pulses and fresh fruits and vegetables, which are estimated to account for 44% of annual food losses. (Gustavsson et al., 2011).

According to WWF (2017), food losses amount to about 2.1% of South Africa's GDP, equivalent to R61.5 billion, while the energy costs associated with this food loss are roughly R1 billion annually. Considering that agriculture constitutes 62% of the country's total freshwater consumption, this is a huge waste of scarce water resources, considering that globally, South Africa is considered the 30th driest country. This in turn affects the competitiveness of the food system in South Africa by constraining the development and employment opportunities of the agricultural sector (WWF, 2017).

South Africa also experiences significant levels of post-harvest losses among vegetable farmers, but quantifiable measures are limited. Main causes of the losses reported by several studies in the country include insufficient cold storage infrastructure, long distances to markets, poor harvesting time, and adverse weather conditions (Qande, 2025; Mashau et al., 2012). Research by Qange et al. (2024) mentioned that agribusiness investment, such as the development of cold storage infrastructure and transport, can reduce post-harvest losses by 61%, demonstrating that infrastructural investment can materially reduce losses in vegetable value chains. In South Africa, the literature highlights that post-harvest losses in fruits and vegetables are significant among smallholder farmers, with studies reporting over 50% of losses resulting from inadequate infrastructure and insufficient knowledge, as well as poor market access (Mashau et al., 2012 and Garikia, 2014).

Furthermore, the South African government developed initiatives capable of reducing farm-to-farm and post-harvest losses. For example, the government has introduced "National Policy Framework on the support and development of Agro-Processing Enterprises in the Republic of South Africa" that promotes agro-processing among small-holder farmers in rural communities. Studies indicate that agro-processing has the capacity to lower post-harvest losses, ultimately contributing to improved food supply, nutritional quality, and safety standards (National Policy on Food and Nutrition Security, 2013). This policy is designed to boost food security and enhance food supply through decreasing post-harvest losses and addressing the seasonal and perishable nature of agricultural produce, particularly fruits and vegetables.

2.2.7. Implications of Food Loss on Food Security among Smallholder Farmers

Food loss significantly affects the environment, the economy, and food security (Tanye, 2016). It is acknowledged as one of the major key contributors to food security among smallholder farmers (Kotze, 2023). Food loss results in reduced disposable income for farmers and affects job opportunities for communities and family members (Machete, 2004). This ultimately results in lower income for purchasing other food items for household' consumption. A reduction in food

quantity leads to market price volatility, driving food prices higher and making it costly for poor households and farmers.

The study undertaken by Kotze (2023) on the perspective on food loss found that farmers perceive food loss not as a loss per se but as an opportunity, as they can redirect the lost food to animal feeds or turn them back into the soil as organic matter. This perspective overlooks the initial purpose of food production within the human food supply chain. Although such diversion presents a value-adding opportunity for sustainable agriculture, it nonetheless represents a loss in the food system. This is because the food was produced for human consumption, and its failure to fulfil this purpose signifies a breakdown in the human food supply chain. Thus, while alternative uses of lost food may mitigate economic and environmental impacts, they do not eliminate the loss from a food security perspective.

According to the study conducted by Adepoju (2014), post-harvest losses have proved to adversely affect on farmers' income. In the study, Adepoju (2014) determined the gross margin of farmers after and before postharvest losses and found that the gross margin after post-harvest losses was 345,551.00 Naira, down from 800,921.80 Naira before post-harvest losses. Similarly, Vianney and Nepo (n.d) concluded that farmers faced food insecurity due to price fluctuations and low revenues, which reduced their purchasing power and dietary diversity. Minimizing food loss can enhance the ability to feed the increasing global population and thereby enhance food security. The study by Machete (2004 and Oluwatayo (2019) noted the significant contribution of smallholder farmers in obtaining household food and income security in poor rural areas.

Unharvested crops lead to reduced income for farmers, affecting their purchasing power and ability to access other food products necessary for healthy lives (HPLE, 2014). Reduced income also leads to reduced investment in farming, exacerbating food unavailability. Moreover, food loss results in the loss of nutrients and calories, leading to health issues such as undernourishment and increased exposure to other diseases. The FAO study (2015) assessed fruit and vegetable losses and their impact on the availability of vitamins A and C across seven global regions. Findings indicated that reducing vegetable losses would increase nutrient intake and phytochemical availability, thereby helping address micronutrient deficiencies and related health issues. In South Africa, these deficiencies are pronounced, with 43.6% of children lacking sufficient vitamin A and 10% affected by iron-deficiency anaemia. Therefore, reducing vegetable loss can benefit the community's health and well-being, especially children's.

The study that took place in Kano State, Nigeria, on the implications of post-harvest losses on the poverty status of vegetable farmers found that 59,9% of the 192 farmers surveyed were living in poverty, with 35.7% of those farmers experiencing poverty due to post-harvest losses (Bada, Mohammed, Shettima, Sambo, Abdulaziz and Ghiye, 2023). This demonstrates a significant relationship between food loss and deteriorating livelihoods. This also underscores the mechanism by which food loss could exacerbate food insecurity, especially for smallholder farmers who rely on vegetable farming for both income and livelihood sustenance.

Several studies have been conducted globally showing various causes and solutions to food loss, but due to differences in local settings, it is important to also know if such causes and solutions adopted by other countries could also work in South Africa to develop targeted interventions instead of a uniform approach to avoid adopting solutions that are not effective for our region.

2.2.8. Socioeconomic determinants of household food security status

Socio-economic conditions influence a critical part in evaluating the food security status of farming households, especially in developing countries. Household food insecurity is a multidimensional problem determined by a range of factors, from socio-economic, agricultural and market-related, among others. Several studies have highlighted socioeconomic characteristics such as household income, educational level, gender of the household head, age, household size, and access to resources as major determinants of food security outcomes.

Age

Age of the household head has been one of the socio-economic factors that influence food security. The study by Mujeyi et al. (2021) shows that older household heads often possess more farming experience, better risk management skills, and greater capital, which can strengthen household access to food and stable income. Additionally, Adeyanju et al (2023) also emphasise this by noting that they may also accumulate productive assets such as land, which may contribute to greater household resilience and stability. This shows that age can positively influence food security. These results correspond with the those of Awobusuyi et al. (2020) in Nigeria, who found that elderly household heads tend to experience greater food security than their younger counterparts.

Conversely, the research carried out in Brazil by Ribeiro et al. (2023) observed that households with elderly heads are likely to face food insecurity. This was attributed to limited economic opportunities and declining health of the elderly household heads. This is supported by Oluyole

and Taiwo (2015) in Nigeria, who found that with every extra year in the household head's age, the chances of a household being food secure decline by 0.000074 (Smith et al., 2019). The literature implies that the relationship between household head age and levels of food security is context-specific and complex, depending on other determinants such as access to resources. Furthermore, Hall et al. (2009), Oliveira et al. (2014), and Xaba et al. (2020) reported that higher age was linked to reduced consumption of fruits and vegetables, which may lead to reduced dietary diversity and mineral intake.

Household size

Household size is a key factor influencing food security, as identified by several studies. The literature demonstrates that households with more members tend to experience reduced food security, as food insecurity is often more common in larger households than in households with fewer members. This suggests that households with more members put pressure on available food resources, which negatively affects food security status (Akello & Mwesigwa, 2023; Moncada et al., 2022; Aidoo, Mensah and Tuffour, 2013). Studies in Ethiopia and Uganda found that households with a greater number of members tend to face higher food insecurity, as consumption outweighed food production and income generated (Ayele et al., 2020; Akello & Mwesigwa, 2023). A negative correlation between household size and food security was observed from studies across different regions, in sub-Saharan Africa, South Africa and in Limpopo (Tambe et al, 2023). For example, Ayele et al. (2020) conducted a study in Ethiopia and the study showed that each extra family member increases the likelihood of food insecurity by 18%.

Household income

Income is a critical and consistently reported socioeconomic determinant of food security in the world. Research shows that higher income levels enhance households' ability to acquire adequate, safe, and nutritious food, while households with low income tend to experience food insecurity and malnutrition (FAO, 2023). Income affects the availability and access components of food security because it impacts households' financial ability to purchase food, capacity to invest in agricultural inputs, and ability to diversify diets. As noted by Moncada et al. (2022), a strong link exists between income poverty and food insecurity in both developing and developed countries. These findings align with those of Loopstra and Tarasuk (2013), who showed that low household food security is associated with lower income levels.

In sub-Saharan Africa, household income has been identified as a consistent predictor of food security outcomes. Rural households that depend primarily on subsistence farming often face seasonal fluctuations in income, which directly affect food consumption patterns. Studies from Kenya, Ethiopia and Lesotho (Langat et al., 2010; Woldehanna and Behrman, 2013 and Nkoko, 2024) demonstrate that households earning higher and consistent incomes are less prone to hunger while being more inclined to maintain diverse diets throughout the year. Moreover, income diversification through off-farm employment, small enterprises, or remittances has been shown to buffer households against shocks such as drought, crop failure, or price fluctuations (Ogunniyi et al., 2018). This highlights that not only income level but also income stability and diversity are crucial determinants of food security in African contexts. The findings from sub-Saharan Africa are consistent with those from Limpopo (Tambe et al. 2023; De Cock et al., 2013), where the majority of the studies found a similar relationship between income and food security.

