

**Agribusiness Investments and Postharvest Losses in Smallholder Vegetable Supply Chains:
Insights from eThekweni Municipality, KwaZulu-Natal.**

By

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DEDICATION

This thesis is dedicated to my family, whose unwavering support, love, and encouragement have been the guiding light throughout this journey.


DECLARATION 01 – PLAGIARISM

I, Siphesihle Qange, solemnly declare that:

1. The content presented in this thesis results from my original work.
2. All sources used and referenced in this work have been appropriately cited and acknowledged.
3. The work in this thesis has not previously been submitted for any degree or examination at any other university.
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Date: 05 August 2024

DECLARATION 02 – PUBLICATIONS

The following manuscripts (under review and published) form part of the research presented in this thesis:

Manuscript 1 (Chapter 3) - Published

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ABSTRACT

Smallholder agriculture, constituting over 60% of Africa's population, is vital for the continent's economy. However, it often faces neglect in development policies, hindering its potential contributions to income and welfare improvement. Postharvest losses, particularly in the vegetable supply chain, are a major challenge, with a 30–40% loss in sub-Saharan Africa's chain of fruits and vegetables. Moreover, over 10 million tons of annual food waste are reported in South Africa. These postharvest losses impact food availability and threaten agribusiness investment, discouraging local and foreign investors. Therefore, this study aimed to comprehensively investigate the dynamics of agribusiness investments, perceptions, and the impacts of postharvest losses within the smallholder vegetable supply chains, focusing on insights from smallholder farmers in the eThekweni Municipality in the KwaZulu-Natal Province. The study adopted a cross-sectional research design and multi-stratified random sampling technique to gather primary data from 238 smallholder vegetable farmers through structured questionnaires in 10 district municipalities based on smallholder farmers' vegetable production intensity. Descriptive statistics revealed that most (56%) of the farmers are females with an average of 45 years and a household size of 5 members. Farmers spent an average of 12 years in school, mostly unemployed (76%), relying on farming for income (78%), and earning an average monthly income of R8,568.37. The Zero-inflated Poisson model was used to estimate the drivers of postharvest losses. The results indicated that demographic factors such as age and household size positively influence postharvest losses, with older farmers and larger households experiencing higher rates of PHLs. Conversely, higher educational levels, greater farm experience, and access to extension services are associated with reduced PHLs. The Ordered Probit Model (OPM) revealed that older farmers and those with larger household sizes experience more severe postharvest losses. In contrast, higher education levels, greater farm experience, and access to extension services are associated with reduced severity of losses. Specifically, an increase in household size decreases postharvest loss severity during harvesting but increases it at the market stage. Each additional year of schooling decreases loss severity during harvesting but increases it at the market stage. An increase in the distance from the market decreases loss severity during harvesting but increases it during transportation and at the market stage. Using the Log-linear regression model, the study delved into the principal causal factors contributing to PHLs along the vegetable supply chain. The log-linear regression analysis

reveals several factors significantly impacting postharvest losses among smallholder vegetable farmers in eThekweni Municipality. Adverse weather conditions emerge as a major determinant, significantly increasing postharvest losses at both the harvest and market stages due to crop damage and unfavourable handling conditions. The analysis also highlights that greater distance to markets exacerbates postharvest losses by prolonging travel times and stressing inadequate infrastructure, affecting the availability and price of fresh produce. Farm experience is crucial in reducing losses, as experienced farmers employ more effective practices. Conversely, older farmers face challenges in adopting modern postharvest management practices, resulting in increased spoilage and waste at the market stage. The relationship between agribusiness investments and postharvest losses among smallholder vegetable farmers was also explored using Ordinary Least Squares (OLS), which revealed that investing in transport infrastructure, providing financial support, and managing input costs are crucial for mitigating postharvest losses (PHLs) in the vegetable supply chain. Improved transport infrastructure reduces PHLs by 61%, financial support decreases PHLs by 54%, and managing input costs reduces PHLs by 23%. These strategic investments enhance efficiency, profitability, and sustainability, benefiting smallholder farmers and the broader agricultural economy. Additionally, the study looked at the environmental impact of postharvest losses along the vegetable supply chain: the case of smallholder vegetable farmers. Greenhouse gas emissions were quantified using the IPCC principles. The findings suggested that the greenhouse gas emissions generated by the tractor during ploughing were estimated at 0.0159349 metric tons of CO₂, indicating a low level of emissions. Furthermore, emissions resulting from crop residues were calculated for each crop, with cabbage emitting 72.8063 kgCO₂-eq and spinach emitting 83.2072 kgCO₂-eq. Emission from other crops was also estimated, and the cumulative total greenhouse gas emissions amounted to 2256.9963 kgCO₂-eq. Lastly, Multinomial Endogenous Switching Regression (MESR) provided significant insights into the impact of postharvest losses (PHLs) on farm income at different stages of the vegetable supply chain. The estimated treatment effects highlight that PHLs during the harvesting, transportation, and marketing stages substantially negatively impact farm income. Based on these findings, it is recommended that policymakers and stakeholders adopt a multifaceted approach to address the critical challenges identified in the smallholder vegetable farming sector. Primarily, targeted interventions should be prioritized to mitigate the pervasive issue of postharvest losses. This entails strategically improving existing infrastructure, particularly transportation networks, and

implementing modern storage facilities. By integrating sustainable practices into policy frameworks, policymakers can mitigate the environmental impact of conventional fertilizers and promote a harmonious balance between agricultural productivity and ecological well-being.

LIST OF ACRONYMS

CAS	Controlled Atmosphere Storage
CO ₂	Carbon dioxide
COGTA	Cooperative Governance and Traditional Affairs
FAO	Food and Agriculture Organisation
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
ICT	Information and Communication Technologies
IPCC	Intergovernmental Panel on Climate Change
KCl	Potassium Chloride
kgCO ₂ -eq	Kilograms of carbon dioxide equivalent
KZN	KwaZulu Natal
MAP	Modified Atmosphere Packaging
MAP	Monoammonium Phosphate
MESR	Multinomial Endogenous Switching Regression
NAMC	National Agricultural Marketing Council
NGO	Non-governmental Organizations
OLS	Ordinary Least Squares
PHL	Postharvest losses

SME	Small and Medium-sized Enterprise
SSA	Sub-Saharan Africa
Stats SA	Statistic South Africa
ZIP	Zero-Inflated Poisson

PREFACE

This thesis is a compilation of manuscripts, each chapter containing an independent article introduced disjointedly. Hence, some repetition between individual chapters has been inevitable.

Table of Contents

DEDICATION.....	i
DECLARATION 01 – PLAGIARISM.....	ii
DECLARATION 02 – PUBLICATIONS.....	iii
ACKNOWLEDGEMENTS	iv
ABSTRACT.....	v
LIST OF ACRONYMS.....	viii
PREFACE.....	x
LIST OF TABLES.....	xi
LIST OF FIGURES	xiii
CHAPTER 1	2
INTRODUCTION	2
1.1 Background	2
1.2 Problem Statement	5
1.3 Objectives of the study	6
1.4 Research Questions.....	7
1.5 Justification of the study	7
1.6 Delineation and the limitation of the study	8
1.7 References.....	9
CHAPTER 2	14
The Effects and Causal Factors of Postharvest Losses Among Smallholder Vegetable Supply Chains in South Africa: A Review	14
2.1 Introduction	14
2.2 Definitions of terms	14
2.3 Overview of Smallholder Vegetable Farmers in South Africa	16
2.4 Smallholder Vegetable Supply Chain Analysis.....	17
2.4.1 Input suppliers.....	18
2.4.2 Producers	19
2.4.3 Aggregators.....	19
2.4.4 Processors.....	19
2.4.5 Distributors and Markets	20
2.4.6 Consumers	20
2.5 Factors that hinder smallholder vegetable farmers’ participation in value addition	21
2.5.1 Access to credit	21

2.5.2	Access to Technology.....	22
2.5.3	Storage Infrastructure.....	22
2.5.4	Lack of market information.....	23
2.5.5	Farming experience.....	23
2.6	Key factors contributing to postharvest losses.....	24
2.6.1	Inadequate storage facilities.....	24
2.6.2	Poor handling practices.....	24
2.6.4	Pest and disease damage.....	25
2.7	Impact of postharvest losses.....	26
2.7.1	Food security.....	26
2.7.2	Social Impact.....	27
2.7.3	Environmental impact.....	27
2.7.4	Economic losses.....	28
2.8	Relationship between postharvest losses and agribusiness investments.....	29
2.8.1	Impact on Profitability.....	29
2.8.2	Vegetable Supply Chain.....	30
2.8.3	Policy and Regulatory Considerations.....	30
2.9	Approaches to mitigate postharvest losses.....	30
2.9.1	Infrastructure development.....	30
2.9.2	Technological innovations.....	31
2.9.3	Capacity building and training programs.....	31
2.9.4	Value addition and diversification.....	32
2.10	Summary.....	33
2.11	References.....	34
CHAPTER 3.....		44
Modelling Drivers of Postharvest Losses among Smallholder Vegetable Farmers in eThekweni Metropolitan: An Examination of a Zero-Inflated Poisson (ZIP) Approach.....		44
Abstract.....		44
3.1	Introduction.....	45
3.2	Research Methodology.....	47
3.2.1	Description of the study area.....	47
3.2.2	Research Design.....	49
3.2.3	Sampling procedure, frame, and sample size.....	49
3.2.4	Conceptual framework of the drivers of postharvest losses among smallholder vegetable farmers.....	50

3.2.5	Data collection	53
3.2.6	Data analysis	54
3.2.7	Model specification.....	54
3.3	Results and Discussion.....	56
3.3.1	Demographic and socioeconomic characteristics of smallholder farmers	56
3.3.2	Drivers of Postharvest Losses among Smallholder Vegetable Farmers.....	60
3.4	Conclusion and Recommendations	67
3.5	References.....	69
CHAPTER 4	74
	Perceptions and Determinants of Severity of Postharvest Losses Among Smallholder Vegetable Farmers in eThekweni Municipality: An Ordered Probit Analysis.....	74
	Abstract	74
4.1	Introduction.....	75
4.2	Conceptual framework of a Systems Approach to Postharvest Management by smallholder farmers.....	76
4.3	Research Methodology	78
4.3.1	Data Analysis	78
4.3.2	Model Specification.....	79
4.4	Results and Discussion.....	81
4.4.1	The demographic and socioeconomic characteristics of smallholder farmers.	81
4.4.2	Perception of smallholder farmers on postharvest losses.	81
4.4.3	Determinants of postharvest losses among smallholder farmers.....	83
4.5	Conclusion and Recommendations	86
4.6	References.....	88
CHAPTER 5	95
	Evaluating the Critical Causal Factors of Postharvest Losses in the Vegetable Supply Chain in eThekweni Metropolitan: The Log-linear regression model.	95
	Abstract	95
5.1	Introduction.....	96
5.2	Conceptual framework showing the critical causal factors of postharvest losses in the vegetable supply chain.....	99
5.3	Research Methodology	102
5.3.1	Model Specification.....	102
5.4	Results and Discussions	104
5.4.1	Critical Causal Factors of Postharvest Losses in the Vegetable Supply Chain in eThekweni Metropolitan	104

5.5	Conclusion and Recommendations	107
5.6	References.....	109
CHAPTER 6.....		114
Exploring the Relationship Between Agribusiness Investments and Postharvest Losses (PHLs) among Smallholder Vegetable Farmers in the eThekweni Municipality.....		114
	Abstract	114
6.1	Introduction.....	115
6.2	Conceptual framework exploring the relationship between agribusiness investments and postharvest losses among smallholder vegetable farmers.....	117
6.3	Research methodology.....	119
6.3.1	Model Specification.....	119
6.4	Results and Discussion.....	122
6.4.1	Impact of postharvest Losses (PHL) on agribusiness investment.....	122
6.4.2	The relationship between agribusiness investments and postharvest losses	124
6.5	Conclusion and Recommendations	127
6.6	References.....	129
CHAPTER 7.....		136
Assessing the environmental impact of postharvest losses along the vegetable supply chain: the case of smallholder vegetable farmers in eThekweni Municipality		136
	Abstract	136
7.1	Introduction.....	137
7.2	Conceptual framework showing the environmental impact of postharvest losses along the vegetable supply chain.....	139
7.3	Research Methodology	141
7.3.1	Data Analysis	141
7.4	Results and Discussion.....	142
7.4.1	Common fertilizers used by smallholder farmers.....	142
7.4.2	Agricultural practices and their potential implications for greenhouse gas (GHG) emissions.....	144
7.4.3	Reducing postharvest losses through value addition	147
7.4.4	Environmental implications of postharvest losses: Insights from IPCC principles	148
7.5	Conclusion and Recommendations	149
7.6	Reference	150
CHAPTER 8.....		155
The impact of postharvest losses among smallholder farmers' household welfare in eThekweni Municipality, KwaZulu Natal.....		155

Abstract	155
8.1 Introduction	156
8.2 The causes of postharvest losses impacting smallholder farmers' household welfare	158
8.3 Research Methodology	159
8.3.1 Model specification	160
8.4 Results and Discussion	163
8.4.1 The demographic and socioeconomic characteristics of smallholder farmers in eThekweni Municipality	163
8.4.2 The common vegetables grown by smallholder farmers in eThekweni Municipality	163
8.4.3 Determinants of postharvest losses among smallholder farmers	164
8.4.4 Marginal effect	167
8.4.5 Impact of Postharvest Losses on Farm Income (Household Welfare)	168
8.5 Conclusion and Recommendations	170
8.6 References	172
CHAPTER 9	179
Summary, conclusion, and recommendations	179
9.1 Summary	179
9.2 Conclusion	183
9.3 Recommendations	184
9.4 Future research areas	185
9.5 Limitations of the study	186
Appendix A: Survey questionnaire	187
Appendix B: Ethical Clearance	198

LIST OF TABLES

Table 3.1: The description of the variables and their units of measurement.....	56
Table 3.2: Smallholder farmers' demographic and socioeconomic characteristics in eThekweni Municipality.....	57
Table 3.3: The mean and the variance of the postharvest losses among smallholder vegetable farmers in eThekweni Municipality.....	61
Table 3.4: The ZIP model estimates postharvest loss drivers among smallholder vegetable farmers in eThekweni Municipality.....	64
Table 4.1: The description of the variables to be estimated by Ordered Probit Model.....	81
Table 4.2: Perception of smallholder vegetable farmers on postharvest losses in eThekweni Municipality.....	82
Table 4.3: Smallholder farmers indicating postharvest losses along the supply chain	83
Table 4.4: The determinants of postharvest losses among smallholder vegetable farmers in eThekweni Municipality.....	84
Table 5.1: The description of variables to estimate the causal factors of postharvest losses	104
Table 5.2: The log-linear regression estimating the critical causal factors of postharvest losses within the vegetable supply chain in eThekweni Municipality	105
Table 6.1: Gross margin analysis of smallholder vegetable farming in eThekweni Municipality	122
Table 6.2: Analysis of marketing margin of vegetable sales in eThekweni Municipality.....	123
Table 6.3: OLS estimating the relationship between agribusiness investments and postharvest losses among smallholder vegetable farmers in eThekweni Municipality.....	125
Table 7.1: The IPCC principles used to estimate the environmental impact of postharvest losses.	142
Table 7.2: Agricultural practices by smallholder vegetable farmers in eThekweni Municipality and their potential implications for greenhouse gas (GHG) emissions.....	144
Table 7.3: Greenhouse gas emission from crop residues among smallholder vegetable farmers in eThekweni Municipality.....	146
Table 7.4: Value addition practices and reducing postharvest losses among smallholder vegetable farmers in eThekweni Municipality.....	147
Table 8.1: The description of the variables to estimate the impact of postharvest losses on welfare.	162
Table 8.2: Postharvest Losses Experienced by Smallholder Vegetable Farmers.	164
Table 8.3: Determinants of Severity of Postharvest Losses among Smallholder Vegetable Farmers.....	165
Table 8.4: The marginal effects of factors on the Severity of Postharvest Losses	167
Table 8.5: Estimated Effects of Postharvest Losses on Farm Income using MESR Model.....	169

LIST OF FIGURES

Figure 2.1: Key components and stakeholders within the smallholder vegetable supply chain.	18
Figure 3.1 : Map showing the location of eThekweni Metropolitan Municipality.....	48
Figure 3.2: Conceptual framework of the drivers of postharvest losses among smallholder vegetable farmers	53
Figure 3.3: The Postharvest loss scores of smallholder vegetable farmers in eThekweni Municipality.	62
Figure 4.1: Conceptual Framework of a Systems Approach to Postharvest Management	78
Figure 5.1: Conceptual framework showing the critical causal factors of postharvest losses in the vegetable supply chain.....	99
Figure 6.1: Exploring the Relationship Between Agribusiness Investments and Postharvest Losses among Smallholder Vegetable Farmers	117
Figure 7.1: Environmental impact of postharvest losses along the vegetable supply chain.	139
Figure 7.2: Common fertilizers used by smallholder vegetable farmers in eThekweni Municipality.....	144
Figure 8.1: Conceptual Framework demonstrating the causes of postharvest losses impacting smallholder farmers' household welfare.	158
Figure 8.2: Common vegetables grown by smallholder vegetable farmers in the eThekweni municipality.	163

CHAPTER 1

INTRODUCTION

1.1 Background

Smallholder farming holds promise in mitigating poverty, hunger, and malnutrition while significantly contributing to rural development, particularly in developing countries (Manandhar et al., 2018). Gashu et al. (2019) noted that smallholder agriculture plays a substantial role in Africa's economic and social landscape. Over 60% of the continent's population engaged in smallholder farming and agriculture, accounting for more than 23% of its gross domestic product (GDP) (Woldemichael et al., 2017). However, despite its significance, smallholder farming often receives inadequate attention from development policies despite its vital role in the rural economy (Melembe et al., 2020). According to Brown and Ledermann (2024), many smallholder farmers cannot fully benefit from increased income, enhanced profit, and improved welfare due to various factors, including limited access to profitable markets. Postharvest losses emerge as a significant challenge impacting smallholder farmers' vegetable supply chains while negatively impacting agribusiness investments (Kariuki, 2018).

The agriculture sector in sub-Saharan Africa plays a crucial role in the region's development, supporting over 70% of the rural population and ensuring food security (Uduji et al., 2019). Additionally, as of 2020, agriculture accounted for approximately 43.8% of all African jobs (Mkombe, 2021). However, there has been a gradual decline in the proportion of people employed in agriculture across the continent, with the figure at 49.3% in 2010 (Mkombe, 2021). Agriculture is essential for driving economic development, poverty reduction, and food security in the Southern African region, with South Africa as its focal point. More than 70% of the rural population depends on agriculture for their livelihoods, and the underperformance of the agricultural sector has been identified as a hindrance to regional economic growth (Jayne et al., 2021).

Unfortunately, several factors have negatively affected the sector's performance, such as poor infrastructure, poor extension service, food waste, and loss (Brown and Ledermann, 2024). As Kariuki (2018) highlighted, postharvest losses significantly impact smallholder agriculture. Globally, approximately one-third of food produced, roughly 1.3 billion tons, is lost annually

during postharvest activities (Wunderlich and Martinez, 2018). Ansah et al. (2018) noted that the high incidence of postharvest losses, particularly in developing countries, is often attributable to poor postharvest management practices. In sub-Saharan Africa, an estimated 30–40% of the value of fruits and vegetables is lost within the horticulture supply chain (Stathers et al., 2020).

South Africa stands out as one of the most secure food countries on the African continent, owing to its robust, resilient, and world-class agricultural sector at the commercial level (Sibanda and Workneh, 2020). Nevertheless, Dunga (2020) argued that food insecurity persists at the household level in South Africa, with approximately 12 million individuals experiencing hunger daily. While smallholder farmers play a crucial role in ensuring food security at the household level, their performance in South Africa has been below average, failing to meet development objectives aimed at increasing crop production and improving rural livelihoods (Mabhaudhi et al., 2022). Furthermore, Strecker et al. (2022) highlighted that although farmers gain access to supply markets, deterioration in crop quality after maturity and postharvest losses wear down profits, negatively impacting agribusiness and farmers' involvement in the supply chain.

According to research by Kolade et al. (2020), connecting small vegetable farmers with established commercial channels (supply chains) is crucial for enhancing agricultural productivity, food security, and nutrition. Overcoming obstacles to accessing these modern supply chains necessitates institutional innovations facilitating coordination among smallholder farms, including methods like group lending and producer associations. However, as Fan and Rue (2020) emphasized, such mechanisms depend on robust institutional capacity within a stable policy environment that encourages private sector investments tailored to the needs of smallholder farms. Information and communication technologies, as explored by Kayamo and Tebeka (2021), present promising opportunities. These technologies can link smallholder farmers to markets by reducing transaction costs, enhancing bargaining power, and providing real-time market information. Scaling up financial services and insurance and investing in rural infrastructure is also essential. By bundling financial and non-financial solutions, such as insurance and agricultural advisory services, as proposed by Fan and Rue (2020), a conducive environment for comprehensive risk management solutions can be established.

Postharvest losses can occur at any stage in the vegetable supply chain (Mabusela et al., 2021). These losses are often attributed to poor postharvest handling, transportation challenges, and inadequate storage facilities (Cherono and Workneh, 2018). If food production and distribution remain inadequately integrated with effective management of postharvest losses, food security will persist as a pressing issue (Clark and Hobbs, 2018). Simply increasing food production without addressing corresponding wastage is unsustainable. Aworh (2021) emphasized that improving food security requires effective management of postharvest losses alongside increased production efforts. Furthermore, reducing postharvest losses can lead to higher incomes and enhanced investments in agribusiness, which are pivotal for global competitiveness in agriculture (Kumar and Underhill, 2019). Despite substantial Foreign Direct Investment inflows into Africa, local investor participation in the agricultural sector remains low and requires policy interventions to strengthen it (Mkombe, 2021). Additionally, Norton and Alwang (2020) suggested that factors such as postharvest losses and declining vegetable production in the supply chain may contribute to the limited involvement of local investors in the agricultural sector.

Recognizing the pivotal role of postharvest losses in shaping perceptions of agribusiness investment underscores the need for careful, country-level efforts to develop solutions that recognize each aspect's significant impact on the problem and its remedies (Alulu et al., 2023). As highlighted by Mangla et al. (2018), an effective reduction strategy must be accompanied by a thorough understanding of product flow within the supply chain, as this is where critical decisions are made regarding the types, levels, and costs of investments required—both monetary and non-monetary—to address the issue or face the consequences of inaction. Additionally, Musonda and Mwila (2024) identified market access and functional infrastructure as crucial factors for successfully preventing postharvest losses. Improved access to roads and infrastructure and enhanced connectivity among stakeholders through infrastructure investments can make postharvest loss prevention methods more economically viable for farmers and agricultural investors. By reducing postharvest losses among smallholder farmers, the standard of agribusinesses can be elevated, leading to more substantial contributions to economic and rural development (Bisheko and Rejikumar, 2024).

Postharvest losses remain a significant concern, underscoring the necessity for enhanced and sustained postharvest handling strategies to mitigate losses along the supply chain and improve

agribusiness. A study by Ali et al. (2021) concluded that neglecting postharvest practices adversely affects agribusiness performance, as improved market facilities and other factors positively influence farmers' participation in market services. Therefore, there is a pressing need for research to develop effective postharvest guidelines tailored to meet the needs of agribusiness enterprises, particularly those among low-income earners. Consequently, this study aims to investigate agribusiness investments, perceptions, and the impacts of postharvest losses within smallholder vegetable supply chains in KwaZulu Natal.

1.2 Problem Statement

The agricultural sector in South Africa is predominantly comprised of numerous smallholder farmers (Gwiriri et al., 2019). South Africa has approximately 2 million smallholder farmers, compared to only 35,000 commercial farmers (Zwane and Nekhavhambe, 2023). However, despite its significant contribution to the rural economy, smallholder farming often receives inadequate attention from development policies. Nonetheless, about 80% of the food produced in sub-Saharan Africa is cultivated by smallholder farmers, who also serve as the primary employers for the local labour force in these countries (Giller et al., 2021). Smallholder farming is widely believed to hold substantial potential for enhancing food security. However, the performance of smallholder farming has been subpar since the beginning of democracy, with blame often attributed to what is termed as "double-barreled" exclusion. This refers to the historical marginalization of smallholder farmers by past political regimes and their current marginalization by market forces such as scale, consistency, and compliance (Sinyolo, 2020).

Moreover, postharvest losses often have a negative impact on agribusiness investment, as investors either experience reduced returns due to these losses or become hesitant to invest altogether, viewing postharvest losses as a significant threat (Balana et al., 2022). Additionally, agribusiness investments play a crucial role in enhancing the global competitiveness of African agriculture (Geza et al., 2023). Despite the growing Small and Medium-sized Enterprise (SME) subsector, agricultural investments at the level of industrial consumption of crop products have been relatively low, as noted by Solaymani (2021). Local investors' participation level in the agriculture sector has significantly declined compared to other industries, with agricultural investors typically seeking secure markets for smallholder farmers (Sinyolo, 2020). Furthermore, according to Stathers et al. (2020), smallholder farmers face limited access to markets due to volume,

consistency, and quality, resulting in many smallholder farmers experiencing poverty due to inadequate market opportunities for their products.

Postharvest losses release greenhouse gases, adversely affecting the environment (Gage et al., 2024). Furthermore, greenhouse gas emissions are increasing faster than anticipated, leading to accelerated global warming (Blanckenberg et al., 2022). Despite compelling scientific evidence, governments and businesses have been slow to implement measures to reduce emissions. South Africa lacks published literature on small-scale greenhouse gas emissions, such as provincial or farm-level estimates of agriculture-based emissions. Consequently, there is a need for a comprehensive literature database on agricultural greenhouse gas emissions at the farm level in South Africa. Since agricultural census data lacks detailed farm inventories, municipal or farm inventories are essential for accurately identifying emission sources from agricultural activities. This information is crucial for municipalities to establish effective emission reduction policies.

Insufficient understanding of vegetable postharvest handling practices among farmers has emerged as a significant barrier to enhancing agricultural productivity, market access, and farm incomes. Previous research on vegetable production in smallholder farming has primarily concentrated on crop yields, irrigation efficiency, organic agriculture, and risk perceptions. However, limited focus has been on studying postharvest losses in smallholder vegetable production. This study examines postharvest losses' impact on smallholder farmers, agribusinesses, and the vegetable supply chain in the KwaZulu-Natal province, South Africa.

1.3 Objectives of the study

The overall objective of this study is to analyze agribusiness investments and postharvest losses in smallholder vegetable supply chains, providing insights from eThekweni Municipality, KwaZulu-Natal.

The study specifically aims:

- 1.3.1 To examine the drivers of postharvest losses among smallholder vegetable farmers.
- 1.3.2 To examine the perceptions and determinants of the severity of postharvest losses among smallholder vegetable farmers.

- 1.3.3 To determine the principal causal factors contributing to postharvest losses along the vegetable supply chain.
- 1.3.4 To examine the relationship between agribusiness investments and postharvest losses.
- 1.3.5 To determine the environmental impact (Greenhouse gas emissions) of postharvest losses and strategies to reduce them.
- 1.3.6 To assess the impact of postharvest losses on smallholder farmers' household welfare.

1.4 Research Questions

- 1.4.1 What are the drivers of postharvest losses among smallholder vegetable farmers?
- 1.4.2 What are the perceptions and determinants of the severity of postharvest losses among smallholder vegetable farmers?
- 1.4.3 What are the principal causal factors contributing to postharvest losses along the vegetable supply chain?
- 1.4.4 What is the relationship between agribusiness and postharvest losses?
- 1.4.5 What environmental impact is caused by postharvest losses, and what are the strategies to reduce it?
- 1.4.6 What impact do postharvest losses impose on smallholder farmers' household welfare?

1.5 Justification of the study

Smallholder agriculture is pivotal to Africa's economy and society. Over 60% of the continent's population is engaged in smallholder farming, contributing more than 23% to its GDP (Woldemichael et al., 2017). However, these farmers, who primarily supply local markets, face significant postharvest losses, leading to a decline in the sector. These losses adversely impact agribusiness investment, which is crucial for enhancing the global competitiveness of African agriculture. Despite the growth of the Small and Medium-sized Enterprise (SME) subsector, investments in agribusiness, particularly at the industrial level, remain low. Additionally, local investor participation in agriculture has significantly decreased compared to other industries, underscoring the need for heightened support for agribusiness investments.

Postharvest losses also contribute to greenhouse gas emissions, posing severe environmental risks. The emission rates are surpassing predictions, accelerating global warming. Despite compelling scientific evidence, governmental and business measures to mitigate emissions have been slow. In

South Africa, there is a notable lack of literature addressing greenhouse gas emissions at small scales, such as provincial or farm-level estimates related to agriculture. Therefore, developing a searchable literature database focusing on agricultural greenhouse gas emissions at the farm level in South Africa is essential.

Given these challenges, this study investigates the impact of vegetable postharvest losses on smallholder farmers, agribusinesses, and the vegetable supply chain. The lack of comprehensive understanding of vegetable postharvest handling practices among farmers hinders improvements in agricultural productivity, market access, and farm incomes. Previous research on smallholder vegetable production has predominantly focused on crop yields, irrigation efficiency, organic agriculture, and risk perceptions, with a significant gap in studying postharvest losses. This study addresses this gap by examining the impact of postharvest losses on various stakeholders within smallholder vegetable production.

This study provides insights into critical factors within the smallholder vegetable farmers' value chain that must be addressed to mitigate postharvest losses, enhance profitability, and stimulate agribusiness investment. Additionally, the study examines the environmental impact associated with postharvest losses and proposes strategies for its reduction, an often-overlooked aspect in existing research. The findings will offer a comprehensive analysis of methods for managing postharvest losses, facilitating smallholder vegetable farmers' access to formal markets, ultimately improving their livelihoods and ensuring a sustainable return on investment. Furthermore, the study will inform policymakers about the environmental implications of agricultural activities, bridging the gap where most research focuses solely on the economic aspects of agriculture.

1.6 Delineation and the limitation of the study

This study sought to investigate the impact of vegetable postharvest losses on smallholder farmers, agribusinesses, and the vegetable value chain within the KwaZulu-Natal province, South Africa. Geographically, the study was conducted in the eThekweni Municipality, covering regions including North, West, South, and Central. The sample comprised smallholder vegetable farmers operating within these regions of the eThekweni Municipality. Notably, the eThekweni Municipality distinguishes itself with its extensive land area compared to other South African cities, featuring hilly topography with numerous gorges, ravines, and limited coastal plains. Data

about farm assets, socio-economic status, institutional factors, technical practices, and marketing aspects was gathered using structured questionnaires. However, budget constraints restricted the study to the eThekweni Municipality. Moreover, challenges such as time limitations and inadequate infrastructure posed hurdles to data collection

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CHAPTER 2

The Effects and Causal Factors of Postharvest Losses Among Smallholder Vegetable Supply Chains in South Africa: A Review

2.1 Introduction

Smallholder vegetable farmers are critical in ensuring food security, contributing to local economies, and preserving biodiversity through sustainable agricultural practices. However, smallholder vegetable farmers still face challenges such as postharvest losses, which lead to reduced income, food insecurity, negative environmental impact, and hindered agribusiness investments in rural communities. Therefore, this chapter provides a comprehensive literature review concerning the critical factors influencing postharvest losses among smallholder vegetable farmers. Additionally, it examines the analysis of vegetable supply chains and the involvement of smallholder vegetable farmers in value addition. Moreover, it delves into the literature on the environmental impact of postharvest losses, the effects of such losses on agribusiness investments, and strategies to mitigate postharvest losses.

2.2 Definitions of terms

2.2.1 Smallholder vegetable farmers

Smallholder vegetable farmers are rural producers who primarily rely on family labor, with their farms serving as the primary source of income (Mujuru and Obi, 2020). Moreover, smallholder vegetable farmers utilize family labor, allocating part of their produce for household consumption and selling the surplus (Ndlovu et al., 2021). Historically, smallholder agriculture has revolved around various rainfed, seasonal food crops, ensuring balanced household nutrition and mitigating risks (Mkuhlani et al., 2020). In Southern Africa, smallholder farming is emblematic of the agricultural landscape, yet poverty remains pervasive despite farmers' adoption of intensive farming practices and adaptive strategies for survival (Edwards et al., 2021). However, smallholder farmers typically face significant economic challenges, worsened by globalization's competitive pressures and integration into broader economic systems (Mamabolo et al., 2021). Moreover, their agricultural viability and contributions to cultural diversity are at risk, with the potential outcomes being either subsistence farming or expansion into more extensive operations capable of competing with industrialized farms (Hornby, 2020). Smallholder farmers primarily rely on

rainfall and seasonal cropping to fulfill their household food and consumption needs, often with minimal capital investment.

2.2.2 Postharvest losses

Postharvest losses encompass the deterioration or reduction in the quantity and quality of agricultural produce between harvest and consumption or processing (Tatsi et al., 2021). Moreover, these losses are caused by improper handling, inadequate storage facilities, improper transportation methods, and exposure to unfavorable environmental conditions (Bedeke, 2023). Additionally, postharvest losses occur due to pest infestations, diseases, and physiological changes in the harvested crops (Tadesse, 2020). The impact of postharvest losses extends beyond mere economic implications for farmers, as it significantly affects global food security and nutrition (Blanckenberg et al., 2022). Consequently, when agricultural products are lost after harvest, it reduces food availability for consumers, worsening hunger and malnutrition (Stathers and Mvumi, 2020). Moreover, the wastage of resources involved in producing these lost crops, including water, energy, labor, and inputs, further compounds the environmental footprint of agriculture (Nkansah-Dwamena, 2023). Addressing postharvest losses is imperative for sustainable agricultural development and resilient food systems.

2.2.3 Agribusiness investment

Agribusiness investment refers to allocating financial resources, expertise, and technology to various agricultural industry sectors, including farming, processing, distribution, and marketing (Ayele et al., 2020). Moreover, these investments aim to enhance agricultural productivity, efficiency, and profitability while contributing to broader economic development and food security goals (Mujuru and Obi, 2020). Additionally, agribusiness investments take various forms, such as funding for infrastructure development, research and development initiatives, mechanization and market access expansion (Smidt and Jokonya, 2022). These investments drive innovation, increase competitiveness, and foster sustainable agricultural practices. Moreover, agribusiness investment stimulates job creation, income generation, and rural development, thereby contributing to poverty alleviation and socio-economic empowerment of farming communities (Geza et al., 2022). Agribusiness investment is necessary for unlocking the full potential of the farm sector and achieving long-term growth and success in the agri-food economy.

2.3 Overview of Smallholder Vegetable Farmers in South Africa

Smallholder vegetable farming in South Africa remains a critical component of the agricultural sector, with significant implications for food security, rural development, and economic growth. Vegetable farming is significant in South Africa's agricultural landscape, providing crucial sustenance and economic opportunities for smallholder farmers (Ndlovu et al., 2021). Moreover, over the past few decades, the vegetable sector has undergone notable transformations, influenced by several factors such as technological advancements, shifts in agricultural policies, international trade dynamics, and emerging trends like the growing demand for organic produce (Fernqvist and Göransson, 2021). The agricultural sector in South Africa comprises smallholder farmers (Gwiriri et al., 2019), and there are approximately 2 million smallholder vegetable farmers compared to 35,000 commercial growers (Carelsen et al., 2021). Moreover, about 80% of the food produced in sub-Saharan Africa is produced by smallholder vegetable farmers, and these farmers are also the largest employers of the local labour force in these countries (Kom et al., 2020).

South Africa consumes a substantial number of vegetables annually, with smallholder vegetable farmers playing a pivotal role in meeting this demand (Sinyolo et al., 2021). As highlighted by Giller et al. (2021), vegetable farming is not just a livelihood but a cornerstone for a substantial portion of South Africa's smallholder farming households, encompassing over 90% of the total farming population. This statistic highlights the general involvement of smallholder farmers in vegetable production, emphasizing their significance in strengthening the country's food security and nutritional well-being. Moreover, the expansive production of vegetables extends across a significant region of South Africa's arable land, with 60% of the total annual cropped area dedicated to vegetable production (Mujuru and Obi, 2020). This widespread cultivation signifies the agricultural diversity within the country, with smallholder vegetable farmers actively contributing to the utilization of available land resources for vegetable cultivation.

According to Gashu et al. (2019), smallholder agriculture has a significant economic and social footprint in Africa. Over 60% of the continent's population comprises smallholder farmers, and over 23% of its GDP comes from agriculture (Woldemichael et al., 2017). Moreover, In South Africa, smallholder vegetable farmers have been able to meet the country's vegetable demand and even export surplus produce to neighboring countries. However, challenges such as fluctuating weather patterns, limited resource access, and market volatility have affected the sector's

productivity and profitability in recent years. Moreover, postharvest losses have also been noted as the critical factor influencing smallholder vegetable farmers' productivity and profitability. Over 10 million tons of food is wasted or lost in South Africa due to poor postharvest handling and value-addition techniques (Melembe et al., 2020). Despite these challenges, smallholder vegetable farmers remain vital in ensuring food security and contributing to rural livelihoods.

2.4 Smallholder Vegetable Supply Chain Analysis

Smallholder vegetable supply chains play a critical role in the agricultural sector, particularly in regions with a high prevalence of smallholder farming. The vegetable supply chain can be described as activities and individuals producing and consuming a primary agricultural product (Sharma et al., 2020). Understanding the dynamics and interactions within the supply chain is essential for enhancing smallholder farmers' productivity, profitability, and sustainability. Figure 2.1 illustrates the key components and stakeholders within the smallholder vegetable supply chain. Smallholder vegetable supply chains encompass the various stages of producing, processing, distributing, and consuming vegetables. These stages include production activities such as cultivation and postharvest handling and downstream activities such as processing, marketing, and retailing. The interactions among stakeholders, including smallholder farmers, input suppliers, aggregators/traders, processors, retailers/markets, and consumers, shape the flow of goods, services, and information along the supply chain.