Educational level

Education is also identified as a significant driver of household food security globally. Studies have consistently shown that higher educational attainment, especially among household heads, is linked to better access to food, dietary diversity, and nutritional outcomes (FAO, 2022; Smith & Subandoro, 2007). Education enhances individuals' knowledge of nutrition, health, and agricultural practices, which improves food utilisation and resource management within households (UNICEF, 2021). The results of the Stats SA report show that those with a tertiary education earn seven times more than those with no schooling. It also increases the likelihood of engaging in income-generating activities and adopting innovative farming technologies, both of which contribute to better food availability and stability (FAO, 2023). Research in developing countries demonstrates that households managed by more educated individuals tend to experience lower levels of hunger or malnutrition, highlighting education as both a direct and indirect driver of food security (Mutisya, Ngware, Kabiru, *et al.*, 2016; Gebre, 2012). This is the trend and relationship that is observed in sub-Saharan countries and even in South Africa and Limpopo province. Studies indicate a positive association between educational level and food security (Stats SA, 2021; Sharaunga et al., 2016). Education improves decision-making and problem-solving capacities, enabling households to reduce potential risks such as drought, crop failure, and price fluctuations more effectively (Aidoo et al., 2013).

In Limpopo province, similar findings were observed. A province-level analysis of socioeconomic determinants in Limpopo identified education as a key factor linked to food security: the study

reported that low education, together with low income and large household size, correlated with greater risk of food insecurity. This relationship was further supported by De Cock et al (2013), Oni et al (2010), and Tambe et al. (2023).

There is notable proof from sub-Saharan Africa that reveals that higher educational attainment within the household or by the household head, normally shown by years of schooling and educational level, improves household food security. For instance, a longitudinal analysis of two informal settlements in Kenya by Mutisya et al. (2016) found that every extra year of household schooling significantly reduced the probability of being food insecure, even after controlling for household wealth, suggesting an independent, protective effect of education on food access and coping capacity. Similar observations have been made in South Africa and Ethiopia, where Ngema (2018) identifies education as a positive determinant of household dietary diversity and food consumption score in rural KwaZulu-Natal. Agidew (2018) and Feyisa (2018) report that educated households are significantly have a lower risk of food insecurity compared to households without education in Ethiopia. These SSA studies attribute this relationship to improved uptake of agricultural innovations, more effective use of market opportunities and better access to employment. Moreover, even high-income countries corroborate the role of education as a positive determinant of food security. For instance, population studies in the United Kingdom show that low educational level is a strong factor influencing household food insecurity, with lower-educated adults experiencing substantially higher chances of food insufficiency even after adjusting for income and other socioeconomic factors (Loopstra, Reeves & Tarasuk, 2019). Moreover, in the United States, recurrent USDA analyses of the nationally representative food-security survey consistently show that households with a reference person who has higher education have a lower rate of food insecurity, supporting the conclusion that educational attainment is associated with greater food-security resilience across diverse institutional contexts (Coleman-Jensen et al., 2022).

Gender

There remains a substantial prevalence of gender inequality in farming. Madula (2023) noted that male farmers likely to be successful than female farmers. This is likely influenced by their relatively greater access to resources inputs than their female counterpart (FAO, 2023; Tibesigwa and Visser, 2016).

Globally, research shows that gender is a major factor in shaping household food security. According to FAO (2023), Women tend to suffer food insecurity more frequently than men,

largely due to gender-based inequalities in land access, credit, and other production resources. The State of Food Security and Nutrition in the World (FAO, IFAD, UNICEF, WFP and WHO, 2025) report highlighted that women make up approximately 60% of the global malnourished population. Gender inequalities in resource ownership and decision-making power contribute to differences in productivity and food security outcomes.

In Africa, the gender gap in agriculture remains a critical issue for food security. Women contribute to food production in the region, producing about 60 – 80% of food in several African countries, but continue to face constraints in accessing land, credit, and extension services (FAO, 2022; Doss et al., 2018). While in South Africa, the contribution of gender in food security is multifaceted and context specific. National household survey reveals that as compared to male-headed households, female-headed households are usually at greater risk of food insecurity, primarily due to income disparities and restricted access to productive resources. (Stats SA, 2022; Sharaunga et al., 2016). However, research carried out by Kassie et al. (2015) emphasized that women are key decision-makers regarding household nutrition, often prioritizing food quality and family welfare, which reinforces their importance in achieving household-level food security. Despite this, gender inequality in resource ownership and control continues to undermine the potential of women in contributing effectively to production and household welfare. Households headed by women living in agricultural areas experiencing moderate to severe food insecurity showed the highest prevalence rates estimated at 22% in 2019, 25% in 2022 and increased by 12,4% to 28% in 2023. This study emphasised that households residing on farms and traditional areas were more affected by food insecurity than the national average. The study also reported that female-headed households in urban areas have lower prevalence rates, even below the national average, as compared to those in rural areas (Stats SA, 2025).

In Limpopo province, women are key contributors to small-scale agriculture and household food security. The research carried out in Limpopo by Hlatshwayo et al. (2021) shows that female farmers are active in crop production, processing and marketing of indigenous vegetables, which is essential for food nutrition and security. However, resource constraints, such as access to land and credit, continue to restrict their productivity and income generation.

2.2.9. Determinants and management of food loss

Causes and drivers of food loss differ greatly around the world, depending on local settings, crop type, and supply chain stage (Gustavsson et al., 2011). For instance, fruits and vegetables are mostly lost at the farm level and earlier in the food supply chain, while grains and staples

are more vulnerable during storage and processing. In industrialized countries, losses are often concentrated at harvest, sorting, and grading due to stringent quality requirements imposed by retailers (FAO, 2011). Conversely, in developing economies, losses occur at production and earlier stages of the food supply chain, typically exacerbated by financial, managerial, and technical limitations that affect farmers' capacity to manage production and post-harvest processes effectively.

Several studies have been conducted globally, showing various causes and solutions to food loss, but due to differences in regions and local settings, it is necessary to also identify drivers of food loss in our country or region and solutions to it, as this can't be a one-size-fits-all approach. The study conducted by Alidu, Ali and Aminu (2016) in Ghana identified high temperatures and pest infestations as key factors reducing tomato quality and shelf-life, while Vianney and Nepo (n.d) linked food loss to socio-economic factors such as farmer age and limited access to extension services. In South Africa, the study conducted by Fourie et al. (2023) identified weather variability, chemical mismanagement, and oversupply as critical contributors to farm-level food loss, while Ramukhwatho et al. (2021) found that oversupply, pest damage, and adverse weather resulted in both on-farm losses and wastage at fresh produce markets. The literature reiterates that causes are not limited to biological and environmental conditions but also stem from socio-economic and market-related challenges such as volatile prices, consumer preferences, and strict grading standards (Gille, 2012; Gillman et al., 2022).

Globally, Junaid and Gokce (2024) reported in their study that 38% of farm losses are caused by pests and insects, while abiotic factors account for more than 50% of the losses. They further noted that these losses are associated with the farming systems adopted by farmers, which are determined by economic well-being and technology adaptation.

Addressing these diverse causes require context-specific, multidimensional strategies. Studies by HLPE (2014) and Kotze (2023) found that solutions such as cold chain infrastructure, improved storage facilities, and greenhouse technologies can mitigate losses caused by temperature fluctuations and environmental stressors. Moreover, Fourie et al. (2023) and FAO (2013) highlighted capacity development initiatives that equip farmers and workers with knowledge on proper practices for harvesting, handling, and chemical applications. Extension services have been shown to contribute significantly to ensuring that farmers receive up-to-date information, access technologies, and improved market linkages, which, in turn, reduce harvest and post-harvest losses (Mmbando, 2014; FAO, 2020).

Beyond technical and knowledge-based interventions, cooperative and community-based approaches such as shared storage facilities and collective marketing can enhance farmers' resilience to oversupply, price volatility, and infrastructural constraints (Gustavsson et al., 2011). Importantly, strategies should be adapted to local conditions, as solutions yield similar results elsewhere. For instance, while farmers in developed economies may benefit more from consumer education and retail-level interventions, smallholder farmers in developing countries call for strategic investment in both infrastructure and training programs to minimize food loss.

Reducing food loss offers multiple benefits, including advancing progress towards the United Nations Sustainable Development Goals (SDGs), fulfilling the Paris Agreement's climate targets, and enhancing food security for a rapidly rising population (HLPE, 2014). Effective management requires a combination of technical, institutional, and behavioral strategies tailored to local conditions.

For products with perishable product temperature management through cold chain infrastructure, storage facilities, and improved transport systems is critical (HLPE, 2014). Greenhouse technology has also been identified as interventions to reduce the effects of extreme weather on production (Kotze, 2023).

Fourie et al. (2023) and FAO (2013) highlight the critical role of training both farmers and farm workers in proper harvesting, handling, storage, and chemical application techniques. The effectiveness of extension services in reducing food loss has also been demonstrated in studies such as FAO (2020) and Mmbando (2018), which highlight their role in enhancing farmers' knowledge, harvest timing, and market access.

Community-based solutions such as shared cold storage facilities, cooperative processing centers, and coordinated marketing efforts have been recommended as cost-effective strategies for resource-constrained smallholder farmers (Gustavsson et al., 2011). These strategies both minimize losses and enhance farmers' negotiating position in the market. Of all fresh fruits and vegetables produced, only 10% are refrigerated. Considering the perishable nature of fruits and vegetables, it is highly important for them to have a cold storage facility, as harvested fresh produce is not always consumed right away. Ridolfi et al. (2018) observed that insufficient cold-storage facilities are a primary factor contributing to significant post-harvest losses in highly perishable crops such as tomatoes, which adversely impacts farmers' income and livelihoods.

At the policy level, socioeconomic considerations such as income, employment, and market access must be integrated into food loss reduction strategies (Chrisendo et al., 2023). This

holistic approach emphasizes the significance of approaches that tackle both the technical and socio-economic dimensions of food loss.

Previous studies emphasize that food loss represents a complex challenge affected by environmental, biological, socio-economic, infrastructural, and institutional determinants. While studies in Africa have largely focused on staple crops such as maize, there is a research gap regarding how vegetables and pre-harvest conditions shape food loss outcomes. Addressing food loss requires integrated management strategies that combine technological innovations, farmer training, infrastructure development, and supportive policies. Implementing this approach reduces waste and contributes to greater food security, climate change mitigation, and sustainable agricultural development.

2.3. Summary of literature

The literature focused on the vegetable industry in South Africa, highlighting the significance of smallholder farmers in enhancing food security; the food security situation in the country; and an overview of food loss globally and in South Africa.

The literature indicates that South Africa has sufficient food nationally through production and imports, and this may come from commercial farmers. Many smallholder farmers are based in rural areas and contribute to local food security. Yet these group of farmers encounter difficulties, including limited access to proper infrastructure, market and credit making them particularly susceptible to shocks especially food loss. This consequently reduces the food available in the local market and reduces their profitability and income, thereby making them even more susceptible to food insecurity.

2.4. Gaps in Previous Literature

The literature reviewed demonstrates that food loss and food insecurity remain major concerns in the agricultural value chain and household livelihoods, particularly in developing countries. Furthermore, the literature emphasis the role of smallholder farmers in enhancing food security and high levels of household food insecurity in South Africa and in Limpopo province. Although numerous studies have examined food loss and food security in South Africa, majority of them analyzed food loss and food insecurity separately, leaving several gaps in the literature. Firstly, most studies focused on post-harvest losses leaving the knowledge gap in the losses that occur at the farm level. Moreover, existing studies on vegetable losses focused mostly on causes and magnitude of food loss. While on the other hand studies that have examined factors influencing food security have focused on socioeconomic and institutional characteristics of respondents.

But limited studies have been conducted on how food loss directly influences household food security outcomes among smallholder vegetable farming households. Therefore, this study seeks to address these gaps by examining the impact of food loss on household food security among smallholder vegetable farmers while also identifying causes of food loss and reduction strategies employed by the smallholder vegetable farmers in Capricorn district municipality.

CHAPTER THREE

METHODOLOGY

3.1. Introduction

This section explains the methods applied for analysing the objectives of the study. It outlines the area where the study was conducted, methodological framework, population and sampling procedures, data collection process, methods of analysis, and ethical considerations.

3.2. Study area

The Capricorn District Municipality (CDM) is among the five districts of the Limpopo province of South Africa. The area is 2,180,531 hectares with a population per square kilometre of 58.1km² (CDM IDP, 2016/2017). Within the Capricorn District Municipality, there are four constituent local municipalities: Polokwane, Molemole, Blouberg and Lepelle-Nkumpi. CDM comprises a population of 1.372 million individuals and 378,301 households (Statistics South Africa, 2016). The area is predominantly rural, characterized by dispersed small villages. This represents 23.3% of Limpopo's population and approximately 2.3% of the national population (CDM IDP, 2016/2017). The district has a low-rainfall climate, characterised by wet, hot summers and cold, dry winters. In CDM, agriculture is the second-largest local economic sector (after mining), with key products including potatoes, tomatoes, citrus, and livestock, particularly goats and cattle (CDM, 2015). Many households in Capricorn districts engage in agricultural activities. The area was chosen due to the prevalence and likelihood of experiencing food insecurity (Nengovhela et al., 2022).

The Blouberg Local Municipality (BLM) is primarily rural and lies on the northwest frontier of South Africa, bordering Botswana and Zimbabwe. According to the IDP report, Blouberg Local Municipality, alongside Molemole, are the biggest producers of tomatoes, onions and potatoes in the Limpopo province. The major activities of Blouberg Municipality are agriculture, mining, and tourism. While Molemole local municipality is rural in nature and distinguished by high levels of poverty and socio-economic disparities. And main activities include agriculture, plantations and small-scale mining. The municipality's economy is largely driven by agricultural activities. It is known for producing high-quality potatoes and tomatoes destined for international markets. However, the agricultural sector has declined considerably, leading many commercial farmers to shift towards game farming (IDP 2021/22-2025-2026).

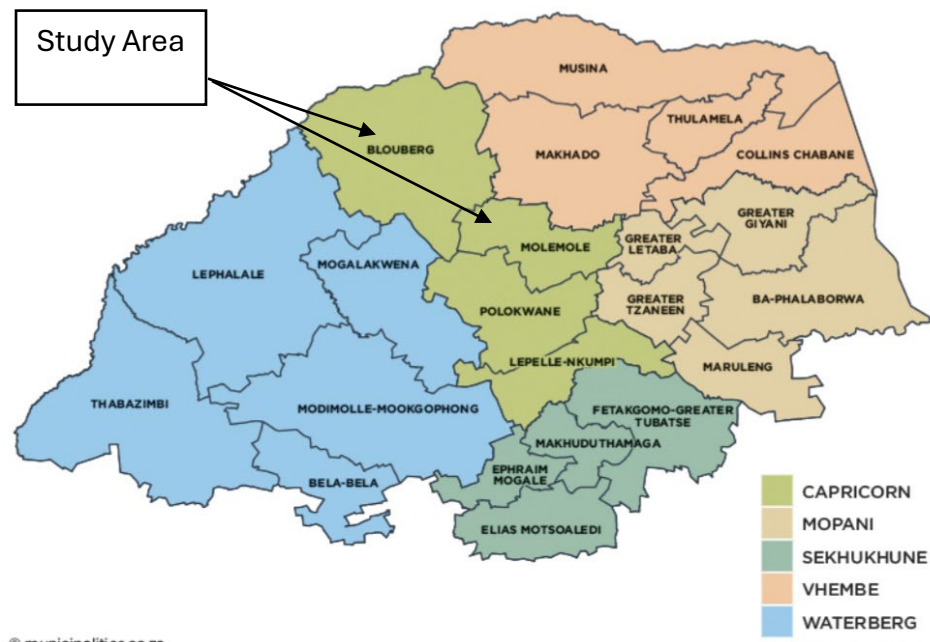


Figure 3: A geographical map of Limpopo showing the research site (Capricorn District Municipality).

3.3. Study design

Research design is a procedure for how the study and analysis of the data will be conducted. Asenahabi (2019) describes it as the arrangement of the research project, a structure within which research will be conducted and a way in which the study's data will be collected, measured, and analysed. It offers the framework for collecting, analyzing and interpreting data in a structured and systemized way (Asenahabi, 2019). The core objective of this research design is to ensure that research questions are answered effectively and that objectives are achieved. Du Plooy (2009) confirmed that a research design serves as a roadmap for the study, detailing what will be examined, who will be involved, and when and where the research will take place.

The study employed a quantitative research design to explore how food loss impacts food security. Quantitative research entails collecting and analyzing numerical data using statistical methods to address questions about who, how much, what, where, when, and how (Apuke, 2017). A quantitative research design was adopted for the study, as it was found to be statistically relevant. Creswell (2009) describes quantitative research as evaluating objective theories through the measurement and examination of relationships between variables. Therefore, in the study, quantitative research provides objective measures of food loss and the extent of its influence on food security status amongst smallholder farmers' households.

Moreover, a quantitative approach allows us to gather data collected from a bigger sample through random sampling method to ensure that findings are more generalizable and can be widely applicable to other regions, thereby increasing their relevance to a broader audience (Etikan & Babatope, 2019)

A descriptive research design was then used to describe the socio-economic background of the respondents. This research design intends to describe the attributes of a particular phenomenon. Descriptive statistics identify demographic and socio-economic characteristics of the participating smallholder vegetable farmers. According to Cooskey (2020), descriptive statistics is useful for characterizing a population or phenomenon with the aim of identifying trends and characteristics, and it is relevant when limited information is available on this particular topic or population. The study utilized descriptive statistics to profile the socio-economic characteristics of smallholder vegetable farmers, to assess the factors driving food loss and to explore strategies to minimise food loss among smallholder vegetable farmers.

3.4. Population and sampling

The population of a study comprises a subset of the population the researcher intends to examine, which shares a set of characteristics the researcher wants to explore (Ahmad, Alias, and Razak, 2023). Understanding the study population is crucial, as it allows for setting boundaries and defining the study's scope. For this study, the population involved smallholder vegetable farmers in the Capricorn district. The study population consisted of 840 smallholder farmers who grew vegetables to support their families.

Sampling is described by Williams (2006) as a method for selecting elements from a population to generalize about the population. The sample is part of the population that the researcher examines to make conclusions about the whole population (Taherdoost, 2018 and Bhardwaj, 2019). Sampling is important in a study with limited resources as it is impractical, costly and time-consuming to study all members of the population for research (McCombes, 2019).