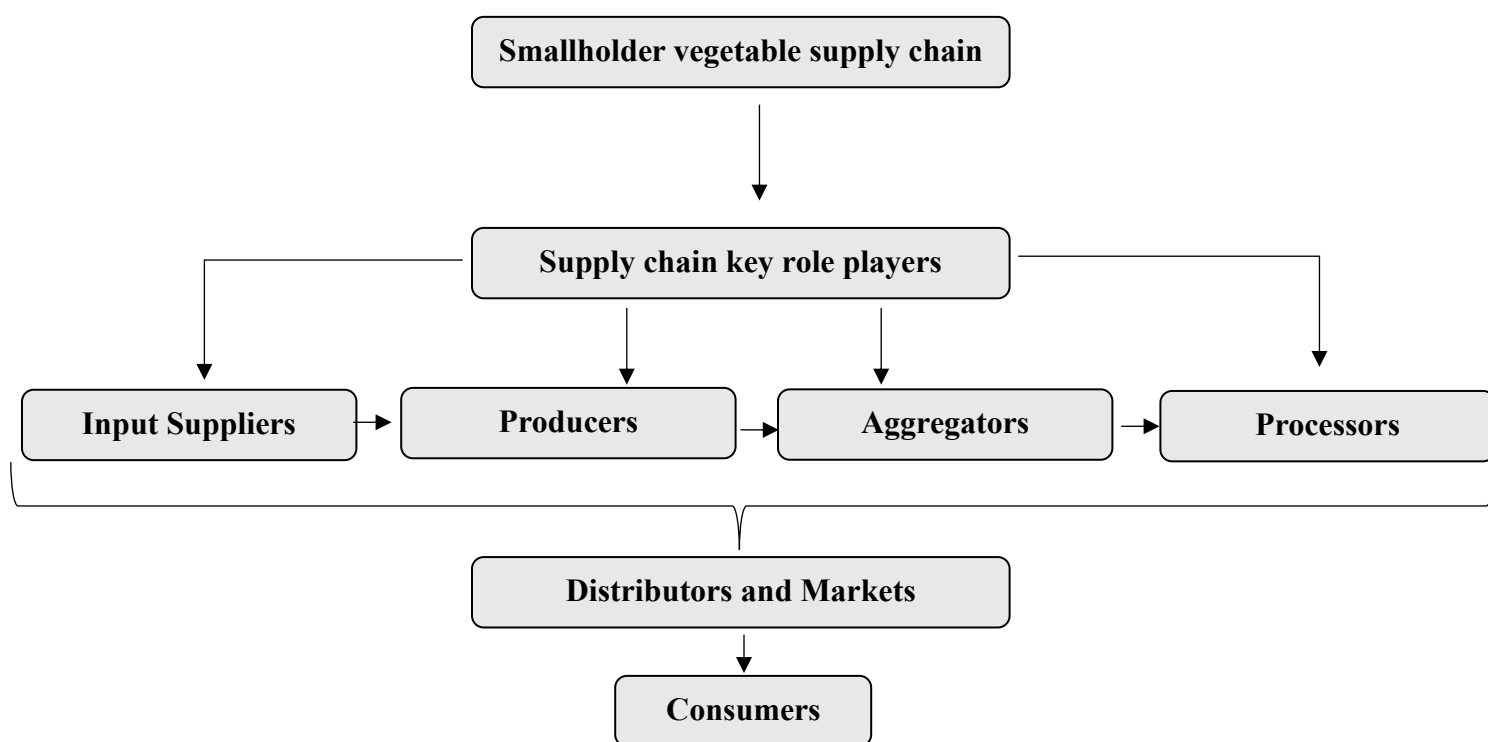


Figure 2.1: Key components and stakeholders within the smallholder vegetable supply chain.

2.4.1 Input suppliers

Quality inputs are imperative for farmers, including seeds, seedlings, fertilizers, pesticides, and herbicides. However, Snyder (2021) highlighted the prevalent challenges faced by smallholder farmers, encompassing issues of affordability, availability, and a shortage of knowledge regarding the optimal utilization and handling of these inputs. In response, governmental bodies and non-governmental organizations (NGOs) endeavour to address these hurdles through various initiatives such as subsidies, capacity-building programs, financial support, and extension services. Among the essential inputs, fertilizers stand out as pivotal in enhancing soil fertility, thereby amplifying the productivity and yields of smallholder farmers (Cairns et al., 2021). Nevertheless, the instability of fertilizer prices in South Africa emerges as a significant obstacle impacting the productivity of smallholder farmers. The National Agricultural Marketing Council (NAMC) (2022) has indicated a substantial increase in fertilizer prices, notably for key varieties like Potassium chloride (KCl), Monoammonium phosphate (MAP) and Urea, between May 2021 and May 2022. These price hikes are attributed primarily to global market fluctuations and diminished

nutrient supplies. South Africa's reliance on fertilizer imports makes the local market susceptible to unpredictable price shifts, posing additional challenges for smallholder farmers.

2.4.2 Producers

As primary producers within the vegetable supply chain, smallholder farmers typically contend with constrained arable land and limited resources (Langyintuo, 2020). These constraints limit their production capacities, disrupting the smooth supply chain flow within the economy. Consequently, to maintain stability, there arises a necessity to import certain products from other countries (Magidi et al., 2020). Furthermore, Snyder et al. (2020) emphasize that smallholder farmers often rely on modern farming techniques and traditional methods to produce vegetables within their limited land resources. However, despite their efforts, several factors, such as climate variability, soil fertility, and water access, significantly influence their production outcomes. These complex challenges highlight the dynamics within the smallholder farming sector and its impact on the vegetable supply chain.

2.4.3 Aggregators

Smallholder farmers, characterized by operating on a small scale, often face challenges in meeting the market demand individually due to limited production volumes (Dlamini-Mazibuko et al., 2019). Consequently, these farmers must aggregate produce to bridge this gap and satisfy market requirements. However, as Amare et al. (2019) highlighted, pooling produce can overwhelm many smallholder farmers due to their constrained access to markets and resources. In such circumstances, the intervention of aggregators or cooperatives becomes crucial, as they support these farmers, enabling them to overcome logistical and resource-related obstacles and achieve economies of scale. Through collaboration with aggregators or cooperatives, smallholder farmers can enhance their market access, increase their bargaining power, and improve their overall profitability and sustainability in the agricultural sector (Abraham et al., 2022).

2.4.4 Processors

Smallholder farmers often face challenges in engaging more extensively in processing or value-addition activities due to inadequate equipment and resources (Kapari et al., 2023). However, research by Soni et al. (2022) highlighted the potential profitability and marketability of vegetables through value-added activities, including packaging, washing, and cutting. Smallholder farmers

can enhance market appeal and command higher prices by adding value to their produce. Moreover, as noted by Mazenda et al. (2022), supporting smallholder farmers in agro-processing is essential for capitalizing on market access and premium prices associated with value-added products. This support enables farmers to meet consumer preferences, capitalize on market opportunities, and improve their livelihoods and economic resilience.

2.4.5 Distributors and Markets

Distributors play a crucial role in connecting smallholder farmers to formal markets. However, smallholder farmers often face challenges in accessing these markets directly, leading them to sell their produce at farm gates or within local neighborhoods (Mnukwa et al., 2023). This limited access can be attributed to several factors, such as high transportation costs and inadequate infrastructure (Bosona, 2020). Moreover, the absence of essential components like transportation networks and market information further complicates the distribution process, particularly in rural areas. Additionally, Hlatshwayo et al. (2021) highlighted that smallholder farmers' participation in agricultural markets is hindered by factors such as a lack of market information, limited experience in market dealings, and institutional constraints. Distributors could alleviate some of these challenges by providing market insights, facilitating transportation, and offering support in navigating market dynamics. However, the prevailing difficulties contribute to the decline of smallholder farmers' involvement in agricultural markets, limiting their potential for economic growth and prosperity.

2.4.6 Consumers

In the vegetable supply chain, consumers play a significant role in shaping market demand and influencing farmers' decisions (Kalimuthu et al., 2024). They typically prefer processed or value-added produce, often opting for packaged or washed items for convenience and hygiene. However, smallholder farmers, as highlighted by Alemu et al. (2021), face constraints such as limited labor availability and the need to minimize costs, including expenses related to packaging. This often leads consumers to purchase vegetables from markets rather than directly from farmers. Furthermore, farmers may encounter challenges in adding value to their produce, which can result in lower prices for their goods. Melovic et al. (2020) noted that price, nutritional content, and overall quality influence consumer demand for vegetables. As consumers drive market demand, their preferences directly impact the decisions made by farmers regarding production methods and

product offerings (Stampa et al., 2020). Perdana et al. (2022) suggested that consumers must be educated about the benefits of locally grown vegetables to address these dynamics and enhance smallholder farmers' competitiveness in the vegetable supply chain.

2.5 Factors that hinder smallholder vegetable farmers' participation in value addition

Participation of smallholder farmers in value-addition processes is crucial for meeting the increasing demand for vegetables, especially in developing countries where population growth drives market expansion (Giller et al., 2021). However, Rutta (2022) highlights that despite this opportunity, smallholder farmers' involvement in postharvest processing remains low due to limited access to capital, technology, and infrastructure constraints. Langyintuo (2020) attributes this limited participation to the lack of resources and suitable facilities among smallholder farmers, which hinders their ability to engage in value-added activities effectively. Value addition to horticultural produce is critical to enhance marketability and economic returns by extending shelf life and improving product quality (Palumbo et al., 2022).

Moreover, there is a need for improved postharvest management practices in horticultural enterprises, emphasizing the scarcity of evidence supporting current approaches and the potential for increased value addition (Swain et al., 2021). Arias et al. (2021) also noted the absence of research on the factors influencing smallholder farmers' selection and adoption of postharvest techniques, indicating a need for further investigation into this area. Mazenda et al. (2022) further highlight the low participation of smallholder farmers in value-addition processes, suggesting a lack of understanding regarding their preferences and decision-making processes, which could be addressed through targeted interventions and capacity-building initiatives. The following are the factors that hinder smallholder vegetable farmers' participation in value addition:

2.5.1 Access to credit

Limited access to credit hinders smallholder vegetable farmers' engagement in value-addition processes. Langyintuo (2020) highlighted credit's crucial role in empowering these farmers, particularly in developing countries, by enabling postharvest technologies and infrastructure investments. This enhances produce quality, shelf life, and overall efficiency in the vegetable supply chain, thereby mitigating food insecurity. However, the persistent lack of credit access exacerbates challenges faced by farmers, limiting their ability to capitalize on value addition

opportunities. Bisheko and Rejikumar (2024) emphasized the importance of credit in agricultural development and urged addressing constraints hindering farmers' adoption of postharvest technologies. Addressing credit accessibility is crucial for unlocking smallholder farmers' potential and promoting sustainable farming practices (Rutta, 2022). Improved credit access can also reduce postharvest losses by facilitating investments in technologies like cold storage, efficient packaging, and transportation infrastructure while promoting best practices in handling and processing (Stathers et al., 2020).

2.5.2 Access to Technology

In developing countries, the absence of appropriate technology poses a significant barrier for smallholder producers seeking value-added food production (Walker, 2021). Technology integration holds immense potential in bolstering farmers' income and safeguarding food security within local communities. Smidt and Jokonya (2022) shed light on rural farmers' challenges, including the shortage of suitable technology and the scarcity of critical resources such as electricity and water. These challenges hinder farmers' ability to adopt value-addition practices and impede their overall productivity and economic resilience (Stathers et al., 2020). Additionally, the prohibitive costs associated with accessing technology, compounded by high-interest rates and limited working capital, further exacerbate the plight of smallholder producers, inhibiting their capacity to invest in essential infrastructure and innovative solutions (Smidt and Jokonya, 2022). Addressing these systemic barriers and enhancing access to appropriate technology are imperative steps toward empowering rural farmers to unlock their full potential, improve their livelihoods, and contribute meaningfully to sustainable agricultural development.

2.5.3 Storage Infrastructure

It is important to stress the importance of postharvest technologies and infrastructure, such as on-farm storage and agro-processing equipment, in prolonging the shelf life of agricultural products (Grover and Sharma, 2020). These technologies are vital for preserving product quality, enhancing market value, and minimizing postharvest losses. However, Mthombeni et al. (2021) highlighted a significant challenge smallholder farmers face: the high energy requirements of such technologies, particularly refrigeration, which are often cost-prohibitive. Consequently, many smallholder farmers cannot afford these facilities, leaving their produce susceptible to spoilage and forcing them to sell at lower prices to avoid financial losses, perpetuating economic insecurity

(Mthombeni et al., 2021). Moreover, the detrimental effects of inadequate processing equipment and storage facilities on smallholder farmers lead to increased postharvest losses (Mudgal and Kumar, 2023). The lack of modern infrastructure worsens the challenges of smallholder farmers, resulting in economic losses and jeopardizing agricultural livelihoods. Addressing these infrastructure gaps and promoting access to energy-efficient postharvest technologies are crucial steps in empowering smallholder farmers to enhance the quality and marketability of their produce while minimizing losses in the agricultural supply chain.

2.5.4 Lack of market information

Access to information is vital for smallholder farmers, enabling them to make informed decisions regarding marketing, finance, and production, optimizing their operations and marketing strategies (Kumarathunga et al., 2022). However, there are significant challenges in accessing such information, particularly in rural areas where costs can be prohibitive. To overcome this obstacle, smallholder farmers often rely on accessible communication channels like cell phones, radios, and extension agents, which are crucial conduits for accessing market intelligence and agricultural best practices (Nedumaran et al., 2020). Despite the widespread availability of these information-sharing platforms, Mapiye et al. (2023) noted a persistent disparity in the availability of comprehensive market data tailored to the specific needs of smallholder farmers. This gap limits farmers' ability to capitalize on value-addition opportunities and optimize their participation in agricultural markets (Gwagwa et al., 2021). Therefore, enhancing the accessibility and relevance of market information for smallholder farmers remains a crucial area for intervention, necessitating collaborative efforts from policymakers, agricultural extension services, and technology providers to ensure equitable access to vital information resources.

2.5.5 Farming experience

Farming experience is pivotal in shaping smallholder farmers' decisions regarding value addition, providing them firsthand insights into the benefits and challenges of different practices (Meemken and Bellemare, 2020). This experiential knowledge enables farmers to make informed choices based on their understanding of potential market returns. It empowers them to explore more complex value-adding ventures and expand their options for improving their produce (Thinda et al., 2020). In contrast, inexperienced farmers may be limited by their lack of practical knowledge, hindering their ability to capitalize on value-addition opportunities. Additionally, as farmers gain

experience over time, they may become less inclined to adopt innovative techniques, potentially hindering their ability to innovate and optimize postharvest processes (Hlatshwayo et al., 2021).

2.6 Key factors contributing to postharvest losses.

2.6.1 Inadequate storage facilities

The absence of adequate storage facilities, including cold storage or appropriate packaging, presents a substantial risk to the quality and longevity of perishable produce (Negi and Trivedi, 2021). Proper storage conditions, such as controlled temperature and humidity levels, are essential for maintaining freshness and extending the shelf life of fruits and vegetables (Rutta, 2022). However, without these conditions, produce becomes highly susceptible to spoilage and rapid deterioration, significantly increasing postharvest losses (Stathers et al., 2020). Moreover, inadequate packaging further compounds the problem by exposing the product to physical damage, moisture loss, and contamination, worsening the spoilage rate. Furthermore, the absence of suitable storage infrastructure challenges farmers and distributors in maintaining product freshness during transportation and storage (Thinda et al., 2020). This inability to preserve product quality leads to significant economic losses and contributes to food waste. Therefore, investing in proper storage facilities and packaging solutions is critical for reducing postharvest losses, ensuring food security, and maximizing economic returns for farmers and distributors.

2.6.2 Poor handling practices

Poor handling practices during critical stages like harvesting, sorting, and transportation have profound implications for the quality and longevity of agricultural produce (Rutta, 2022). Moreover, when fruits and vegetables are subjected to rough handling or improper techniques, they become vulnerable to physical damage such as bruising, crushing, or puncturing, accelerating their deterioration (Adewoyi et al., 2022). Additionally, mishandling can create entry points for pathogens, heightening the risk of decay and spoilage. Furthermore, inadequate handling may lead to improper storage arrangements or prolonged exposure to adverse environmental conditions, compromising the product's quality and marketability (Mapiye et al., 2023). Consequently, implementing proper handling procedures throughout the postharvest chain is paramount to minimizing losses and preserving the freshness and value of agricultural products. This highlights the importance of training and education initiatives to ensure all stakeholders adhere to best practices in handling agricultural produce, enhancing overall product quality, and reducing waste.

2.6.3 Lack of infrastructure

Insufficient transportation networks and infrastructure present a significant challenge in the postharvest phase, potentially worsening spoilage and economic losses for agricultural products (Negi and Trivedi, 2021). Moreover, when there is a lack of adequate infrastructure, such as well-maintained roads, cold storage facilities, or reliable transportation systems, agricultural products are subjected to delays and prolonged exposure to environmental factors during transit (Khumalo et al., 2023). These delays significantly increase the risk of spoilage, as fruits and vegetables are more prone to decay when exposed to unfavorable conditions for extended periods. Furthermore, inadequate infrastructure hampers efficient distribution and market access, limiting farmers' ability to sell their produce on time (Mapiye et al., 2023). Therefore, investing in robust transportation networks and storage facilities is crucial for reducing postharvest losses and ensuring the freshness and quality of agricultural products. Such investments benefit farmers by minimizing losses and contribute to overall food security and economic development by facilitating efficient agricultural supply chains.

2.6.4 Pest and disease damage

Pest and disease damage significantly threaten agricultural produce during storage and transportation, often resulting in accelerated deterioration and substantial economic losses (Tadesse, 2020). Moreover, when agricultural products are infested by pests or affected by diseases, their quality rapidly declines, rendering them unsuitable for consumption or sale (Kolli et al., 2021). Pests such as insects and rodents can directly consume or damage the produce, while diseases can lead to rotting, mold growth, or other spoilage. Furthermore, infestation or disease can spread rapidly in storage facilities or during transportation, exacerbating the damage and increasing losses (Adewoyi et al., 2022). Therefore, implementing effective pest management and disease control measures is essential to mitigate these risks and preserve the quality and marketability of agricultural products throughout the postharvest process. By implementing proper hygiene practices, utilizing pest-resistant packaging, and employing appropriate chemical treatments, when necessary, farmers and distributors can minimize the impact of pests and diseases on their produce, thereby reducing losses and ensuring the delivery of high-quality products to consumers.

2.6.5 Environmental conditions

Exposure to adverse environmental conditions poses a significant risk to perishable produce during the postharvest period (Sharma et al., 2021). Fluctuations in temperature, high humidity, and prolonged sunlight exposure can all harm the quality and longevity of fruits and vegetables (Medda et al., 2022). Moreover, temperature variations can disrupt physiological processes, leading to accelerated ripening, increased respiration rates, and heightened susceptibility to decay (Prusky and Romanazzi, 2023). High humidity levels create favourable conditions for mould growth and microbial proliferation, further deteriorating the produce's quality. Additionally, prolonged exposure to sunlight can result in wilting, dehydration, and discolouration, compromising the appearance and marketability of the products (Damerum et al., 2020). To mitigate these risks, it is essential to implement appropriate storage and handling practices. This includes utilizing controlled storage environments, such as cold storage facilities, to regulate temperature and humidity levels and minimize exposure to sunlight during transportation. By implementing these measures, the freshness and quality of perishable produce can be preserved, ensuring that consumers receive high-quality products while minimizing postharvest losses.

2.7 Impact of postharvest losses

2.7.1 Food security

Postharvest losses have a profound impact on food security, as they directly contribute to the reduction of food availability. In a global landscape characterized by a growing population and increasing food demand, minimizing postharvest losses becomes crucial for maintaining a stable and adequate food supply (Barrett, 2021). Moreover, Hashim et al. (2024) suggested that by reducing these losses and improving food distribution systems, stakeholders can enhance food security, alleviate hunger, and foster resilience against various food-related challenges, including climate change and disruptions to global food markets. Additionally, when postharvest losses are minimized, more food reaches consumers, thereby increasing the overall availability of food supplies (Ali et al., 2021). Increased availability helps meet immediate nutritional needs and strengthens food security by ensuring a steady and reliable supply chain. Additionally, by optimizing storage, transportation, and handling practices, stakeholders can enhance the efficiency of food distribution networks, reducing the likelihood of food shortages or disruptions in supply chains (Kumar et al., 2021). Furthermore, Sharma et al. (2021) highlighted that reducing

postharvest losses can positively impact food security efforts. It can help stabilize food prices, making food more affordable and accessible to vulnerable populations. Moreover, Rutta (2022) noted that by preserving food for extended periods, communities can better withstand food availability fluctuations caused by climate variability or market disruptions.

2.7.2 Social Impact

Postharvest losses have significant social impacts, particularly on vulnerable populations such as smallholder farmers and low-income communities (Totobesola et al., 2021). Moreover, postharvest losses disproportionately affect these groups due to their limited access to resources, infrastructure, and technology needed to mitigate these losses effectively (Stathers and Mvumi, 2021). As a result, postharvest losses exacerbate existing inequalities, perpetuate poverty, and hinder socio-economic development in rural areas. Smallholder farmers, who often rely on agriculture for their livelihoods, bear a disproportionate burden of postharvest losses (Mapiye et al., 2023). These losses result in decreased income for farmers and undermine their ability to provide for themselves and their families. Moreover, in low-income communities where access to food is already limited, postharvest losses further exacerbate food insecurity and malnutrition (Stathers et al., 2020). Additionally, postharvest losses hinder inclusive economic growth by impeding the development of rural economies (Damerum et al., 2020). When farmers cannot sell their produce due to spoilage or lack of market access, it disrupts local supply chains and reduces economic opportunities for communities (Binge et al., 2023). Furthermore, the continuation of postharvest losses reinforces cycles of poverty, making it more challenging for marginalized communities to break free from poverty traps. Addressing postharvest losses is essential for empowering marginalized communities and fostering inclusive economic growth (Kimani et al., 2022). By improving access to markets, storage facilities, and agricultural knowledge, stakeholders can help smallholder farmers mitigate losses and improve their livelihoods. Moreover, investing in infrastructure and technology to reduce postharvest losses can enhance the resilience of rural economies and promote sustainable development in the long term.

2.7.3 Environmental impact

Postharvest losses have significant environmental impacts, leading to wasted resources and increased greenhouse gas emissions. Agricultural production involves substantial inputs of water, energy, and land, all of which are expended in producing crops that go to waste due to postharvest

losses (Comfort et al., 2022). Moreover, this inefficient use of resources worsens resource scarcity and contributes to environmental degradation. Furthermore, disposing of spoiled produce contributes to landfill waste and emissions, worsening environmental problems (Bhatia et al., 2023). As organic matter decomposes in landfills, it releases methane, a potent greenhouse gas contributing to climate change. Additionally, Galford et al. (2020) suggested that the energy and resources expended in the production, transportation, and disposal of wasted food result in unnecessary greenhouse gas emissions, worsening climate change impacts. Mitigating postharvest losses is crucial for promoting environmental sustainability and conserving natural resources in agricultural production systems (Stathers et al., 2020). By reducing losses and improving efficiency throughout the supply chain, stakeholders can minimize the environmental footprint of food production. This includes implementing measures to optimize storage, transportation, and handling practices and investing in infrastructure and technologies that reduce waste and enhance resource efficiency.

2.7.4 Economic losses

Postharvest losses have devastating economic implications for farmers, distributors, and consumers, creating significant financial burdens throughout the agricultural supply chain. For farmers, reduced marketable yield directly translates into income losses, jeopardizing their livelihoods and economic stability (Holmelin, 2021). Similarly, distributors incur financial losses from unsold or spoiled products, impacting their profitability and overall business viability (Adams et al., 2021). Moreover, investments in acquiring and transporting produce are wasted when products are lost postharvest, leading to reduced profit margins and potential disruptions to operations (Binge et al., 2023). Furthermore, consumers are affected by postharvest losses through higher prices and decreased availability of fresh produce (Ali et al., 2021). When supply is constrained due to losses, market prices tend to rise, straining household budgets and limiting consumers' access to nutritious foods (Omotayo et al., 2022). This can adversely affect vulnerable populations with limited purchasing power, exacerbating food insecurity and malnutrition. The economic implications of postharvest losses highlight the urgency of addressing this issue to safeguard the economic well-being of all stakeholders in the agricultural supply chain. By implementing measures to reduce losses and improve efficiency throughout the supply chain,

stakeholders can minimize economic losses, enhance profitability, and ensure a more sustainable and resilient food system.

2.8 Relationship between postharvest losses and agribusiness investments

Postharvest losses pose a significant challenge to agribusiness investments, with implications for the global competitiveness of African agriculture (Nyam et al., 2022). Local investors' limited participation in the sector underscores the need to strengthen their engagement (Nohamba et al., 2022). The profitability of agribusiness investments is directly impacted by postharvest losses, affecting returns and reducing market value and revenue potential (Gashu et al., 2019). This situation, compounded by the substantial food loss between production and consumption in Sub-Saharan Africa, diminishes the attractiveness of investments in the sector (Noort et al., 2022). Investments in agribusiness are exposed to various risks associated with postharvest losses, including unpredictable weather patterns, inadequate infrastructure, and poor management practices (Singh and Khanna, 2019). Such risks can deter investors from engaging in South Africa's agribusiness industry, potentially jeopardizing long-term viability (Nohamba et al., 2022; Brenya et al., 2022). The relationship between postharvest losses (PHLs) and agribusiness investments is complex and interconnected, with each influencing the other in diverse ways:

2.8.1 Impact on Profitability

Increased postharvest losses (PHLs) have a profound impact on the profitability of agribusinesses. Research by Stathers and Mvumi (2020) highlighted that PHLs could result in substantial economic losses for agribusinesses, with estimates suggesting that up to one-third of global food production is lost or wasted annually. These losses translate into wasted investments in agricultural production, including inputs, labour, and technology. For example, a study by Stathers et al. (2019) emphasized that investments in improved farming practices and technologies may fail to yield optimal returns if a portion of the harvested produce is lost due to inadequate postharvest management. Consequently, the profitability of agribusinesses is compromised, undermining their financial sustainability and hindering efforts to enhance agricultural productivity and food security (Mbuli et al., 2021). Therefore, addressing postharvest losses is essential for maximizing the returns on agribusiness investments and ensuring the economic viability of the agricultural sector.

2.8.2 Vegetable Supply Chain

Postharvest losses (PHLs) play a significant role in shaping the dynamics of the vegetable supply chain, with ramifications for all stakeholders involved. Research by Benyam et al. (2021) highlighted that PHLs result in direct economic losses for agribusinesses and have ripple effects throughout the supply chain. Agribusinesses' investments to mitigate PHLs, such as improved storage and transportation infrastructure, can yield substantial benefits for farmers, distributors, retailers, and consumers (Mvumi and Stathers, 2020). Moreover, Makule et al. (2022) suggested that reducing losses during transit and storage through infrastructure investments can enhance the quantity and quality of produce reaching the market. This can lead to stabilized prices, improved supply chain efficiency, and enhanced stakeholder economic outcomes. Consequently, addressing PHLs through agribusiness investments is crucial for optimizing the performance of the vegetable supply chain and promoting sustainable economic development in the agricultural sector.

2.8.3 Policy and Regulatory Considerations

Policy and regulatory considerations are pivotal in shaping the relationship between postharvest losses (PHLs) and agribusiness investments. As highlighted by research conducted by Nohamba et al. (2022), government interventions are instrumental in incentivizing agribusiness investments to mitigate PHLs. Policies that support investments in postharvest infrastructure, such as storage facilities and transportation networks, are essential for reducing losses along the supply chain. Financial incentives or subsidies for adopting advanced postharvest technologies can encourage agribusinesses to invest in innovative solutions (Mutungi et al., 2023). Furthermore, Zamiri and Esmacili (2024) suggested that fostering collaboration between public and private sector entities can facilitate knowledge sharing and resource pooling, enhancing the effectiveness of PHL reduction efforts. Moreover, agribusinesses may also actively advocate for policy reforms that create a favourable environment for investment in postharvest management, thereby contributing to sustainable agricultural development and improved food security (Ali et al., 2021).

2.9 Approaches to mitigate postharvest losses.

2.9.1 Infrastructure development

Investment in infrastructure is paramount for reducing postharvest losses (PHLs) in agricultural supply chains. Cold storage facilities, transportation networks, and packaging technologies play

crucial roles in maintaining the quality and extending the shelf life of perishable products during transit and storage (Rutta, 2022). Studies by Mvumi and Stathers (2020), Cossam et al. (2023), and Barrett et al. (2022) highlighted the positive impact of improved infrastructure on reducing PHLs by providing suitable conditions for preserving agricultural produce. Moreover, Nohamba et al. (2022) suggested that investments in cold storage infrastructure can significantly reduce losses in perishable commodities, such as fruits and vegetables, by slowing the ripening process and inhibiting microbial growth. Parimia and Chakraborty (2022) suggested that investments in transportation infrastructure, including refrigerated vehicles and efficient planning systems, can minimize delays and ensure timely product delivery to markets, thereby reducing losses due to spoilage and quality deterioration. Furthermore, Barrett et al. (2022) argued that packaging technologies, such as modified atmosphere packaging (MAP) and vacuum packaging, can help extend the shelf life of products by creating optimal storage conditions and reducing exposure to external factors that accelerate deterioration.

2.9.2 Technological innovations

Adopting advanced postharvest technologies is essential for mitigating PHLs and improving the efficiency of agricultural supply chains. Innovations such as modified atmosphere packaging (MAP), controlled atmosphere storage (CAS), and temperature monitoring systems offer practical solutions for extending the shelf life of perishable products and minimizing losses (Almenar, 2020). Moreover, Bischoff et al. (2022) highlighted the significant impact of technological innovations in reducing PHLs across various agricultural commodities and geographical regions. Almenar (2020) also emphasized that MAP and CAS technologies can help maintain product quality and freshness by controlling temperature, humidity, and gas composition within storage environments. Similarly, Kumar et al. (2021) highlighted the role of temperature monitoring systems in ensuring the integrity of the cold chain and preventing temperature-related losses during transportation and storage. Additionally, Mvumi and Stathers (2020) stressed the importance of investing in innovative postharvest technologies to enhance the competitiveness of smallholder farmers and improve food security in developing countries.

2.9.3 Capacity building and training programs

Providing training and capacity-building programs for farmers, handlers, and other stakeholders is crucial for promoting best practices in postharvest management and minimizing losses. These

programs offer practical guidance on proper harvesting, handling, storage, transportation techniques, and knowledge about quality standards and market requirements. Studies by Midamba and Kizito (2022) and Nohamba et al. (2022) highlighted the effectiveness of capacity-building initiatives in reducing PHLs and improving the overall efficiency of agricultural supply chains. Moreover, Mvumi and Stathers (2020) emphasized the importance of farmer training programs in imparting skills and knowledge about postharvest handling practices, leading to significant reductions in losses and improvements in product quality. Similarly, Smidt and Jokonya (2022) suggested that capacity-building interventions targeting smallholder farmers can enhance their understanding of market requirements and enable them to adopt appropriate postharvest technologies and techniques. Additionally, Tafesse et al. (2020) emphasized the role of extension services and farmer field schools in promoting peer learning and knowledge exchange on postharvest management practices. Furthermore, Debebe (2022) highlighted the importance of continuous education and training for all stakeholders involved in the agricultural supply chain to ensure compliance with quality standards and market demands.

2.9.4 Value addition and diversification

Value addition and diversification strategies are essential for reducing postharvest losses (PHLs) and enhancing the economic viability of agricultural produce. Value addition involves transforming raw agricultural commodities into processed or semi-processed products with higher market value, while diversification entails expanding the products offered to consumers (Woomer et al., 2023). Moreover, Rutta (2022) highlighted the potential of value-addition activities, such as processing, packaging, and branding, in increasing the shelf life and market value of agricultural products, thereby reducing losses and enhancing profitability for farmers. Similarly, Brown and Ledermann (2024) emphasized the role of product diversification in mitigating risks associated with seasonal fluctuations and market uncertainties, allowing farmers to capitalize on niche markets and command premium prices for their produce. Furthermore, Hlophe-Ginindza and Mpandeli (2020) suggested the importance of promoting value addition and diversification as critical strategies for enhancing the competitiveness of smallholder farmers and improving food security in developing countries. Mulema et al. (2021) added that value-addition initiatives, such as producing dried fruits and vegetables, can reduce losses and create income generation and employment opportunities, particularly for women and youth in rural areas.

2.10 Summary

The literature review delves into the vital role of smallholder vegetable farming in South Africa's agricultural landscape, emphasizing its significance for food security, rural development, and economic growth. Despite weather variability and market volatility, these farmers remain resilient contributors to food production and employment. However, a critical issue affecting their productivity and profitability is the prevalence of postharvest losses, leading to significant food waste. Moreover, understanding smallholder vegetable supply chains is crucial, especially in regions dominated by smallholder farming. These supply chains play a pivotal role in shaping the dynamics of the agricultural sector, encompassing various stages from production to consumption. The interactions among stakeholders dictate the flow of goods, services, and information throughout the supply chain, impacting productivity and sustainability.

Furthermore, the participation of smallholder vegetable farmers in value-addition processes is deeply intertwined with the broader agricultural landscape and socioeconomic context. Addressing their multifaceted challenges, including limited access to resources and market information, requires collaborative efforts across the supply chain. By investing in targeted interventions, such as improving access to resources and strengthening market linkages, smallholder farmers can overcome barriers to value addition and unlock their full potential. In addition to smallholder farmers' challenges, several factors contribute to postharvest losses, including inadequate storage facilities, poor handling practices, and environmental conditions. These factors collectively hinder the efficiency and profitability of vegetable supply chains, worsening food waste and economic losses. Strategic interventions to address these challenges, such as improving storage facilities and implementing pest management measures, are essential for minimizing postharvest losses and promoting sustainable agricultural practices.

Moreover, the relationship between postharvest losses and agribusiness investments is intricate and multifaceted. Factors like unpredictable weather patterns and inadequate infrastructure increase investment risks, posing challenges for agribusiness ventures. Policy and regulatory considerations are crucial in incentivizing investments to mitigate postharvest losses. In contrast, strategic investments in infrastructure, technological innovations, and capacity building are critical approaches to enhancing the efficiency and profitability of agricultural supply chains. In conclusion, addressing postharvest losses through collaborative efforts and strategic investments

is vital for promoting sustainable agricultural development, improving food security, and fostering economic growth in South Africa's agricultural sector. Stakeholders can work towards a more resilient and prosperous agricultural future by tackling these challenges holistically and fostering an enabling environment for investment and innovation.

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CHAPTER 3

Modelling Drivers of Postharvest Losses among Smallholder Vegetable Farmers in eThekweni Metropolitan: An Examination of a Zero-Inflated Poisson (ZIP) Approach

Abstract

Postharvest losses (PHLs) challenge smallholder vegetable farmers in developing countries, notably sub-Saharan Africa, impacting food security and economic sustainability. Despite efforts to mitigate PHLs, understanding remains insufficient. Therefore, this study investigated the key drivers of postharvest losses among smallholder vegetable farmers in eThekweni Municipality. The study adopted a cross-sectional research design and multi-stratified random sampling technique to gather primary data from 238 smallholder vegetable farmers through structured questionnaires. Descriptive statistics and Zero-Inflated Poisson (ZIP) Regression were used for analysis. The results indicate that demographic factors such as age and household size positively influence postharvest losses, with older farmers and larger households experiencing higher rates of PHLs. Conversely, higher educational levels, greater farm experience, and access to extension services are associated with reduced PHLs. Additionally, better storage facilities significantly decrease PHLs, while the increased distance to markets exacerbates them. These findings underscore the need for targeted interventions, including enhanced educational opportunities, improved storage infrastructure, and better market access to mitigate postharvest losses effectively.

Keywords: Food security, Livelihoods, Postharvest losses, Smallholder vegetable farmers, Zero-Inflated Poisson (ZIP) Regression

3.1 Introduction

Postharvest losses represent a critical challenge within the agricultural sector, encapsulating both quantitative and qualitative diminutions in produce between harvest and consumption (Debebe, 2022). This pervasive issue is multifaceted, comprising factors such as physical damage, spoilage, and deterioration across the supply chain's handling, transportation, storage, and marketing stages, as highlighted by Vikram et al. (2023). Understanding the intricate nature of postharvest losses is paramount as they can manifest at various points of the supply chain, from the initial harvesting and handling processes to transportation, storage, and, ultimately, marketing. Addressing this issue demands comprehensive strategies that mitigate losses and enhance agricultural practices' efficiency and sustainability.

In the global context, postharvest losses present a significant challenge affecting food security, economic sustainability, and environmental conservation (Kumar and Kalita, 2017). It is estimated that approximately one-third of all food produced for human consumption is lost or wasted annually, amounting to about 1.3 billion tons of food (Gatto and Chepeliev, 2024). Debebe (2022) highlighted that postharvest losses occur throughout the food supply chain, from production and harvesting to processing, distribution, and consumption. Moreover, Stathers et al. (2020) suggested that postharvest losses in developing countries, particularly in sub-Saharan Africa (SSA), Asia, and Latin America, are a significant challenge due to inadequate infrastructure, poor storage facilities, limited market access, and technological resources. These losses can be reduced through a combination of consumer education, taxation, and public-private partnerships in developed countries, farmer education, improved infrastructure, and better technologies in developing countries (Singh et al., 2023).

Postharvest losses (PHLs) in Africa significantly threaten food security and livelihoods (Bechhoff et al., 2022). Moreover, Thomas and Benjamin (2021) highlighted that these losses are often economic rather than physical and are worsened by inadequate loss assessment methodologies and a lack of holistic approaches to mitigation. This challenge is particularly acute in sub-Saharan Africa, where smallholder farmers form the backbone of agricultural production, yet about 37%, which is 120 – 170 kg/year per capita of postharvest losses are experienced annually (Tamako et al., 2022). Despite their vital role in food production, smallholder farmers often face many challenges that contribute to substantial losses of harvested crops. Among these, the vegetable

sector stands out as a crucial component of agricultural production, providing both sustenance and income for countless families across the continent (Magidi, 2022).