Therefore, the study employed a multistage sampling method in combination with random sampling. Multistage sampling is a process in which samples are selected from a population in successive smaller groups, allowing data collection from large, geographically dispersed populations (Williams, 2006). The method is deemed relevant to the study because the population is geographically dispersed and large, making it hard to draw a simple random sample from the entire population.

For the study, which intends to understand the effects of food loss on food security among smallholder vegetable farmers in Capricorn district, the sample size of 230 smallholder vegetable farmers was found adequate as determined using the sampling formula based on a 99% level of confidence and a 0.05 margin of error. The population consisted of 580 smallholder vegetable farmers which was obtained from Department of Agriculture and Molemole Farmers Association.

In the first stage, the Capricorn district was selected because it produces some of the major vegetables in Limpopo, such as potatoes, tomatoes, and pumpkins. The area is relevant to the study objectives and likely to provide meaningful insights. In the second stage, the local municipalities of Blouberg and Molemole within the district were randomly selected to capture farmers from different production zones, thereby ensuring representativeness while maintaining feasibility in terms of time and cost. Within each selected local municipality, villages with more smallholder vegetable farmers were selected for the study. This was done to capture the diversity of respondents' socio-economic characteristics. Within each village, simple random sampling was then employed to select individual smallholder vegetable farmers from the available list provided by crop farmers' associations in the area. The researcher obtained the list of farmers from the local farmers' association (Mole-Mole Farmers Association) to compile a list of all farmers in the area.

The combination of multistage and random sampling was therefore suitable, as it enabled efficient handling of a large, geographically dispersed population. This helps to capture the diversity of farming practices, food loss challenges and levels of food security across different areas. To ensure population representation, the study adopted a sampling formula to obtain an adequate number of participants.

$$N_0 = z^2 pq / e^2$$

$$N_0 = \frac{(1.96)^2 (0.01)(1-0.01)}{(0.05)^2}$$

$$= 380,3184$$

Where:

e = Margin of error

p = Estimated proportion or variance (0.05)

$$q = 1 - p$$

Z = Z-value corresponding to the chosen significance level (1.96)

$$N_1 = \frac{N_0}{1 + \left(\frac{N_0}{\text{Population}} \right)}$$

$$= 230$$

Proportion of sample for the selected local municipalities.

Blouberg sample size= 150

Molemole sample size = 80

3.5. Data collection

Data collection involves obtaining information essential to achieving the study's objectives (Burns & Grove, 2005). This study utilized questionnaires as the primary instrument to collect relevant data for research purposes. Primary data were gathered via a structured questionnaire carried out through personal interviews. The questionnaire comprised closed-ended items, which are appropriate for the quantitative nature of this study.

The instrument employed to gather data for this research was a questionnaire that was divided into four sections. Section A of the questionnaire asked about the respondents' socio-economic characteristics. Section B consisted of questions from the Household Food Insecurity Access Scale, which measures the access component of household food insecurity. This section included 9 questions that asked respondents about their experiences with food insecurity over the past production season. Section C consisted of causes of food loss among smallholder vegetable farmers. And section D was about food loss reduction strategies utilized by the respondents.

The questionnaires were issued to the sample number of participants. And it was clearly explained to the respondents in the area's native language (Sepedi/Northern Sotho), and they were asked to provide as accurate and honest information as possible. During data collection, the researcher informed respondents of the research purpose and their willingness to take part in the research

To guarantee that the questionnaire produced valid and reliable results, the questionnaire was tried out using five smallholder vegetable farmers in the study area before the primary data

collection. The preliminary study was conducted in Kibi, a village in the Blouberg Local Municipality.

3.6. Methods of data analysis

This involves the methods and software used in analyzing data. Data capture was done using SPSS for descriptive data analysis, and STATA was used for the Ordered Probit Model. The study employed the following techniques for data analysis: descriptive statistics and the Ordered Probit Model.

3.6.1. Objective 1: Profile of the socioeconomic characteristics of small-holder vegetable farmers

The study applied descriptive statistical methods, including the use of tables, frequency distributions and percentages, to assess the socioeconomic profile of smallholder vegetable farmers in the Capricorn district. The method allows the researcher to organise data in a table and graphical form and percentages to show the proportion of respondents in each category.

3.6.2. Objective 2: Assess the factors driving food loss among smallholder vegetable farmers

Descriptive statistics were used to identify factors driving food loss among smallholder vegetable farmers. This method enables researchers to analyze patterns and trends in a data set. Frequency and percentages were presented in a table to show the proportion of respondents in each category of the causes of food loss.

3.6.3. Objective 3: Determine the food security status of the smallholder vegetable farmers

To establish the impact of food loss on food insecurity among these farmers in the study, the Household Food Insecurity Access Scale (HFIAS) was employed to ascertain the food security status of the respondents. The HFIAS is a scale based on experience that measures food insecurity by capturing the behavioral and psychological signs of a household's limited access to food (Coates, 2007). This method involves two kinds of questions: "occurrence" and "frequency of Occurrence" on poor access to, and availability of food (Castell et al., 2015). Normally, this method in the questionnaire involves 9 questions that determine the level of concern and cover a period of 30 days (Coates, Swindale and Bilisky, 2007). However, for this study, a recall period of 30 days after their previous production cycle was used to get a better view of the food insecurity situation affected by food loss during that production season. These

questions were presented as a 4-Point Likert scale, where never means the condition did not occur in the 30-day recall period, rarely means the condition occurred once or twice a month, sometimes means that the condition occurred three to ten times, and often means the condition occurred more than ten times a month.

The respondent is given 9 questions to answer regarding the frequency of occurrence, each with 3 possible frequencies or scores. The nine questions were scored as 1-3, with Never = 0, Rarely = 1, Sometimes = 2, and Often = 3. Data were then entered into SPSS, and a composite HFIAS score for each household was computed by adding nine frequency responses, yielding a continuous score from 0 to 27. Following the HFIAS indicator guide developed by Coates et al. (2007), the households were classified into four mutually exclusive and ordered categories such as food secure, mildly food secure, moderately food secure and severely food insecure. This method was also applied by the study of Devereux and Tavener-Smith (2019). The responses from each respondent were then classified into food security categories: 0-1 = Food secure; 2-7 = mildly food insecure; 8-14 = moderate food insecure and 15 - 27 = Severely food insecure. The household food insecurity access scale categories were then examined using descriptive statistics, including frequencies, to determine the state of food insecurity. Household Food Insecurity was measured using Household Food Insecurity Access Scale.

3.6.4. Objective 4: Investigate the relationship between food loss and food security among smallholder vegetable farmers

To achieve this objective, the Ordered Probit Model (OPM) was employed to assess the link between food loss and food insecurity. Food loss is the key explanatory variable in the study, represented by the percentage share of food lost. The Ordered Probit Model is a useful tool when the dependent variable is ordinal, meaning it represents categories with a meaningful order but no fixed interval between them. Since food security measures are categorical and ordinal, the Ordered Probit Model is the most relevant for the analysis. This model is suitable when there is a natural ordering of the different values, but no cardinal value.

In terms of analysing the impact of food loss on food security, the dependent variable: food security levels are: 0 - food secure, 1-mildly, 2- moderately, and 3-severe insecure).

In this objective, food loss is the key independent variable which influences food security. Then we have other influencing variables, including gender, age, household size, years of schooling, access to markets, distance to markets, etc included in the estimation. Within the scope of this

study, other variables included in the model are factors that may affect food security but are not the main focus.

Model specification:

$$Y = X\beta + e$$

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \dots + \beta_{16}X_{16} + e$$

Fitted Model:

$$Y = \beta_0 + \beta_1X_{1\text{Gen}} + \beta_2X_{2\text{Age}} + \beta_3X_{3\text{HSize}} + \beta_4X_{4\text{Edu}} + \beta_5X_{5\text{Exp}} + \beta_6X_{6\text{FSize}} + \beta_7X_{7\text{Income}} + \beta_8X_{8\text{Mcoop}} + \beta_9X_{9\text{Credit}} + \beta_{10}X_{10\text{Exten}} + \beta_{11}X_{11\text{Market}} + \beta_{12}X_{12\text{distance}} + \beta_{13}X_{13\text{CStorage}} + \beta_{14}X_{14\text{Train/infor}} + \beta_{15}X_{15\text{Packhouse}} + \beta_{16}X_{16\%ShareFL} + e$$

Table 1: The explanatory variables employed in the model

Variable label	Independent Variable label	Description	Expected signs
X ₁	Gender	Dummy	-/+
X ₂	Age (Age) in years	Continuous	-/+
X ₃	Household Size	Continuous	+
X ₄	Educational level	Dummy	-
X ₅	Farming experience (Years)	Continuous	-
X ₆	Farm size (Hectares)	Continuous	-
X ₇	Farm Income (Rands)	Continuous	-
X ₈	Member of cooperative	Dummy	+
X ₉	Access to agricultural credit	Dummy	+
X ₁₀	Access to agricultural extension	Dummy	+
X ₁₁	Access to market	Dummy	+
X ₁₂	Distance to market (Kilometers)	Continuous	-

X ₁₃	Access to a cold storage facility	Dummy	+
X ₁₄	Access to training and information	Dummy	+
X ₁₅	Access to the packhouse	Dummy	+
X ₁₆	Estimated share of food Lost (%)	Continuous	+

Where Y stands for the unobserved (latent) variable standing for food security, X is a vector of independent variables, β is the vector of variables to be measured, and e represents the error term. STATA was used to analyse the data for the ordered probit model.

3.6.5. Objective 5: Explore strategies to minimize food loss among smallholder vegetable farmers

The study employed descriptive statistics presented as frequencies, tables and percentages to analyse the objective, mean and standard deviation were used to understand the strategies farmers use in minimising food loss. Frequency distributions were used to categorise and count how many farmers adopted specific food loss reduction strategies. These assisted in identifying which strategies were most effective and most common among respondents, guide conclusions and recommendations, and inform the selection of strategies for future implementation.

3.7. Ethical Considerations

Ethical considerations are a form of code of conduct that the researcher must adhere to when collecting data. These guidelines safeguard the rights of research participants, strengthen the credibility of the study, and uphold scientific integrity. They consist of a set of principles that direct the planning and conduct of research. Key principles include voluntary participation, adhering to ethical principles, including informed consent and the protection of anonymity and confidentiality, minimizing potential harm, and properly communicating research findings.

Ethical approval was granted by the Research Ethics Committee at the University of Venda, and written permission to implement the study was obtained from the Blouberg and Molemole local municipalities and the local traditional leaders. Then consent, including voluntary participation,

informed consent, anonymity, confidentiality, and communication of results, was explained to participants and signed by them.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Introduction

The results of the study are presented and interpreted in this chapter, guided by the research objectives as presented in the questionnaire. The chapter presented findings on socioeconomic characteristics, the causes of food loss among smallholder vegetable farmers, the food security status of farming households and the factors influencing it, with the main focus on food loss as a key variable in the study. Lastly, strategies employed by smallholder vegetable farmers to minimise food loss were presented and discussed.

4.2. Socioeconomic characteristics of the respondents

Understanding respondents' socio-economic profiles provides insight into their livelihoods, the production constraints they encounter, and how these factors shape their choices and farming practices. The socio-economic profile of farming households significantly shapes their overall food security situation.

Table 2: Summary statistics of continuous socioeconomic variables

Characteristics	Minimum	Maximum	Mean	Std. Deviation
Age	18	78	44.13	14.70
Years of schooling	0	19	12.23	3.60
Household size	1	12	4.91	2.07
Annual farm income	7220	950 000	141 538.87	184136.00
Farming experience	1	39	7.27	6.62
Distance to market	2	550	68.53	103.76
Farm size	0.15	15	4.68	4.62

Table 3 below shows the gender of the respondents who participated in the study. The table shows that the sample comprised 54.6% males and 45.2% female smallholder vegetable farmers, indicating a slightly balanced representation of both male and female farmers. This

slightly balanced representation of both gender shows that there is gender equality in vegetable farming, unlike the trends in rural farming communities, where men often dominate agricultural activities. The meaningful participation of women in farming is relevant for food security, as they play a critical role in household nutrition.

Table 3 below shows the respondents' age groups. As presented in Table 3, the majority of respondents were adults (47.4%), followed by youth (36.1%), and only 16.5% of the respondents were pensioners. This indicates that farming in the area is dominated by an economically productive population. The high involvement of youth in farming is positive, suggesting potential for innovation and adoption of new technologies, while participation of a large adult population in farming may represent farmers with a wide experience, with potential to transfer skills and knowledge to the youth. The summary descriptive statistics show that the average age of the respondents was 44.13 years, with a minimum of 18 years and a maximum of 78 years. These results are in line with those of Gwebu (2022), who reported an average age of 48, with a similar age range (18 - 77), indicating that smallholder vegetable farmers are predominantly middle-aged.

Table 3 indicates that over 50% of households have medium-sized households (55,7%), with 36,1% small-sized households, and only 8.3% are large households. The summary of descriptive results shows that the mean household size is 4.45, with households ranging from 1 to 12 members. This indicates that most households are medium-sized. Household size can influence labour availability and food consumption patterns, which in turn affect farming practices and management decisions (Mango et al, 2018; Tambe et al., 2023). Moreover, larger households may rely more heavily on farm produce for food and making them especially prone to experiencing the harmful impacts of food loss on household food security. The results are similar to those of Mdoda, Mdletshe, Dyiki, and Gidi (2022), who conducted their study in the Eastern Cape and also found an average family size of about 4 members. The mean household size in this study aligns closely with the average household size of 3.2–3.5 members reported by Statistics South Africa (2023) for South Africa.

The data reported in Table 3 show that many smallholder farmers possessed secondary education (65.2%), followed by those with tertiary education (23%), while a smaller proportion of respondents had primary education (9%), and only 3% had no formal education. The results point out that the majority of respondents possess higher levels of formal education, which is crucial for the adoption of new technologies and decision-making (Mathobo, 2023). This is also emphasised by Akamin, Bidogeza, Minkoua and Afari-Sefa (2017), who stated in their study that

vegetable production in Cameroon is more efficient when farmers have secondary education than with primary education. The average years of schooling were 12.23, with a maximum of 19 years, indicating that most respondents had attained at least secondary education. This concurs with the findings reported by Tambe et al. (2023) and Belemu and Oluwatayo (2025), who found that most farmers had attained at least secondary education.

Table 3 also shows the results on the main income-generating activity for farmers and farming appeared as the primary source of income for 76% of the respondents. This reflects that many smallholder vegetable farmers rely on agriculture for livelihoods. Employment accounted for 16%, and social grants accounted for only 7%. This indicates that most farmers depend heavily on farming activities for income, making agricultural productivity and profitability critical for their economic well-being. These results also mean that farmers are more vulnerable to food loss, as this may directly affect their buying capacity and consequently their access and affordability to food, risking food insecurity. The results align with earlier findings in Limpopo by Ramigo (2017), who found farming as the primary source of livelihood. Moreover, the results were supported by the findings of Belemu and Oluwatayo (2025) in Limpopo and Mdoda et al. (2022) in Eastern Cape and further Bada et al. (2023), who conducted their study in Nigeria found that found that more than 80% of farmers relied primarily on agriculture as a primary income source. Moreover, the results by Stats SA (2025) revealed that among farming households surveyed, 23.6% rely on farming as their source of earning. This emphasises the contribution of agriculture to the economic well-being of those in rural areas.

Moreover, in terms of income, Table 3 reveals that the largest proportion of the respondents (41.3%) earn less than R50 000 per annum from their farming operations. This is followed by those earning between R100 000 and R500 000, at 39.6%, and 14.8% earning between R50 000 and R100 000. Only 4.3% of the respondents earn more than R500 000. Farmers' earnings can be correlated with land size and the experience of the farmer. The high proportion of farmers in the low-income category indicates limited financial returns for vegetable farmers. Annual income varied widely from R7220 to R950 000, with an average of R141 538.87. Income levels are linked to farmers' financial capacity for investing in agricultural technologies and for improved food security. The study's findings imply that many respondents are low-income earners compared to South Africa's national income distribution. The results additionally show that many of the households are economically vulnerable, with more than 50% of the respondents living below or near the poverty line (When adjusted for household size, the average is 4.5). According to Stats SA (2024), the lower-bound poverty line was R1109 as of

May 2024, with the upper-bound poverty line at R1634 in the same period. This result corroborates South Africa's situation of large low-income earners and a very limited proportion of high-income earners.

The findings of the survey in Table 3 show that most respondents (65.7%) operated on farms of less than 5ha, while 25.2% operated on land between 5 and 10ha and only 9.1% farmed on over 10 hectares of land. The results indicate that smallholder farming in the area is largely carried out by farmers operating on small plots of land, limiting their production capacity and rising risk of food loss.

In terms of the farming experience among smallholder vegetable farmers. The results from Table 3 suggests that most respondents (52.2%) had between 1 and 5 years of farming experience. A considerable proportion (23.9%) had more than 10 years of experience, while 17.8% had between 6 and 9 years of farming experience and only 6.1% of respondents had less than one year of farming experience. The high proportion of farmers with 1-5 years of experience suggests that most respondents have considerable exposure to farming with better knowledge of farming practices, while 23.9% of highly experienced farmers is also noteworthy, as this may possess advanced skills in crop management, pest and disease control and post-harvest handling and better market access. Their experience could be a valuable source of knowledge transfer to less experienced farmers. Prior studies have shown that farming experience is positively linked with adoption of improved practices, resilience against crop losses and better decision-making in production and marketing (Alhassan, Salifu, and Adebajji, 2016; Alam, Alam, and Mushtaq, 2016).

Regarding market distance, about 23% of respondents reported accessing markets within 10km, suggesting they could sell their produce locally or in nearby villages. While 46% of the respondents reported accessing markets between 10 and 50km, this may be because supermarkets are about 45 to 50km from the farmers, both in Molemole and Blouberg, and several farmers in this area supply fresh produce to supermarkets such as Boxer, Savemor, and others. However, a notable proportion of respondents (32 out of 230) accessed markets between 50 and 100km, while 13.9% were over 100km from their main markets. The results suggest that over 30% of respondents face long distances to market, a factor that has been consistently associated with higher post-harvest losses of perishable crops such as vegetables due to delays, exposure to heat and physical damage during transport (Kader, 2005; Sheahan & Barrett, 2017). This was also emphasised by the study by Sreenivasa et al (2009), who found

that farmers experienced around 29.7% loss with the local market, while 35.4% loss was experienced when supplying to the distant market.