According to Mujuru and Obi (2020) and Sihlobo (2023), South Africa, as a country with diverse agricultural landscapes and a significant portion of its population engaged in farming, it faces similar issues surrounding food insecurity and poverty. Moreover, smallholder farmers in South Africa face many challenges that hinder their productivity, including postharvest losses, worsened by limited access to improved technologies and quality agricultural inputs (Stathers and Mvumi, 2020). Phasha et al. (2020) further highlighted that South Africa experiences about 10 million tonnes of food waste out of 31 million tonnes produced annually. These postharvest losses primarily occur at the farmer-consumer stage of the supply chain. The most common causes of postharvest losses among these farmers include improper handling, poor infrastructure, physical damages, and limited market access.

In the rural regions of South Africa, agriculture serves as the cornerstone of local economies, playing a vital role in providing employment, sustenance, and income for a substantial portion of the population (Hlongwane et al., 2021). Notably, smallholder farmers dominate this agricultural landscape, comprising over 80% of the farming community and relying predominantly on traditional farming methods and constrained resources to cultivate crops (Mathinya et al., 2022). Despite their critical contribution, smallholder farmers grapple with persistent postharvest losses, characterized by the deterioration of harvested crops from harvest to final consumption (Stather and Mvumi, 2020). These losses are staggering, with studies indicating that postharvest losses in South Africa can range from 15% to 50% of total production, depending on the crop and region (FAO, 2019). Furthermore, inadequate storage facilities contribute significantly to these losses, with approximately 30% of smallholder farmers lacking access to proper storage infrastructure (Hlongwane et al., 2021). Moreover, the susceptibility of perishable vegetables to spoilage exacerbates these challenges, resulting in significant wastage of valuable produce.

Efforts to mitigate postharvest losses among smallholder farmers face significant hurdles stemming from a lack of comprehensive understanding of the underlying drivers (Balana et al., 2022). While lack of infrastructure and market access constraints are recognized factors, a notable gap exists in research that prioritizes and ranks these factors based on their impact on postharvest losses. This knowledge gap presents a barrier to developing and implementing effective

interventions to reduce losses and improve smallholder farmers' outcomes. Despite the recognition of various challenges, including those related to infrastructure and market access, limited attention has been paid to the significant role of climate change in exacerbating postharvest losses. Postharvest losses have profound implications for producers, retailers, consumers, and the broader agricultural sector (Binge et al., 2023).

Despite these implications, there has been limited effort to identify the primary drivers of postharvest losses and the handling practices used by smallholder farmers. Moreover, documentation of the lost quantities and the associated income loss quantification are lacking. Understanding these aspects is crucial for developing targeted interventions to reduce food loss and waste in the agricultural sector. Moreover, the study's findings are expected to have significant implications for policy and practice aimed at reducing postharvest losses and improving outcomes for smallholder farmers. By identifying the key drivers of losses and their relative importance, policymakers and practitioners can develop targeted interventions that address farmers' specific challenges within the eThekweni Metropolitan Municipality. These interventions may include investments in infrastructure, improved access to markets, and capacity-building initiatives to enhance postharvest management practices among smallholder farmers.

3.2 Research Methodology

3.2.1 Description of the study area

The study was conducted in eThekweni Municipality in KwaZulu Natal Province. Figure 3.1 shows the map of eThekweni Metropolitan Municipality. The municipality occupies about 2,555 km² of land characterized by hills and ravines. The coordinates for the eThekweni Municipality are approximately 29.8120° S latitude and 30.8039° E longitude. The region experiences an average annual rainfall of about 1000 mm, which supports its agricultural activities. The main types of vegetables farmed in this area include tomatoes, spinach, cabbage, and green peppers. These crops were selected for the study due to their economic importance and prevalence in the region's agricultural practices.

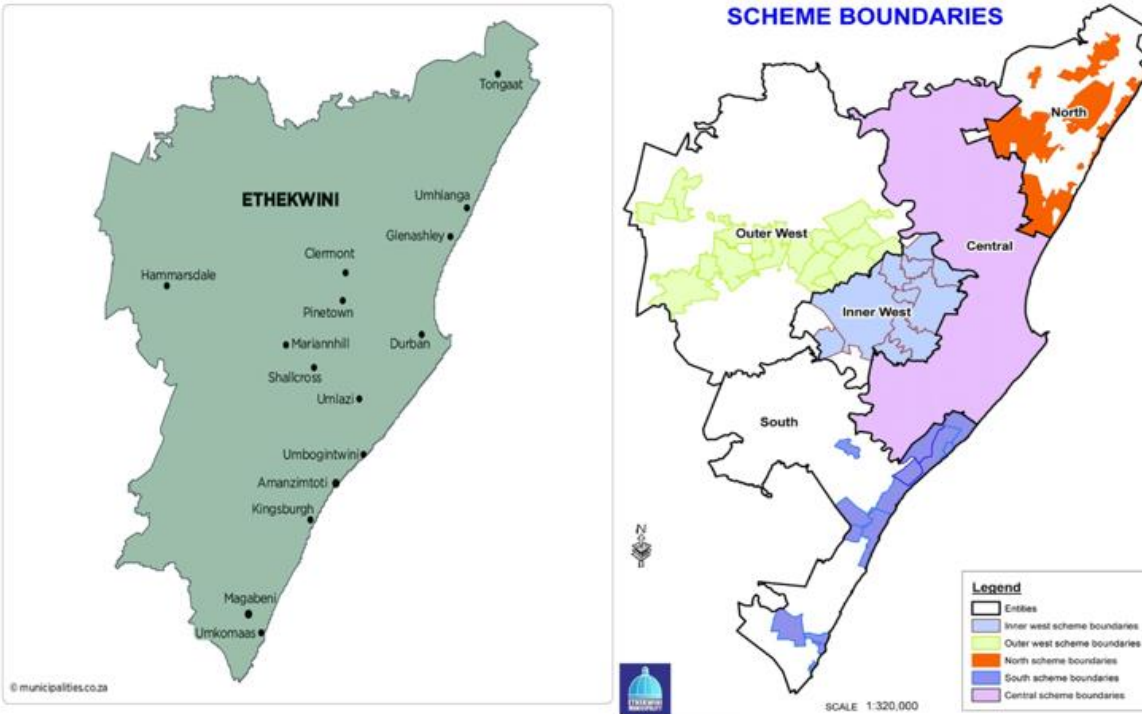


Figure 3.1: Map showing the location of eThekweni Metropolitan Municipality

Source: Cooperative Governance and Traditional Affairs (2020)

The eThekweni Municipality region, characterized by a unique combination of urban and rural landscapes and abundant natural resources, offers promising opportunities for utilizing the agricultural sector as a critical driver for poverty alleviation (Cooperative Governance and Traditional Affairs, 2020). Economic growth and empowerment can be catalyzed by establishing connections between primary, secondary, and tertiary sectors, such as agribusiness and agro-processing. However, challenges identified by Cogta (2020) and the eThekweni Municipality, including economic constraints, insufficient infrastructure, and slow progress in land reform and redistribution, underscore the need to improve government initiatives and agricultural policies. These enhancements are crucial for fostering sustainable farm development and reducing poverty.

Despite the hurdles highlighted by Cogta (2020) and the eThekweni Municipality, KwaZulu-Natal's agricultural sector benefits from favorable natural conditions, such as reliable rainfall and fertile soils, which contribute to its reputation for high productivity and specialized expertise in various farming disciplines. With approximately 6.5 million hectares of farming land, of which 82% is suitable for extensive livestock production, and 18% is designated as arable land, the province holds significant potential for agricultural advancement (KZN DARD, 2019). Agriculture

is prioritized in the Integrated Development Plans of municipalities, offering opportunities for economic development through surplus food and fibre production, job creation, and implementing agricultural programs within the eThekweni Metro, as outlined in the eThekweni Agribusiness Master Plan of 2022. By capitalizing on these strengths and addressing the identified challenges, KwaZulu-Natal can unlock the full potential of its agricultural sector, contributing to broader socioeconomic development and poverty alleviation efforts in the region.

3.2.2 Research Design

This research utilized a mixed approach, deemed most appropriate for exploring relationships among variables to interpret and forecast outcomes and phenomena. Additionally, a cross-sectional research design was employed, enabling data collection at a specific moment, chosen for its cost-effectiveness and time efficiency. Descriptive and inferential analytical techniques were employed to ensure comprehensive findings, complemented by further analysis utilizing an econometric model.

3.2.3 Sampling procedure, frame, and sample size

The study was conducted in eThekweni Municipality, purposefully selected due to its high concentration of smallholder vegetable farmers. This selection aligns with the study's focus on investigating postharvest losses within the vegetable farming sector. The adoption of multi-stratified random sampling was a deliberate choice to ensure the representation of diverse demographics and geographical locations within the municipality. This sampling procedure enables the researchers to effectively capture variations in farming practices, environmental conditions, and socio-economic factors that may influence postharvest losses among smallholder vegetable farmers. By stratifying the population into distinct groups based on relevant criteria such as farm size, location, and farming practices, and then randomly selecting samples from each stratum, the study can yield more robust and generalizable findings. This approach enhances the study's ability to draw meaningful conclusions and inform targeted interventions tailored to the specific needs of different segments of the smallholder vegetable farming community in eThekweni Municipality.

The first stage was the selection of district municipalities, followed by the selection of wards and villages. In the second stage, farmers were stratified according to what they produce, such as

livestock, field, and vegetable crops, and the vegetable farmers' strata were selected. The last stage was the random selection of smallholder vegetable farmers. The study's unit of analysis is smallholder vegetable farmers.

To determine the appropriate sample size for this study, Cochran's formula was used (Krejcie and Morgan, 1970):

$$n_0 = \frac{z^2 pq}{e^2} \dots\dots\dots(3.1)$$

n_0 = Sample size

z = is the selected critical value of desired confidence level (1.96)

p = is the estimated proportion of an attribute that is present in the population,

$q = 1 - p$

e = the desired level of precision

This formula is widely used in social science research to estimate sample sizes for survey studies.

$$n_0 = \frac{(1.96)^2(0.5)(0.5)}{(0.5)^2} = 384$$

Upon completing the data cleaning process, 238 out of 384 questionnaires were processed, meticulously scrutinized, and rectified for any inconsistencies, inaccuracies, or missing values. This rigorous process ensured the dataset's reliability and integrity, a testament to our commitment to providing high-quality research. With the refined dataset and completed questionnaires, the subsequent analysis was conducted, forming the basis for deriving meaningful insights and conclusions. This thorough data-cleaning process is not just a formality but a crucial step in maintaining the quality and accuracy of the research findings, providing a solid foundation for drawing meaningful interpretations from the collected information.

Thus, $n_0 = 238$

3.2.4 Conceptual framework of the drivers of postharvest losses among smallholder vegetable farmers

The conceptual framework in Figure 3.2 demonstrates how factors like farmer knowledge, limited access to markets, limited access to postharvest technologies, and lack of proper storage and facilities affect postharvest losses among smallholder vegetable farmers. Addressing these issues requires targeted training and extension programs to improve farmer knowledge and promote best

postharvest handling practices along the supply chain. Market dynamics also play a crucial role in postharvest losses, mainly due to market volatility and demand fluctuations. Singh et al. (2020) noted that unpredictable market conditions increase losses as farmers struggle to align supply with demand. Pathare et al. (2021) identified market volatility as a critical driver of postharvest losses, with farmers facing challenges securing reliable markets. Ayisi et al. (2020) also highlighted the impact of fluctuating demand on postharvest losses, particularly for perishable vegetables, and suggested that interventions to improve market access, market information systems, and value chain coordination are essential.

The term "technological constraints" refers to the limited access that smallholder farmers have to modern postharvest technologies and preservation techniques, which are crucial for maintaining the quality and freshness of harvested produce. Mishra and Satapathy (2021) emphasized that adopting suitable technologies can significantly reduce postharvest losses. Balana et al. (2022) demonstrated the effectiveness of improved postharvest technologies, such as modified atmospheric packaging, in extending the shelf life of vegetables and reducing losses. However, smallholder farmers often lack access to these technologies due to affordability and availability (Elolu et al., 2023). Mapiye et al. (2023) suggested that addressing technological constraints requires targeted interventions, including capacity-building programs and disseminating affordable technologies tailored to the needs of smallholder farmers.

Another critical factor influencing postharvest losses among smallholder vegetable farmers is the lack of proper infrastructure. Lack of infrastructure represents a significant challenge for smallholder vegetable farmers, particularly in regions with limited resources and underdeveloped agricultural infrastructure. Negi and Trivedi (2021) highlighted that inadequate storage facilities and transportation systems contribute significantly to postharvest losses. Parimia and Chakraborty (2022) agreed that poor storage infrastructure results in substantial losses of perishable vegetables because of spoilage and deterioration during produce transportation to the market. Additionally, Sibanda and Workneh (2020) highlighted the critical role of transportation infrastructure in minimizing postharvest losses by reducing transport times and ensuring proper handling of produce, further suggesting that there is an urgent need for investments in infrastructure to address postharvest losses among smallholder farmers.

Postharvest losses occur at various supply chain stages: harvest, transportation, and market. During harvest, improper techniques, insufficient labour, and harvesting at the wrong maturity stages cause physical damage and spoilage, reducing shelf life and marketability (Rutta, 2022). In the transportation stage, inadequate infrastructure, long transit times, and poor handling practices lead to losses, with the lack of refrigerated trucks and improper packaging exacerbating spoilage risks (Singh, 2020; Mapiye et al., 2023). At the market stage, market volatility, inadequate information, and limited access cause surplus production and wastage (Sibanda & Workneh, 2020). Addressing these challenges requires infrastructure investments, improved logistics, training programs, and enhanced market information systems and value chain coordination.

Furthermore, Cattaneo et al. (2021) indicated that postharvest losses (PHLs) cause economic hardships for farmers and reduce food availability, exacerbating food insecurity and malnutrition in agriculturally dependent regions. PHLs decrease household incomes, perpetuating poverty and hindering welfare improvements (Stathers and Mvumi, 2020). They also cause price fluctuations in food markets, affecting consumers' purchasing power (Mapiye et al., 2023). Furthermore, PHLs worsen environmental degradation and resource scarcity (Stathers and Mvumi, 2020). Addressing PHLs through targeted interventions is crucial for improving economic prosperity, societal well-being, food security, farmer incomes, and sustainable development.

Stathers et al. (2020) further highlighted that postharvest losses compromise the economic viability of farming operations and directly diminish the overall food supply. PHLs represent a significant waste of resources, including labour, water, and land, ultimately reducing the quantity of food available (Balana et al., 2022). Such losses worsen food scarcity, particularly in regions heavily reliant on agriculture for sustenance, ultimately contributing to increased food prices and decreased accessibility for vulnerable populations (Debebe, 2022). Moreover, Magidi (2022) added that postharvest losses perpetuate inefficiencies in the food supply chain, leading to further waste and resource misallocation. Thus, to address postharvest losses, it is important for economic sustainability and to ensure a stable and sufficient food supply to meet the nutritional needs of communities worldwide.

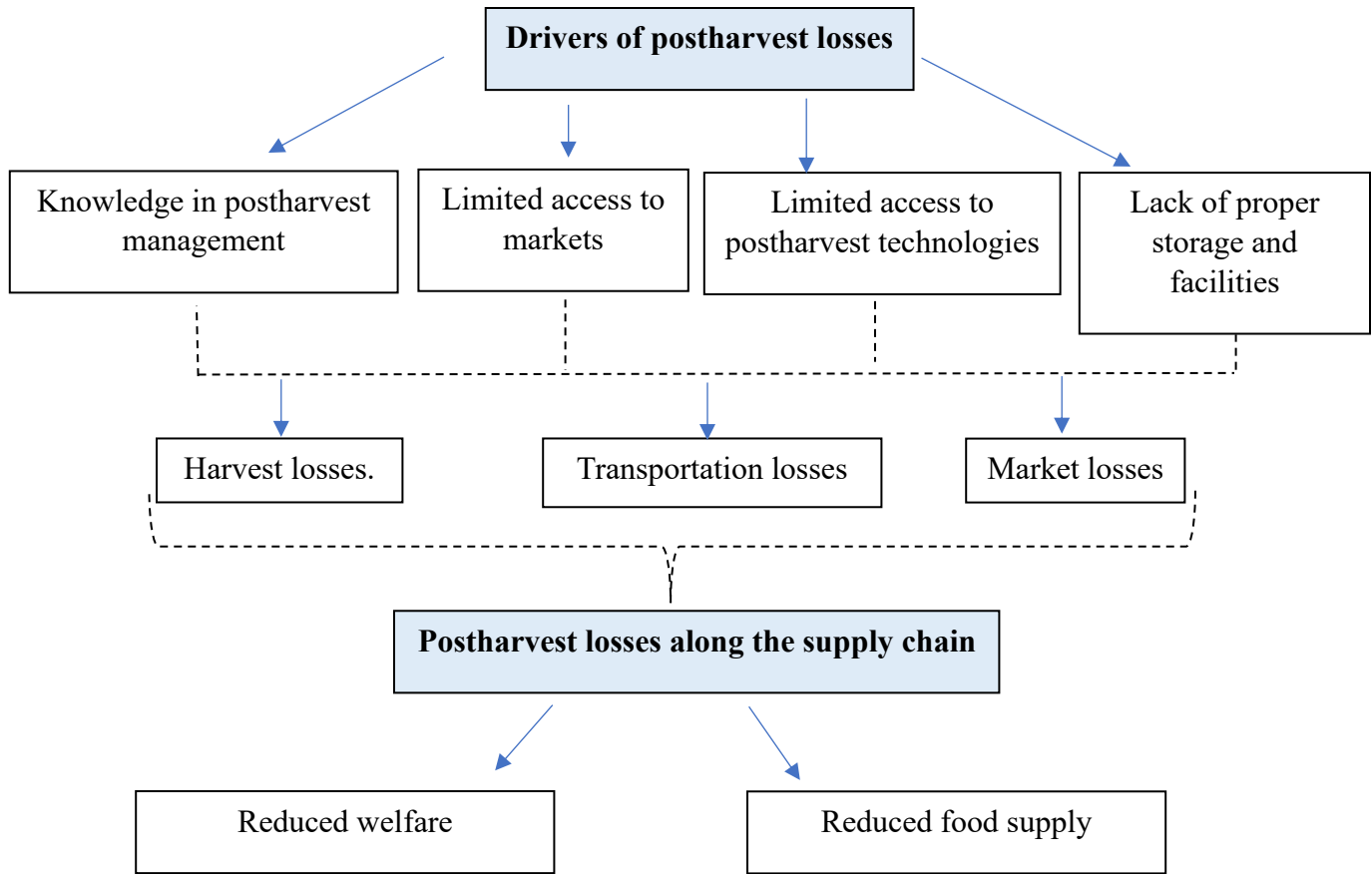


Figure 2.2: Conceptual framework of the drivers of postharvest losses among smallholder vegetable farmers

Source: Figure created by the author (2023)

3.2.5 Data collection

The study utilized primary data collected by five local enumerators proficient in the native language (IsiZulu) of the study area. These enumerators administered a structured questionnaire in English, which was translated into the native language during data collection. Before data collection, enumerators underwent training to ensure a consistent understanding of the questionnaire and accurate translation. The researcher reviewed completed questionnaires for completeness and accuracy. The data encompassed demographic and socioeconomic details of farmers, as well as their perceptions and causes of postharvest losses. Data were collected using a structured questionnaire administered to smallholder vegetable farmers in the eThekweni Municipality. The questionnaire was designed to gather comprehensive information across several key areas relevant to the study's objectives. Specifically, the questionnaire sought to collect the

following information from the farmers: Demographic Information, Farm Characteristics, Postharvest Practices, Economic Data, Market Access, Production Challenges and Knowledge and Training. A pre-test was conducted with 10% of the sample size from the study area to validate questionnaire consistency, reliability, and relevance and to identify any missed variables or translation errors. Adjustments were made to the questionnaire following the pre-test. The study's data collection procedures and instruments received approval from the Human and Social Sciences Research Ethics Committee (HSSREC) of the University of KwaZulu-Natal (Reference No.: HSSREC/00005449/2023).

3.2.6 Data analysis

Descriptive and inferential statistics were employed to address the study's objective. Descriptive statistics involve analyzing data to provide insights into the characteristics of the population, typically through numerical calculations, graphs, tables, and charts. Conversely, inferential statistics allow for inferences and predictions about a population based on a sample of data drawn from that population (Amrhein and Greenland, 2018). Mean and percentages were utilized in this study to simplify the data and provide a clearer understanding of the findings. Descriptive and inferential statistics are well-suited for analyzing this objective due to the quantitative nature of the collected data. Descriptive statistics are handy for summarizing and presenting numerical data, providing insights into the characteristics of the population under study. Meanwhile, inferential statistics are apt for concluding the entire population based on a sample of data, making it suitable for quantitative and qualitative data. In this study, where quantitative data were predominant, descriptive statistics, which offer summaries of the data, and inferential statistics, which allow for inferences about the entire population, were employed to provide a comprehensive analysis. Moreover, to examine the drivers of postharvest loss among smallholder vegetable farmers, the Zero-inflated Poisson (ZIP) model was adopted.

3.2.7 Model specification

To examine the drivers of postharvest loss among smallholder vegetable farmers, the Zero-Inflated Poisson (ZIP) model was adopted. According to Bekalo and Kebede (2021), Zero-Inflated Poisson regression is suitable for modelling count data characterized by excess zero counts. This model is appropriate when the data generation process suggests that the excess zeros are produced by a mechanism different from the count values, allowing for independent modelling of the excess

zeros. This separation is crucial as it aligns with our objective to examine farmers' likelihood of exposure to multiple postharvest loss dimensions.

The dependent variable in our model, Y , represents the count of postharvest loss (PHL) dimensions experienced by vegetable farmers. Given the nature of our data and the focus of our study, the ZIP model was deemed relevant and robust. Additionally, we used standard errors for parameter estimates to control for mild violations of the equidispersion assumption, which states that the variance equals the mean—a common assumption in count data models (Yadav et al., 2021).

$$\ln(\hat{Y}_i) = \ln(\lambda_i) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \dots + \beta_k X_{ki} \quad i = 1, 2, 3, \dots \quad (3.2)$$

where λ_i represents the expected number of occurrences (or the incidence rate ratio—IRR) of the phenomenon under study for a given exposure (i.e., a fixed interval of time in which a particular number of events is registered), β_0 is the intercept, the coefficients estimated for each predictor variable X_j are represented by β_j , and i represents each observation in the sample. This approach allows us to effectively capture and model the distribution and drivers of postharvest loss among smallholder vegetable farmers, providing a comprehensive understanding of the factors influencing these losses.

Table 3.1 outlines the variables, their descriptions, and the units of measurement. It is essential to comprehend the factors included in our study and the metrics by which they are evaluated. It also serves as a reference point for interpreting the statistical analyses presented in subsequent sections of this study.

Table 3.1: The description of the variables and their units of measurement.

	Variable	Description	Type	Unit
1	Age	Age of the participant	Numerical	Years
2	Years in School	Total years of formal education completed	Numerical	Years
3	Household Size	Number of individuals living in the same household	Numerical	Members
4	Total Income	Average monthly income of the household	Numerical	ZAR
5	Gender	Gender of the participant (Male/Female)	Categorical	-
6	Marital Status	Current marital status of the participant (Single/Married/Widowed/Divorced)	Categorical	-
7	Land Tenure	Type of land ownership or use (Private/Lease/Communal)	Categorical	-
8	Transport	Access to transport for market or inputs	Categorical	Binary
9	Storage	Availability of storage facilities	Categorical	Binary
10	Pest and Diseases	Presence of pest and disease management	Categorical	Binary
11	Distance to Market	Distance from the farm to the nearest market	Numerical	Kilometres
12	Weather Condition	Impact of weather conditions on farming activities	Categorical	Binary
13	Farm Experience	Number of years of experience in farming	Numerical	Years
14	Extension Service	Access to agricultural extension services	Categorical	Binary
15	Labour	Availability of labour for farming operations	Categorical	Binary
16	Employment Status	Current employment status of the household head (Employed/Unemployed/Other)	Categorical	-
17	Income source	The main source of income for the household	Categorical	-

Source: Table created by the author (2024)

3.3 Results and Discussion

3.3.1 Demographic and socioeconomic characteristics of smallholder farmers

Understanding smallholder vegetable farmers' demographic and socioeconomic characteristics is crucial for tailoring agricultural policies and interventions that effectively address the unique needs and challenges. In the eThekweni Municipality, the diverse backgrounds of these farmers influence

their farming practices, access to resources, and, ultimately, their productivity and sustainability. The following table, Table 3.2, illustrates a detailed breakdown of these characteristics. By examining variables such as age, education, household size, and income, we gain valuable insights into the factors that shape the agricultural landscape in this region.

Table 3.2: Smallholder farmers' demographic and socioeconomic characteristics in eThekweni Municipality.

	Continuous variables	Mean (n = 238)	Unit
1	Age	45	Years
2	Years in school	12	Years
3	Household size	6	Members
4	Total income	8,568.37	ZAR
5	Farm Experience	5	Years
6	Distance to the market	6.18	Kilometers
	Categorical Variables	Frequency	Percentage (%)
7	Gender		
	Male	104	43.7
	Female	134	56.3
8	Marital Status		
	Single	184	77.31
	Married	45	18.91
	Widowed	7	2.94
	Divorced	2	0.84
9	Employment Status		
	Unemployed	180	75.63
	Employed	41	17.23
	Pension	13	5.46
	Other	4	1.68
10	Income source		
	Farming	186	78.15
	Salary	21	8.82
	Pension	16	6.72
	Grant	9	3.78
	Remittance	2	0.84
	Other	4	1.68
11	Land Tenure		
	Private	98	41.18
	lease	15	6.30
	Communal	63	26.47
	other	62	26.05
12	Access to transport	24	10.13
13	Access to storage	43	18.14
14	Affected by Pests and Diseases	169	71.31

15	Affected by weather conditions	167	70.46
16	Access to extension service	194	81.86
17	Access to Labour	19	8.02

Source: Results from the survey (2023)

Kansanga et al. (2021) highlighted the significance of analyzing demographic and socioeconomic characteristics to develop targeted, effective, and equitable strategies for sustainable agricultural development. Furthermore, Magidi et al. (2021) underscored the importance of understanding smallholder vegetable farmers' demographic and socioeconomic profiles to ensure that interventions are contextually appropriate, inclusive, and capable of addressing the unique challenges different groups face within the smallholder farming community.

The study reveals a detailed demographic overview of smallholder vegetable farmers in the eThekweni Municipality, highlighting crucial findings that require further examination and contextualization. The average age of 45 years among farmers presents an intriguing departure from previous studies by Zantsi (2019) and Nxumalo (2013), which reported an older average age for smallholder farmers in South Africa. Conversely, the slightly younger average age reported by Nkonki-Mandleni et al. (2022) for smallholder farmers in KwaZulu-Natal signals ongoing productivity and receptiveness to innovation within the sector. This is because younger individuals often exhibit a greater propensity for adopting new technologies and practices, which can contribute to increased efficiency and innovation within agricultural operations.

However, the revelation of an average of 12 years of formal education among farmers, equivalent to completing secondary school in South Africa, underscores the challenges posed by relatively low education levels in adopting new agricultural practices, such as climate-smart agriculture. Moreover, the average household composition of 6 members highlights the significant workforce within these households, necessitating strategic resource management strategies. However, the monthly earnings averaging around ZAR8,568.37 expose income disparities within the smallholder farming community, warranting closer examination and targeted interventions to enhance income stability, as advocated by Hlophe-Ginindza and Mpandeli (2020) and Giller et al. (2021).

An average farm experience of 5 years among smallholder farmers highlights a critical phase in their farming where they transition from novice to more experienced farmers. This experience

level suggests a moderate understanding of agricultural practices yet may not encompass extensive knowledge of advanced postharvest techniques that significantly reduce losses (Sibanda and Workneh, 2020). As farmers with this experience are still refining their skills, particularly in crop handling, storage, and transportation, they represent a key demographic for targeted interventions. Extension services and training programs tailored to this group can effectively bridge the gap by introducing innovative practices and technologies that minimize postharvest losses, thus improving overall crop yield and profitability (Balana et al., 2021).

The average distance of 6.18 kilometres to the market for farmers indicates a potentially significant impact on postharvest losses (Debebe, 2022). Shorter distances can lead to reduced transportation time, which is crucial for maintaining the freshness of vegetables and minimizing physical damage during transit (Stathers and Mvumi, 2020). Moreover, proximity to markets allows for quicker response times to market demands and can reduce the need for long-term storage, often associated with higher loss rates (Maziya, 2020). Thus, understanding and optimizing market access routes could be a strategic intervention point to mitigate postharvest losses effectively.

Notably, the predominance of women, constituting 56% of smallholder farmers, underscores their pivotal role in the sector. However, findings by Maziya (2020) emphasized the vulnerability of female-headed households to poverty and food insecurity, particularly in rural areas. This vulnerability is attributed to several factors, including limited access to land, resources, and financial services, as well as social and economic constraints that disproportionately affect women. The results highlight that female-headed households often have smaller landholdings and face greater challenges in obtaining credit and agricultural inputs. These challenges necessitate targeted interventions to address gender disparities in food security and support female smallholder farmers effectively.

Additionally, the distribution of marital status, with 77% of vegetable farmers reported as unmarried, raises questions about the vulnerabilities within this demographic and emphasizes the need for tailored support initiatives. This is particularly pertinent given indications by Hlatshwayo (2021) that marital status can impact market participation among smallholder vegetable farmers. Moreover, the revelation that 76% of farmers are unemployed, with 78% primarily dependent on farming for income, highlights the significant reliance on agriculture for livelihoods. However,

this dependence underscores the vulnerability of smallholder vegetable farming systems to various challenges, including low market demand, adverse climate conditions, and postharvest losses, all of which threaten the profitability of vegetable production.

Land tenure shows a diverse distribution, with 41.18% of farmers owning private land, 6.30% on lease, 26.47% using communal lands, and 26.05% categorized under other tenure arrangements. Access to essential resources plays a critical role, as only 10.13% have adequate transport, and 18.14% have proper storage facilities, which are crucial for reducing losses after harvest. Most of these farmers face biological and environmental challenges; 71.31% are affected by pests and diseases, and 70.46% are impacted by weather conditions, which can drastically increase postharvest losses. Despite these challenges, a high percentage (81.86%) have access to extension services, providing them with vital information and techniques to mitigate losses. However, access to labour remains a critical issue, with only 8.02% reporting adequate labour availability, reflecting the labour-intensive nature of postharvest activities and the importance of labour availability in managing these tasks effectively.

3.3.2 Drivers of Postharvest Losses among Smallholder Vegetable Farmers

(i) Estimating postharvest losses

Table 3.3 presents the mean and the variance of the Postharvest loss. A zero-inflated Poisson (ZIP) model was employed to identify the factors influencing the likelihood of encountering various dimensions of postharvest losses (PHL) among smallholder vegetable farmers in the eThekweni municipality. The zero-inflated Poisson (ZIP) model was selected for this study due to the substantial number of zero counts in the postharvest loss data, a common occurrence in agricultural studies where many farmers may report no losses during certain periods. This model allows for a dual process that models both the excess zeros and the count nature of the data, providing a more accurate representation of the distribution of postharvest losses among smallholder vegetable farmers (Onyango et al., 2023). Although the ZIP model is an extension of the Poisson model, it accommodates overdispersion and excess zeros, relaxing the strict assumption of equal mean and variance typically required by the Poisson distribution.

In this study, the assumption of equal mean and variance may not hold true due to the heterogeneity in farming practices and environmental factors affecting postharvest losses. To ensure the validity

of this modelling approach, thorough diagnostic checks were conducted, including goodness-of-fit tests and examined residual plots. These diagnostic procedures confirmed that the ZIP model adequately captured the distribution of postharvest loss data compared to alternative models like the negative binomial. Furthermore, sensitivity analyses were performed to assess the impact of model assumptions on the findings. The significant factors influencing the likelihood and magnitude of postharvest losses among smallholder vegetable farmers more accurately were identified using the ZIP model. This approach enhances the robustness of our statistical inferences and provides valuable insights into the specific dimensions of postharvest losses that can inform targeted interventions and policies.

Table 3.3: The mean and the variance of the postharvest losses among smallholder vegetable farmers in eThekweni Municipality

Variable	Mean	Variance	Difference Factor
Postharvest Losses _{total}	0.609	0.234	61%
Postharvest Losses _{Non-zeros}	0.391	0.151	39%

Source: Results from the survey (2023)

The analysis of postharvest losses using a Zero-Inflated Poisson (ZIP) model reveals significant insights into the distribution and variability of losses among smallholder vegetable farmers. With a mean of 0.609 and a variance of 0.234, the total postharvest losses demonstrate a moderate level of variability, with the difference factor revealing that 61% of the mean is attributed to the variance. Similarly, for non-zero postharvest losses, characterized by a mean of 0.391 and a variance of 0.151, there appears to be relatively lower variability, with a difference factor of 39%. These findings underscore the presence of excess zeros in the data, aligning with studies by Onyango et al. (2023), which applied ZIP models to similar agricultural contexts, thereby emphasizing the importance of understanding both the factors contributing to excess zeros and the determinants of variability in non-zero losses. Table 3.3 illustrates the distribution of postharvest losses, depicting the excess zeros and the variability around the mean. This analysis emphasizes the need for targeted interventions to effectively address postharvest losses, considering both the excess zeros and the variability in losses among smallholder vegetable farmers.

(ii) Postharvest Scores

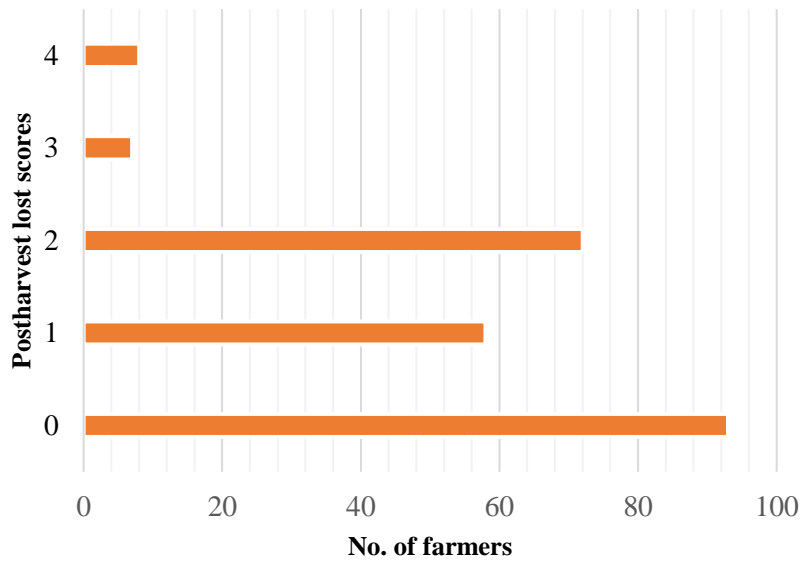


Figure 3.3: The Postharvest loss scores of smallholder vegetable farmers in eThekweni Municipality.

Source: Survey results (2023)

The ZIP model is particularly suitable for count data with excess zeros, such as postharvest loss scores, where more zeros are observed than expected under a standard Poisson distribution. Figure 3.3 illustrates the frequency distribution of postharvest loss scores among smallholder vegetable farmers in this case. The excess zeros are represented by the 93 farmers reporting zero postharvest losses. These excess zeros can arise from various factors such as measurement errors, structural zeros, or true excess zeros. For the non-zero counts, the distribution shows a decreasing frequency as the postharvest loss score increases, with 58 farmers reporting a score of 1, 72 farmers reporting a score of 2, 7 farmers reporting a score of 3, and 8 farmers reporting a score of 4. This pattern suggests that while many farmers experience minimal postharvest losses, a smaller but still notable proportion faces higher levels of losses. When fitting a ZIP model to this data, the excess zeros would be modelled separately from the non-zero counts. The ZIP model allows for separate estimation of the zero-inflation component, which captures the excess zeros, and the Poisson component, which models the count data. The data provided would be used to estimate the parameters of both components, allowing for a comprehensive understanding of the factors influencing postharvest loss scores among smallholder vegetable farmers.

(iii) Zero-Inflated Poisson (ZIP) model estimating the drivers of postharvest losses among smallholder vegetable farmers

Table 3.4 shows the Zero-Inflated Poisson (ZIP) model estimating the drivers of postharvest losses among smallholder vegetable farmers in eThekweni Municipality. Utilizing a Zero-Inflated Poisson (ZIP) model in analyzing a dataset comprising 238 observations, with 145 instances of non-zero counts and 93 cases of zero counts, yielded notable findings. The likelihood ratio chi-square value, recorded at 24268.71 with 17 degrees of freedom, signifies a significant fit of the model to the data, underpinned by a log-likelihood of -759.6069. This underscores the model's capability to explain the observed data sufficiently. Moreover, the negligible probability (0.0000) associated with the chi-square value solidifies the statistical significance of the model, affirming its superiority over a model devoid of predictors. The selection of the ZIP model stems from its adeptness in handling datasets characterized by excessive zeros, a prevalent challenge in count data analysis.

By simultaneously addressing excess zeros and overdispersion, inherent complexities are effectively navigated. Notably, the ZIP model segregates the zero-inflation component, capturing excess zeros, and the Poisson component, which models count data. This approach provides nuanced insights into the determinants of postharvest losses among smallholder vegetable farmers, surpassing the limitations of conventional Poisson regression models. Furthermore, integrating discussions on the rationale behind employing ZIP models and Odds Ratio (OR) analysis would enhance the analytical depth. ZIP models offer a robust framework for handling excess zeros, while OR analysis supplements by elucidating the relative effects of predictors on the count outcome variable. Studies showcasing the efficacy of ZIP models and OR analysis in similar contexts provide valuable support for the chosen analytical strategy, reinforcing its applicability and relevance in this study.

Table 3.4: The ZIP model estimates postharvest loss drivers among smallholder vegetable farmers in eThekweni Municipality.

	ZIP Model		Incident rate ratio (IRR/OR) for Postharvest losses	
Count components				
Variable	Coefficient	Robust SE	Coefficient	SE
Years in school	-0.056**	0.028	0.069**	0.029
Household size	0.088**	0.027	0.117**	0.036
Total income	0.209	0.068	0.256	0.082
Gender Male	0.154	0.045	0.185	0.053
Gender Female	0.125	0.038	0.149	0.048
Marital Status				
Single	0.077	0.025	0.107	0.032
Married	0.129	0.037	0.156	0.043
Widowed	0.056	0.021	0.084	0.028
Divorced	0.086	0.029	0.117	0.036
Land tenure				
Private	0.208	0.058	0.245	0.066
Lease	0.158	0.043	0.186	0.051
Communal	0.129	0.036	0.158	0.042
Logit component				
Age	0.125**	0.010	0.147**	0.018
Farm Experience	- 0.157**	0.029	- 0.205	0.063
Extension Service	- 0.290***	0.039	- 0.169	0.049
Labour	- 0.575	0.056	- 0.127	0.043
Number of observed = 238				
Nonzero observed = 145				
Zero observed = 93				
LR chi2(17) = 24268.71				
Log likelihood = -759.61				
Prob > chi2 = 0.0000				

Note ** 5% significance level and *** 1% significance level

Source: Results from the survey, Regression ran by STATA 18 (2023)

The findings show that age has a positive coefficient and is significant at a 5% level, implying a positive relationship between age and incident rate ratio for postharvest losses. This suggests that for every one-year increase in age, there is an estimated 4% increase in the incidence of postharvest

losses. The study aligns with the findings of Bisheko and Rejikumar (2023), suggesting that older farmers are more traditional in their farming practices, which could potentially lead to higher rates of postharvest losses due to outdated storage or handling methods. Moreover, Sibanda and Workneh (2020) agreed that as individuals age, they may face challenges related to physical capabilities or access to technology that could effectively affect their ability to mitigate postharvest losses.

Furthermore, the study shows a negative relationship between years in school and the likelihood of IRR of postharvest losses at a 5% significance level. This implies an estimated 5.6% decrease in the IRR of postharvest losses for each additional year of schooling after accounting for zero inflation. This suggests that higher levels of education may correlate with lower incident rates of postharvest losses. These findings corroborate those of Balana et al. (2022), who reported a strong link between higher levels of education and better mitigation practices or strategies for postharvest losses. This could include improved knowledge of agricultural techniques, better utilization of storage and handling technologies, or enhanced decision-making skills in managing postharvest processes. Moreover, Debebe (2021) argues that even though higher education levels may generally correlate with better postharvest management practices, other underlying factors may vary depending on the specific agricultural setting, socioeconomic conditions, or cultural factors.

Household size was found to have a positive coefficient and statistically significant at 5%. This implies that for each additional member in a household, there is an estimated 8% increase in the expected count of postharvest losses after accounting for zero inflation. This suggests that larger household sizes are associated with higher postharvest losses. Tsatsi et al. (2021) supported that households with more members face challenges related to postharvest management, such as increased food handling and storage requirements, which leads to a higher likelihood of postharvest losses. Additionally, larger households have greater food consumption needs, potentially resulting in more significant quantities of produce being susceptible to spoilage or waste (Aryal et al., 2022). Thus, it is critical to implement education and training programs aimed at improving postharvest management practices specifically tailored to larger households.

The study further revealed a negative relationship between the farm experience and the IRR of postharvest losses. A negative coefficient indicates this relationship at a 5% significance level.

This suggests that for each additional year of farm experience, there is an estimated decrease of 5.7% in postharvest losses after accounting for zero inflation. Stathers et al. (2020) agreed that more experienced farmers experience lower postharvest losses than less experienced farmers. This may be attributed to better knowledge of agricultural practices, improved decision-making skills, and more effective management of postharvest processes. Moreover, experienced farmers typically possess a better understanding of farming practices gained through years of hands-on experience and exposure to different situations. Their accumulated knowledge and practical insights enable them to make more effective decisions, minimizing losses.

Extension service was found to be statistically significant at a 1% level while it has a negative coefficient, which suggests a negative relationship exists between the extension service and the IRR of the postharvest losses. This implies that the availability of extension services results in an estimated decrease of 9% in the expected count of postharvest losses after accounting for zero inflation. The results align with the findings of Mapiye et al. (2021), which suggested that extension services play a crucial role in improving farmers' knowledge and skills related to postharvest management practices, including harvesting techniques, storage methods, pest control, and quality preservation. Furthermore, Kassem et al. (2021) added that by enhancing farmers' capacity to implement effective postharvest strategies, extension services reduce losses and improve overall agricultural productivity and food security.

Storage was statistically significant at a 5% level, showing a negative coefficient indicating the negative relationship with the IRR of postharvest losses. This suggests that improvement in storage facilities results in an estimated decrease of 12.8% in the expected count of postharvest losses after accounting for zero inflation. Effective storage methods can help maintain the quality and freshness of harvested produce, preventing spoilage, damage, or waste. Improved storage facilities, such as cold storage units, hermetic bags, or proper packaging materials, can extend the shelf life of perishable crops and minimize losses due to environmental factors (Onwude et al., 2020). Rutta (2022) further emphasized the importance of investing in appropriate storage infrastructure and promoting the best postharvest handling and storage practices.

Distance to the market shows a positive coefficient and is statistically significant at a 1% level. This implies that an additional kilometre distance to the market results in an estimated increase of

32% in the expected count (IRR) of postharvest losses after accounting for zero inflation. These findings suggest that longer transportation times and distances can increase the likelihood of spoilage, damage, or deterioration of harvested produce, especially for perishable crops. The findings align with the study by Giri (2023), which highlighted that perishable crops are particularly vulnerable to postharvest losses during transportation due to their delicate nature and limited shelf life. Investing in efficient transportation networks, cold chain facilities, and market integration initiatives can help reduce transportation times and distances, minimize postharvest losses, and improve market access for smallholder farmers (Rutta, 2022).

3.4 Conclusion and Recommendations

This study revealed several significant relationships between various factors and the incident rate ratio (IRR) of postharvest losses among smallholder vegetable farmers in eThekweni Municipality. Firstly, age demonstrates a positive correlation with postharvest losses, indicating a 4% increase in losses for every one-year increase in age, attributed to potentially outdated farming practices among older farmers. Conversely, years in school exhibit a negative correlation, with each additional year in school associated with a 5.6% decrease in losses, suggesting that higher education levels may lead to better postharvest management practices. Moreover, household size is positively related to postharvest losses, with larger households facing increased challenges in managing food handling and storage requirements. On the other hand, farm experience demonstrates a negative correlation, as more experienced farmers tend to experience lower losses due to better agricultural practices and decision-making skills. Additionally, the availability of extension services is associated with decreased losses, underscoring the importance of knowledge transfer and capacity-building initiatives. Labour and improved storage facilities also reduce losses, emphasizing the significance of efficient harvesting practices and appropriate storage infrastructure. However, distance to the market and adverse weather conditions exhibit positive correlations with losses, indicating the challenges posed by longer transportation times and unfavourable climatic conditions on harvested produce's quality and shelf life. These findings underscore the multifaceted nature of postharvest losses and the importance of targeted interventions, such as education and training programs, access to extension services, and investments in storage infrastructure and transportation networks, to mitigate losses and enhance food security among smallholder vegetable farmers.

The study, therefore, recommends:

- **Targeted Training for Older Farmers:** Given the positive relationship between age and postharvest losses, it is essential to provide training programs tailored specifically for older farmers. These programs should focus on modern storage and handling techniques to help them transition from traditional practices that may contribute to higher losses.
- **Promote Education in Agriculture:** The negative correlation between school years and postharvest losses suggests that higher educational levels are associated with better postharvest management practices. Therefore, promoting educational opportunities for farmers, including adult education and agricultural training programs, can help reduce losses.
- **Support for Larger Households:** Larger household sizes are linked to increased postharvest losses. Implementing education and training programs focusing on efficient postharvest management practices for larger households can help mitigate these losses. These programs should address larger households' specific challenges, such as increased food handling and storage needs.
- **Enhance Extension Services:** The significant negative relationship between extension services and postharvest losses highlights the importance of these services in educating farmers about effective postharvest practices. Expanding and improving extension services can provide farmers with the necessary knowledge and skills to reduce postharvest losses, ultimately enhancing agricultural productivity and food security.
- **Invest in Storage Infrastructure:** Improving storage facilities significantly reduces postharvest losses. Investments in appropriate storage infrastructure, such as cold storage units, hermetic bags, and proper packaging materials, can help maintain the quality and freshness of harvested produce, extending its shelf life and minimizing losses due to environmental factors.
- **Improve Transportation Networks:** The positive relationship between distance to the market and postharvest losses suggests that longer transportation times increase the likelihood of spoilage and damage. Investing in efficient transportation networks and cold chain facilities can reduce transportation times and distances, minimizing postharvest losses and improving market access for smallholder farmers.

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CHAPTER 4

Perceptions and Determinants of Severity of Postharvest Losses Among Smallholder Vegetable Farmers in eThekweni Municipality: An Ordered Probit Analysis

Abstract

Smallholder farmers are crucial to many developing countries' economic and rural development. In South Africa, agriculture significantly contributes to the economy's gross domestic product (GDP). However, smallholder farmers face significant challenges, particularly postharvest losses, which impact their profitability and sustainability. This study uses an ordered probit analysis to examine the perceptions and determinants of the severity of postharvest losses among smallholder vegetable farmers in eThekweni Municipality. Data was collected from 238 farmers through structured questionnaires. The analysis revealed that older farmers and those with larger household sizes experience more severe postharvest losses. In contrast, higher education levels, greater farm experience, and access to extension services are associated with reduced severity of losses. Specifically, an increase in household size decreases postharvest loss severity during harvesting but increases it at the market stage. Each additional year of schooling decreases loss severity during harvesting but increases it at the market stage. An increase in the distance from the market decreases loss severity during harvesting but increases it during transportation and at the market stage. Extension services significantly reduce loss severity during both harvesting and market stages. These findings highlight the need for targeted interventions, such as enhancing educational opportunities, improving storage infrastructure, and developing better market access to mitigate the severity of postharvest losses. The study recommends collaboration between agricultural extension services and local communities to promote sustainable practices and reduce postharvest loss severity.

Keywords: Smallholder farmers, postharvest losses, perceptions, Likert scale, ordered probit model

4.1 Introduction

Smallholder farmers usually produce small quantities in a limited land area to generate income for their households and livelihoods (Ruwanza et al., 2022). Moreover, smallholder farmers contribute substantially to many developing countries' gross domestic product (GDP) (Khoza et al., 2019). However, smallholder farmers are still experiencing challenges that hinder their progress in their farming operations. Postharvest losses are a major global challenge affecting farmers (Hlatshwayo et al., 2021). Giller et al. (2021) highlighted that smallholder farmers are often neglected; poor infrastructure and limited resources farmers usually characterize them. Consequently, smallholder farmers lose much produce during their harvesting practices due to poor harvesting techniques. Rusere et al. (2019) indicated that postharvest losses hinder smallholder farmers' participation in the vegetable supply chain.

Globally, about 2.5 billion tons of food waste has been experienced during postharvest losses, while Sub-Saharan Africa lost about 37%, which is 120 – 170 kg/year per capita (Chirsanova and Calcatiniuc, 2021). Furthermore, over 10 million tons of food waste are lost in South Africa due to poor postharvest handling and value-addition techniques (Melembe et al., 2020). Cheron and Workneh (2018) suggested that postharvest loss is expected for smallholder farmers as they do not have adequate resources for value addition and are not capacitated on good postharvest practices. Debebe (2022) agreed that the primary cause of postharvest losses among smallholder farmers is primarily attributed to deficiencies in handling techniques stemming from ineffective management practices, insufficient infrastructure and equipment, and restricted market access.

Smallholder farmers' perceptions revolve around factors such as inadequate storage, transportation difficulties, market conditions, and susceptibility to adverse weather, with limited access to markets and infrastructure exacerbating the issue (Fanadzo et al., 2021). Bisheko and Rejikumar (2023) added that socioeconomic constraints, particularly financial limitations, hinder smallholder farmers from adopting modern postharvest technologies. Despite these challenges, there is an emerging recognition that education and training programs can empower farmers with the knowledge to mitigate postharvest losses. Understanding smallholder farmers' perspectives on postharvest losses is crucial for developing tailored interventions that address their specific challenges and promote sustainable agricultural practices.

Moreover, determinants of postharvest losses are multifaceted and encompass a range of factors, such as inadequate storage facilities, transportation challenges, poor infrastructure, and market conditions (Magalhaes et al., 2021). Sibanda and Workneh (2020) highlighted that adverse weather conditions, including temperature and humidity fluctuations, can contribute significantly to postharvest losses. Additionally, socio-economic factors such as limited access to markets, financial constraints, and the lack of knowledge regarding proper postharvest handling practices play a pivotal role (Beharielal et al., 2022). Thus, this study focuses on understanding smallholder farmers' demographic and socio-economic characteristics in the eThekweni Municipality and their perceptions of postharvest losses and their determinants.

4.2 Conceptual framework of a Systems Approach to Postharvest Management by smallholder farmers.

Postharvest management refers to the process or practices of handling produce after harvesting to maintain its quality until consumption. Stathers et al. (2020) highlighted postharvest management, which includes sorting, cleaning, packaging, storage, and transportation, all aimed at preserving the value of harvested crops and minimizing losses. However, postharvest handling poses various challenges, including the risk of spoilage due to microbial growth, enzymatic reactions, and physical damage (Florkowski et al., 2021). Sibanda and Workneh (2020) stated that quality deterioration during storage and transportation and concerns about food safety and hygiene further compound these challenges, leading to significant economic losses and food waste.

A systems approach is essential for addressing the complexity of postharvest management, which involves multiple interconnected stages and factors. By considering the entire supply chain from the farm to the table as an integrated system, stakeholders can better understand the interactions between different components and develop more effective strategies for managing postharvest activities (Florkowski et al., 2021). Adopting a systems approach to postharvest management includes ensuring product quality and safety, minimizing losses and waste, enhancing market access and competitiveness, and promoting environmental sustainability. Ali et al. (2021) suggested that by pursuing these objectives, stakeholders can optimize resource utilization and improve the overall efficiency of agricultural value chains.

The literature emphasizes the importance of quality and safety assurance in postharvest management. By implementing integrated strategies and technologies, stakeholders can mitigate

risks related to spoilage, contamination, and foodborne illnesses, thus safeguarding public health and market integrity (Barreiro-Hurlé et al., 2014). By meeting quality standards, ensuring traceability, and adopting innovative postharvest practices, producers can access higher-value markets and command premium prices for their products (Gómez-López et al., 2020). Advances in packaging, storage facilities, cold chain logistics, and monitoring systems are crucial in improving product quality, extending shelf life, and reducing postharvest losses (Kader, 2005).

The systems approach to postharvest management encompasses various vital components, including system thinking, supply chain perspective, multi-disciplinary approach, quality and safety assurance, technological innovation, environmental sustainability, market access and value addition, and capacity building and knowledge sharing. Implementing a systems approach offers numerous benefits, including increased efficiency in postharvest handling processes, reduced food losses and waste, enhanced product quality and safety, improved market access and competitiveness, and greater resilience to environmental and economic challenges. By adopting this approach, stakeholders can achieve more sustainable and profitable outcomes in the agricultural sector.

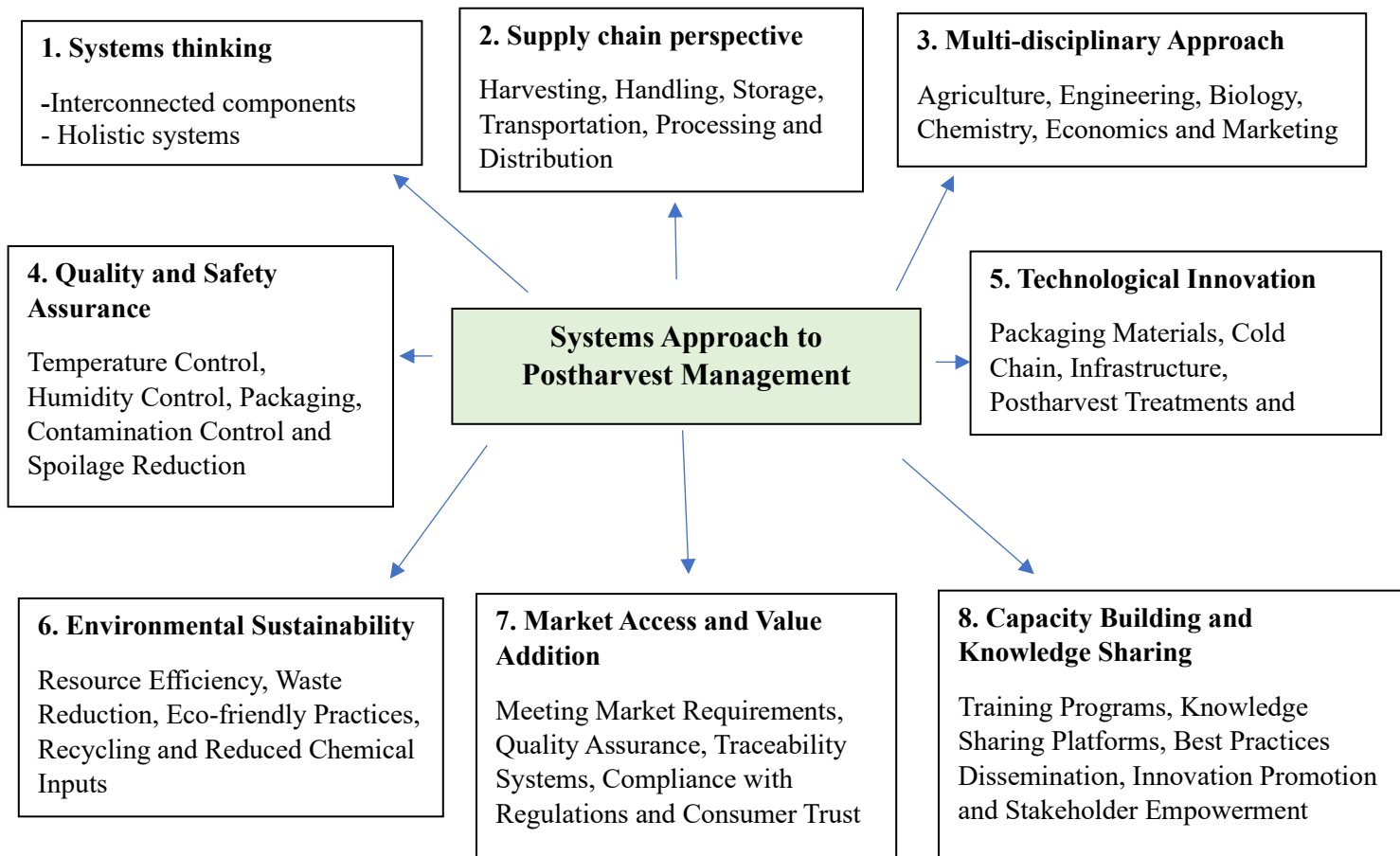


Figure 4.1: Conceptual Framework of a Systems Approach to Postharvest Management

4.3 Research Methodology

The research methodology, including study area, research design, sampling procedure, sample size and data collection, is discussed in detail in Chapter 3.

4.3.1 Data Analysis

The study utilized the Likert scale to determine smallholder farmers' perceptions of postharvest losses. Developed by sociologist Rensis Likert in 1932, the Likert scale is a scientifically accepted and validated method for quantifying psychological approaches, particularly attitudes. Questionnaires commonly employ it to assess participants' preferences by measuring the degree of agreement or disagreement with a set of statements. The Likert scale assumes a linear relationship between the strength or intensity of an attitude and the response options, typically ranging from strongly disagree to agree strongly. Moreover, the ordered probit model was

employed to assess the factors influencing postharvest losses among smallholder farmers in eThekweni Municipality, KwaZulu-Natal province, South Africa.

4.3.2 Model Specification

The ordered probit model was employed to assess the factors influencing postharvest losses. The Ordered Probit Model is a statistical tool for analyzing ordered categorical data, where the response variable exhibits a natural ordering but may not possess equal intervals between categories. Other studies employing the ordered probit model include the investigation conducted by Das and Ahmed (2023) on the evaluation of postharvest losses among banana growers in North East India. Additionally, Dooga et al. (2021) utilized the ordered probit model to assess determinants of postharvest losses among orange farmers. Furthermore, Abubakar et al. (2023) employed the ordered probit model in their study, examining farmers' choices regarding postharvest management practices and their implications for food security.

The Ordered Probit Model offers several advantages for analyzing ordinal response variables. Firstly, it accounts for the ordinal nature of the response variable, allowing for the estimation of the relationship between predictor variables and the ordered categories of the response variable. Secondly, it provides estimates of the probability that the response variable falls into each category, thereby offering insights into the likelihood of different outcomes. Thirdly, the model allows for the inclusion of continuous and categorical predictor variables, making it flexible for analyzing complex datasets. In the context of the study on postharvest losses among smallholder farmers, the ordered probit model was well-suited because it allowed for the estimation of factors influencing the severity of postharvest losses while accounting for the ordinal nature of the response variable (e.g., low, moderate, high losses).

The Ordered Probit Model is widely used in empirical econometric applications to estimate the determinants, and it can be described as follows: Following Wooldridge (2019), let the ordinal dependent variable y take the values $\{0, 1, 2, \dots, J\}$ for some known integer J . The variable y can be derived (conditional on explanatory variable x) from a latent continuous variable y^* (unobservable), which can be determined as follows:

$$y_i^* = x_i' \beta + U_i \dots\dots\dots(4.1)$$

where U_i is normally distributed with mean zero and variance one, β is a vector of unknown parameters to be estimated, and x is a matrix of independent variables, including households' socio-economic characteristics and existing postharvest handling practices used in each stage of the value chains. Following recent literature (Kaminski and Christiaensen 2014; Hengsdijk and de Boer 2017; Kikulwe et al. 2018), the socio-economic variables that will be explored include gender, age, years of education, etc. Following Wooldridge, assume $\alpha_1 < \alpha_2 < \dots < \alpha_j$ to be unknown threshold points and define these thresholds such that:

$$y = 0 \text{ if } y^* \leq \alpha_1 \dots\dots\dots(4.2)$$

$$y = 1 \text{ if } \alpha_1 < y^* \leq \alpha_2 \dots\dots\dots(4.3)$$

$$y = J \text{ if } y^* > \alpha_j \dots\dots\dots(4.4)$$

In this case, y takes on 3 values: 1 ('low loss'), 2 ('moderate loss'), and 3 ('high loss'). The three threshold points are 1%, 3%, and 7%. Since the error term is usually distributed, each response probability can be written as follows.

$$P(y = 0 \vee x) = \Phi(\alpha_1 - x'\beta) \dots\dots\dots(4.5)$$

$$P(y = 1 \vee x) = \Phi(\alpha_2 - x'\beta) - \Phi(\alpha_1 - x'\beta) \dots\dots\dots(4.6)$$

$$P(y = J \vee x) = 1 - \Phi(\alpha_j - x'\beta) \dots\dots\dots(4.7)$$

where $\Phi(\cdot)$ is the standard normal cumulative distribution. This is a generalized version of the binary probit model in which parameters α and β can be estimated by maximizing the following log-likelihood function:

$$Li(\alpha, \beta) = [y_i = 0] \log[\Phi(\alpha_1 - x'\beta)] + [y_i = 1] \log[\Phi(\alpha_2 - x'\beta) - \Phi(\alpha_1 - x'\beta)] + \dots + [y_i = J] \log[1 - \Phi(\alpha_j - x'\beta)] \dots\dots\dots(4.8)$$

The marginal effect of an increase in x on the probability of selecting alternative j can be written as

$$\partial P_{ij} / \partial x_i = [\phi(\alpha_j - 1 - x'\beta) - \phi(\alpha_j - x'\beta)] \beta \dots\dots\dots(4.9)$$

where $\phi(\cdot)$ is the standard normal density function.

Table 4.1: The description of the variables to be estimated by Ordered Probit Model

	Variable	Description	Type	Unit
1	Gender	Gender of the participant (Male/Female)	Categorical	-
2	Marital Status	Current marital status of the participant (Single/Married/Widowed/Divorced)	Categorical	-
3	Household Size	Number of individuals living in the same household	Numerical	Members
4	Years in School	Total years of formal education completed	Numerical	Years
5	Age	Age of the participant	Numerical	Years
6	Distance to market	Distance from the farm to the nearest market	Numerical	Kilometers
7	Farm Experience	Number of years of experience in farming	Numerical	Years
8	Extension service	Access to agricultural extension services	Categorical	-

Source: Table created by the author (2024)

4.4 Results and Discussion

4.4.1 The demographic and socioeconomic characteristics of smallholder farmers.

The demographic and socioeconomic characteristics of smallholder farmers have been described in Table 3.1 in the previous chapter. The descriptive statistics shed light on the characteristics of the farmers involved. On average, the farmers are 45 years old, have spent 12 years in school, and have a household size of 6 members. They also have an average of 5 years of farm experience and are located an average distance of 6.18 kilometres from the market. Regarding gender distribution, 43.7% of the farmers are male, while 56.3% are female. The participants' marital status shows that 77.31% are single, 18.91% are married, 2.94% are widowed, and 0.84% are divorced. Furthermore, 81.86% of the farmers have access to extension services. These statistics provide a comprehensive overview of the demographic and socioeconomic background of the smallholder vegetable farmers in the study area, which is crucial for understanding the factors influencing the severity of postharvest losses

4.4.2 Perception of smallholder farmers on postharvest losses.

Table 4.2 indicates the perception of smallholder farmers on postharvest losses. The perception of smallholder farmers on postharvest losses was derived from Likert scale results based on their experiences with postharvest practices, where they have realized significant losses. The Likert scale, "Strongly Disagree" to "Strongly Agree," reflects farmers' opinions on postharvest handling, storage, and value-addition techniques. These results provide a quantitative measure of the

perceived challenges and strengths in the postharvest process, guiding targeted interventions to address identified areas of concern and enhance overall agricultural sustainability.

Table 4.2: Perception of smallholder vegetable farmers on postharvest losses in eThekweni Municipality.

Postharvest Practices	Strongly Disagree (%)	Disagree (%)	Undecided (%)	Agree (%)	Strongly Agree (%)
Harvesting	0	0	0	79.83	20.17
Sorting	0	0	19.75	58.82	21.43
Storage	0	9.66	0	50.84	39.5
Packaging	0	10.08	0	68.07	21.85
Transportation	0	9.66	9.66	60.08	20.59
Market	0	9.66	19.75	38.66	31.93

Source: Field result, 2023.

The Likert scale results yield insightful views on smallholder farmers' perceptions across various stages of the postharvest process. Notably, 79.83% of smallholder farmers agree that most postharvest losses occur during the harvesting phase, with an additional 20.17% firmly aligning with this view. Debebe (2022) agreed that most losses, especially for smallholder farmers, occur during the harvesting phase due to poor harvesting techniques and a lack of proper harvesting equipment. Furthermore, 50.84% of smallholder farmers agree that inadequate storage contributes to their postharvest losses, while 39.5% strongly agree. Chegere et al. (2022) suggested that storage is critical, especially for perishable products; lack of storage may lead to significant losses. Packaging emerges as a pivotal factor, with 68.07% recognizing postharvest losses during this process and 21.85% strongly supporting this perception. Mvumi and Stathers (2020) similarly posited that, during packaging and postharvest handling, significant losses occur due to the packaging material that does not account for the specific needs of the produce, such as ventilation requirements or fragility. Such challenges can easily contribute to spoilage, bruising, and deterioration during transportation and storage. About 60.08% of smallholder farmers agree that substantial losses occur during the transportation of the produce to the market, and 20.59% strongly agree. Dora et al. (2021) suggested that incorrect loading and unloading practices, such as dropping or mishandling of produce, can lead to physical damage and bruising, contributing to postharvest losses. Sorting stands out as a stage where opinions diverge, with 19.75% undecided, though a majority (58.82%) agree that damage during sorting leads to significant losses. A noteworthy proportion of smallholder farmers perceive substantial losses in the market due to high

supply and low demand, as 38.66% agree, 31.93% strongly agree, and 19.75% undecided. These results emphasize the need for tailored interventions addressing specific stages of the postharvest process, ensuring considerate support based on smallholder farmers' diverse experiences and perspectives. Enhancing practices during harvesting, storage, packaging, transportation, sorting, and market activities should be done with an understanding of the unique challenges these farmers face.

Table 4.3: Smallholder farmers indicating postharvest losses along the supply chain

Severity of postharvest losses	Supply chain stages		
	During harvest (%)	During transport (%)	At the Market (%)
Low	9.66	15.55	4.62
Moderate	4.62	20.17	8.82
High	3.80	26.05	6.72

Source: Field survey (2023)

The analysis of postharvest losses among smallholder vegetable farmers in eThekweni Municipality reveals varying severity levels across different supply chain stages: during harvest, transport, and at the market. During the harvest stage, the severity of postharvest losses is generally low, with 9.66% of farmers reporting low severity, 4.62% reporting moderate severity, and 3.80% reporting high severity losses. This indicates that most farmers experience minimal losses at the point of harvest, suggesting that harvesting practices may be relatively well managed. In contrast, the transport stage exhibits a higher severity of postharvest losses. Specifically, 15.55% of farmers reported low-severity losses during transport, 20.17% reported moderate severity, and 26.05% reported high-severity losses. This stage appears particularly critical, as many farmers experience high-severity losses, likely due to inadequate transportation facilities, poor handling practices, or the long distances that produce must travel to reach the market. At the market stage, the severity of postharvest losses shows a different distribution. Here, 4.62% of farmers reported low severity losses, 8.82% reported moderate severity, and 6.72% reported high severity losses. While the market stage does not exhibit the highest severity losses compared to the transport stage, it still represents a significant point where improvements could reduce overall postharvest losses.

4.4.3 Determinants of postharvest losses among smallholder farmers.

The Ordered Probit Model was employed to analyze the determinants of postharvest losses among smallholder farmers, with the severity of postharvest loss as the dependent variable. This severity

was assessed across three critical stages of the supply chain: Harvest, Transportation, and Market. Table 4.4 presents the estimated determinants of postharvest losses for each stage. The model's Pseudo R-squared value is 66.08%, and the p-value is 0.000, indicating that the model is statistically significant and that several estimated variables significantly influence postharvest losses.

Table 4.4: The determinants of postharvest losses among smallholder vegetable farmers in eThekweni Municipality.

Independent variable	Coefficient (Standard Error)		
	Harvest	Transportation	Market
Gender	0.061 (0.122)	-0.031 (0.102)	-0.030 (0.042)
Marital Status	0.016 (0.040)	-0.008 (0.010)	-0.008 (0.010)
Age	0.001 (0.002)	-0.000 (0.001)	-0.000 (0.001)
Household Size	-0.043** (0.001)	-0.001 (0.010)	0.125** (0.026)
Years in School	-0.055** (0.006)	0.007 (0.011)	0.007 (0.009)
Distance from the Market	-0.062*** (0.012)	0.056*** (0.006)	0.056*** (0.006)
Farm Experience	-0.002 (0.181)	-0.001 (0.002)	0.002 (0.181)
Extension Service	-0.080** (0.019)	0.021 (0.032)	-0.063** (0.015)
The number of obs. = 238 LR $\chi^2(11)$ = 292.41 Prob > χ^2 = 0.000 Log-likelihood = -175.053554 Pseudo R ² = 0.6608			

Note ** 5% significance level and *** 1% significance level

Source: Field survey (2023) Regression ran by Stata 18.

According to the results presented in Table 4.4, distance from the market, farm experience, and financial support are statistically significant at a 1% significance level. At the same time, household size, years in school, training attended, and extension services are statistically significant at a 5% significance level.

The household size variable shows a significant negative coefficient at the 5% significance level in the harvest stage, indicating that a unit increase of one additional household member is associated with a 2.3% decrease in the severity of postharvest losses during harvesting. This suggests that larger households have more family members available to contribute to agricultural activities, including harvesting, as proposed by Maziku (2019). Ngowi and Selejio (2019) further explain that with more hands available, there may be improved efficiency and speed in the harvest, reducing losses due to delays. However, in the transportation stage, the coefficient for household size is not statistically significant, indicating that household size does not significantly impact the severity of postharvest losses during transportation. In contrast, the household size variable has a significant positive coefficient at the market stage, implying that an increase in household size is associated with a 2.5% increase in the severity of postharvest losses at the market stage. Stathers et al. (2020) found a similar positive association, suggesting that as household size increases, the likelihood of experiencing higher postharvest losses at the market stage also increases. Debebe (2022) noted that larger households often face challenges in efficiently managing and distributing harvested produce, leading to increased postharvest losses at the market stage.

The variable "years in school" shows a significant negative coefficient at the 5% significance level in the harvest stage, indicating that each additional year of schooling is associated with a 1.5% decrease in the severity of postharvest losses during harvesting. This suggests that more educated vegetable farmers will likely experience fewer losses at this stage. A study by Nohamba et al. (2022) supports this finding, revealing that individuals with more education tend to adopt better harvesting practices, use improved technologies, and make more informed decisions, thereby reducing postharvest losses. However, in the transportation stage, the coefficient for years in school is not statistically significant, indicating that education does not significantly impact the severity of postharvest losses during transportation. In the market stage, years in school are associated with an increase in the severity of postharvest losses. This counterintuitive finding suggests that while education helps reduce losses during harvesting, it may not be as effective in the market stage, possibly due to other confounding factors such as market conditions or handling practices that education alone cannot address.

In the harvest stage, a unit increase of 1 kilometre in the distance from the market is associated with a significant 3.2% decrease in the severity of postharvest losses, as evidenced by the

significant negative coefficient at the 1% level. These results suggest that smallholder farmers located further from markets may be more oriented towards market demands and consumer preferences, possibly due to the need to maintain quality over longer distances. Debebe (2022) supports this finding, noting that a market-driven focus can lead to better postharvest management practices and reduced losses. Conversely, in both the transportation and market stages, a unit increase in the distance from the market is significantly associated with a 1.6% increase in the severity of postharvest losses at the 1% significance level. This suggests that smallholder farmers closer to the market have better access to transportation and market facilities, which reduces the time it takes to transport harvested crops. According to Sibanda and Workneh (2020), this proximity can result in fresher produce reaching the market, lowering the risk of postharvest losses.

Extension service shows a significant negative association with the severity of postharvest losses at the harvest stage, as indicated by the negative coefficient at the 5% significance level. This suggests that each additional visit by extension agents is linked to a 4% decrease in the severity of postharvest losses that vegetable farmers experience during harvesting. Stathers and Mvumi (2020) highlighted that extension services provide farmers with timely information, enabling them to make informed decisions about when to harvest, leading to better postharvest outcomes. Balana et al. (2022) also supported the idea that farmers who receive effective and efficient extension services are more likely to harvest at the optimal time, thereby reducing the severity of losses. In the transportation stage, the coefficient for extension service is not statistically significant, indicating that variations in extension services do not significantly impact the severity of postharvest losses during this stage. This suggests that while extension services are crucial during harvest, their direct influence may diminish once the produce is in transit. However, during the market stage, a unit increase in extension services is associated with a 4.3% decrease in the severity of postharvest losses. This indicates that extension services continue to play a vital role in reducing the severity of postharvest losses even at the market stage, likely through improved market-related practices and decision-making.

4.5 Conclusion and Recommendations

Smallholder farmers make a significant contribution to the country's economy. Moreover, smallholder farmers dominate the agricultural sector compared to commercial farming. However, smallholder farmers still suffer challenges that hinder their development. Smallholder farmers are

not getting adequate support that they should be getting. Smallholder farmers still operate with limited resources, and the extension services are ineffective. Moreover, most of the farmers are unemployed, and their primary source of income and livelihood strategy is farming. This suggests that they should be given adequate attention as they hold the potential to create more job opportunities. One of the critical challenges that smallholder farmers are struggling with is postharvest losses, which have a negative impact on their profitability. Extension services mainly focus on the production stage, ignoring the other stages in the value chain. Smallholder farmers are not well informed about effective and efficient postharvest practices. Moreover, the losses are caused by a lack of proper infrastructure, poor postharvest practices, and a lack of a reliable market. One of the major factors that was found was a lack of adequate transportation, which resulted in significant losses. The farmers perceived that most losses occur during harvesting, sorting, transportation, and marketing. Furthermore, the study revealed that other contributing factors to postharvest losses are distance from the market, farm experience, and lack of financial support.

Therefore, the study recommends:

- a) Develop community programs that educate households on the benefits of involving all available members in harvesting. Provide tools and resources to support larger groups working efficiently.
- b) Expand agricultural education programs that focus on postharvest management practices, emphasizing the importance of education in reducing losses. Offer workshops and training sessions that provide practical, hands-on learning experiences.
- c) Develop training programs that teach farmers to implement market-driven practices, such as better packaging and handling techniques, to help maintain product quality over longer distances.
- d) Invest in improving road networks and transportation facilities to ensure quicker and safer produce transport. Develop local markets and cold chain facilities to support smallholder farmers.
- e) Enhance the capacity of extension services by training extension agents in the latest postharvest management practices. Increase the number of extension officer visits and ensure they are tailored to address specific postharvest challenges at different supply chain stages.

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CHAPTER 5

Evaluating the Critical Causal Factors of Postharvest Losses in the Vegetable Supply Chain in eThekweni Metropolitan: The Log-linear regression model.