Greater distances to market tend to increase post-harvest losses due to longer transportation times, poor roads, and inadequate storage infrastructure. This was supported by the study by George and Mwangangi (1994), who reported that bananas transported over longer distances on poor roads in Kenya experienced higher spoilage rates, reducing marketable quantities. Similarly, Choudhury, Sharma and Sharma (2025) found that shorter vegetable supply chains in Fiji and Laos incurred lower losses than those with intermediaries, while longer distances in Cambodia and Vietnam correlated with increased losses.

Table 3: Socioeconomic characteristics of respondents

Socioeconomic characteristics of respondents		Frequency	Percentage
Gender	Male	126	54.8
	Female	104	45.2
Age	Youth (younger than 35 years)	83	36.1
	Adult (36-59 years)	109	47.4
	Pensioner (over 60 years)	38	16.5
Household size	Small (1-3 members)	83	36.1
	Medium (4-6)	128	55.7
	Large (7 or more)	19	8.3
Educational level	No formal education	7	3
	Primary education	21	9.1
	Secondary education	150	65.2
	Tertiary education	52	22.6
Main source of income	Employment	36	15.7
	Farming	175	76
	Social grants	16	7
	Other businesses	3	1.3

Annual income	Less than R50 000	95	41.3
	Between R50 000 and R100 000	34	14.8
	Between R100 000 and R500 000	91	39.6
	More than R500 000	10	4.3
Farm size	Less than 5ha	151	65.7
	Between 5 and 10ha	58	25.2
	More than 10ha	21	9.1
	Less than 5ha	151	65.7
Farming experience	Less than 1 year	14	6.1
	Between 1 and 5 years	120	52.2
	Between 6 and 9 years	41	17.8
	Over 10 years	55	23.9
Distance to market	Less than 10km	52	22.6
	Between 10 and 50km	106	46.1
	Between 50 and 100km	40	17.4
	Over 100km	32	13.9

4.3. Causes of food loss among smallholder vegetable farmers in Capricorn district municipality of Limpopo province, South Africa

With regard to factors influencing food loss in the study area, Table 3 shows the various factors causing food loss at different stages of the production chain. The majority of respondents (89%) reported losses during the production stage. Losses were also significant during the post-harvest stage, where 69% of farmers experienced produce loss. Losses during the harvesting stage were relatively low but still notable, with 47% of farmers reporting losses. At every stage of the production chain, farmers reported different causes of loss.

At the production stage, pests and diseases were determined as the main contributors to food loss, affecting 38% of farmers. Similarly, unfavourable weather conditions (27%) contributed substantially to losses, underscoring how climate variability affects the resilience of farmers including drought, excessive rainfall, and temperature fluctuations. Poor farming techniques (16.1%), including inappropriate planting methods or lack of crop management knowledge, also played a role. Furthermore, mismanagement of chemicals reported by 8.3% of the respondents, such as overuse, underuse or incorrect application of pesticides and fertilisers, contributed to food loss, suggesting a gap in farmers' technical skills and knowledge. This is similar to the results of Ramukhwatho et al. (2021), who found weather conditions as the main cause of food loss among smallholder farmers in Limpopo, which may be due to extreme climatic conditions in Limpopo. The issue of pests and diseases and extreme weather conditions was supported by several studies conducted in South Africa, such as Kotze (2023), Le Roux et al. (2018) and Fourie et al. (2023), who noted pests and diseases as a major contributor to food loss among farmers. Furthermore, the findings are consistent with those of Alidu, Ali and Aminu (2016) in Ghana, who found that major factors contributing to PHL were higher temperatures prior to harvest, which accelerated spoilage and pest and diseases, which reduce fruit quality and shelf-life of produce.

During harvesting, crop damage (29.6%) was the most common cause of losses. This can be linked to inadequate harvesting tools or poor handling practices, which often lead to bruising and spoilage of perishable vegetables. Labour shortages (8.7%) also led to crop losses, as delayed or rushed harvesting increases the likelihood of quality deterioration. Similarly, delayed harvesting (8.3%) resulted in crops becoming overripe or unmarketable. Although other factors were minimal (0.9%).

The post-harvest stage recorded the highest food losses, with poor market access (54.4%) as the most significant cause. This indicates that even when crops are successfully produced and harvested, many farmers face difficulties in selling their produce due to limited market linkages, low prices or oversupply. Poor access to cold storage facilities (18.1%) and poor storage facilities (14.4%) were also key drivers, reflecting inadequate infrastructure to maintain freshness and reduce spoilage of highly perishable vegetables. Rough roads to market (11.9%) further exacerbated post-harvest losses by increasing transport time and damaging produce during transit. Lastly, poor packaging and handling (1.3%) also contributed to loss, although at a lower rate, indicating the need for training in post-harvest handling techniques. The findings align with those of Chisoro and Padayachie (2023), who found that smallholder vegetable

farmers still face challenges accessing stable markets, leading to food loss. These findings agree with prior studies that show that in developing countries, post-harvest constraints such as poor market access and inadequate infrastructure account for a greater share of food losses than on-farm production factors (FAO, 2019).

Table 3: Factors driving food loss among smallholder vegetable farmers

Stage of food loss		Frequency	Percentage
Experienced loss at production stage	Yes	204	89
	No	26	11
Major causes of loss	Pests & diseases	87	37.8
	Unfavourable weather conditions	61	26.5
	Poor farming techniques	37	16.1
	Mismanagement of chemicals	19	8.3
Experienced loss at the harvesting stage	Yes	108	47
	No	122	53
Major causes of loss	Damage during harvest	68	29.6
	Delayed harvesting	19	8.3
	Labor shortages	20	8.7
	Other	2	0.9
Experienced loss at the post-harvest stage	Yes	159	69
	No	71	31
Major causes of loss	Poor storage facilities	23	14.4
	Poor market access	87	54.4
	Poor access to cold storage	29	18.1
	Rough roads to markets	19	11.9
	Poor packaging skills and materials	2	1.3

4.4. The food security status of the smallholder vegetable farmers

The study used the Household Food Insecurity Access Scale (HFIAS) to assess respondents' food security status. Table 4 presents the results from the Household Food Insecurity Access

Scale (HFIAS), which illustrate food security levels among smallholder vegetable farming households. The findings reveal that food insecurity persists as a significant issue among respondents. Specifically, only 30.4% of households were food secure, while 30.0% experienced mild food insecurity, 22.2% moderate food insecurity, and 17.4% severely food insecurity. This indicates that nearly 70% of the surveyed households suffered some level of food insecurity.

These outcomes reflect trends reported in other South African studies, particularly in rural communities where food insecurity is prevalent. For instance, Cele and Mudhara (2024) reported that 64% of farming households struggled with food insecurity, while Tambe et al. (2023) found that about 52% of rural households in Limpopo Province experienced severe food insecurity. Similarly, Sithole et al. (2023) found that 54% of households faced food insecurity, reinforcing the persistence of the problem in the province. Earlier, Sekhampu (2013) also found that merely 26% of households were found to be food secure, suggesting that food insecurity has long been a pressing issue in rural South Africa. Comparable findings were observed by De Cock et al. (2013) and Nengovhela et al. (2022). Overall, the alignment between the findings of the study and existing literature confirms that household food insecurity remains widespread among smallholder vegetable farmers in Limpopo Province. Despite their involvement in food production, many households still struggle to access adequate, nutritious food.

Table 4: Household Food Insecurity Access Scale status

	Frequency	Percentage (%)
Food secure	70	30.4
Mildly food insecure	69	30.0
Moderately food insecure	51	22.2
Severely food insecure	40	17.4
Total	230	100

4.5. The relationship between food loss and food security

An ordered probit model was employed to determine factors affecting household food security among smallholder vegetable farmers. The food security status (levels) of the farming households was measured using the Household Food Insecurity Access Scale (HFIAS) categories. Table 5 presents the findings from the Ordered Probit Model employed to investigate the relationship between food loss and other control variables and food security. The model

converged successfully, with a log-likelihood of -208.54. The likelihood ratio (LR) chi-square statistic of 209.19 was highly significant ($p > \chi^2 = 0.000$), indicating the joint contribution of the independent factors to differences in household food security levels.

The analysis revealed several variables with statistically significant effects on household food insecurity levels. The main factor of focus in the study, food loss, shows statistical significance at 1% level ($p = 0.000$) and positively ($\beta = 0.594$) associated with food insecurity. A higher percentage of food loss increases the risk of food insecurity within households. This supports the central argument of the literature that food loss directly undermines household food security by lowering the amount of food available for household consumption and earnings obtained from sales (FAO, 2011; Gustavsson et al, 2011; Oelfse et al., 2021; Junaid & Gokce, 2024). The findings of the marginal effects suggest that each additional unit in the share of food lost lowers the chances of being food secure by 11.8 percentage points while raising the chances of being severely food insecure by 8.8 percentage points.