Abstract

Vegetables are essential sources of bioactive compounds crucial for human health and are central to the global food supply. However, the complexity and sensitivity of vegetable supply chains, characterized by product seasonality, demand fluctuations, and short shelf lives, contribute to significant waste. Approximately 44% of fresh vegetables produced worldwide are lost within the food chain. These postharvest losses (PHLs) pose a significant challenge, impacting food security and economic sustainability. Despite efforts to address PHLs, a comprehensive understanding of the primary causal factors remains lacking, hindering effective and sustainable interventions. This study aims to investigate the principal causal factors contributing to PHLs along the vegetable supply chain. Using structured questionnaires, a cross-sectional research design, and a multi-stratified random sampling technique, primary data were collected from 238 farmers. The study employed descriptive statistics and log-linear regression to analyze the data. The log-linear regression analysis reveals several factors significantly impacting postharvest losses among smallholder vegetable farmers in eThekweni Municipality. Adverse weather conditions emerge as a major determinant, significantly increasing postharvest losses at both the Harvest and Market stages due to crop damage and unfavourable handling conditions. The analysis also highlights that greater distance to markets exacerbates postharvest losses by prolonging travel times and stressing inadequate infrastructure, affecting the availability and price of fresh produce. Farm experience is crucial in reducing losses, as experienced farmers employ more effective practices. Conversely, older farmers face challenges in adopting modern postharvest management practices, resulting in increased spoilage and waste at the market stage. These findings underscore the need for targeted interventions to enhance postharvest practices and infrastructure, thereby improving the efficiency and sustainability of the vegetable supply chain. By addressing these key factors, stakeholders can enhance the efficiency and sustainability of the vegetable supply chain, ultimately improving food security and economic outcomes for smallholder farmers.

Keywords: Causal factors, log-linear regression, Postharvest losses, Smallholder vegetable farmers, Vegetable supply chain.

5.1 Introduction

Vegetables, as primary sources of bioactive compounds crucial for human health, occupy a pivotal position in the global food supply (Shashirekha et al., 2015; Kumar, 2017; Kainat et al., 2022). Moreover, Harris et al. (2022) suggested that vegetables are essential for balanced nutrition and contribute significantly to the culinary diversity and cultural heritage of societies worldwide. The importance of vegetables in the diet cannot be overstated, with research indicating that vegetables play a crucial role in preventing chronic diseases such as cardiovascular diseases, diabetes, and certain cancers (Lockyer et al., 2021). However, despite their nutritional significance and cultural value, the journey of vegetables from farm to consumption is fraught with challenges, resulting in significant losses along the supply chain. According to recent estimates by Debebe (2022), postharvest losses (PHLs) in the vegetable supply chain are alarmingly high, with approximately 44% of fresh vegetables produced worldwide being lost within the food chain, while Sub-Saharan Africa lost about 37%, which is 120 – 170 kg/year per capita (Chirsanova and Calcatiniuc, 2021). Furthermore, over 10 million tons of food waste are lost in South Africa due to poor postharvest handling and value-addition techniques (Melembe et al., 2020).

Furthermore, Abbas et al. (2023) highlighted that the vegetable supply chain is characterized by its complexity and sensitivity, influenced by various factors such as product seasonality, demand fluctuations, and short shelf lives. This complexity adds layers of challenge to the management of the supply chain, as stakeholders must navigate fluctuating demands and delicate handling requirements to ensure the timely delivery of fresh produce to consumers. Working and Enyew (2021) agreed that, unlike many other food commodities, vegetables are highly perishable, requiring proper handling and prompt processing to preserve their quality and nutritional content. The perishability of vegetables necessitates swift action at every stage of the supply chain, from harvesting to distribution, to minimize losses. Consequently, the postharvest and marketing system for vegetables entails a complex chain of interlinked activities, from harvest to the delivery of products to end consumers (Bhatt et al., 2020).

Postharvest losses plague the vegetable supply chain despite technological advancements and agricultural improvement. While innovations such as advanced packaging techniques, cold chain logistics, and postharvest practices have been developed to mitigate losses, their widespread adoption remains limited, particularly in regions with limited resources and infrastructure (Rutta,

2022). Additionally, Makule et al. (2022) highlighted that the inherent perishability of vegetables poses a persistent challenge, as factors such as temperature fluctuations, humidity levels, and inadequate storage facilities can accelerate deterioration and spoilage. Furthermore, Stathers and Mvumi (2020) suggested that the global nature of the vegetable supply chain introduces additional complexities, including transportation challenges, regulatory hurdles, and market dynamics, which worsen the risk of postharvest losses. As a result, despite concerted efforts to address the issue, postharvest losses persist, highlighting the need for comprehensive and sustainable solutions to enhance the efficiency and resilience of the vegetable supply chain.

Postharvest losses encompass all deterioration and waste between harvest and consumption, affecting various supply chain stages, including harvesting, handling, storage, transportation, and marketing. According to Bisht and Singh (2024), harvesting practices significantly impact vegetables' quality and shelf life, with improper techniques like untimely harvesting or damage during harvest accelerating deterioration. Moreover, Singh et al. (2022) highlighted that inadequate handling and transportation procedures, such as rough handling, improper packaging, and insufficient temperature control, exacerbate postharvest losses during transit. Storage facilities also contribute significantly to postharvest losses, with inadequate infrastructure, ventilation, and temperature and humidity control promoting spoilage and microbial growth (Rutta, 2022). Binge et al. (2023) agreed that in developing countries, the lack of access to reliable storage facilities, particularly in rural areas, further exacerbates the PHLs.

The economic consequences of postharvest losses extend beyond the immediate impact on farmers and distributors to affect entire economies (Balana et al., 2022). Not only do these losses result in a loss of potential revenue for producers, but they also contribute to increased food prices, reducing affordability and accessibility for consumers, particularly in low-income households, as Mvumi and Stathers (2020) suggested. Furthermore, Ali et al. (2021) indicate that the resources invested in producing, transporting, and processing lost vegetables represent a significant economic loss for the entire supply chain. These losses undermine efforts to alleviate poverty and food insecurity, hindering economic development and worsening social inequalities. Consequently, addressing postharvest losses is crucial for enhancing food security and nutrition and promoting economic growth, poverty reduction, and sustainable development.

Blanckenberg et al. (2021) suggested that postharvest losses have far-reaching environmental implications, worsening resource depletion, greenhouse gas emissions, and environmental pollution. Opara et al. (2021) agreed, highlighting that the energy, water, and land resources utilized in producing lost vegetables are effectively wasted, contributing to environmental degradation and climate change. Moreover, Stathers et al. (2020) added that disposing of spoiled vegetables generates additional waste, further straining waste management systems and worsening environmental pollution. Anand and Barua (2022) highlighted that the efforts to mitigate postharvest losses in the vegetable supply chain face several challenges, ranging from technological limitations to socio-economic constraints. Stathers and Mvumi (2021) specified that limited access to appropriate technologies and infrastructure, especially in rural and remote areas, hinders the adoption of best harvesting, handling, and storage practices. Additionally, the lack of awareness and training among farmers and other stakeholders exacerbates the problem, leading to suboptimal practices and increased losses (Makule et al., 2022).

However, despite these challenges, various opportunities exist to reduce postharvest losses and enhance the efficiency of the vegetable supply chain. Onwude et al. (2020) suggested that technological advances, such as improved storage facilities, cold chain logistics, and packaging innovations, offer promising solutions to prolong the shelf life of vegetables and minimize losses during transit. Furthermore, Halbherr et al. (2021) added that investments in infrastructure development and capacity-building initiatives can strengthen the supply chain's resilience and improve the livelihoods of smallholder farmers. Considering the pressing need to address postharvest losses in the vegetable supply chain, this study aims to identify, investigate, and prioritize the primary causal factors contributing to PHLs. By comprehensively understanding these factors, the study seeks to provide actionable recommendations to stakeholders, including policymakers, agricultural practitioners, and supply chain actors, to develop effective interventions and strategies for reducing losses and enhancing the sustainability of the vegetable supply chain.

5.2 Conceptual framework showing the critical causal factors of postharvest losses in the vegetable supply chain.

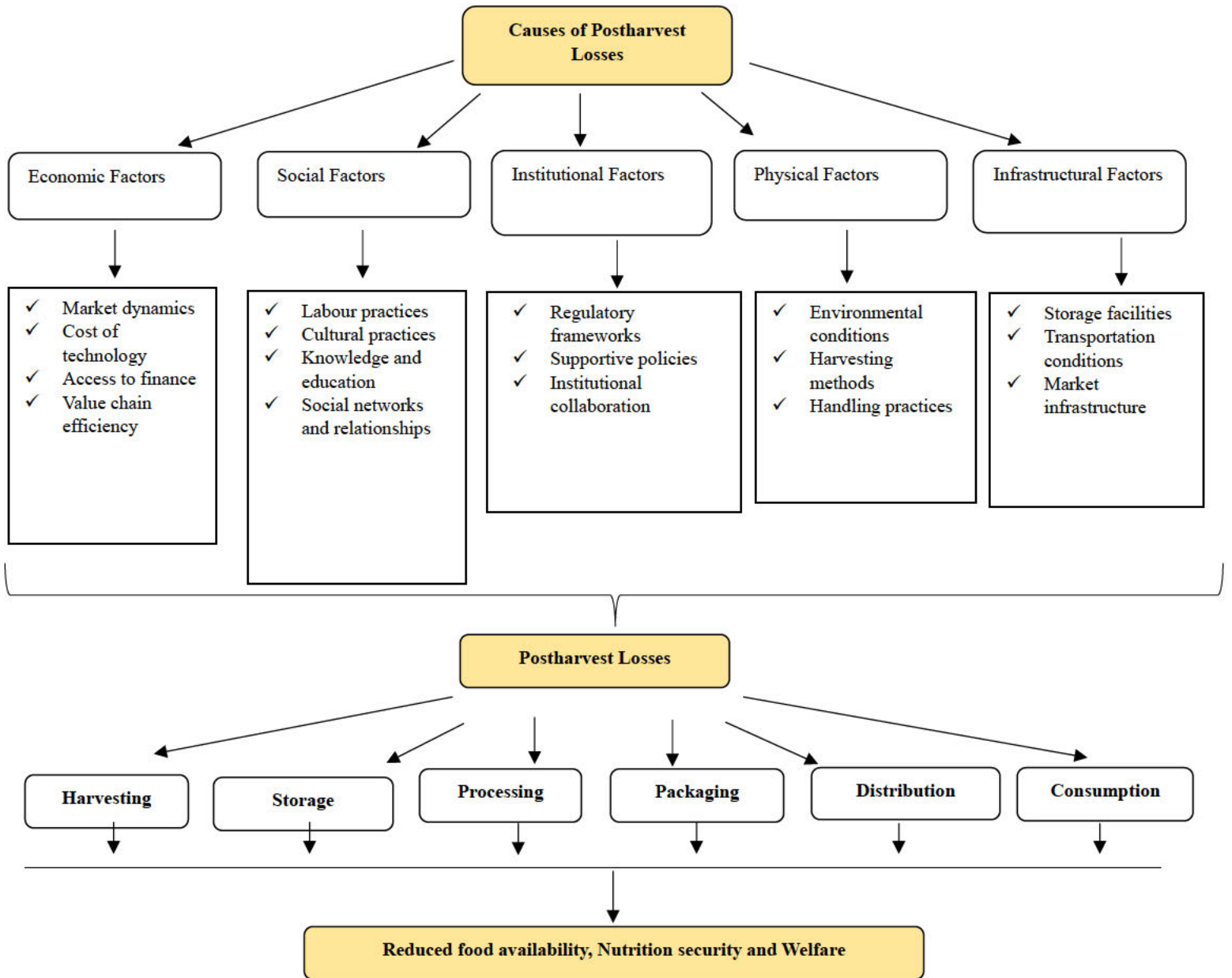


Figure 5.1: Conceptual framework showing the critical causal factors of postharvest losses in the vegetable supply chain

Figure 5.1 demonstrates the critical causal factors of postharvest losses in the vegetable supply chain. Figure 5.1 suggests that variations in weather, including changes in temperature, precipitation, and humidity, directly impact the quality of vegetables at every stage, from growth and harvest to postharvest handling (Prasad et al., 2023). For instance, extreme temperatures or

sudden temperature changes can harm vegetables. Onwude et al. (2020) agreed that hot temperatures may accelerate the deterioration of perishable produce, leading to rapid spoilage and increased losses. Similarly, fluctuations in humidity levels can affect the moisture content of vegetables, potentially causing rotting (Alegbeleye et al., 2022). Furthermore, climate change worsens these challenges by altering long-term weather patterns and increasing the frequency and intensity of extreme weather events (Opara et al., 2021). This can disrupt regular growing seasons, affect crop yields and quality, and create favourable conditions for pests and diseases. For example, Singh et al. (2023) suggested that prolonged droughts or heavy rainfall can damage crops, while warmer temperatures may favour the proliferation of certain pests and pathogens, further increasing postharvest losses.

Economic factors are dominant in influencing postharvest losses within the vegetable supply chain. Market dynamics, encompassing fluctuations in demand and prices, can precipitate overproduction or undersupply, leading to surpluses or shortages of vegetables and ensuing losses (Giri, 2023). Moreover, Mutungi et al. (2023) highlighted that the accessibility and affordability of postharvest technologies are crucial; inflated costs associated with their adoption may dissuade investment, hindering efforts to mitigate losses. Concurrently, limited credit or investment capital access can impede farmers' ability to implement improved postharvest practices. Additionally, inefficiencies within the supply chain, such as transportation delays or suboptimal handling practices, further exacerbate losses by prolonging transit times and compromising product quality (Ambuko and Owino, 2023). Addressing these economic challenges requires interventions that enhance market stability, improve access to finance, and streamline supply chain operations to minimize postharvest losses effectively.

Social factors are pivotal in shaping postharvest losses within the vegetable supply chain, encompassing labour practices, cultural norms, knowledge dissemination, and social networks (Assan, 2023). Inadequate availability of skilled labour for harvesting and handling can lead to mishandling, bruising, or damage to vegetables, thereby exacerbating losses (Binge et al., 2023). Stathers et al. (2020) also highlighted that cultural beliefs or practices may influence postharvest handling techniques, potentially impacting product quality and longevity. Moreover, Fernandez et al. (2021) suggested a lack of awareness or training on proper postharvest practices can accelerate spoilage and waste. However, strong social networks and collaborations among stakeholder

farmers offer knowledge-sharing and resource-pooling opportunities, fostering collective action and innovative solutions to reduce losses (Phillips et al., 2021). By leveraging social capital and promoting collaboration, stakeholders can effectively address postharvest challenges and enhance the efficiency and sustainability of the vegetable supply chain.

Institutional factors exert considerable influence over postharvest losses within the vegetable supply chain, comprising regulatory frameworks, supportive policies, and institutional collaboration (Rutta, 2022). Insufficient regulations concerning food safety or quality standards can erect barriers to adopting best practices, thereby worsening postharvest losses (Stathers et al., 2020). Conversely, supportive policies and stakeholder collaborative efforts are pivotal in effectively addressing postharvest challenges. Supportive policies may include incentives for adopting innovative technologies, subsidies for infrastructure development, or grants for training programs to enhance postharvest practices (Balana et al., 2022). Moreover, Fernandez et al. (2021) highlighted that institutional collaboration fosters knowledge sharing, resource mobilization, and coordinated action, enabling stakeholders to implement holistic solutions that mitigate losses and enhance the resilience of the vegetable supply chain. By cultivating an enabling institutional environment, policymakers and stakeholders can play a pivotal role in minimizing postharvest losses and promoting sustainable agricultural practices.

Physical factors are crucial determinants of postharvest losses within the vegetable supply chain, encompassing temperature and humidity control, packaging materials, storage facilities, and harvesting methods (Onwude et al., 2020). Moreover, effectively controlling temperature and humidity levels during storage and transportation is essential for preserving vegetable quality and minimizing spoilage (Alegbeleye et al., 2022). Inadequate control in these aspects can accelerate deterioration, leading to significant losses. Similarly, choosing packaging materials and designs is critical in protecting vegetables from damage or contamination during handling and transit (Gordon and Williams, 2020). Poor packaging materials or designs can compromise the integrity of the produce, rendering it vulnerable to spoilage and deterioration. Furthermore, Rutta (2022) suggested that the availability and condition of storage facilities significantly impact postharvest losses. Insufficient or improper storage facilities may lack adequate ventilation or temperature control, worsening losses due to accelerated spoilage. Additionally, improper harvesting techniques, such as rough handling or untimely harvesting, can cause physical damage or bruising

to vegetables, reducing their shelf life and market value (Singh et al., 2021). Therefore, addressing these physical factors is essential for minimizing postharvest losses and ensuring the quality and safety of vegetables throughout the supply chain.

Infrastructural factors significantly contribute to postharvest losses within the vegetable supply chain, encompassing transportation and market infrastructure, processing facilities, and packaging design (Magalhaes et al., 2022). Lack of transportation infrastructure or market integration can result in delays, temperature fluctuations, and increased losses during transit. For instance, inefficient cold chain logistics or inadequate storage facilities can lead to spoilage and deterioration of vegetables, particularly perishable varieties. Similarly, poor processing facilities or packaging designs may compromise product quality and marketability, increasing the risk of rejection or reducing consumer appeal (Fernandez et al., 2021). Addressing these multifaceted factors necessitates a comprehensive approach involving stakeholder collaboration, investment in infrastructure and technology, supportive policies, and knowledge dissemination initiatives. By enhancing transportation networks, upgrading processing facilities, improving packaging standards, and fostering market integration, stakeholders can mitigate postharvest losses, optimize resource utilization, and enhance the overall efficiency and sustainability of the vegetable supply chain.

5.3 Research Methodology

The research methodology, including study area, research design, sampling procedure, sample size and data collection, is discussed in detail in Chapter 3.

5.3.1 Model Specification

The study employed log-linear regression analysis to investigate the critical causal factors contributing to postharvest losses within the vegetable supply chain. Log-linear regression, a statistical modelling technique, was chosen for its suitability in examining relationships between dependent and independent variables, mainly when they exhibit multiplicative properties, as commonly encountered in agricultural studies like postharvest loss analysis (Murray, 2021). Log-linear regression involves transforming both the dependent variable (Y) and independent variables (X_1, X_2, \dots, X_k) using natural logarithms to linearize the relationship, making it amenable to regression analysis (Park et al., 2020). This transformation helps handle multiplicative

relationships effectively, pertinent in understanding the complexities of postharvest loss dynamics in the vegetable supply chain. One significant advantage of log-linear regression is its ability to model multiplicative relationships, often observed in agricultural systems, due to factors affecting postharvest losses (Khan et al. 2020). Using logarithmic transformations, the model captures the proportional changes in postharvest losses associated with changes in independent variables, providing valuable insights for mitigation strategies.

Furthermore, log-linear regression ensures unbiased parameter estimates by adhering to certain assumptions, such as the linearity of the logarithmic relationship, independence of errors, homoscedasticity, normality of errors, absence of multicollinearity, and absence of perfect collinearity (Bala and Umar, 2022). These assumptions contribute to the robustness and validity of the model, enhancing its utility in understanding and addressing postharvest losses in the vegetable supply chain. In contrast to other regression techniques, such as linear regression, which assumes additive relationships between variables, log-linear regression better captures the multiplicative nature of relationships in agricultural contexts, thereby offering a more suitable approach for analyzing postharvest loss data (Imani et al., 2022). By adopting log-linear regression, the study ensures a rigorous analytical framework tailored to the complexities of postharvest loss dynamics, thereby enhancing the reliability and relevance of its findings for stakeholders in the agricultural sector. The general equation for log-linear regression is as follows:

$$\log(Y_i) = \beta_1 \log(X_{1i}) + \beta_2 \log(X_{2i}) + \dots + \beta_k \log(X_{ki}) + \varepsilon_i \dots \dots \dots (5.1)$$

Where:

Y_i = Dependent Variable

β = Estimated parameters

X_k = Set of independent variables

ε = Error term

This equation signifies that the dependent variable, postharvest losses (Y), is modeled as a function of the independent variables, with each variable's logarithmically transformed values serving as predictors. The coefficients ($\beta_1, \beta_2, \dots, \beta_k$) represent the proportional change in postharvest losses

for a one-unit change in the corresponding independent variable, while other variables remain constant.

Table 5.1: Description of variables to estimate the causal factors of postharvest losses

Variables	Description	Type	Unit
Age	The age of the farmer in years	Numerical	Years
Years in School	Total years of formal education completed	Numerical	Years
Farm Experience	Number of years of experience in farming	Numerical	Years
Market access	Access to markets for selling produce.	Categorical	-
Distance from the Market	Distance from the farm to the nearest market	Numerical	kilometres
Weather Conditions	Impact of weather conditions on farming activities.	Categorical	-
Lack of transport	Access to agricultural extension services	Categorical	-

Source: Table created by the author (2024)

5.4 Results and Discussions

This section primarily focuses on analyzing the acquired findings. Table 3.1 describes the demographic and socioeconomic characteristics of the farmers. Moreover, this section will explore the empirical outcomes derived from the log-linear model utilized to assess the critical causal factors of postharvest losses within the vegetable supply chain.

5.4.1 Critical Causal Factors of Postharvest Losses in the Vegetable Supply Chain in eThekweni Metropolitan

This section focuses on the critical causal factors of postharvest losses in the vegetable supply chain. The dependent variable in this analysis is the log-transformed value of postharvest losses. Table 5.2 presents the estimates from the log-linear regression model used to identify these factors. The log-linear regression model was adopted to estimate the critical causal factors of postharvest losses based on a dataset of 238 observations. The analysis indicates that the model provides a statistically significant fit to the data for predicting postharvest losses. The likelihood ratio chi-square test yielded a chi2 value of 64.82 with 16 degrees of freedom, resulting in a p-value of 0.00466. This significant p-value suggests that the independent variables included in the model collectively contribute to explaining the variability in postharvest losses.

The model's log-likelihood value of -264.44297 indicates a good fit to the observed data. Additionally, the Pseudo R² value of 0.711 suggests that the independent variables in the model can explain approximately 71.1% of the variability in postharvest losses. This high explanatory power highlights the model's effectiveness in understanding the factors contributing to postharvest losses. These results indicate that the log-linear regression model provides valuable insights into the determinants of postharvest losses in the dataset. Identifying these critical causal factors is essential for developing targeted interventions or improvements in postharvest management practices to reduce losses and enhance agricultural productivity.

Table 5.2: The log-linear regression estimating the critical causal factors of postharvest losses within the vegetable supply chain in eThekweni Municipality

Variables	PHL Stage		
	Harvest Coefficient (SE)	Transportation Coefficient (SE)	Market Coefficient (SE)
Age	-0.001 (0.020)	-0.073 (0.164)	0.112 (0.034) **
Years In School	0.233 (0.256)	-0.023 (0.278)	0.080 (0.136)
Farm Experience	-0.064 (0.007) **	0.058 (0.898)	0.341 (0.158) **
Market Access	-0.015 (0.010)	-0.073 (0.164)	0.112 (0.734)
Distance from the Market	-0.030 (0.102)	-0.164 (0.152)	0.089 (0.036) **
Weather Conditions	-0.050 (0.001) ***	-0.073 (0.164)	0.142 (0.015) ***
Lack of transport	0.233 (0.256)	0.058 (0.064)	0.341 (1.158)
_cons	-0.942 (1.001)	0.941 (1.000)	0.311 (0.421)
Log-linear regression			
Number of observations = 238			
LR chi ² (16) = 64.82			
Prob > chi ² = 0.00466			
Log likelihood = -264.44297			
Pseudo R ² = 0.711			

Note ** 5% significance level and *** 1% significance level

Source: Field result, 2023. Regression run by Stata 18

The results reveal a significant positive relationship between age and postharvest losses at the market stage of the vegetable supply chain, which is significant at the 5% level. This suggests that for every one-year increase in age among smallholder vegetable farmers, there is an associated increase in postharvest losses of 11.2%, aligning with findings from Bechoff et al. (2022) and Kulwijila (2021). These studies noted that older farmers often struggle with adopting modern

postharvest management practices, leading to higher levels of crop spoilage. Given this, targeted support and training programs focused on improving postharvest practices for older farmers could significantly reduce losses and enhance the efficiency and sustainability of the vegetable supply chain. Interventions like these, aimed at equipping older farmers with the necessary knowledge and skills, are crucial for mitigating postharvest losses and improving the overall profitability of vegetable farming in the region (Bisheko and Rejikumar, 2023).

Moreover, there is a negative relationship between farm experience and postharvest losses at the harvest stage and the Market stage, both significant at the 5% level. This suggests that each additional year of farming experience correlates with reduced postharvest losses among smallholder vegetable farmers, 1.4% and 3.4% at the harvest and market stage, respectively, aligning with findings from Opara and Pathare (2014) and Kumar et al. (2018). These studies emphasize that accumulated knowledge and practical skills are crucial in reducing losses within the vegetable supply chain. Experienced farmers are more adept at implementing effective harvesting, handling, and storage practices, significantly reducing wastage (Rutta, 2022). Their familiarity with best practices, developed over years of hands-on experience, enables them to anticipate and mitigate potential issues that can lead to postharvest losses. This loss reduction has significant implications for the vegetable supply chain, including improved farmer profitability and sustainability. Enhanced quality assurance, as fewer products are lost to spoilage, ensures that more high-quality produce reaches the market. This leads to increased economic viability and better livelihoods for smallholder farmers, thus contributing positively to the broader agricultural economy.

The results further show a positive and statistically significant relationship between distance to the market and postharvest losses at the market stage, at the 5% significance level. This indicates that for every kilometre increase in distance to the market, postharvest losses increase by approximately 4%. This finding is supported by Johnson et al. (2019), who noted that greater distances to markets correlate with higher postharvest losses. The increased distance exacerbates logistical challenges, such as prolonged travel times and inadequate infrastructure, leading to increased spoilage and wastage of vegetables (Fernandez et al., 2021). These delays result in longer transit times, exposing produce to conditions that accelerate spoilage. These losses are significant, affecting farmers' income and causing ripple effects throughout the supply chain, impacting

distributors, retailers, and consumers (Stathers and Mvumi, 2020). As postharvest losses increase with market distance, sourcing fresh produce becomes more challenging, reducing availability and higher consumer prices. Additionally, food waste contributes to environmental degradation and exacerbates food insecurity (Dora, 2021). Addressing these logistical issues is crucial for improving the efficiency and sustainability of the vegetable supply chain.

The negative and statistically significant relationship between weather conditions and postharvest losses at the harvest and market stages was found, both significant at the 1% level. This indicates that adverse weather conditions significantly influence postharvest losses among smallholder vegetable farmers. Poor weather conditions, such as extreme temperatures, droughts, floods, and storms, can substantially increase postharvest losses. Studies by the Food and Agriculture Organization (FAO, 2020) and the International Food Policy Research Institute (IFPRI, 2018) support these findings, emphasizing that extreme weather events harm agricultural production and postharvest management practices. Adverse weather conditions can damage crops during the growing season and create unfavourable harvesting, handling, and storage conditions, leading to higher spoilage rates and increased postharvest losses. Additionally, Johnson et al. (2019) highlight that adverse weather conditions not only directly impact crop yields but also exacerbate logistical challenges and reduce the effectiveness of postharvest management practices. For instance, heavy rains and flooding can damage infrastructure, delay transportation, and complicate storage conditions, contributing to higher postharvest losses. These findings underscore the importance of developing resilient agricultural practices and infrastructure to mitigate the impact of adverse weather conditions on the vegetable supply chain.

5.5 Conclusion and Recommendations

The log-linear regression analysis demonstrates that several factors significantly impact postharvest losses among smallholder vegetable farmers in eThekweni Municipality. The results indicate that adverse weather conditions are a major determinant, with significant coefficients at both the Harvest and Market stages. Poor weather conditions, such as extreme temperatures, droughts, floods, and storms, significantly increase postharvest losses by damaging crops and creating unfavourable harvesting, handling, and storage conditions. These conditions also exacerbate logistical challenges, delay transportation, and complicate storage, leading to higher spoilage rates. Additionally, the findings highlight the influence of distance to the market, with

longer distances resulting in increased postharvest losses due to prolonged travel times and inadequate infrastructure. This logistical challenge affects farmers' income and ripple effects on distributors, retailers, and consumers, leading to reduced availability of fresh produce and higher consumer prices. Farm experience is crucial in mitigating postharvest losses, as experienced farmers are more adept at implementing effective harvesting, handling, and storage practices. This accumulated knowledge and practical skills significantly reduce wastage and improve the overall efficiency of the vegetable supply chain. Furthermore, farmers' age shows a significant positive relationship with postharvest losses at the market stage. Older farmers may face challenges in adopting modern postharvest management practices, leading to higher levels of spoilage and waste. These findings underscore the importance of addressing age-related factors, enhancing postharvest practices, and improving infrastructure and logistical systems to mitigate postharvest losses. Targeted support and training programs for older farmers, combined with strategies to develop resilient agricultural practices, can significantly enhance the efficiency and sustainability of the vegetable supply chain in eThekweni Municipality.

The study recommends the following:

- Develop targeted training programs to help older farmers adopt modern postharvest management practices. These programs should include workshops and hands-on training sessions to improve their practical skills in handling and storage.
- Leverage Farm Experience: Facilitate mentorship programs where experienced farmers share best practices with less experienced ones. Incorporate experienced farmers into training and advisory roles to recognize and utilize the value of farming experience.
- Invest in better transportation infrastructure to reduce travel time and spoilage. Develop local markets closer to farming areas to minimize travel distance for produce. Implement efficient logistics solutions such as cold chain systems to ensure quick and safe delivery of vegetables.
- Enhance weather forecasting and early warning systems to help farmers prepare for extreme weather. Promote resilient agricultural practices, such as drought-resistant crops and improved irrigation systems. Invest in infrastructure that can withstand extreme weather and provide training on protective measures.
- Provide affordable and reliable transport options for smallholder farmers. Improve transportation infrastructure, such as roads and transport facilities, to reduce delays and

spoilage. Offer logistical support, including access to vehicles designed for transporting perishable goods.

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CHAPTER 6

Exploring the Relationship Between Agribusiness Investments and Postharvest Losses (PHLs) among Smallholder Vegetable Farmers in the eThekweni Municipality.

Abstract

Smallholder vegetable farmers constitute the backbone of agricultural production in many developing economies. Despite their crucial role, the efforts of smallholder vegetable farmers are often hampered by significant postharvest losses (PHLs). These losses occur at various stages along the supply chain. However, agribusiness investments can potentially address the challenges regarding postharvest losses. Given agribusiness investments' potential benefits and unforeseen consequences, a deeper understanding of the relationship between these investments and PHL among smallholder vegetable farmers is essential. Therefore, this study explores the relationship between agribusiness investments and postharvest losses among smallholder vegetable farmers, focusing on the eThekweni Municipality. Using structured questionnaires, a cross-sectional research design and a multi-stratified random sampling technique were employed to collect primary data from 238 farmers. The Gross Margin and Ordinary Least Square (OLS) regression analysed the data. The analysis reveals that household size, education level, distance to market, and extension services significantly influence the severity of PHL. Larger households reduce losses during harvesting but increase them at the market stage. Education reduces losses during harvesting but has mixed effects at other stages. Greater distance to the market increases losses, while effective extension services mitigate them. Financial support and improved transport infrastructure significantly reduce PHL, enhancing profitability. The gross margin analysis indicates a 13.54% decrease in profitability due to PHL, while the retail marketing margin analysis shows a drastic 91.60% reduction due to PHL. The findings highlight the need for targeted interventions, such as better postharvest management practices, infrastructure improvements, financial support, and training programs to mitigate losses and enhance the vegetable value chain's sustainability and profitability. The study, therefore, recommends investing in transportation infrastructure, promoting climate-resilient agriculture, facilitating market access, providing financial support, and strengthening extension services to reduce postharvest losses in the agricultural sector.

Keywords: Agribusiness investments, financial support, ordinal least square regression, postharvest losses, smallholder vegetable farmers.

6.1 Introduction

Feeding a growing global population necessitates a delicate balancing act within the agricultural sector. There is an urgent need to increase food production, and on the other hand, there is a critical challenge of minimizing food waste among smallholder vegetable farmers (De Boni et al., 2022). Smallholder vegetable farmers, typically cultivating less than five hectares of land, play a pivotal role in ensuring food security and poverty, especially at the household level (Mujuru and Obi, 2020). Moreover, Ola and Menapace (2020) highlighted that smallholder vegetable farmers' adaptability and familiarity with local conditions make them well-positioned to respond to market demands and contribute significantly to food security, especially in developing economies. However, a significant paradox emerges when considering the postharvest stage of their operations. While agribusiness investments hold the potential to strengthen production and market access for smallholder farmers, a persistent challenge remains – substantial postharvest losses (PHL) that reach over 50% for certain perishable vegetables in developing countries (Mujuka et al., 2021). These losses reduce farmers' income and represent a waste of precious resources like water, land, and agricultural inputs, making investors reluctant to invest in agribusiness (Nkansah-Dwamena, 2023).

The significance of smallholder vegetable farmers cannot be overstated. Smallholder farmers constitute the backbone of agricultural production in many developing economies, especially in sub-Saharan Africa (Akanmu et al., 2023). Moreover, compared to large-scale commercial farms, smallholder vegetable farmers often cultivate more vegetables, catering to diverse local dietary needs (Hendriks et al., 2020). Serote et al. (2021) also highlighted that smallholder farmers are more efficient in land utilization, maximizing productivity on smaller plots. Beyond food security, smallholder vegetable farming plays a critical role in rural livelihoods while providing income-generation opportunities, improving household food security, and empowering women through their participation in cultivation and marketing activities (Ndlovu et al., 2022). Therefore, investing in smallholder vegetable production can alleviate poverty, enhance food security, and promote rural development (Hlophe-Ginindza and Mpandeli, 2020).

Despite smallholder farmers' crucial role, the efforts of smallholder vegetable farmers are often hampered by significant PHL (Stathers and Mvumi, 2020). These losses occur at various stages along the value chain, including harvesting, handling, storage, transportation, and marketing.

Moreover, the perishable nature of vegetables makes them particularly susceptible to deterioration due to improper handling, inadequate storage facilities, and lack of access to appropriate cooling technologies (Makule et al., 2022). The consequences of PHL are far-reaching; smallholder farmers experience significant income reductions, disincentivizing them from further production and potentially leading to food insecurity at the household level (Akuriba et al., 2021). Additionally, Stathers and Mvumi (2020) highlighted that these losses represent a substantial waste of resources invested in production, impacting everything from water and fertilizers to land utilization. Gnedeka and Wonyra (2023) further suggested that at a national level, PHL contributes to food insecurity and inflates food prices for consumers, hindering economic development and worsening nutritional deficiencies.

Agribusiness investments can potentially address the challenges faced by smallholder vegetable farmers regarding PHL. Improved access to technology, training, and infrastructure can equip farmers with the tools to handle and store their produce correctly, leading to increased shelf life and reduced losses (Aworh, 2021). Additionally, Louman et al. (2020) advised that by integrating smallholders into organized value chains with reliable markets, investments can provide greater predictability and stability for farmers' income, incentivizing them to invest in PHL reduction technologies. However, the relationship between agribusiness investments and PHL is not always straightforward. Several factors can influence the effectiveness of these investments, such as power dynamics: contractual agreements between agribusinesses and farmers may place the latter in a vulnerable position (Ncube, 2020). Moreover, Cohen et al. (2022) highlighted that unfair pricing structures, stringent quality standards, and limited bargaining power can disincentivize farmers from investing in PHL reduction practices that may not be immediately profitable. Smidt and Jokonya (2022) added that access to advanced technologies may not translate into their effective utilization. The affordability, training needs, and maintenance capabilities of farmers need to be considered. Beyond these factors, market access also presents a challenge; even with improved production, farmers may struggle to find buyers for their produce if they are not adequately integrated into established market channels (Hlatshwayo et al., 2021).

Given agribusiness investments' potential benefits and unforeseen consequences, a deeper understanding of the relationship between these investments and PHL among smallholder vegetable farmers is essential. Therefore, this study explores the relationship between agribusiness

investments and postharvest losses among smallholder vegetable farmers, explicitly focusing on the eThekweni Municipality. The study will examine how agribusiness investments influence postharvest handling practices among smallholder vegetable farmers and how agribusiness investments contribute to reducing postharvest losses.

6.2 Conceptual framework exploring the relationship between agribusiness investments and postharvest losses among smallholder vegetable farmers.

The conceptual framework presented in Figure 6.1 provides a holistic perspective on the relationship between agribusiness investments and postharvest losses among smallholder vegetable farmers. It integrates key concepts and variables to guide research, policy development, and practical interventions in this critical area of agricultural development.

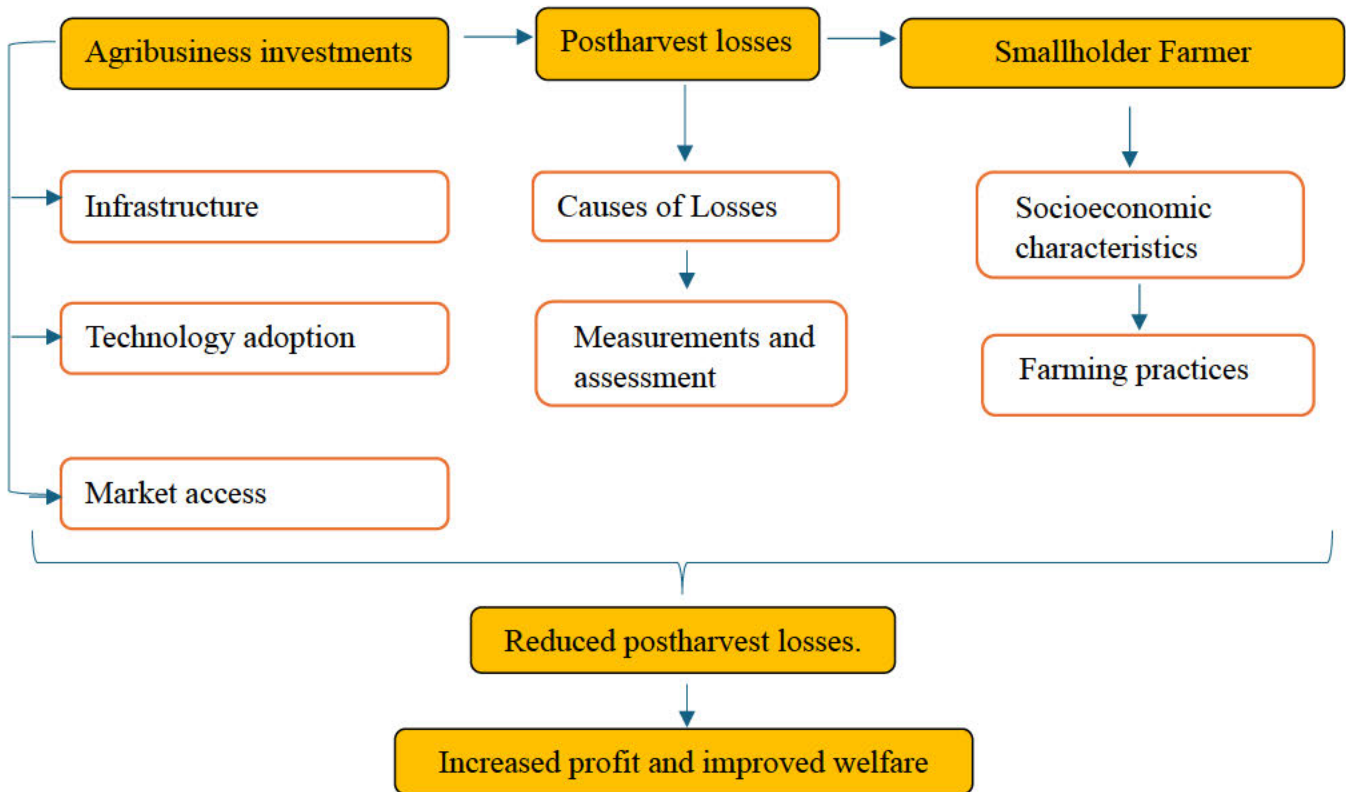


Figure 6.1: Exploring the Relationship Between Agribusiness Investments and Postharvest Losses among Smallholder Vegetable Farmers

Figure 6.1 examines the complex relationship between agribusiness investments and postharvest losses (PHL) among smallholder vegetable farmers. Three central components define this dynamic: agribusiness investments, PHL, and the smallholder vegetable farming context.

Agribusiness plays a crucial role in addressing postharvest losses through investments in infrastructure, technology adoption, and improving market access (Smidt and Jokonya, 2022). Moreover, Makule et al. (2022) suggested that infrastructure development, such as cold storage facilities and transportation networks, enhances the efficiency of handling and preserving harvested crops, reducing losses due to spoilage. Additionally, promoting innovative technologies, such as improved packaging methods or pest management solutions, further mitigates losses along the supply chain (Benyam et al., 2021). Moreover, facilitating market access for smallholder farmers through agribusiness initiatives opens opportunities to sell their produce in more lucrative markets, thereby minimizing losses stemming from inadequate market linkages and price fluctuations (Ncube, 2020).

Furthermore, understanding the causes of postharvest losses and implementing effective measurement and assessment techniques are essential aspects of addressing postharvest losses (Stathers et al., 2020). The causes of postharvest losses range from inadequate handling practices during harvesting and transportation to storage facility deficiencies and pest infestations (Tadesse, 2020). Moreover, accurate measurement and assessment methods enable stakeholders to quantify the extent of losses and identify specific points in the supply chain where interventions are most needed (Chauhan et al., 2021). Moreover, postharvest loss audits, quality assessments, and monitoring systems help track losses and evaluate interventions' effectiveness over time (Binge et al., 2023).

Smallholder farmers, characterized by diverse socioeconomic backgrounds and farming practices, are central to efforts aimed at reducing postharvest losses. Socioeconomic characteristics, including access to resources, education level, and household income, influence farmers' ability to adopt technologies and practices that mitigate losses (Myeni et al., 2020). Farming practices such as harvesting techniques, storage methods, and pest management strategies also significantly determine the extent of postharvest losses (Ngwenyama et al., 2023). Understanding the unique context of smallholder farmers is crucial for designing interventions tailored to their needs and circumstances, enhancing their resilience and productivity.

The reduction of postharvest losses holds significant implications for improving food security, economic stability, and sustainability within the agricultural sector (Stathers et al., 2020). Cattaneo et al. (2021) noted that more food reaches consumers by minimizing food losses along the supply chain, contributing to food security, and reducing pressure on natural resources. Additionally, decreasing losses translate into higher marketable yields for farmers, enhancing their incomes and livelihoods (Cammarano et al., 2020). Moreover, Ali et al. (2021) suggested that mitigating postharvest losses reduces agriculture's environmental footprint by decreasing wasted resources in production and transportation, thereby promoting sustainability and resilience in food systems.

The impact of reducing postharvest losses extends beyond immediate economic gains to encompass broader improvements in welfare and livelihoods (Assan, 2023). Moreover, increased profits resulting from reduced losses provide smallholder farmers with more excellent financial stability and opportunities for investment in their farms and communities (Ruwanza et al., 2022). This, in turn, enhances their resilience to economic shocks and improves their overall standard of living. Furthermore, by reducing losses and increasing productivity, interventions addressing postharvest losses contribute to poverty alleviation and socio-economic development, fostering inclusive growth and prosperity within rural communities (Assan, 2023).

6.3 Research methodology

The research methodology, including study area, research design, sampling procedure, sample size, and data collection is discussed in detail in Chapter 3.

6.3.1 Model Specification

i. Gross Margin and Marketing Margin Analysis

To comprehensively assess the impact of postharvest losses (PHL) on agribusiness investment, the gross margin and marketing costs associated with vegetable production and marketing were examined. The gross and marketing margin analyses allowed us to investigate the costs and returns linked to vegetable production and marketing within the study area. Gross and marketing margins were analysed to explain how PHL directly influences profits and marketing strategies within the vegetable value chain. Specifically, the gross margin represents the difference between gross income (GI) and total variable cost (TVC), providing a clear understanding of the profitability dynamics affected by PHL. The following equations were used to compute the Gross Margin:

Calculation of Marketing Margin:

$$\text{Gross Margin} = \text{Selling Price/kg} - \text{Purchasing Cost} \dots\dots\dots(6.2)$$

Marketing Margin Calculation:

$$\text{Marketing Margin Percentage} = (\text{Marketing Margin} / \text{Total Revenue without PHLs}) * 100 \dots\dots(6.3)$$

Reduction in Marketing Margin due to Loss:

$$\text{Reduction in Marketing Margin due to Loss} = \text{Total Revenue without PHLs} - (\text{Total Revenue without PHLs} * (\text{Marketing Margin Percentage} / 100)) \dots\dots\dots(6.4)$$

Marketing Margin without PHL(s):

$$\text{Marketing Margin without PHL(s)} = \text{Total Revenue without PHLs} - \text{Reduction in Marketing Margin due to Loss} \dots\dots\dots(6.5)$$

$$\text{GM} = \text{GI} - \text{TVC} \dots\dots\dots(6.6)$$

Where:

GM = Gross Margin

GI = Gross Income (R)

TVC = Total Variable Cost (R)

$$\text{Percentage Marketing Margin} = \frac{\text{Selling Price} - \text{Purchase Price}}{\text{Selling Price}} * 100 \dots\dots\dots(6.7)$$

ii. Ordinary Least Squares regression

The study employed Ordinary Least Squares regression to analyze the relationship between agribusiness and postharvest losses. Ordinary Least Squares (OLS) regression is a statistical method used to model the association between one or more independent variables (predictors) *X* and an ordinal dependent variable *Y* (Burton, 2021). Moreover, an ordinal variable exhibits a natural order, although the intervals between categories may not be uniform (Tutz, 2022). OLS regression extends the principles of linear regression to accommodate ordinal dependent variables.

It assumes a linear relationship between the independent variables and the ordinal dependent variable:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + \epsilon \dots\dots\dots(6.8)$$

where:

- Y is the ordinal dependent variable,
- X_1, X_2, \dots, X_k are the independent variables,
- $\beta_0, \beta_1, \beta_2, \dots, \beta_k$ are the regression coefficients representing the relationship between the independent variables and the dependent variable,
- ϵ is the error term.

The primary objective of OLS regression is to estimate the parameters $\beta_0, \beta_1, \beta_2, \dots, \beta_k$ of this linear relationship in a manner that minimizes the disparity between the observed values of the ordinal dependent variable and those predicted by the regression model (Weisburd et al., 2022). Moreover, Acito (2023) highlighted that the core concept underlying OLS regression is the minimization of the sum of squared differences between observed and predicted values of the ordinal dependent variable:

$$\min \sum_{i=1}^n (Y_i - \hat{Y}_i)^2$$

Where Y_i represents the observed value of the ordinal dependent variable for observation i and \hat{Y}_i represents the predicted value of the ordinal dependent variable for observation i . This involves estimating coefficients for each independent variable, typically achieved through techniques such as ordinary least squares or maximum likelihood estimation (Williams and Quiroz, 2020). Moreover, Gregorich et al. (2021) highlighted that it is imperative to recognize that OLS regression shares key assumptions with linear regression, including the relationship between independent variables. The ordinal dependent variable adheres to a linear pattern, observations are independent of each other, the variance of errors remains constant across all levels of the ordinal dependent variable, and the independent variables do not exhibit high correlation with each other.

6.4 Results and Discussion

This section primarily focuses on analyzing the acquired findings. Table 3.1 describes the demographic characteristics of smallholder vegetable farmers in eThekweni Municipality. To comprehensively assess the impact of postharvest losses (PHL) on agribusiness investment, the gross margin and marketing costs associated with vegetable production and marketing were examined. Subsequently, it explores the relationship between agribusiness investments and postharvest losses within this demographic group.

6.4.1 Impact of postharvest Losses (PHL) on agribusiness investment

(i) *Gross margin analysis of smallholder vegetable farming*

Before delving into the gross margin and marketing margin analysis, it is crucial to understand how postharvest losses (PHL) impact profits and marketing in smallholder vegetable farming. Interpreting the influence of PHL on agribusiness investment allows for a comprehensive understanding of the economic effects throughout the value chain. Analyzing gross and marketing margins subsequently provides quantitative insights into the extent of financial losses incurred by vegetable producers and marketers due to PHL. The gross margin formula has been correctly applied to ensure clarity and accuracy. The gross margin is calculated as:

$$\text{Gross Margin} = (\text{Revenue} - \text{Cost of Goods Sold}) / \text{Revenue} * 100$$

Table 6.1: Gross margin analysis of smallholder vegetable farming in eThekweni Municipality

Variable	Cost (ZAR)	Percentage
Total Variable Cost	5054.3	
Total Revenue	6421.72	
Gross Margin	1367.42	21.29%
Total Revenue without PHLs	7755.94	
Reduction in Gross Margin Due to Loss	1334.22	13.54%
Gross Margin without PHLs	2701.64	34.83%

Source: Field survey, 2023.

Table 7.1 presents a comprehensive analysis of the gross margin for smallholder vegetable farming in eThekweni Municipality, illustrating the significant impact of postharvest losses (PHL) on profitability. The total variable cost for farming operations is ZAR 5 054.30, which encompasses seeds, fertilizers, and labour expenses. The total revenue generated from vegetable sales is ZAR 6

421.72, reflecting the income received by farmers before accounting for any losses. Consequently, the gross margin is 21.29%, indicating the portion of revenue remaining after covering variable costs and representing the profitability of farming activities under current conditions.

Without postharvest losses, the total revenue could have been ZAR 7 755.94, underscoring the potential income achievable with effective postharvest management practices. The reduction in gross margin attributable to postharvest losses is ZAR 1 334.22, equivalent to 13.54%, highlighting the adverse impact of PHLs on farmers' profitability. The gross margin without PHLs would increase to 34.83%, demonstrating the potential benefits of reducing PHLs through improved management practices. These findings reveal that postharvest losses significantly reduce the gross margin for smallholder vegetable farmers, with a 13.54% decrease in profitability due to PHLs.

(ii) Analysis of marketing margin of vegetable sales

These findings from Table 6.2 highlight the critical need for interventions to reduce postharvest losses in the vegetable supply chain. Addressing issues such as inadequate storage facilities, poor transportation infrastructure, and inefficient handling practices can help mitigate these losses. Implementing better postharvest management techniques, such as improved harvesting methods, advanced storage solutions, and effective transportation systems, can enhance the profitability of retailers and other stakeholders in the vegetable value chain. By doing so, the overall economic welfare of farmers, retailers, and consumers can be significantly improved, contributing to a more sustainable and resilient agricultural sector.

Table 6.2: Analysis of marketing margin of vegetable sales in eThekweni Municipality.

Variable	Retailers Cost (Average)	Percentage
Purchasing cost	31.84	
Selling price/kg	50.95	
Marketing margin	19.11	37.50%
Total revenue without PHLs	609.4	
Reduction in marketing margin due to loss	558.4	91.60%
Marketing margin without PHL(s)	577.6	100%

Marketing Margin:

Marketing margin is calculated as Selling price per kg - Purchasing cost per kg. Therefore, Marketing margin = 50.95 - 31.84 = 19.11 ZAR.

Percentage Marketing Margin:

Percentage Marketing Margin is calculated as (Marketing Margin / Selling Price per kg) * 100.
Percentage Marketing Margin = $(19.11 / 50.95) * 100 \approx 37.50\%$.

Total Revenue without PHLs: Given as 609.40 ZAR.

Reduction in Marketing Margin due to Loss: Given as 558.40 ZAR.

To find the percentage reduction: (Reduction / Total Revenue without PHLs) * 100. Percentage Reduction = $(558.40 / 609.40) * 100 \approx 91.60\%$.

Table 7.2 provides a comprehensive analysis of the marketing margin for retailers within the vegetable supply chain, highlighting the significant financial implications of postharvest losses (PHLs). The table details that the average purchasing cost for retailers is ZAR 31.84 per kilogram, while the selling price per kilogram is ZAR 50.95. This results in a marketing margin of ZAR 19.11 per kilogram, 37.50% of the selling price. This margin represents the profitability before accounting for any postharvest losses and is essential for covering the costs associated with marketing, transportation, storage, and other operational expenses.

The total revenue that could be generated without considering PHLs is noted to be ZAR 609.40. However, PHLs lead to a significant reduction in the marketing margin, amounting to ZAR 558.40. This reduction represents a drastic 91.60% decrease in the marketing margin, highlighting the severe impact of PHLs on retailers' profitability. Such a high percentage loss underscores the critical need for effective postharvest management practices to prevent spoilage and waste.

Without PHLs, the marketing margin would be ZAR 577.60, representing the full potential revenue without any losses. This stark contrast between potential and actual revenue due to PHLs emphasizes the vulnerability of the vegetable supply chain to inefficiencies in postharvest handling and storage.

6.4.2 The relationship between agribusiness investments and postharvest losses

Table 6.3 demonstrates the relationship between agribusiness investments and postharvest losses. This analysis examines how factors affecting agribusiness investment are linked to postharvest losses in the vegetable supply chain, using data from 238 observations. The overall model is statistically significant (p-value = 0.0433) at a 5% level, indicating that at least one of the

considered factors has a measurable impact on how much produce is lost after harvest. However, the explanatory power of the model is somewhat limited. The R-squared value (2.15%) suggests that the included factors only explain a small portion of the variation in postharvest losses. While the adjusted R-squared (8.3%) indicates a slightly better fit when considering the number of factors analysed. The root mean squared error (RMSE) of 0.2970 represents the average difference between actual and predicted losses, with a lower RMSE suggesting a more accurate model.

Table 6.3: OLS estimating the relationship between agribusiness investments and postharvest losses among smallholder vegetable farmers in eThekweni Municipality

Variables	Coefficient	Std. Err.	t-value
Poor transport infrastructure	0.610	0.220	2.77 ***
Financial Support	-0.540	0.166	-3.25 ***
Cost of Inputs	0.230	0.101	2.27 **
Market Demand	-0.120	0.120	-1.00
Weather Conditions	0.141	0.150	0.94
Adoption of New Farming Practices	-0.151	0.110	-1.37
Market Access	-0.242	0.140	-1.73
cons	0.712	0.156	4.56 ***
Number of observations = 238 F(7, 230) = 0.72 Prob > F = 0.0433 R-squared = 0.0215 Adjusted R-squared = 0.083 Root MSE = 0.2970			

Note ** 5% significance level and *** 1% significance level

Source: Field result (2023). Regression run by Stata 18

Poor transport infrastructure shows a positive coefficient and is statistically significant at the 1% level. This implies that poor transport infrastructure is associated with a 61% increase in postharvest losses. These results underscore the importance of investing in transport infrastructure to ensure effective agricultural supply chains. The study by Parimia and Chakraborty (2022) supports the idea that investments in improving transportation infrastructure, such as roads, railways, and storage facilities, could help mitigate postharvest losses by ensuring timely and

efficient transportation of agricultural produce to markets. Furthermore, Binge et al. (2023) highlighted the need for agribusiness investors and policymakers to consider broader infrastructure development initiatives as part of their investment strategies. Additionally, Jayne et al. (2021) suggested that by addressing transportation challenges, investors can create an enabling environment for agricultural growth and profitability, contributing to the sustainability and resilience of the agribusiness sector.

Financial support has a negative coefficient and is statistically significant at the 1% level. This implies that increased financial support is associated with a 54% decrease in postharvest losses. Therefore, the findings highlight the importance of financial assistance and support mechanisms for smallholder vegetable farmers in mitigating postharvest losses. The study by Bisheko and Rejikuma (2023) agrees that increased access to financial resources enables farmers to invest in technologies, infrastructure, and practices to improve postharvest handling, storage, and transportation of agricultural produce. Additionally, financial support facilitates investments in training programs, education, and capacity-building initiatives focused on postharvest management practices (Stathers et al., 2020). By empowering farmers with the necessary knowledge and skills, financial support can enhance their ability to minimize losses and optimize the value chain from farm to market (Smidt and Jokonya, 2022).

The input cost shows a positive coefficient and is statistically significant at the 5% level. This implies that a unit increase in the price of inputs is associated with an increase in postharvest losses by 23%. Therefore, high input prices reduce profit margins for agribusinesses, leading investors to hesitate to invest in farming ventures. Mensah et al. (2021) supported the findings, highlighting that there is a need for policymakers and stakeholders to address factors contributing to input price volatility, including measures to stabilize commodity prices, improve market transparency, and enhance access to affordable inputs for farmers. Moreover, Akinyi et al. (2022) agreed that the reduction in input prices not only enhances the profitability for agribusiness investors but also contributes to mitigating postharvest losses, which can further amplify the gains in overall profitability and market competitiveness of agricultural enterprises, thus fostering a more conducive environment for continued investment in the sector.

6.5 Conclusion and Recommendations

The gross margin analysis revealed that improved harvesting techniques, storage facilities, transportation methods, and market infrastructure can help minimize losses and enhance vegetable producers' and marketers' income and livelihoods. By implementing better harvesting techniques, physical damage to vegetables can be minimized, reducing potential sources of postharvest losses. Moreover, upgrading storage facilities is crucial for preserving the freshness and quality of vegetables while enhancing transportation methods to ensure prompt delivery in optimal condition and minimize transit-related losses. Additionally, investing in market infrastructure, such as cold storage facilities and proper packaging, can maintain vegetable quality throughout the marketing process. Collectively, these interventions have the potential to maximize returns on investment for producers and ensure the availability of high-quality produce in the market, benefiting both parties economically and fostering a more sustainable and profitable vegetable value chain. The marketing margin analysis of vegetables reveals the financial dynamics within the market. Retailers lost about 558.40 ZAR. However, without losses, they would make a total revenue of 609.40 ZAR. This emphasizes the significant impact of PHLs on retailer profitability and highlights the necessity of mitigating these losses for enhanced profitability and sustainability in the vegetable market.

Furthermore, the analysis of agribusiness investments and postharvest losses underscores the importance of addressing transportation constraints, providing financial assistance, managing input prices efficiently, understanding market dynamics, and enhancing climate resilience strategies. These findings provide valuable insights for policymakers and agribusiness investors to implement strategies to reduce postharvest losses, strengthen the resilience of agricultural supply chains, and promote sustainable agricultural development.

Therefore, the study recommendations are as follows:

- The analysis identified poor transport infrastructure as a critical factor in increased postharvest losses. Investing in improving transportation infrastructure, such as roads, railways, and storage facilities, is essential to mitigate these losses. Enhanced infrastructure will ensure timely and efficient transportation of agricultural produce to markets, thereby reducing spoilage and waste. Agribusiness investors and policymakers should consider broader infrastructure development initiatives to create a more enabling agricultural growth and profitability environment.

- Increased financial support was found to significantly reduce postharvest losses. Financial assistance to smallholder vegetable farmers can enable them to invest in technologies, infrastructure, and practices that improve postharvest handling, storage, and transportation. Financial support should also facilitate investments in training programs, education, and capacity-building initiatives focused on postharvest management practices. Empowering farmers with the necessary knowledge and skills through financial support can enhance their ability to minimize losses and optimize the value chain from farm to market.
- High input costs were shown to correlate with increased postharvest losses. Policymakers and stakeholders must address factors contributing to input price volatility by implementing measures to stabilize commodity prices, improve market transparency, and enhance farmers' access to affordable inputs. Reducing input prices can enhance profitability for agribusiness investors and mitigate postharvest losses, fostering a more conducive environment for continued investment in the agricultural sector.
- A significant reduction in gross margin due to postharvest losses highlights the need for effective postharvest management practices. Interventions such as improved harvesting techniques, better storage facilities, and enhanced transportation methods can help minimize losses. Investing in market infrastructure, such as cold storage facilities and proper packaging, can maintain vegetable quality throughout the marketing process. These measures can maximize returns on investment for producers and ensure the availability of high-quality produce in the market, benefiting farmers and consumers economically.
- Comprehensive policies that support the adoption of innovative postharvest management technologies and practices are crucial. These policies should prioritize investments in infrastructure and provide a framework for sustainable agricultural practices. By creating a supportive policy environment, stakeholders can enhance the efficiency and profitability of the vegetable supply chain, contributing to improved livelihoods for smallholder farmers and overall economic welfare.

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CHAPTER 7

Assessing the environmental impact of postharvest losses along the vegetable supply chain: the case of smallholder vegetable farmers in eThekweni Municipality

Abstract

Postharvest losses occur throughout the vegetable supply chain, resulting in economic losses for farmers and significant environmental implications, including increased greenhouse gas emissions. Smallholder vegetable farmers often experience postharvest losses, particularly during harvesting, where crop remains are left on the ground. This phenomenon imposes environmental effects as the discarded crop residues decompose, releasing greenhouse gases into the atmosphere. However, the lack of understanding regarding the magnitude of these environmental effects results in inadequate mitigation efforts and further environmental degradation. Therefore, this study assessed the environmental impact of postharvest losses along the vegetable supply chain among smallholder vegetable farmers in eThekweni Municipality. Using structured questionnaires, a cross-sectional research design and a multi-stratified random sampling technique were employed to collect primary data from 238 farmers. The study used descriptive statistics and Intergovernmental Panel on Climate Change (IPCC) principles to analyze the data. The findings indicated that 89% of the farmers use manure, while 59% use compost in their agricultural practices. Additionally, 73% of the farmers apply NPK fertilizers, with 10% opting for urea fertilizers. Applying IPCC principles, the average greenhouse gas emissions generated by the tractor during ploughing for all farmers were estimated at 0.0159349 metric tons of CO₂, indicating a relatively low level of emissions. Furthermore, emissions resulting from crop residues were calculated for each crop, with cabbage emitting 72.8063 kgCO₂-eq and spinach emitting 83.2072 kgCO₂-eq. Emission from other crops was also estimated, and the cumulative total greenhouse gas emissions amounted to 2256.9963 kgCO₂-eq. Therefore, the study recommends that policymakers prioritize incentivizing sustainable agricultural practices, investing in infrastructure, and strengthening regulatory frameworks to mitigate postharvest losses.

Keywords: Environmental implications, greenhouse gas emissions, intergovernmental panel on climate change, postharvest losses, smallholder vegetable farmers, vegetable supply chain.

7.1 Introduction

The deterioration of food quality and quantity between harvest and consumption poses significant challenges to global food security and sustainability. Postharvest losses occur throughout the vegetable supply chain, resulting in economic losses for farmers and significant environmental implications, including increased greenhouse gas emissions (Sibanda and Workneh, 2020). Moreover, Barrett (2021) highlighted that meeting the food demands of a rapidly growing global population while ensuring sustainability is one of the significant challenges; hence, reducing postharvest losses remains critical. Postharvest losses are responsible for an estimated annual carbon footprint of 3.3 gigatons of CO₂ equivalent, constituting 8.0% of total anthropogenic greenhouse gas emissions (Ali et al., 2021). The greenhouse gas emissions from postharvest food loss were calculated to be approximately 1.4 kilograms of CO₂ per year (FAO, 2021). Furthermore, with climate change worsening environmental challenges and altering agricultural production systems, the need to minimize waste and optimize resource use in the vegetable supply chain has become pivotal.

Approximately one-third of all food produced for human consumption is globally lost or wasted yearly (FAO (2021)). In Africa, postharvest losses are estimated to be above 30%, while they are estimated to be over 32% in South Africa (Osabohien, 2022). These losses are often caused by a lack of access to proper storage and transportation infrastructure, resulting in food shortages, malnutrition, and a detrimental environmental impact (Stathers et al., 2020). Furthermore, postharvest losses represent a significant loss of income for farmers and may lead to higher production costs as resources invested in planting, cultivating, and harvesting crops are wasted, further reducing the economic viability of agriculture (Debebe, 2022). In addition to their impact on food security and financial stability, postharvest losses have significant environmental implications, including greenhouse gas emissions, primarily methane and carbon dioxide, as organic matter decomposes in landfills or during storage and transportation (Neme et al., 2021).

The greenhouse gas emissions from postharvest losses contribute to global warming and climate instability, worsening environmental challenges. Moreover, postharvest losses can lead to soil degradation and nutrient depletion, as organic matter is lost from agricultural systems (Gamage et al., 2023). Organic matter is crucial in maintaining soil health and fertility, providing essential nutrients for plant growth, and supporting soil structure and water retention. However, when

organic matter is lost due to postharvest losses, soils become less resilient to erosion, nutrient leaching, and other forms of degradation, compromising agricultural land's long-term productivity and sustainability (Mahmud et al., 2021). Furthermore, Khatri et al. (2023) suggested that the environmental impact of postharvest losses extends beyond the farm gate to affect surrounding ecosystems and biodiversity. Moreover, improper disposal of spoiled or discarded vegetables can lead to pollution of water bodies and habitats, harming aquatic life and disrupting ecosystems (Kolawole and Iyiola, 2023).

A comprehensive approach is essential to mitigate postharvest losses and their environmental impact within the vegetable supply chain. Gokarn and Choudhary (2021) suggested that stakeholders must consider various strategies encompassing different supply chain stages to reduce losses and promote sustainability effectively. This entails advocating for improved harvesting practices among farmers, including harvesting at optimal maturity stages and employing sharp tools to minimize damage (Gokarn and Choudhary, 2021). Moreover, investment in infrastructure and technology to enhance handling and transportation, such as providing adequate packaging materials and refrigerated storage facilities, is crucial (Makule et al., 2022). Additionally, promoting postharvest management practices like proper cleaning, sorting, packaging, and value-added processing activities such as drying and canning extend shelf life and minimize food waste (Singh et al., 2024). Also, Collaborative efforts among stakeholders, including government agencies, research institutions, and private sector entities, are vital for effectively implementing and scaling up postharvest loss mitigation strategies (Mvumi and Stathers, 2020).

Insufficient understanding of the environmental effects of postharvest losses results in ineffective mitigation strategies and contributes to environmental degradation. This lack of understanding hampers stakeholders' ability to implement targeted interventions to reduce the ecological footprint of postharvest losses. Moreover, it extends the cycle of resource wastage, pollution, and ecosystem disruption. Therefore, the study assessed the environmental impact of postharvest losses along the vegetable supply chain among smallholder vegetable farmers in eThekweni Municipality.

7.2 Conceptual framework showing the environmental impact of postharvest losses along the vegetable supply chain.

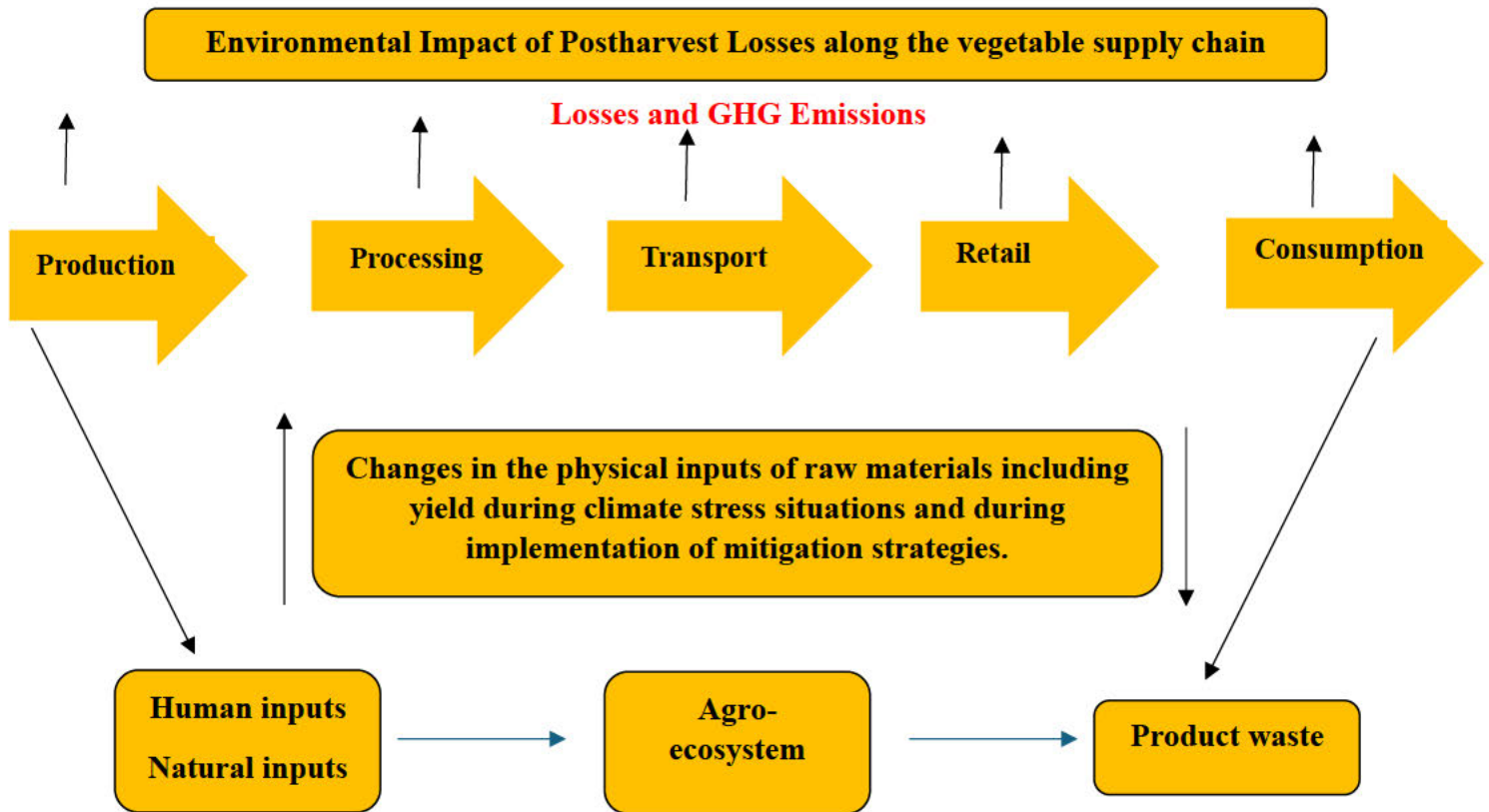


Figure 7.1: Environmental impact of postharvest losses along the vegetable supply chain.

Figure 8.1 demonstrates the greenhouse gas (GHG) emissions throughout the vegetable supply chain due to postharvest losses. Postharvest losses at the production stage contribute significantly to greenhouse gas (GHG) emissions through various pathways. Ntinyari and Gweyi-Onyango (2020) highlighted that inefficient farming practices, such as excessive use of synthetic fertilizers and pesticides to mitigate potential losses, result in emissions of nitrous oxide (N_2O) and carbon dioxide (CO_2) from soil and fertilizer application. Moreover, expanding agricultural areas to compensate for lost production can lead to deforestation or habitat conversion, releasing stored carbon dioxide into the atmosphere (Olorunfemi et al., 2022). Additionally, the decomposition of organic matter from spoiled crops emits methane (CH_4), a potent greenhouse gas (Sangotayo, 2023). These emissions further contribute to climate change and environmental degradation, worsening the impact of postharvest losses on the environment.

Postharvest losses also have environmental effects during the processing stage, particularly in energy consumption and emissions (Blanckenberg et al., 2021). Processing facilities often require substantial energy inputs for refrigeration, heating, and packaging operations, leading to indirect emissions of greenhouse gases (Rahman et al., 2022). Moreover, disposing of spoiled or unsellable vegetables further contributes to emissions, especially if waste management practices are not environmentally friendly (Ali et al., 2021). Additionally, burning of waste can release greenhouse gases, while landfilling contributes to methane emissions as organic matter decomposes anaerobically (Scharff et al., 2023). Thus, addressing postharvest losses at the processing stage is crucial for reducing the environmental impact and promoting sustainability along the vegetable supply chain.

Transportation of vegetables to the market adds to the environmental footprint through increased fuel consumption and vehicle emissions (du Plessis et al., 2022). Moreover, prolonged transit times and inefficient logistics increase emissions per unit of transported goods (Galford et al., 2020). Refrigerated trucks, commonly used to maintain the quality of perishable vegetables during transit, further worsen emissions due to the energy-intensive nature of refrigeration units (Salami et al., 2022). Additionally, Stathers et al. (2020) highlighted that emissions from transportation contribute to air pollution and climate change, highlighting the need for efficient transportation practices and logistics optimization to minimize the environmental impact of postharvest losses.

Postharvest losses at the retail stage also have significant environmental implications, particularly concerning energy use and waste management (Ali et al., 2021). Retail outlets require energy for refrigeration, lighting, and other operational activities, contributing to greenhouse gas emissions (du Plessis et al., 2022). Moreover, discarded vegetables, whether spoiled or unsold, contribute to emissions if sent to landfills, where they decompose and produce methane (Khalid et al., 2023). Additionally, the disposal of packaging materials used for retail display and transportation adds to the environmental footprint, emphasizing the importance of sustainable packaging and waste management practices in reducing the environmental impact of postharvest losses (Aslam et al., 2024).

At the consumption stage, postharvest losses result in emissions primarily from food waste disposal methods and energy use in food preparation (Padi and Chimphango, 2021). Additionally, the energy and resources expended in producing, transporting, and preparing wasted food add to

indirect emissions (Nyika et al., 2020). Furthermore, consumer behavior, such as overbuying and improper storage, worsens the environmental impact of postharvest losses by increasing the volume of wasted food and associated emissions (Balan et al., 2023). Thus, addressing postharvest losses at the consumption stage requires interventions to promote responsible consumption habits and reduce food waste.

7.3 Research Methodology

The research methodology, including study area, research design, sampling procedure, sample size and data collection, is discussed in detail in Chapter 3.

7.3.1 Data Analysis

The study employed descriptive statistics, inferential analysis, and the IPCC principles presented in Table 7.1 to analyze the collected data comprehensively. Firstly, the data was captured, coded, and cleaned using Microsoft Excel. Outliers and incomplete questionnaires were excluded. The data was then exported to Stata 18 for the analysis. Descriptive statistics was utilized to summarize the data through measures like mean and standard deviation, simplifying the data and facilitating a clearer understanding of the findings. Meanwhile, inferential analysis enables the researchers to make inferences and predictions about the entire population based on the sample data, thus extending the findings beyond the specific sample studied. The IPCC principles presented in Table 7.1 were applied to quantify the environmental effects (GHG emissions) of postharvest losses in the vegetable supply chain.

Table 7.1: The IPCC principles used to estimate the environmental impact of postharvest losses.

Principle	Description
Lifecycle Assessment (LCA)	Considers environmental impacts throughout the entire lifecycle of a product or process, from raw material extraction to disposal.
Carbon Footprint Analysis	Quantifies greenhouse gas emissions associated with specific activities, processes, or products.
Waste Management Guidelines	Provides methodologies for assessing environmental implications of waste generation and disposal.
Emission Factors	Standardized coefficients for calculating greenhouse gas emissions based on input data such as fuel consumption and agricultural practices.
Global Warming Potential (GWP)	Measures the heat-trapping ability of greenhouse gases relative to CO ₂ over a specific time horizon.
IPCC Inventory Guidelines	Outlines methodologies for compiling national greenhouse gas inventories relevant to assessing PHLs' environmental impact.

Source: IPCC report 2018/19

To calculate the emission from the tractor, the following formula was used:

$$GHG\ Emission = Fuel\ Consumption\ Rate \times Emission\ Factor \dots\dots\dots(8.1)$$

Where:

- Fuel Consumption Rate = Average fuel consumption per hour
- Emission Factor = 74.1 tCO₂/TJ (as per the National Inventory)
- Operating time = Average time taken

The GHG emissions from the crop residues are calculated as follows:

$$GHG\ emissions = Carbon\ content \times conversion\ factor \times crop\ residue \dots\dots\dots(8.2)$$

Carbon content and conversion factors are based on the national inventory and IPCC principles.

7.4 Results and Discussion

7.4.1 Common fertilizers used by smallholder farmers.

The data on fertilizer use among smallholder farmers, presented in Figure 7.2, reveals a diverse landscape of agricultural practices with implications for environmental impact. A notable trend is

smallholder vegetable farmers using organic fertilizers such as manure and compost, at 89% and 59%, respectively. Research by Zondo and Baiyegunhi (2021) supported the findings, indicating that smallholder vegetable farmers often prefer compost and manure over synthetic fertilizers. They are more accessible and affordable than chemical fertilizers, which can be prohibitively expensive and may require specialized application equipment. Moreover, using these fertilizers reflects a positive inclination toward sustainable farming practices that contribute to improved soil health and structure (Tolessa et al., 2020). However, using synthetic fertilizers, specifically NPK fertilizers and urea, by 73% and 10% of farmers raises concerns about the potential environmental impact. If not applied carefully, synthetic fertilizers can lead to nutrient imbalances, soil degradation, and water pollution through runoff (Bindhya et al., 2021). Additionally, even though smallholder vegetable farmers tend to use whatever kind of fertilizer is available, all farmers indicated that they use inorganic fertilizers because sometimes the government gives them. However, Bese et al. (2021) highlighted that even if smallholder farmers use organic fertilizers, careful management is still required to ensure optimal benefits without compromising the environment. Therefore, it is crucial for agricultural extension services and policymakers to promote best farming practices, educate farmers on balanced fertilizer use, and encourage the adoption of environmentally friendly alternatives to achieve a harmonious balance between agricultural productivity and environmental sustainability (Tolessa et al., 2020).