Education level ($\beta = -0.352$, $p = 0.012$) was linked to lower levels of food insecurity, suggesting that educated households are unlikely to fall into severe food insecurity categories. An additional unit increase in educational level improves chances of being food secure by 7 percentage points while reducing the probability of moderate by 2.11 percentage points and severe food insecurity by 5.2%. The findings may suggest that education enhances farmers' ability to access information, diversify livelihoods, and adopt improved farming technologies, thereby improving food access and stability. This result aligns with Sharaunga et al. (2016), who observed that education positively influences household resilience to food insecurity. Moreover, Parr and Taylor (2015) noted that educational level and employment status determine an individual's earning potential and affect household food security. The results, therefore, align with findings from sub-Saharan Africa and South Africa, as the majority of studies have discovered that educational level enhances food security.

Table 5 also shows that household size ($\beta = 0.103$, $p = 0.002$) had a strong and direct association with food insecurity, pointing out that larger households tend to face food insecurity as a result of higher food consumption requirements. This outcome is in line with Bashir et al. (2012), who reported that larger family sizes often strain household resources, thereby increasing the risk of food insecurity. The findings are consistent with broader literature. In sub-Saharan Africa (Ayele et al., 2020; Akello & Mwesigwa, 2023), similar findings were observed, as in South Africa (Tambe et al, 2023). The studies emphasise that a larger household size puts pressure on available food resources, which negatively affects food security.

Market access showed statistical significance at 5% with a coefficient of 0.046. This shows that there is a positive connection between access to the market and food security. Those farmers who could access markets tended to be more food secure. The marginal effects show that poor market access lessens the possibility of a household attaining food security by 9% while simultaneously increasing the likelihood of experiencing food insecurity by 6.7%. This highlights the crucial effects of market access on strengthening household food security among smallholder vegetable farmers. The findings correspond with Cele and Mudhara (2024), who found that sustainable market integration improves food security. Market access improves farmers' income and stability, thereby improving their purchasing power to afford and access other food items. Moreover, Tibesigwa and Visser (2016) found that South African rural households with greater market access were significantly more food secure than those in remote areas. Similarly, Mujeyi et al. (2021) noted that integrating smallholder farmers into markets reduces post-harvest losses and improves food access by increasing earnings. The findings from the literature imply that market access is a consistent factor influencing household food security among farmers.

Age was significant at the 10% level, with a negative coefficient (-0.014). This means that as farmers grow older, the likelihood of experiencing food insecurity declines. The marginal effects indicate that a one-year increase in age raises the chances of being food secure by 0.3% and lowers the risk of experiencing severe food insecurity by 0.2%. However, the effect is relatively small and weakly significant. The results suggest that older household heads are marginally better positioned to secure household food needs, possibly due to accumulated farming experience and resources. This supports the studies by Malik et al. (2025) and Adeyanju et al. (2023), who observed that the age of a household head significantly and positively predicts the likelihood of achieving food security. However, this is in contrast to the findings of Mango et al. (2018) and Ogunniyi et al., (2017), who found that younger household heads typically have a higher likelihood of being food secure., arguing that as farmers grow older, their physical strength and adaptability to modern technologies tend to decline, potentially increasing their exposure to food insecurity. These differences in outcomes may highlight variations in study contexts and the availability of resources to households. For example, in areas where older farmers have secured land and farming resources, age may be an advantage, while in areas where farming is more labour-intensive and less mechanised, older farmers may be at a disadvantage.

Other variables, including gender, farm experience, farm size, cooperative membership, access to agricultural extension, access to cold storage, and training information, were not statistically significant. While these factors may still influence food security in practice, their effects were not strong enough in this data set to establish statistical significance. Cold storage and agricultural extension services were also not significant. The lack of statistical significance may stem from the distribution of these variables in the dataset. Almost all farmers reported having access to agricultural extension, but they do not have access to cold storage. This may make it difficult for the model to capture its effect on household food security (Gujarati & Porter, 2009). As a result, the insignificance of the variables does not necessarily imply that agricultural extension and cold storage are not important; rather, it reflects the structural and contextual realities of the study area. To check for multicollinearity, the variables were tested for high correlation.

Table 5: Relationship between food loss, food security and other influencing variables

Variables	Coefficient	Std. err.	P> z	Marginal Effects			
				Food secure	Mildly food insecure	Moderately food insecure	Severely food insecure
Age	-0.014	0.007	0.055*	0.003	0.000	-0.001	-0.002
Gender	0.192	0.168	0.253	-0.038	-0.002	0.011	0.028
Edu level	-0.352	0.140	0.012**	0.070	0.003	-0.021	-0.052
Household size	0.103	0.034	0.002***	-0.021	-0.001	0.006	-0.015
Farm experience	0.018	0.014	0.189	-0.004	-0.000	0.001	0.003
Farm size	-0.017	0.022	0.431	0.003	0.000	-0.001	-0.003
Coop member	0.174	0.194	0.370	-0.035	-0.001	0.010	0.026
Market distance	-0.001	0.001	0.331	0.000	0.000	-0.000	-0.000
Agri credit access	0.312	0.223	0.163	-0.062	-0.003	0.019	0.046
Market access	0.453	0.227	0.046**	-0.090	-0.003	0.027	0.067
Agri extension access	-0.075	0.205	0.715	0.015	0.001	-0.004	-0.011
Cold storage	0.545	0.373	0.144	-0.109	-0.005	0.033	0.081

access							
Training and Information access	-0.155	0.192	0.420	0.031	0.001	-0.009	-0.023
Packhouse access	0.033	0.274	0.905	-0.007	-0.000	0.002	0.005
Food loss	0.594	0.058	0.000***	-0.118	-0.005	0.036	0.088
Farm income	-0.001	0.001	0.086*	0.000	0.000	-0.000	-0.000

Number of obs: 230; LR chi2 (16) = 209.19; Prob > chi2 = 0.000; Pseudo R2 = 0.334; Log likelihood = -208.54

Note: *, ** and *** means coefficients statistically significant at 10%, 5% and 1% levels respectively.

Table 6 shows results for Multicollinearity Assessment through the Variance Inflation Factor. To test for multicollinearity, the study used the Variance Inflation Factor (VIF), and the results highlighted that for all variables, the VIF value ranges from 1.12 to 2.01. This means that there is no evidence of harmful multicollinearity among independent variables and that the regression model is well-specified.

Table 6: Assessment of multicollinearity using Variance Inflation Factor (VIF)

Variable	VIF	1/VIF
Packhouse	2.01	0.50
Age	1.85	0.54
Stable market	1.80	0.55
Cold storage	1.80	0.55
Agric. Credit	1.75	0.57
Farm size	1.52	0.66
Farm experience	1.47	0.68
Income	1.45	0.69

Educational level	1.42	0.70
Training Infor	1.38	0.73
Agric. Extension	1.35	0.74
Distance to market	1.33	0.75
Share of food lost	1.28	0.78
Coop. member	1.26	0.80
Gender	1.14	0.88
Household size	1.12	0.89
Mean VIF	1.49	

4.6. Strategies to minimize food loss among smallholder vegetable farmers

In analysing the strategies to minimise food loss among smallholder vegetable farmers, descriptive statistics in frequencies and percentages were presented in Table 7. Table 7 shows that of the 230 respondents, 182 (77.8%) reported adopting measures to reduce food loss, while 22.2% had not. This suggests that most smallholder vegetable farmers are informed about the challenges associated with food loss and are actively engaging in strategies to mitigate it.

Furthermore, Table 7 shows various measures to reduce food loss that were adopted by the respondents. The most common measure reported was training on good practices and proper handling (40.7%), followed by improved market access (13.7%) and better pest and disease management (13.2%). By adopting improved handling practices, farmers are likely to minimise bruising, spoilage and contamination of fresh produce. Access to markets reduces the time produce spends on the farm, thereby lowering the risk of spoilage. Similarly, effective pest and disease management reduces losses during the production stage, which was also highlighted as a significant cause of food loss in related studies (Kotze, 2023; Fourie, 2020). The least reported measures adopted were investing in greenhouses (2.2%), preparing labour on time (1.6%) and improving storage facilities and cold storage at 1.6% and 1.1% respectively. This may be due to the high cost or capital investment needed for such measures. Among other methods (6%) reported by farmers was processing; some farmers mentioned that they process their produce for longer shelf life and better prices.

Table 7: Measures utilized by smallholder farmers to reduce food loss (n=230)

Measures to reduce food loss		Frequency	Percentage
Do you take measures to reduce food loss?	Yes	182	77.8
	No	48	22.2
Preferred measure to reduce food loss	Improved storage facility	3	1.6
	Training on good practices and proper handling of produce	74	40.7
	Using improved harvesting techniques	23	12.6
	Investing in cold storage	2	1.1
	Better access to markets	25	13.7
	Training on chemical management	13	7.1
	Good pest and disease management	24	13.2
	Investing in greenhouses	4	2.2
	Preparing labour on time	3	1.6
	Other	11	6
	Total	230	100

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary

This research sought to examine how food loss influences household food security among smallholder vegetable farmers in the Capricorn District. Literature reviewed in the study focused on food loss across emerging economies and industrialized nations with emphasis on South Africa's food security context and the ways in which food loss contributes to households' vulnerability. The research took place in the Capricorn district municipality, with a population of 580 obtained from Department of Agriculture and gathered information from a sample of 230 smallholder vegetable farmers.