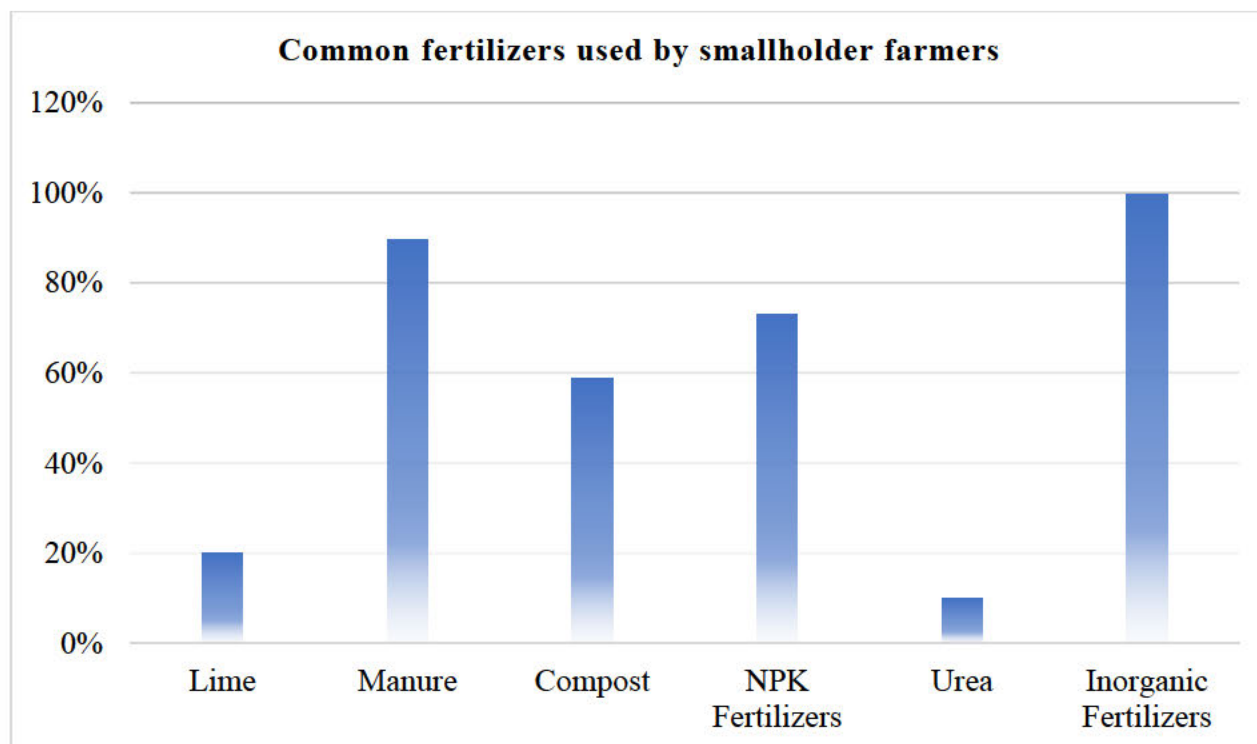


Figure 7.2: Common fertilizers used by smallholder vegetable farmers in eThekweni Municipality.

Source: Field survey, 2023.

7.4.2 Agricultural practices and their potential implications for greenhouse gas (GHG) emissions

Table 7.2 presents the critical variables related to agricultural practices and their potential implications for greenhouse gas (GHG) emissions. The data includes the time the tractor takes to plough, the quantity of crop residue remaining after cultivation, and the amount of organic fertilizer used. These factors play a crucial role in understanding the environmental impact of agricultural activities, particularly in terms of GHG emissions. Analyzing these variables allows for insights into the efficiency and sustainability of farming practices, guiding efforts toward minimizing environmental footprints while maintaining agricultural productivity.

Table 7.2: Agricultural practices by smallholder vegetable farmers in eThekweni Municipality and their potential implications for greenhouse gas (GHG) emissions

Variables	Mean	Std. error	95% confidence interval	
Time taken by tractor to plough	0.8655462	0.0538714	0.7594182	0.9716742
Crop residue remained	283.4034	10.03658	263.6311	303.1757

Organic fertilizer used	378.7815	8.772019	361.5004	396.0626
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Source: Field survey, 2023. Estimated from Stata (18) and

i. GHG Emissions by tractor

Table 7.2 indicates that the average time the tractor takes to plough is about 1 hour, implying that smallholder vegetable farmers hold a small portion of arable land. Ndlovu et al. (2022) agreed, highlighting that smallholder vegetable farmers are known for planting small areas of land, and they produce for both selling and home consumption. Equation (1) calculates a tractor's greenhouse gas (GHG) emissions during operational activities. This estimation was computed using IPCC principles and the National inventory. IPCC principles stated the formula to estimate this emission, while the National inventory stated the emission factor for the tractor. Utilizing equation 8.1, key parameters such as the fuel consumption rate, emission factor, and operating time were considered.

$$\text{Fuel Consumption Rate} = \frac{8.5 \text{ liters per hour}}{3.6 \frac{\text{MJ}}{\text{L}}} * \frac{10^{-6} \text{ GJ}}{\text{hr}}$$

Therefore, the estimated emission from the tractor was computed as follows:

$$E = \left(\frac{8.5}{3.6} \times 10^{-6} \text{ GJ per hour} \times 0.8655462 \text{ hours} \right) \times (74.1 \text{ tCO}_2/\text{TJ})$$

$$E \approx 0.0159349 \text{ tCO}_2$$

Thus, the emissions generated from tractor operations are relatively low, highlighting the significance of prioritizing fuel efficiency and implementing emission control measures in modern agricultural machinery. This finding highlights the potential for reducing greenhouse gas emissions and mitigating environmental impact through farm technology and equipment advancements. Moreover, Tolessa et al. (2020) added that by optimizing fuel efficiency and integrating emission control technologies, such as catalytic converters and particulate filters, into tractor designs, farmers can minimize the carbon footprint associated with agricultural activities. Furthermore, adopting cleaner fuel sources, such as biodiesel or renewable energy-powered machinery, can further reduce emissions and promote the sustainability of farm operations (Bese et al., 2021).

ii. Greenhouse gas emissions from crop residues (after harvesting)

Table 8.3 presents the greenhouse gas emissions by various crops among smallholder vegetable farmers, considering their carbon content, conversion factors, total average crop residue, and the

resulting greenhouse gas (GHG) emissions measured in kilograms of carbon dioxide equivalent (kgCO₂-eq). Each crop has a distinct carbon content multiplied by the corresponding conversion factor to determine the total average crop residue. The calculated GHG emissions provide valuable insights into the environmental impact of each specific crop's cultivation and residue management (postharvest losses). This comprehensive overview allows an understanding of how different crops contribute to the overall carbon footprint. These estimates are calculated using equation 8.2.

Table 7.3: Greenhouse gas emission from crop residues among smallholder vegetable farmers in eThekweni Municipality

Crop	Carbon Content (kg)	Conversion factor	Total average crop residue	GHG Emission (kgCO ₂ -eq)
Cabbage	0.07	3.67	283.4034	72.80633346
Spinach	0.08			83.20723824
Potatoes	0.12			124.8108574
Carrot	0.05			52.0045239
Peppers	0.73			759.2660489
Sweet potatoes	0.10			104.0090478
Beetroot	0.08			83.20723824
Butternut	0.21			218.4190004
Tomatoes	0.73			759.2660489
Total				2256.996337

Table 7.3 presents Greenhouse gas emissions from crop residues of various crops planted by smallholder vegetable farmers, quantifying their environmental impact. Cabbage, with a carbon content of 0.07 kg and a conversion factor of 3.67, contributes to a total average crop residue of 283.4034 kg and an associated GHG emission of 72.8063 kgCO₂-eq. With a carbon content of 0.08 kg, Spinach has a total average crop residue of 83.2072 kg and a GHG emission of 83.2072 kgCO₂-eq. Potatoes (124.8108574 kgCO₂-eq), carrots (52.0045239 kgCO₂-eq), peppers (759.2660489 kgCO₂-eq), sweet potatoes (104.0090478 kgCO₂-eq), beetroot (83.20723824 kgCO₂-eq), butternut (218.4190004 kgCO₂-eq) and tomatoes (759.2660489 kgCO₂-eq), each has unique combinations of carbon content and conversion factors, resulting in varying levels of total average crop residue and corresponding GHG emissions. The cumulative total GHG emissions for all crops amount to 2256.9963 kgCO₂-eq, providing a comprehensive overview of the collective environmental impact of crop residues post-harvesting. The calculated GHG emissions are directly

linked to the management and disposal of crop residues after harvesting. Crops with higher carbon content and conversion factors, such as peppers and tomatoes, contribute more substantially to GHG emissions, indicating potentially higher postharvest losses or inefficient waste management practices (Mutengwa et al., 2023). Moreover, the higher GHG emissions suggest that a considerable amount of crop residues are not efficiently utilized or managed after harvest (Tolessa et al., 2020). Additionally, Rutta (2022) indicated that postharvest losses may be attributed to inadequate postharvest processing, storage, or utilization practices, leading to increased emissions. Furthermore, Sayara and Sánchez (2021) suggested that implementing efficient waste management strategies, such as composting or utilizing crop residues for energy generation, can help reduce emissions and contribute to a more environmentally friendly agricultural system.

7.4.3 Reducing postharvest losses through value addition

Promoting and expanding the adoption of specific value-addition practices such as washing, grading, sorting, cooling, storing, and proper packaging can significantly reduce postharvest losses (Rutta, 2022). Additionally, encouraging smallholder vegetable farmers to explore cutting, dehydrating, and sun-drying practices expands available strategies, fostering a more resilient and sustainable vegetable supply chain (Ndlovu et al., 2022). Moreover, education and awareness campaigns are crucial in driving the widespread adoption of these practices (Asadi et al., 2022). Table 7.4 highlights the basic value-addition practices practiced by smallholders and their benefits in reducing postharvest losses.

Table 7.4: Value addition practices and reducing postharvest losses among smallholder vegetable farmers in eThekweni Municipality.

Value addition practice	Percentage of farmers practicing	Benefit
Washing	100%	Proper washing removes contaminants and pathogens, preserving the quality of produce. Strategy: Emphasize and promote thorough washing practices to all smallholder vegetable farmers.
Grading	21%	Grading helps segregate produce based on quality, ensuring only premium items reach the market. Strategy: Encourage wider adoption of grading practices to enhance market value.
Dehydrating	20%	Dehydrating preserves perishable items and extends their shelf life. Strategy: Encourage more farmers to adopt dehydrating methods, especially for crops prone to quick spoilage.

Sorting	50%	Sorting enables the removal of damaged or substandard produce, preventing their inclusion in the market supply. Strategy: Advocate for increased sorting practices among farmers to enhance product quality and reduce losses.
Cooling	20%	Cooling inhibits the growth of microorganisms, delaying the spoilage of perishable goods. Strategy: Promote the use of cooling facilities and technologies to extend the freshness of produce.
Storing	92%	Proper storage facilities help maintain product quality over an extended period, reducing losses. Strategy: Continue supporting and expanding storage infrastructure to accommodate more farmers and diverse produce.
Packaging	82%	Adequate packaging protects items during transportation and storage, minimizing physical damage and contamination. Strategy: Enhance awareness of proper packaging techniques and materials to reduce losses.
Cutting	16%	Cutting and processing surplus produce into smaller portions can add value and reduce losses. Strategy: Encourage more farmers to explore cutting and processing practices for surplus or slightly damaged items.
Sun-drying	51%	Sun drying is a traditional preservation method that reduces moisture content and prevents spoilage. Strategy: Promote sun-drying as an effective, low-cost method for certain crops, emphasizing proper techniques to ensure quality.

Source: Field survey, 2023.

7.4.4 Environmental implications of postharvest losses: Insights from IPCC principles

The greenhouse gas (GHG) emissions resulting from postharvest losses (PHLs) have significant implications for climate change and environmental sustainability (Stathers and Mvumi, 2020). These emissions, encompassing gases like carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), contribute to the warming of the Earth's atmosphere, leading to adverse effects such as global temperature rise, altered weather patterns, and ecosystem disruptions (Stathers and Lamboll, 2023). Moreover, the Intergovernmental Panel on Climate Change (IPCC) principles guide the assessment of these emissions and their impacts. IPCC (2018) stipulated the following tenets: Lifecycle Assessment (LCA) helps quantify the cumulative environmental burden of PHLs, considering emissions throughout the entire lifecycle of agricultural products. Carbon Footprint Analysis enables the measurement of GHG emissions associated with specific activities or processes, offering insights into the carbon intensity of food loss and waste. Waste Management Guidelines assist in evaluating emissions from waste decomposition, highlighting the importance of proper disposal methods to mitigate environmental impacts. Emission Factors provide standardized coefficients for estimating emissions, aiding in quantifying PHL-related GHG

emissions. Global Warming Potential (GWP) values allow for comparing different gases' warming effects, informing decisions on emission reduction strategies. Finally, IPCC Inventory Guidelines offer methodologies for compiling national GHG inventories, facilitating the assessment of PHLs' contribution to overall emissions, and guiding policy interventions to mitigate their environmental impact. Thus, understanding and addressing PHL-related GHG emissions through the lens of IPCC principles is crucial for developing effective strategies to combat climate change and promote sustainable food systems.

7.5 Conclusion and Recommendations

The study highlights the substantial environmental impact of postharvest losses along the vegetable supply chain, particularly among smallholder farmers in eThekweni Municipality. The emissions from the decomposition of crop residues left on the ground during harvesting contribute significantly to increased greenhouse gas emissions. Precisely, the greenhouse gas emissions generated by tractor operations, estimated at 0.0159349 metric tons of CO₂, were low. Additionally, emissions resulting from crop residues varied across different crops, with cabbage emitting 72.8063 kgCO₂-eq and spinach emitting 83.2072 kgCO₂-eq. The cumulative total greenhouse gas emissions from all crops amounted to 2256.9963 kgCO₂-eq. These findings underscore the need for policymakers to prioritize incentivizing sustainable agricultural practices, investing in infrastructure, and strengthening regulatory frameworks to mitigate postharvest losses and curb emissions effectively. By addressing these challenges, stakeholders can work towards fostering a more environmentally sustainable agricultural sector while ensuring the economic viability of farming activities in the region. Adopting value-addition practices among smallholder vegetable farmers in eThekweni Municipality plays a crucial role in reducing postharvest losses and enhancing the overall value of agricultural produce. While practices like washing (100%) and storing (92%) are widely adopted, there remains room for improvement in areas such as grading (21%), dehydrating (20%), and cooling (20%). Encouraging wider adoption of these practices, along with promoting sorting (50%), packaging (82%), cutting (16%), and sun-drying (51%) techniques, can contribute significantly to minimizing losses and preserving product quality. Lastly, understanding and addressing PHL-related GHG emissions through the lens of IPCC principles are crucial for developing effective strategies to combat climate change and promote sustainable food systems.

The study, therefore, recommends:

- Prioritize implementing sustainable agricultural practices to reduce postharvest losses and mitigate greenhouse gas emissions.
- Invest in infrastructure such as cold storage facilities and transportation networks to minimize physical damage and spoilage of produce during transit.
- Strengthen regulatory frameworks to enforce quality standards and promote eco-friendly packaging materials.
- Raise awareness among farmers about the importance of value-addition practices such as grading, dehydrating, and cooling to enhance product quality and market value.
- Provide financial incentives, technical assistance, and training programs to encourage smallholder farmers to adopt improved harvesting, handling, and storage practices.

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CHAPTER 8

The impact of postharvest losses among smallholder farmers' household welfare in eThekweni Municipality, KwaZulu Natal.

Abstract

Smallholder farmers are vital for poverty reduction and food security in developing countries, yet postharvest losses (PHL) significantly challenge their economic sustainability and livelihoods. PHLs are worsened by a lack of comprehensive understanding and targeted strategies to mitigate them. This chapter investigates the impact of PHL on smallholder farmers' household welfare in eThekweni Municipality. Using a cross-sectional research design and a multi-stratified random sampling technique, primary data were collected from 238 farmers through structured questionnaires. The analysis used the Ordinal Logistic Model (OLM), marginal effects, and the Multinomial Endogenous Switching Regression (MESR) model. The OLM results indicate that household size, training attended, distance from the market, farm experience, extension services, and financial support significantly influence the severity of postharvest losses. The marginal effects analysis reveals that each additional household member increases the likelihood of low-severity losses by 3.9% and decreases high-severity losses, though not significantly. Each additional training session increases low-severity losses by 11% and decreases high-severity losses by 16%, both significant at the 5% level. Increased market distance increases low-severity losses by 31% and decreases high-severity losses by 16%, both at the 1% significance level. The MESR model highlights the substantial negative impact of PHL on farm income. Specifically, a unit increase in PHL is associated with a 7% decrease in farm income during the harvesting stage, a 4.4% decrease during transportation, and an 8.4% decrease during marketing. Thus, the study recommends tailored training programs and enhanced extension services for postharvest management, infrastructure improvements for better market access, expanded financial support for postharvest technologies, and improved market linkages for smallholder farmers.

Keywords: Household welfare, Multinomial Endogenous Switching Regression, Ordered logit model, Postharvest losses, Smallholder farmers, Socioeconomic impact

8.1 Introduction

Globally, postharvest loss among smallholder farmers poses a considerable threat to their economic sustainability and hinders progress towards achieving several Sustainable Development Goals (SDGs), notably those focused on eradicating hunger and promoting responsible consumption and production (Mafongoya et al., 2022). These losses can negatively impact food security and environmental stewardship efforts. According to Dhimi (2020), an estimated 2.5 billion tons of produce are lost annually during postharvest operations worldwide. Moreover, Stathers and Mvumi (2020) indicated that the immediate postharvest losses in Africa are approximately 1.3 billion tons of produce. In South Africa alone, roughly 10 million tons of food go to waste annually out of a total production of 31 million tons (Oelofse et al., 2020). These losses affect producers and retailers by causing significant income loss and deeply impact smallholder farmers' households, undermining their overall well-being.

Approximately 2 million smallholder farmers in South Africa occupy about 35 million hectares of arable land (Mujuru and Obi, 2020). This implies that many households generate their livelihoods from farming activities. Moreover, Ncube (2020) highlighted that smallholder farmers play a significant role in the economy, particularly in Africa, where they are responsible for a substantial portion of agricultural production and employment. Furthermore, smallholder farmers play a crucial role in household welfare, particularly in low-income countries, by providing food security and reducing poverty (Giller et al., 2021). Despite their significance to the agricultural sector and the broader economy, smallholder farmers face numerous challenges that hinder their progress and profitability (Nyambo et al., 2022). These challenges include inadequate infrastructure, limited access to financial support, deficient extension services, and restricted market access and information, which lead to postharvest losses (Mapiye et al., 2023). These challenges can be addressed by collaborating with different stakeholders, including government bodies, NGOs, research institutions, private sector actors, and local communities, to promote sustainable agricultural development and enhance the livelihoods of smallholder farmers.

Postharvest losses worsen food insecurity, particularly at the household level, by reducing food availability for consumption (Read et al., 2020). Food shortage leads to inadequate nutrition and hunger among smallholder farmers and their families, further perpetuating poverty and malnutrition (Ngcamu and Chari, 2020). Additionally, income loss resulting from postharvest

losses directly impacts smallholder farmers, making it challenging to afford essential needs such as food, education, and healthcare (Chegere et al., 2022; Negi and Trivedi, 2021). Economically, postharvest losses directly translate into income loss for smallholder farmers. When crops are lost due to improper handling, storage, or transportation, farmers' potential earnings are significantly diminished. Fan et al. (2023) noted that this income reduction threatens the financial stability of farming households and limits their ability to invest in essential resources such as seeds, fertilizers, and agricultural equipment for future farming seasons.

Moreover, the socio-economic consequences of postharvest losses extend beyond individual households to entire communities and regions. Giller et al. (2021) stated that as smallholder farmers struggle to cope with income loss and food insecurity, local economies may suffer, impacting businesses, markets, and employment opportunities in rural areas. Additionally, postharvest losses can contribute to social instability and migration as households seek alternative livelihoods or resources elsewhere, further disrupting community cohesion and resilience (Stathers and Mvumi, 2020). Upton et al. (2021) highlighted that the impact of postharvest losses on smallholder farmers' household welfare is profound and far-reaching, affecting economic stability, food security, and overall well-being. Addressing this challenge requires targeted interventions that improve postharvest management practices, enhance access to market opportunities and financial services, and promote sustainable agricultural development. By reducing postharvest losses, policymakers, stakeholders, and development organizations can help smallholder farmers improve their livelihoods, strengthen local economies, and advance sustainable development goals related to poverty alleviation, food security, and rural prosperity.

Ongoing efforts to mitigate postharvest losses involve a multifaceted approach, as highlighted by Porat (2018). This approach includes technological innovations, infrastructure development, capacity building, market access initiatives, policy support, and partnerships. Technological advancements focus on improving packaging materials and storage systems, while investments in cold chain infrastructure aim to maintain optimal conditions for perishable crops during transportation. Fofana et al. (2021) emphasized that capacity-building programs empower smallholder farmers with the knowledge and skills to implement the best postharvest management practices. Moreover, initiatives to improve market access and information enable farmers to make informed decisions about selling their produce. Furthermore, Stathers et al. (2020) highlighted that

supportive policies and regulatory frameworks create an enabling environment for addressing postharvest losses, while stakeholder partnerships facilitate collaboration and resource sharing to scale up interventions and maximize impact.

Rutta (2022) noted the significant impact of postharvest losses on the welfare of smallholder farmers. Ngcamu and Chari (2020) agreed that postharvest losses, particularly in crop production, lead to a decline in farmers' income and welfare. Moreover, Stathers et al. (2020) highlighted the need for interventions to enhance food, nutrition, and income security to reduce postharvest losses, particularly in perishable crops. Thus, the study aims to assess the socioeconomic impact of postharvest losses on smallholder farmers' household welfare. It seeks to comprehensively understand how postharvest losses affect these farming households' well-being, livelihoods, and socio-economic status. By shedding light on these dynamics, it aims to inform targeted interventions and policy measures to improve the resilience, livelihoods, and socio-economic outcomes of smallholder farming.

8.2 The causes of postharvest losses impacting smallholder farmers' household welfare.

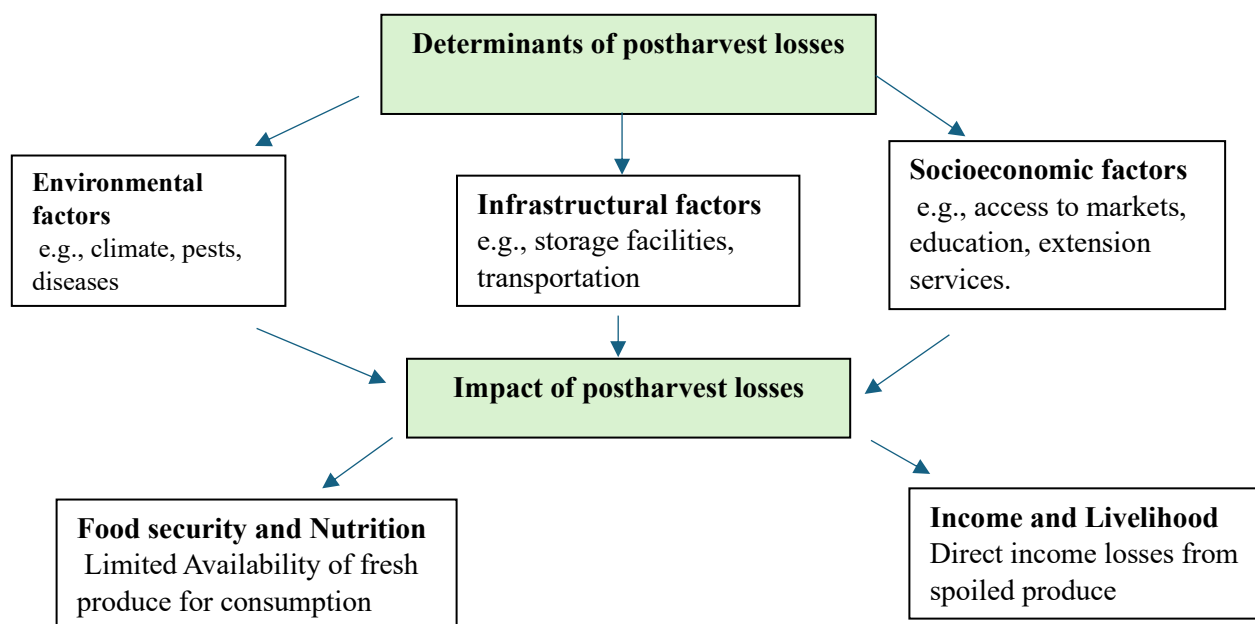


Figure 8.1: Conceptual Framework demonstrating the causes of postharvest losses impacting smallholder farmers' household welfare.

The conceptual framework depicts the interconnected factors influencing smallholder vegetable farmers' postharvest losses and their subsequent impact on their household welfare. At the core of

this framework lie the determinants of postharvest losses, encompassing a range of factors such as environmental conditions, infrastructure, socio-economic constraints, and market dynamics. These determinants directly influence the occurrence and magnitude of postharvest losses experienced by smallholder farmers, shaping the extent to which their produce is spoiled or wasted before reaching consumers. Postharvest losses, in turn, profoundly impact household welfare, manifesting through various dimensions. Economically, these losses diminish farmers' income and livelihood opportunities, constraining their ability to meet basic needs and invest in essential resources for future agricultural endeavors (Olakiumide, 2021). Furthermore, Binge et al. (2023) highlighted that postharvest losses undermine household food security and nutrition, worsening hunger and malnutrition among farmers and their families. This, in turn, contributes to broader socio-economic challenges, including reduced access to education and healthcare, thereby compromising the overall quality of life for smallholder farmers.

Addressing postharvest losses and their effects on smallholder vegetable farmers' household welfare requires a multifaceted approach that targets both the determinants of losses and their impacts. Stathers et al. (2021) suggested that efforts to mitigate postharvest losses should focus on improving agricultural practices, enhancing infrastructure and storage facilities, strengthening market linkages, and providing farmers with access to financial support and extension services. Addressing the root causes of postharvest losses can help minimize economic losses for farmers, enhance food security and nutrition within households, and improve overall well-being (Rutta, 2022). Additionally, Kimengsi et al. (2020) added that interventions to improve household welfare should consider broader socio-economic factors, such as access to education, healthcare, and social support systems, to ensure holistic development and resilience among smallholder farming communities. Through collaborative efforts involving government agencies, NGOs, research institutions, and private sector actors, it is possible to implement sustainable solutions that reduce postharvest losses and contribute to the long-term welfare and prosperity of smallholder vegetable farmers and their households.

8.3 Research Methodology

The research methodology, including study area, research design, sampling procedure, sample size and data collection, is discussed in detail in Chapter 3.

8.3.1 Model specification

The Multinomial Endogenous Switching Regression (MESR) model is a two-step estimation procedure considering selection bias correction among all the options (Momanyi, 2016). Income was used as a proxy for household welfare. In the first stage, smallholder farmers are assumed to face a choice of mutually exclusive practices for responses to postharvest losses. In the second stage, the MESR econometric model was used to investigate the impact of postharvest loss on the household's welfare.

Stage 1: The Ordered Logit Model

The ordered logit model was used to estimate the determinants of postharvest losses among smallholder farmers. The Ordered Logit Model is a statistical technique used to analyze data where the dependent variable is ordinal, meaning it has ordered categories but not necessarily equal intervals between them. This model is commonly employed when the outcome variable represents different levels or degrees of a particular phenomenon or response. One of the critical assumptions of the Ordered Logit Model is the Proportional Odds Assumption, which posits that the relationship between the independent variables and the dependent variable remains constant across all levels or categories of the dependent variable (Williams and Quiroz, 2020). Another critical assumption is the Independence of Irrelevant Alternatives (IIA), which suggests that the odds of choosing one category over another are not influenced by the presence or absence of other categories (Washo et al., 2021).

The Ordered Logit Model estimates the cumulative probabilities of observing each category of the dependent variable or a higher category based on the values of the independent variables. This is done through a logistic regression framework, where the coefficients associated with the independent variables represent the effect of those variables on the likelihood of moving to a higher category (Washo et al., 2021). The threshold parameters separate the categories of the dependent variable and are estimated alongside the coefficients using maximum likelihood estimation (Williams, 2021). Interpreting the coefficients involves understanding their impact on the odds ratios of moving to a higher category than a reference category. A positive coefficient indicates an increase in the odds of moving to a higher category for a one-unit increase in the independent variable. In contrast, a negative coefficient suggests a decrease in the odds (Williams, 2021). The magnitude of the coefficient reflects the strength of the relationship between the independent

variable and the odds of moving to a higher category. The Ordered Logit Model estimates the cumulative probabilities of observing each category of the dependent variable or a higher category. If Y is the ordinal dependent variable with K categories, X_1, X_2, \dots, X_p are the independent variables; the model can be expressed as follows:

$$P(Y \leq j | X_1, X_2, \dots, X_p) = F(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_p X_p - \alpha_j) \dots\dots\dots(8.1)$$

Where:

- $P(Y \leq j | X_1, X_2, \dots, X_p)$ Is the cumulative probability of observing the dependent variable up to category j .
- $F()$ is the cumulative distribution function of the logistic distribution.
- $\beta_0, \beta_1, \dots, \beta_p$ Are the coefficients associated with the independent variables?
- $\alpha_1, \alpha_2, \dots, \alpha_{K-1}$ determine the cut-off points between categories.

Interpreting the coefficients involves considering the odds ratios associated with the independent variables, like logistic regression. These odds ratios represent the multiplicative change in the odds of being in a higher category for a one-unit increase in the independent variable, holding other variables constant.

Stage 2: Multinomial Endogenous switching regression (MESR) was used to investigate the impact of each response practice on income status by applying a selection bias correction model. Farm households face a total of M regimes, with regime $j=1$ being the reference category (non-responsive). The income status equation for each possible regime is defined as:

$$\text{Regime 1: } Q_{i1} = z_i \alpha_1 + \mu_{i1} \quad \text{if } i=1 \dots\dots\dots(8.2)$$

$$\text{Regime 2: } jQ_{if} = z_i \alpha_j + \mu_{if} \quad \text{if } i=1 \dots\dots\dots(8.3)$$

From the above equation, Q_{if} 's represents the income status of the i th farmer in regime j and the error terms Q_{if} 's are distributed with $E(\mu_{if}|x, z) = 0$ and $var((\mu_{if}|x, z) = \sigma_j^2$. Q_{if} Is observed if, and only if, PHL practice j is used, which occurs when $Y_y^* > \frac{\max}{M \neq 1} (Y_{im})$ If the error terms are not independent. Consistent estimation of α_j It requires the inclusion of the selection correction terms of the choices. The MNESR assumes the following linearity assumption:

$E(\mu_{if}|\varepsilon_{i1} \dots \varepsilon_{ij}) = \sigma_j \sum_{M \neq 1}^j r_j (\varepsilon_{im} - E(\varepsilon_{im}))$. By construction, the correlation between the error terms is zero. Using the above assumption, equation (5) can be expressed as follows:

$$\text{Regime 1: } Q_{i1} = z_i \alpha_1 + \sigma_1 \lambda_1 + \omega_{i1} \quad \text{if } i = 1 \dots \dots \dots (8.4)$$

$$\text{Regime } j: Q_{if} = z_i \alpha_1 + \sigma_1 \lambda_1 + \omega_{ij} \quad \text{if } i = 1$$

σ_j is the covariance between ε 's and μ 's while ω_{ij} is the inverse Mills ratio computed from the estimated probabilities in equation (6) as follows:

$$\lambda_j = \sum_{M \neq 1}^j p_j \left[\frac{p_{im}}{1-p_{im}} + \ln(p_{if}) \right] \dots \dots \dots (8.5)$$

P in the above equation represents the correlation coefficient of ε 's and μ 's while ω_{if} are error terms with an expected value of zero. In the multinomial choice setting, there were $j=1$ selection correction terms, one for each alternative postharvest practice.

Table 8.1: The description of the variables used to estimate the impact of postharvest losses on welfare.

Variables	Description	Type	Unit
Average Income	Monthly average household income	Numerical	ZAR
Household Size	Number of individuals living in the same household	Numerical	Members
Years spent in School	Total years of formal education completed	Numerical	Years
Training attended	Agricultural-related training attended	Categorical	-
Distance from the Market	Distance from the farm to the nearest market	Numerical	Kilometers
Farm Experience	Number of years of experience in farming	Numerical	Years
Extension Service	Access to agricultural extension services	Categorical	-
Financial Support	Access to financial support	Categorical	-

Source: Table created by the author (2024)

8.4 Results and Discussion

8.4.1 The demographic and socioeconomic characteristics of smallholder farmers in eThekweni Municipality.

The analysis aimed to determine the impact of postharvest losses (PHL) on household welfare, with farm income used as a proxy for household welfare. The dependent variable, farm income, is the total income earned from farming activities by the household. The descriptive statistics for farm income and other variables used in the analysis are reported in Table 3.1.

8.4.2 The common vegetables grown by smallholder farmers in eThekweni Municipality.

Figure 8.2 visually represents the crop choices made by smallholder farmers in the eThekweni Municipality. As highlighted in the subsequent analysis, certain crops, such as cabbage and spinach, are universally cultivated among smallholders, while others show varying degrees of prevalence. This overview offers a clear insight into the crop preferences of smallholder farmers and can inform targeted agricultural development interventions.

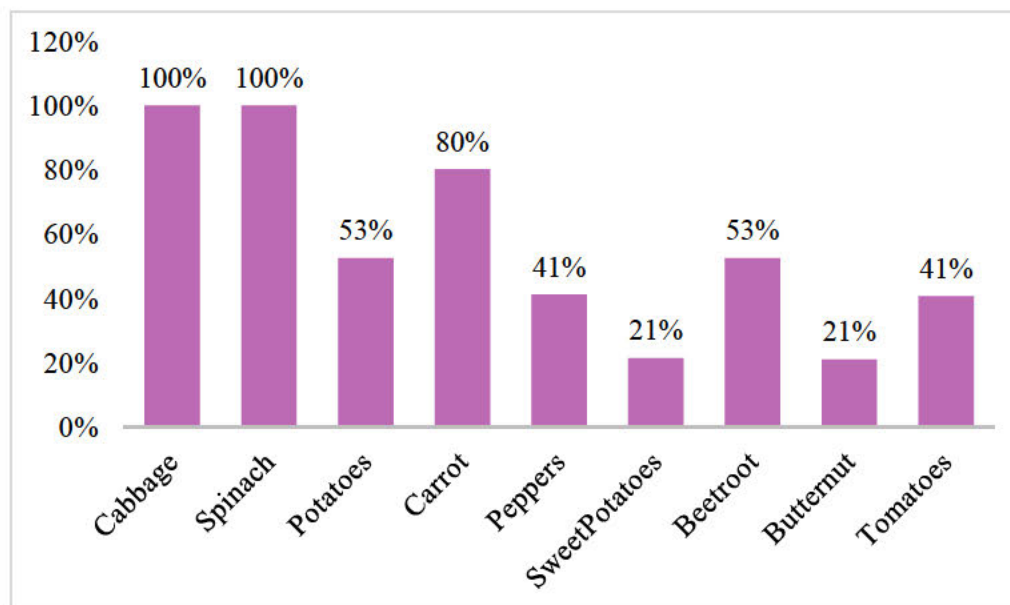


Figure 8.2: Common vegetables grown by smallholder vegetable farmers in the eThekweni municipality.

Source: Field survey, 2023.

The data provided illustrates the widespread cultivation of certain crops among smallholder farmers. Cabbage and spinach stand out as universally grown crops among the surveyed smallholders, with all participants cultivating them. Following closely are potatoes, carrots,

beetroot, and tomatoes, which are grown by a proportion of smallholders, ranging from 53% to 80%. Peppers exhibit a slightly lower presence, being cultivated by 41% of smallholders, while sweet potatoes and butternut have a lower cultivation rate, with only 21% of smallholders growing them. These findings shed light on the prevailing crop choices among smallholder farmers, offering valuable insights for agricultural development strategies and support initiatives tailored to the needs of these farming communities.

8.4.3 Determinants of postharvest losses among smallholder farmers.

The MESR model was applied in two stages. In the first stage, smallholder farmers face mutually exclusive choices for responding to postharvest losses, such as improved storage methods, better transportation logistics, or the use of pesticides to reduce crop damage. adopting specific practices to mitigate these losses. This stage was modelled using an Ordered Logit Model (OLM) to account for the ordinal nature of the response variable and the severity of PHL (low, medium, high).

Table 8.2: Postharvest Losses Experienced by Smallholder Vegetable Farmers.

Severity of Postharvest losses	Frequency	Percentage
Low	71	29.83
Moderate	79	33.19
High	88	36.97

Source: Field survey, 2023

Table 8.2 shows that 29.83% of smallholder vegetable farmers in eThekweni Municipality reported low severity of postharvest losses, indicating effective postharvest management among this group. However, 33.19% experienced medium severity, and 36.97% faced high severity of postharvest losses, highlighting significant challenges. The prevalence of medium and high-severity losses suggests that most farmers struggle with substantial postharvest issues impacting their farm income and household welfare. These findings underscore the need for targeted interventions to address the factors contributing to higher postharvest loss severity, which are further analyzed using the Ordered Logit Model (OLM) in subsequent sections. Identifying and mitigating these factors can help improve smallholder farmers' economic stability and livelihood.

Table 8.3: Determinants of Severity of Postharvest Losses among Smallholder Vegetable Farmers.