The first objective was to describe the socioeconomic profile of the respondents. Findings showed that most participants were males at 54%, aged between 36 and 59 years, attaining a comparatively greater level of education (ranging from 0 to 19, with an average of 12 years of schooling). The respondents' socio-economic profiles showed that most of the participants earned less than R50 000 per year with land size less than 5ha and farming served as the main livelihood source for 76% of the participants, with the remainder relying on salaries from employment and social grants. Education levels were relatively high: 65.2% had attained secondary education, while 22.6% had attained tertiary education. Moreover, 52.2% had experience between 1-5 years.

Regarding the main drivers of food loss, the outcomes of this research highlight that food loss was reported at various stages, with the production stage being the most affected stage (89%), followed by the post-harvest stage (69%) and the harvesting stage (47%). At the production stage, pests and diseases (37.9%) and unfavourable weather conditions (26.5%) were the main causes, while at the harvesting stage, losses were linked to damage during harvesting (29.6%) and labour shortages (8.7%). Post-harvest food losses were driven largely by poor market access (54.4%) and inadequate storage facilities (32.5%), as well as by infrastructure challenges such as rough roads (11.9%).

Regarding respondents' household food security status, the HFIAS analysis indicated that only 30.4% of households were food secure. The majority fell within various levels of food insecurity, such as mildly food insecure (30%), moderately food insecure (22.2%), and severely food insecure (17.4%).

5.2. Conclusion

The study shows that food loss and household food security among smallholder vegetable farmers are closely connected. Other significant contributors to household-level food insecurity in the study were educational level, stable market and household size. Despite relatively high levels of education and farming engagement, farmers face systematic challenges related to pests and diseases, climate-related challenges, and inadequate farming techniques, which contribute significantly to production losses. Post-harvest inefficiencies, such as poor storage, limited market access, and inadequate infrastructure, further exacerbate losses, limiting farmers' incomes and reducing household food availability. The study's findings reveal that food loss undermines household food security by lowering both the quantity of produce available for home consumption and the income that could be earned from sales. This explains the high prevalence of food insecurity (70%). Small farm sizes, long distances to market, and low incomes further intensify vulnerability, indicating that food loss is not only a production-related concern, but a multidimensional issue shaped by economic, infrastructural, and social factors.

In conclusion, food loss significantly affects household food security. While farmers in the area demonstrate awareness of food loss by adopting measures to reduce it, they lack the necessary resources and support to address the issue effectively. The majority of the farmers are young and have the potential to adopt new technologies and participate in training opportunities, which present a positive foundation for interventions. However, ongoing barriers such as limited market access and poor infrastructure remain a burning issue that needs to be addressed.

5.3. Recommendations

Based on the findings from this study, the following recommendations are suggested:

- The study revealed that pests and diseases, as well as extreme weather events, are major causes of production losses. Therefore, the study recommends that the Department of Agriculture and Rural Development agricultural extension officers/advisors and rural development organisations should ensure training on integrated pest management and climate-smart agricultural practices. Timely access to weather information will help farmers cushion against the impact of extreme weather conditions on their crops.
- Furthermore, the government, together with other stakeholders, should strengthen market linkages and promote contract farming. Moreover, they can focus on strengthening value chains and provide affordable and accessible community storage

facilities, such as cold rooms. In addition, it is recommended that farmers be motivated to participate in value addition, such as agro processing, to extend the shelf life of their produce. Decentralized, off-grid solar cold storage systems can effectively preserve produce with a low environmental impact.

- Since the study found that food loss significantly affects food security at household level, it is recommended that major causes of food loss be addressed to reduce food loss to ultimately reduce food insecurity among these farming households. Extension officers and policy makers should prioritise market access by opening more market opportunities for farmers, linking farmers to buyers and promote contract farming.

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APPENDIX A: CONSENT FORM FOR RESPONDENTS

Consent refers to a participant's voluntary agreement to take part in a research study which confirms participant's agreement to partake in the study, to ensure that participants are fully informed about the potential risks and benefits of the study, and that their involvement is entirely voluntary.

University of Venda – Department of Agricultural Economics and Agribusiness

Topic: The Impact of Food Loss on Food Security Among Smallholder Vegetable Farmers in Capricorn district, Limpopo province, South Africa.

Please mark with an X where appropriate:

	Yes	No
1. I confirm that the researcher, Thokolo M. M., has clearly explained to me the purpose of the study, how it will be conducted, as well as the potential benefits and possible risks involved.		
2. I give permission for the information gathered during this research to be captured, stored, and analyzed electronically by the researcher for academic purposes.		
3. I understand that my involvement in this study is entirely voluntary and that I am free to withdraw from the research at any time without having to provide a reason and without facing any negative consequences.		
4. I acknowledge that if any new findings emerge during the course of the study that may affect my participation, I may request to be informed about		

such developments.		
5. I have been given adequate time to ask any questions regarding the study and, of my own free choice, I confirm my willingness to take part in the research.		
6. I understand that all information I provide will be handled confidentially and that my identity will not be disclosed in any reports or publications.		
7. I acknowledge that my involvement in this research is entirely voluntary and that I am under no obligation to participate.		
8. I consent to the use of information obtained during the interview for inclusion in the final research report and for possible academic publications.		
9. I hereby give my consent to participate in this research study.		

Full name of the participant

Signature

Date

APPENDIX B: QUESTIONNAIRE



Faculty of Science, Engineering and Agriculture

Department of Agricultural Economics and Agribusiness

TITLE: THE IMPACT OF FOOD LOSS ON FOOD SECURITY AMONG SMALLHOLDER VEGETABLE FARMERS IN CAPRICORN DISTRICT OF LIMPOPO PROVINCE, SOUTH AFRICA

I, Mmatlou Milicent Thokolo, a registered MSc student of Agricultural Economics at the University of Venda (Student No 17017949) is conducting a study on the impact of food loss on food security status on smallholder vegetable farmers in Capricorn district of Limpopo province, South Africa. The aim of the study is to understand the impact that food loss has on food security among smallholder vegetable farming households, causes of the food loss and the food loss reduction strategies. The confidentiality and

anonymity of all participants will be strictly maintained. No sensitive information such as names, identity numbers and contacts will be requested from the participants. Furthermore, the information obtained from participants will be utilized solely for the purposes of this study.

QUESTIONNAIRE

Questionnaire Number: _____

Name of Municipality: _____

Date of Interview: _____

SECTION A: Socio-economic profile of the participant

1. Age of the participant (Years) _____

2. Gender of the participant

1	Male	
2	Female	

3. Years of schooling _____

4. Educational level of the participant

1	No formal Education	
2	Primary Education	
3	Secondary Education	
4	Tertiary Education	

5. Household size (Number of individuals in the household) _____

6. Farming experience (Years) _____

7. Farm size (Hectares) _____

8. Farm Income (Rands) _____

9. Main source of income

1	Employment	
2	Farming	
3	Social Grants	
4	Other (Specify)	

10. Member of the cooperative

1	Member	
2	Not Member	

11. Distance to the market _____

12. Access to agricultural credit

1	Yes	
2	No	

13. Access to stable market

1	Yes	
2	No	

14. Access to agricultural extension

1	Yes	
2	No	

15. Access to cold storage facility

1	Yes	
2	No	

16. Access to training and information

1	Yes	
2	No	

17. Knowledge of food loss

1	Yes	
2	No	

18. Access to packhouse

1	Yes	
2	No	

19. Do you experience food loss?

1	Yes	
2	No	

20. If yes, estimate share of food lost

1	0 - 10%	
2	11 – 20%	
3	21 – 50%	
4	More than 50%	

Section B: Questions on Household Food Insecurity Access Scale

(Mark relevant answer with X)

Questions	Often (3)	Sometimes (2)	Rarely (1)	Never (0)
1) Were you concerned that your household might run out of food?				
2) Have you or any member of your household been unable to consume the types of food needed due to food losses?				
3) Did you or anyone in your household rely on a limited range of foods as a result of food losses?				
4) Have you or any member of your household consumed foods that were not your preference because there was not enough income to afford other options?				
5) Have you or any household member reduced portion sizes because there was insufficient food available?				
6) Have you or any household member skipped meals				

during the day due to a shortage of food?				
7) Was there a period during which your household completely lacked food because of a lack of resources to obtain more?				
8) Did you or any household member go to bed feeling hungry because there was not enough food in the household?				
9) Did you or any household member spend an entire day without eating due to food shortages?				

SECTION C: Causes of food loss

1. Have you experienced food loss at production level?

1	Yes	
2	No	

If yes, what were the major causes?

1	Pests & Diseases	
2	Unfavorable weather conditions	
3	Poor farming technique	
4	Mismanagement of chemicals	

5. Other (specify) _____

2. Have you experienced food loss at harvesting stage?

1	Yes	
2	No	

If yes, what were the major causes?

1	Damage during harvesting	
2	Delayed harvesting	
3	Labor shortages	
4	Poor storage facilities	
5	Lack of market access	
6	Lack of access to cold storage	

7. Other (specify) _____

SECTION D: Food loss reduction strategies

1. Do you take any measures to reduce food loss?

1	Yes	
2	No	

If yes, what strategies do you use?

1	Improved storage facility	
2	Training in good practices and proper handling of crops	
3	Using improved harvesting techniques	
4	Investing in cold storage facility	
5	Better access to markets	
6	Training in chemical management	
7	Good pest and disease management	
8	Other (Specify):	