Variables	Coefficient	Robust SE	P-value
Average Income	-0.127**	0.050	0.015
Household Size	0.107**	0.032	0.008
Years spent in School	-0.146***	0.044	0.002
Training attended	-0.098**	0.035	0.020
Distance from the Market	0.075***	0.026	0.001
Farm Experience	-0.119**	0.047	0.010
Extension Service	-0.168***	0.056	0.003
Financial Support	-0.139**	0.067	0.025
The number of obs. = 238 LR chi ² (11) = 292.41 Prob > chi ² = 0.000 Log-likelihood = -175.053554 Pseudo R ² = 0.6608			

Note ** 5% significance level and *** 1% significance level

Source: Field result, 2023. Regression run by Stata 18

The analysis shows that household size is a significant determinant at the 5% level with a negative coefficient, indicating that an increase in household size is associated with a decreased likelihood of postharvest losses among smallholder vegetable farmers. Mukarumbwa (2017) supports this finding, suggesting that a larger household provides a greater labor force, which reduces postharvest losses and increases profitability. Conversely, household size has a positive coefficient and is significant at the 5% level, implying that an increase in household size correlates with a higher likelihood of postharvest losses. Chegere (2018) and Stathers and Mvumi (2020) explain that larger households face more logistical challenges in managing and storing harvested crops, leading to increased losses.

Years spent in school show a negative coefficient and are statistically significant at the 5% level. This suggests that additional years of education reduce the likelihood of experiencing postharvest losses, as educated farmers are more likely to adopt improved technologies and practices (Nohamba et al., 2022). However, the relationship is reversed with a positive coefficient at the 5%

level, indicating that more years in school are associated with increased postharvest losses. This counterintuitive result could be due to market-related factors, such as demand and pricing, which education alone cannot address (Stathers et al., 2020).

Training Attended: Training attended shows a negative coefficient and is statistically significant at the 5% level, implying that more training reduces postharvest losses. This is consistent with findings by Stathers and Mvumi (2020), who noted that empowering farmers with knowledge and skills significantly reduces food loss. However, training shows a positive coefficient and is significant at the 5% level, indicating increased postharvest losses despite training. This suggests that other factors, such as infrastructure and market conditions, play a more significant role (Stathers et al., 2020).

Distance from the Market: Distance from the market has a negative coefficient and statistical significance at the 1% level. This finding is supported by Debebe (2022), who highlights that proximity to markets encourages better postharvest practices. Conversely, increased distance is significantly associated with higher postharvest losses, reflecting challenges such as longer transport times and higher spoilage risk (Nohamba et al., 2022; Balana et al., 2022). Furthermore, farm experience has a negative coefficient and is statistically significant at the 1% level, indicating that more years of farm experience reduces the likelihood of postharvest losses. Thibane et al. (2023) support this finding, noting that experienced farmers are better equipped to manage their harvests and make informed decisions. Experienced farmers can better navigate logistical challenges (Shikwambana and Malaza, 2022).

Extension service shows a negative coefficient, significant at the 5% level, suggesting that more frequent extension visits reduce the likelihood of postharvest losses. Balana et al. (2022) found that effective extension services help farmers optimize their harvest timing and techniques. Increased extension services continue to reduce postharvest losses (Mohammed et al., 2020). Moreover, financial support has a negative coefficient and is statistically significant at the 1% level, indicating that financial aid reduces the likelihood of postharvest losses. Mhlanga (2021) emphasizes that financial support enables investments in modern technologies and infrastructure, enhancing harvesting and transportation efficiency. Sibanda and Workneh (2020) also note that financial support improves access to market information, facilitating better decision-making and reducing losses.

8.4.4 Marginal effect

The study also estimated the marginal effect using the market stage. The marginal effect refers to the change in the dependent variable that results from a one-unit change in an independent variable while holding all other variables constant. In other words, it quantifies the impact of an insignificant change in one variable on the outcome of interest. In statistical modelling, marginal effects can be calculated using specific methods tailored to the model type. For instance, in logistic regression, marginal effects represent the change in the probability of the dependent variable occurring due to a one-unit change in the independent variable. This study estimated the marginal effect for the market stage, where most smallholder vegetable farmers experience losses. Table 5.4 below estimates the marginal effects of the determinants of postharvest losses at the market stage.

Table 8.4: The marginal effects of factors on the Severity of Postharvest Losses

Variables	Low	Moderate	High
Household Size	0.039 ** (0.020)	- 0.001 (0.003)	- 0.024 (0.034)
Years spent in School	0.014 (0.020)	- 0.007 (0.080)	- 0.006 (0.070)
Training attended	0.118** (0.021)	- 0.005 (0.101)	- 0.167** (0.070)
Distance from the Market	0.310*** (0.060)	- 0.020** (0.010)	- 0.169*** (0.021)
Farm Experience	0.058*** (0.002)	- 0.043*** (0.001)	- 0.038** (0.013)
Extension Service	0.086** (0.041)	- 0.002 (0.013)	- 0.094** (0.044)
Financial Support	0.466 (0.226)	- 0.027 (0.014)	- 0.468** (0.234)

Note: Standard error in brackets, ** 5% significance level and *** 1% significance level

Source: Field result, 2023. Regression run by Stata 18

The analysis of marginal effects in Table 8.4 reveals how changes in various factors influence the likelihood of experiencing different severity levels of postharvest losses (low, moderate, high).

An increase in household size is associated with a significant 3.9% increase in the likelihood of experiencing low-severity postharvest losses, suggesting that larger households have more labour available to manage harvest effectively. However, the effect on high-severity losses is insignificant, indicating that household size may not substantially impact higher loss levels. Moreover, the results show no significant impact on the severity of postharvest losses for years

spent in school. This suggests that educational attainment alone may not directly influence the severity of postharvest losses among smallholder vegetable farmers.

Attending training has a significant positive effect on reducing postharvest losses. Specifically, attending more training sessions increases the likelihood of low-severity losses by 11% and decreases high-severity losses by 16%, both significant at the 5% level. This highlights the importance of training in equipping farmers with skills to minimize losses. Furthermore, distance from the market significantly affects postharvest losses. An increase of one kilometer in distance is associated with a 31% increase in the likelihood of low-severity losses and a 16% decrease in high-severity losses, both significant at the 1% level. This suggests that proximity to markets facilitates better postharvest management practices.

Farm experience significantly influences the severity of postharvest losses. Each additional year of farm experience increases the likelihood of low-severity losses by 0.8% and decreases moderate and high-severity losses by 0.3% and 3%, respectively. These findings underscore the value of practical experience in reducing postharvest losses. Moreover, extension services play a crucial role in reducing postharvest losses. An increased frequency of extension service visits is associated with an 8% increase in the likelihood of low-severity losses and a 9% decrease in high-severity losses, both significant at the 5% level. This indicates that extension services provide valuable support in postharvest management. Furthermore, financial support significantly reduces high-severity postharvest losses by 46.8%, highlighting its critical role in enabling farmers to invest in better postharvest technologies and practices. However, its effect on low and moderate-severity losses is not statistically significant.

8.4.5 Impact of Postharvest Losses on Farm Income (Household Welfare)

The impact of postharvest losses on household welfare for smallholder vegetable farmers was estimated using Multinomial Endogenous Switching Regression. MESR is a statistical modelling technique that analyzes data with multiple potential outcomes, endogenous variables, and sample selection issues. It combines elements of multinomial regression, endogeneity correction, and sample selection correction within a single framework.

Table 8.5: Estimated Effects of Postharvest Losses on Farm Income using MESR Model

Treatment variable	Postharvest losses	Actual Coefficient (Actual S.E)	Counterfactual Coefficient (Counterfactual S.E)	Treatment Effect (ATT)	Robust S.E
Income	Harvesting	0.352 (0.082)	0.418 (0.095)	-0.070***	0.024
	Transportation	0.278 (0.071)	0.312 (0.085)	-0.044**	0.019
	Marketing	0.467 (0.101)	0.521 (0.112)	-0.084***	0.029

Note: Standard error in brackets, ** 5% significance level and *** 1% significance level

Source: Field result, 2023. Regression run by Stata 18

The estimated treatment effect for the harvesting stage shows a negative coefficient of -0.070, which is statistically significant at the 1% level. This indicates that for each unit increase in postharvest losses during the harvesting stage, farm income decreases by approximately 7%. These results align with the findings of Huang et al. (2018), who highlighted the adverse effects of inefficient postharvest practices, such as poor handling during harvesting, on farm income. The study by Dixon et al. (2020) also supports these findings, emphasizing that ineffective harvesting techniques contribute to increased postharvest losses and, consequently, reduced farm income. The significant impact observed during the harvesting stage underscores the need for improved harvesting practices to minimize losses and enhance farm income.

During the transportation stage, the estimated treatment effect has a negative coefficient of -0.044, which is statistically significant at the 5% level. This suggests that each unit increase in postharvest losses during transportation is associated with a 4.4% decrease in farm income. Smith and Jones (2019) support this finding by noting that inefficient transportation practices, such as poor handling and inadequate infrastructure, contribute to increased losses and reduced farmer income. Stathers et al. (2020) further emphasize that transportation infrastructure plays a crucial role in influencing postharvest losses, and improvements in this area can significantly reduce losses and enhance farm income.

The estimated treatment effect during the marketing stage reveals a negative coefficient of -0.084, significant at the 1% level. This implies that each unit increase in postharvest losses during the market stage results in an 8.4% decrease in farm income. The findings indicate that postharvest losses at the market stage substantially negatively impact farm income. Stathers and Mvumi (2020)

attribute these losses to product deterioration, spoilage, and lower selling prices for damaged goods. The significant impact observed during the marketing stage highlights the need for effective postharvest management practices to minimize losses and protect farm income.

8.5 Conclusion and Recommendations

The study conducted in the eThekweni Municipality provides a comprehensive understanding of the demographic profile, household composition, income, and challenges smallholder vegetable farmers face. Contrary to previous studies, the average age of smallholder vegetable farmers is lower, indicating a more balanced age distribution and the presence of farmers in their productive stages, which could foster innovation in the sector. However, education levels remain low among farmers, posing a significant barrier to adopting new agricultural practices, including climate-smart agriculture. The household composition reveals a considerable workforce, highlighting the importance of efficient resource management. Despite the higher monthly earnings compared to estimates, smallholder farmers still face income disparities and vulnerabilities, underscoring the need for interventions to enhance income stability. Female farmers play a predominant role in vegetable farming, yet they are more vulnerable to poverty and food insecurity compared to male-headed households, necessitating targeted support initiatives. The study also highlights the significance of marital status, with unmarried farmers comprising the majority, emphasizing the need for tailored support for vulnerable demographics. Moreover, factors such as unemployment, dependence on farming as the primary source of income, and challenges related to market participation further highlight the complexities smallholder farmers face. The findings concerning postharvest losses underscore the need for interventions to mitigate losses across various stages, with implications for farm income. Education, farm experience, extension services, and financial support are critical factors influencing postharvest losses and farm income, highlighting the importance of targeted interventions to improve agricultural practices and enhance income stability among smallholder vegetable farmers. Additionally, the Multinomial Endogenous Switching Regression analysis provides further insights into the significant negative impact of postharvest losses on farm income, emphasizing the need for effective postharvest management practices across harvesting, transportation, and market stages to maximize income and profitability for smallholder vegetable farmers.

Thus, the study recommends:

- Encourage smallholder farmers to utilize household labour during the harvest stage effectively. Larger households have a greater labour force, significantly reducing the likelihood of severe postharvest losses. Training programs can be designed to teach farmers how to coordinate and optimize household labour for harvesting activities.
- Expand and intensify training programs focused on postharvest management practices. Training attended by farmers significantly reduces high-severity postharvest losses. Enhanced training initiatives should cover best harvesting, handling, and storage practices to minimize losses.
- Develop infrastructure and logistical support to improve farmers' access to markets. Proximity to markets significantly reduces the severity of postharvest losses. Investments in transportation infrastructure, such as better roads and market facilities, can help farmers reduce the time and effort needed to get their produce to market, thus reducing losses.
- Implement mentorship programs where experienced farmers can share their knowledge with less experienced farmers. Farm experience is associated with reduced postharvest losses, and mentorship programs can facilitate knowledge transfer and improve overall farm management practices.
- Increase the frequency and quality of extension service visits to smallholder farmers. Extension services play a critical role in reducing the severity of postharvest losses. Strengthened extension services can provide timely information and support to farmers on effective postharvest management practices.
- Develop financial products tailored to the needs of smallholder farmers, such as low-interest loans and grants for postharvest technology investments. Financial support significantly reduces the likelihood of severe postharvest losses. Access to credit can enable farmers to invest in necessary technologies and infrastructure to improve postharvest handling and storage.
- Incorporate postharvest management into the curriculum of agricultural education programs. Although years spent in school did not significantly affect postharvest losses, targeted education on postharvest management can provide farmers with the knowledge needed to reduce losses.

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CHAPTER 9

Summary, conclusion, and recommendations

9.1 Summary

Over 60% of Africa's population is dependent on smallholder farming, vital to the continent's economy. Despite this, these farmers are often neglected in development plans, hindering their ability to increase incomes and improve livelihoods. A significant challenge facing this sector is postharvest losses (PHL), particularly in the vegetable supply chain, where 30–40% of the value of fruits and vegetables is lost in sub-Saharan Africa. South Africa alone reports over 10 million tons of food waste annually. These losses impact food availability and deter agribusiness investment, discouraging local and foreign investors. Traditional handling methods and inadequate storage facilities exacerbate these losses, disproportionately affecting smallholder vegetable farmers and leading to significant economic losses, wasted resources, and adverse effects on household income, food security, and overall rural development.

The literature review highlighted the vital role of smallholder vegetable farming in South Africa's agricultural landscape, emphasizing its significance for food security, rural development, and economic growth. Despite weather variability and market volatility, these farmers remain resilient contributors to food production and employment. However, postharvest losses critically affect their productivity and profitability, leading to significant food waste. Understanding smallholder vegetable value chains is crucial, especially in regions dominated by smallholder farming, as these value chains play a pivotal role in shaping the dynamics of the agricultural sector, encompassing various stages from production to consumption.

From the primary data collected, the study revealed a well-balanced demographic profile among smallholder farmers in the eThekweni Municipality, with an average age of 45 years. Female farmers dominated the demographic composition at 56.3%, indicating a significant contribution of women to smallholder agriculture. On average, farmers have attained 12 years of schooling, suggesting a high level of education within the farming community. Household dynamics feature an average size of 6 individuals, with the majority (77.31%) unmarried. The average income for smallholder farmers' households is R8,568.37. Moreover, the study found that a portion of smallholder farmers (75.63%) are unemployed, highlighting the reliance on farming as their

primary source of income. Specifically, 78.15% of the households depend primarily on agriculture for their livelihoods, emphasizing the sector's importance in sustaining rural communities and livelihoods.

The study delved into the drivers of postharvest losses among smallholder vegetable farmers in the eThekweni Municipality, employing a Zero-Inflated Poisson (ZIP) model to discern the underlying factors contributing to these losses. Several significant relationships were identified: age demonstrated a positive correlation with postharvest losses, indicating a 4% increase in losses for every one-year increase in age, attributed to potentially outdated farming practices among older farmers. Conversely, years in school exhibited a negative correlation, with each additional year associated with a 5.6% decrease in losses, suggesting that higher education levels may lead to better postharvest management practices. Household size was positively related to postharvest losses, with larger households facing increased challenges in managing food handling and storage requirements. Farm experience demonstrated a negative correlation, as more experienced farmers tended to experience lower losses due to better agricultural practices and decision-making skills. The availability of extension services was associated with decreased losses, underscoring the importance of knowledge transfer and capacity-building initiatives. Labour and improved storage facilities also reduced losses, emphasizing the significance of efficient harvesting practices and appropriate storage infrastructure. However, distance to the market and adverse weather conditions exhibited positive correlations with losses, indicating the challenges posed by longer transportation times and unfavourable climatic conditions on harvested produce's quality and shelf life.

Furthermore, using an Ordered Probit Model, the study investigated the determinants of postharvest losses among smallholder vegetable farmers in the eThekweni Municipality. The analysis revealed that older farmers and those with larger household sizes experienced more severe postharvest losses. In contrast, higher education levels, greater farm experience, and access to extension services were associated with reduced severity of losses. Specifically, an increase in household size decreased postharvest loss severity during harvesting but increased it at the market stage. Each additional year of schooling decreased loss severity during harvesting but increased it at the market stage. An increase in the distance from the market decreased loss severity during harvesting but increased it during transportation and at the market stage. Extension services significantly reduced loss severity during both harvesting and market stages. These findings

highlight the need for targeted interventions, such as enhancing educational opportunities, improving storage infrastructure, and developing better market access to mitigate the severity of postharvest losses.

The log-linear regression analysis demonstrates that several factors significantly impact postharvest losses among smallholder vegetable farmers in eThekweni Municipality. The results indicate that adverse weather conditions are a major determinant, with significant coefficients at both the Harvest and Market stages. Poor weather conditions, such as extreme temperatures, droughts, floods, and storms, significantly increase postharvest losses by damaging crops and creating unfavourable harvesting, handling, and storage conditions. These conditions also exacerbate logistical challenges, delay transportation, and complicate storage, leading to higher spoilage rates. Additionally, the findings highlight the influence of distance to the market, with longer distances resulting in increased postharvest losses due to prolonged travel times and inadequate infrastructure. This logistical challenge affects farmers' income and ripple effects on distributors, retailers, and consumers, reducing fresh produce availability and higher consumer prices. Farm experience is crucial in mitigating postharvest losses, as experienced farmers are more adept at implementing effective harvesting, handling, and storage practices. This accumulated knowledge and practical skills significantly reduce wastage and improve the overall efficiency of the vegetable supply chain. Furthermore, farmers' age shows a significant positive relationship with postharvest losses at the market stage. Older farmers may face challenges in adopting modern postharvest management practices, leading to higher levels of spoilage and waste. These findings underscore the importance of addressing age-related factors, enhancing postharvest practices, and improving infrastructure and logistical systems to mitigate postharvest losses.

Further analysis revealed the complex relationship between agribusiness investments and PHL within the vegetable supply chain. The analysis revealed that household size, education level, distance to market, and extension services significantly influence the severity of PHL. Larger households reduce losses during harvesting but increase them at the market stage. Education reduces losses during harvesting but has mixed effects at other stages. Greater distance to the market increases losses, while effective extension services mitigate them. Financial support and improved transport infrastructure significantly reduce PHL, enhancing profitability. The gross margin analysis indicates a 13.54% decrease in profitability due to PHL, while the retail marketing

margin analysis shows a drastic 91.60% reduction due to PHL. The findings highlight the need for targeted interventions, such as better postharvest management practices, infrastructure improvements, financial support, and training programs to mitigate losses and enhance the vegetable value chain's sustainability and profitability.

The study further investigated the impact of postharvest losses (PHL) on agribusiness investment and environmental sustainability in the vegetable supply chain, focusing on smallholder farmers in the eThekweni Municipality. Quantitative analysis assessed the economic effects of PHL on farm income, gross margin, and marketing margin. Findings revealed a significant reduction in profitability, with a 49% decrease in gross margin due to PHL and a striking 96.7% reduction for retailers. The study also examined the relationship between agribusiness investments and PHL, identifying influential factors such as poor transport infrastructure, financial support, input costs, market demand, weather conditions, adoption of new farming practices, and market access. Moreover, the study delved into the environmental impact of PHL, particularly greenhouse gas emissions from crop residue decomposition. Quantitative data indicated emissions of 0.0159349 metric tons of CO₂ from tractor operations and varying emissions across different crops, such as 72.8063 kgCO₂-eq for cabbage and 83.2072 kgCO₂-eq for spinach. Cumulatively, greenhouse gas emissions from all crops amount to 2256.9963 kgCO₂-eq. The study emphasized the need for policymakers to prioritize sustainable agricultural practices, invest in infrastructure, and strengthen regulatory frameworks to mitigate PHL and reduce emissions. Additionally, it highlighted the importance of adopting value-addition practices among smallholder vegetable farmers to minimize losses and preserve product quality, with quantitative insights revealing areas for improvement and potential impact on reducing losses. Overall, the study highlighted the connected nature of economic and environmental considerations in addressing PHL and emphasized the importance of comprehensive strategies to promote sustainability in the agricultural sector.

Understanding the impact of postharvest losses (PHL) on agribusiness investment is essential for assessing economic viability along the vegetable value chain. Analyses of gross margin and marketing margin unveiled substantial reductions in profitability attributable to PHL, with a 49% decrease in gross margin and a staggering 96.7% reduction for retailers. These figures highlighted PHL's significant implications for producers and marketers, emphasizing the urgent need for interventions to minimize losses and enhance economic outcomes. Improved harvesting

techniques, storage facilities, transportation methods, and market infrastructure are critical strategies for mitigating PHL and optimizing profitability. By investing in these areas, stakeholders can minimize physical damage to vegetables, preserve product quality, ensure timely delivery, and enhance market competitiveness, strengthening economic welfare throughout the value chain.

Moreover, the impact of postharvest losses on farm income was measured, revealing significant implications for household welfare among smallholder vegetable farmers. The analysis used the Ordinal Logistic Model (OLM), marginal effects, and the Multinomial Endogenous Switching Regression (MESR) model. The OLM results indicated that household size, training attended, distance from the market, farm experience, extension services, and financial support significantly influenced the severity of postharvest losses. The marginal effects analysis revealed that each additional household member increased the likelihood of low-severity losses by 3.9% and decreased high-severity losses, though not significantly. Each additional training session increased low-severity losses by 11% and decreased high-severity losses by 16%, both significant at the 5% level. Increased market distance increased low-severity losses by 31% and decreased high-severity losses by 16%, both at the 1% significance level. The MESR model highlighted the substantial negative impact of PHL on farm income. Specifically, a unit increase in PHL was associated with a 7% decrease in farm income during the harvesting stage, a 4.4% decrease during transportation, and an 8.4% decrease during marketing.

9.2 Conclusion

The study emphasizes the critical importance of addressing postharvest losses (PHL) in the vegetable supply chain, particularly among smallholder farmers in the eThekweni Municipality, South Africa. Smallholder agriculture, representing a significant portion of Africa's population, is vital for economic development, yet PHL remains a prevalent challenge, leading to substantial economic losses and environmental impacts. The study reveals that PHL affects food availability and deters agribusiness investment, hindering local and foreign investors. The study elucidates various factors contributing to PHL and its implications through comprehensive quantitative analysis.

The demographic characteristics of smallholder farmers were identified, highlighting the significant role of women and households' reliance on farming income. The study also revealed

the drivers of PHL, ranging from demographic factors like age and education to infrastructural issues such as transport and market access. These insights underscore the multifaceted nature of PHL and the necessity of targeted interventions to mitigate losses and enhance food security.

Furthermore, the study highlights PHL's economic effects, showcasing significant profitability reductions along the vegetable value chain. Gross margin and marketing margin analyses demonstrate the substantial impact of PHL on farm income and economic welfare, emphasizing the need for interventions to minimize losses and optimize profitability. Additionally, the study quantifies the environmental dimension of PHL, measuring greenhouse gas emissions from crop residue decomposition and highlighting the urgency of adopting sustainable agricultural practices.

The findings stress the interconnectedness of economic, social, and environmental factors in addressing PHL. By implementing targeted interventions, such as improving harvesting techniques, enhancing storage facilities, and investing in infrastructure, policymakers and stakeholders can mitigate losses, promote economic growth, and foster environmental sustainability in the agricultural sector.

9.3 Recommendations

The study recommends:

- Investment in Education and Training Programs: Develop and implement education and training programs tailored to smallholder farmers to enhance their knowledge and skills in modern agricultural practices, postharvest management, and climate-resilient farming techniques. This can help mitigate postharvest losses by improving farmers' capacity to adopt effective agricultural practices.
- Support for Infrastructure Development: Allocate resources for the development of infrastructure, including storage facilities, transportation networks, and market access points, to improve the efficiency of the vegetable supply chain. This will help reduce losses associated with inadequate storage and transportation, ultimately enhancing market access and profitability for smallholder farmers.
- Financial Support and Market Access: Provide financial support and facilitate market access for smallholder farmers to address income disparities, promote gender equity, and enhance economic stability within farming communities. Access to credit, market

information, and value-added opportunities can empower farmers to invest in postharvest management practices and improve their livelihoods.

- **Promotion of Agribusiness Investments:** Encourage investments in agribusiness ventures by addressing transportation constraints, market dynamics, input prices, and climate resilience strategies. This can be achieved through incentives for private-sector investment, public-private partnerships, and policy interventions that promote a conducive business environment for agricultural enterprises.
- **Adoption of Sustainable Agricultural Practices:** Promote adopting sustainable agricultural practices and waste management strategies to mitigate the environmental impact of postharvest losses, particularly in terms of greenhouse gas emissions. This includes investments in renewable energy, climate-resilient agriculture, and efficient waste management systems to promote environmental sustainability while ensuring agricultural productivity and resilience.

9.4 Future research areas

Based on the findings of the study, several future research areas have been identified:

- **Effect of Education on Postharvest Losses:** Investigating the relationship between education levels and postharvest losses can describe how education influences farming practices. This could involve longitudinal studies to assess the long-term impact of educational interventions on reducing losses and improving agricultural outcomes.
- **Technological Innovations:** Research focusing on the technological innovations suitable and affordable by smallholder farmers. Assessing the feasibility and impact of technologies such as improved storage facilities, cold chain infrastructure, and digital market platforms can guide investment decisions and policy development.
- **Market Dynamics and Postharvest Losses:** A deeper exploration of market dynamics and their influence on postharvest losses can provide valuable insights for designing efficient value chains. Understanding market demand fluctuations, pricing mechanisms, and consumer preferences can inform strategies to minimize losses during transportation and marketing stages.
- **Climate Resilience Strategies:** Investigating climate resilience strategies tailored to smallholder vegetable farmers can enhance their adaptive capacity to weather-related

challenges. This may involve studying the effectiveness of drought-resistant crop varieties, water management techniques, and agroforestry systems in mitigating losses and improving resilience.

- **Environmental Sustainability Practices:** Further research on the environmental implications of postharvest loss reduction strategies can inform sustainable agricultural practices. This could include life cycle assessments to evaluate the ecological footprint of different interventions and identify opportunities for minimizing greenhouse gas emissions and resource depletion.
- **Policy and Governance Frameworks:** Analysis of policy and governance frameworks related to postharvest management can highlight gaps and opportunities for enhancing regulatory support. Evaluating the effectiveness of existing policies, incentives, and institutional arrangements can guide policy reforms to promote sustainable agricultural development and reduce postharvest losses.

9.5 Limitations of the study

The study was limited to smallholder vegetable farmers in the eThekweni Municipality of South Africa, which may limit the generalizability of the findings to other regions or agricultural systems with different socioeconomic and environmental contexts. Furthermore, the statistical models used in the analysis, including the Zero-Inflated Poisson (ZIP) model and the Multinomial Endogenous Switching Regression (MESR) model, are based on certain assumptions that may not fully capture the complexity of real-world dynamics, potentially limiting the validity of the results. Moreover, limited engagement with critical stakeholders, such as commercial farmers, policymakers, and agribusinesses, may have restricted the relevance and applicability of the study findings and recommendations. Lastly, resource constraints, including time and budget limitations, may have constrained the depth and breadth of the study, highlighting the need for additional resources to support more comprehensive research endeavors in the future.

Appendix A: Survey questionnaire



The information captured in this questionnaire is strictly confidential and will be used for research by staff and students at the University of KwaZulu-Natal. The data will be used for a study titled “Agribusiness investments, perceptions, and effects of post-harvest losses in the smallholder vegetable value chains: Evidence from smallholder farmers in eThekweni Municipality in KwaZulu-Natal Province.”

There are no wrong or right answers to these questions. Participation is voluntary, and no direct benefit or gain will be obtained from participating. Also, there is no penalty or loss of benefit for non-participation. You are under no obligation to participate. You are free to withdraw at any time during the completion of the questionnaire without giving a reason. Your details will be given a code, and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings.

Would you like to participate in this survey? 1 = Yes 0 = No _____

Questionnaire number:	Ward number:
Enumerator name:	District name:
Name of farmer:	Village name:
Farmer contact details:	Date:

SECTION 1: HOUSEHOLD DEMOGRAPHIC AND SOCIOECONOMIC INFORMATION

1.1 Household head

Gender	Male	Female	Prefer not to say

Marital Status	Single	Married	Widowed	Divorced	Other

Years in School	
-----------------	--

Household size	
----------------	--

Employment Status	Employed	Unemployed	Pension	Social grant	Other

Occupation	
------------	--

Total household income per month	Rands
	R

Farming experience (years)	
----------------------------	--

1.2 Sources of income

Source of income	X	Amount(monthly)
Agricultural Activities		
Salary		
Pension		
Social Grant		
Remittance		
Other (Specify)		

1.3 Land ownership

a. Land size

How much land do you have? (Ha)	
How much of it is arable?	

b. What is the tenure of this land?

Private ownership		Lease		Communal		Specify.....	
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c. Type of soil

Loam		Clay		Sand		Specify.....	
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d. How do you cultivate your land?

Hand		Tractor		Animal draught		Specify.....	
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How much land did you use last season?	
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Do you keep farm records?	Yes		No	
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e. Indicate the farming assets you own

Asset	X
1. Plough	
2. Cultivator	
3. Harrow	
4. Knapsack	
5. Water pump	
6. Scotchcart	
7. Storeroom	
8. Commercial fridge	
9. Other (Specify)	

f. Are you part of any farmer's organization?

Yes		No	
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If not, why?

.....

SECTION 2: VEGETABLE PRODUCTION

2.1 Which vegetable do you grow?

Vegetable	X	Planted	Lost	Harvested	Profit (ZAR)
Cabbage					
Spinach					
Potatoes					
Carrot					
Kale					
Peppers					
Sweet potato					
Beetroot					
Butternut					
Tomatoes					
Other.....					

a. How do you source your seeds or seedlings?

.....

b. What irrigation methods do you use?

.....

c. Do you use any fertilizers or pesticides? If yes, which ones?

.....

d. How do you manage pests and diseases in your crops?

.....

e. Purpose of vegetable Production?

Household Consumption		Selling		Both	
-----------------------	--	---------	--	------	--

f. Do you have access to markets?

Yes		No	
-----	--	----	--

How far is the market?km
------------------------	---------

g. How would you rate the condition of the road to the markets?

Good		Fair		Bad	
------	--	------	--	-----	--

h. Do you have access to extension services?

Yes		No	
-----	--	----	--

If yes, how often do you receive it?

i. Specify the training received in the past three months.

Training	x
1. Postharvest handling	
2. Marketing	
3. Pest and disease control	
4. Organic Farming	
5. Irrigation practices	
6. Soil management	
7. Value addition techniques	
8. Specify.....	

j. From which institution do you receive it?

NGOs	Government Department	Other (Specify).....
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k. Rate the quality of the extension service you received

Good	moderate	Bad
------	----------	-----

l. What is your source of information?

Radio	Television	Newspaper	Internet	Other (specify).....
-------	------------	-----------	----------	----------------------

m. Do you have access to credit?

Yes	No
-----	----

n. If yes, what was the reason for borrowing?

Buy inputs	
Pesticides	
Buy value addition equipment.	
Other specify	

o. What challenges do you face during your farming?

Challenge	X
Price of inputs	
Losses of vegetable production due to natural disaster	
Lack of loan facility	
Lack of technical help	
Lack of high-yield variety seed/seedling,	
Lack of technical knowledge	
Pest and disease attack	
Other (specify).....	

p. Are you part of any cooperative or farmers' association?

Yes	No
-----	----

q. If yes, how do you benefit from it?

Benefits	X
Pooling supply purchases	

Pooling sales	
Reduced handling and selling expenses	
Sharing information	
Other (Specify)	

2.2 Agribusiness Investments:

a. Have you made any recent investments in your farming operations? If yes, please specify.

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.....

b. What factors influenced your investment decisions?

.....

.....

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c. Have you received financial or technical support from government or non-governmental organizations? If yes, please provide details.

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.....

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SECTION 3: POSTHARVEST HANDLING

3.1 During the previous season, have you lost any produce?

Yes		No	
-----	--	----	--

3.2 How much produce have you lost?

<10%		10% - 20%		20% - 40%		>50%	
------	--	-----------	--	-----------	--	------	--

3.3 At which stage of the supply chain?

Input Supply		Production		Harvest		Transportation		Market	
--------------	--	------------	--	---------	--	----------------	--	--------	--

3.4 What caused the food loss?

Cause	X
Shortage of labour	
Inadequate transportation	
Inadequate storage	
Inadequate capital	
Pests and diseases	
Distant Market	
Lack of knowledge	

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3.11 Have you implemented any postharvest management practices or technologies to reduce losses? If yes, what has been the impact on your household's welfare?

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3.12 How do postharvest losses impact your ability to invest in other income-generating activities or improve the overall well-being of your household? Please describe any specific challenges you face due to these losses.

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3.13 As a vegetable farmer, what challenges do you face during harvesting, handling, and transportation that you believe contribute significantly to post-harvest losses?

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3.14 In your experience, what are the main factors that lead to quality deterioration of vegetables along the supply chain from farm to market?

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3.15 How do storage facilities and packaging issues influence post-harvest losses during the transportation and distribution of vegetables?

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3.16 Are there any specific points along the vegetable supply chain where you observe higher losses? If yes, please describe those points and the reasons behind the losses.

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3.17 How does the lack of infrastructure, such as cold storage or transportation facilities, impact the overall magnitude of post-harvest losses along the vegetable supply chain?

.....

3.18 Packaging

a. Do you package your produce after harvesting?

Yes		No	
-----	--	----	--

If yes, specify the packaging material

Packaging	x	Cost
Traditional baskets		
Cardboards		
Plastic crates		
Paper bags		
Sacks		
Packaging plastics		
Other, specify.....		

3.19 Storage

a. Do you have access to a storage facility?

Yes		No	
-----	--	----	--

b. Where do you store your produce during harvest?

Cold rooms	
Under shade	
Sacks	
Other (specify).....	

c. How long do you store your produce before it reaches the market?

1hr		2hr		More than 5hr		A day or more		Specify.....
-----	--	-----	--	---------------	--	---------------	--	--------------

d. How do you transport vegetables?

Bakkie		Truck		wheelbarrow		Other (specify).....
--------	--	-------	--	-------------	--	-------------------------

e. How many vegetables are lost due to poor handling?

<10%		10% - 20%		20% - 40%		>50%	
------	--	-----------	--	-----------	--	------	--

3.20 Perceptions of Smallholder Vegetable Value Chains:

a. How would you rate the overall effectiveness of the vegetable value chains you are part of?

.....

b. What are your main challenges when participating in vegetable value chains?

.....

c. Are you satisfied with the market prices you receive for your vegetables?

.....

d. Do you perceive any differences in market access and opportunities between smallholder farmers and larger commercial farmers? If yes, please explain.

.....

3.21 Labour

a. Do you have adequate family labor on your vegetable production?

Yes		No	
-----	--	----	--

If not, in which activities do you experience labor shortages?

Land preparation	
Planting	
Weeding	
Harvesting	
Other (specify)	

b. How do you deal with labor shortages?

Hire	
Other arrangements (specify)	

D.15 Value-added horticultural produce fetches better and gets sold quickly on the market	
D.16 Reducing packaging costs can assist in improving the processing of produce	
D.17 Postharvest technologies do not enhance the profits of farmers or wholesalers	
D.18 Diversity of value-added horticulture products improves income	
D.19 Advances in postharvest technologies for preservation and processing enable product availability throughout the year	
D.20 Value addition is a way to solve postharvest losses of vegetables	
D.21 Self-help groups are essential in creating awareness of postharvest value addition initiatives	
D.22 Training is not necessary for the adoption of postharvest value addition initiatives	

3.22 Perceptions towards Postharvest Practices

In your own opinion, rate the following statements on a scale of 1-5 (1= Strongly Disagree, 2= Disagree, 3= Undecided; 4= Agree; 5 = Strongly Agree)	
<i>Value addition practices</i>	
D.1 Washing of vegetables does not increase income	
D.2 Grading of vegetables increases income	
D.3 Labelling of vegetables does not increase income	
D.4 Dehydration of vegetables increases income	
D.5 Sorting of vegetables does not increase income	
D.6 Cooling of vegetables increases income	
D.7 Slicing of vegetables does not increase income	
D.8 Sun-drying of vegetables increases income	
D.9 Packaging is not very important for value-added vegetables	
<i>Technological Issues</i>	
D.10 Processing and storage of vegetables assist in preventing distress sale	
D.11 Poor on-farm storage and infrastructure handling facilities affect the quality of crops	
D.12 Value addition assists in improving the shelf life of horticultural crops	
D.13 Possessing necessary value-addition skills influences the adoption of value-addition practices	
D.14 Adopting value addition technologies is not beneficial to a vegetable business venture	
<i>Economic Issues</i>	

3.23 Willingness to pay for postharvest technologies.

	Yes	No
Aware of postharvest technologies		
Willingness to pay for a charcoal cooler		
Willingness to pay for a brick cooler		
Willingness to pay for a tunnel solar drier		

SECTION 4: ENVIRONMENTAL IMPACT

4.1 How much synthetic fertilizer did you use in the previous season?

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4.2 How much organic fertilizer did you use in the previous season?

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4.3 Estimate of the crop residue retained on the soil after harvest.

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4.5 How long does a tractor take to plough, disc, or rip your land?

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4.6 What packaging material do you use for your vegetable?

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The end

Appendix B: Ethical Clearance



21 April 2023

Siphesihle Qange (222130337)
School Of Agri Earth & Env Sc
Pietermaritzburg Campus

Dear S Qange,

Protocol reference number: HSSREC/00005449/2023

Project title: Agribusiness investments, perceptions, and effects of postharvest losses in the smallholder vegetable value chains: Evidence from smallholder farmers in eThekweni Municipality in KwaZulu-Natal Province

Degree: PhD

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 13 March 2023 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 21 April 2024.

To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

HSSREC is registered with the South African National Health Research Ethics Council (REC-040414-040).

Yours sincerely,



Professor Dipane Hlalele (Chair)

/dd

Humanities and Social Sciences Research Ethics Committee

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Founding Campuses:  Edgewood  Howard College  Medical School  Pietermaritzburg  Westville

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