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Exploring the relationship between agribusiness investments and postharvest losses among smallholder vegetable farmers in the eThekweni Municipality

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Smallholder vegetable farmers in developing economies play a crucial role in agricultural production but often face significant postharvest losses at various stages of the value chain. Agribusiness investments have the potential to address postharvest losses for smallholder vegetable farmers. Understanding the impact of these investments is crucial due to their potential benefits. Therefore, this study aims to explore the relationship between agribusiness investments and postharvest losses 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 ordinary least square regression to analyse the data. The study results revealed that the majority (56%) of the farmers were females with an average age of 45 years and a household size of 5 people per household. Farmers spent an average of 12 years in school, with the majority being unemployed (76%) and relying on farming for income (78%). Moreover, the study revealed that 90% of the farmers lose their produce due to less demand, while 88% believe that the cost of inputs affects them. Additionally, 79% of the farmers believe that high competition in the market results in postharvest losses, and 70 and 69% indicate that weather conditions and adoption of farming practices, respectively, influence their postharvest losses. The Ordinary Least Squares regression model results indicated that agribusiness investments, transport infrastructure, financial support, market demand, weather conditions, adoption of new technologies, and market access significantly influence postharvest losses among smallholder vegetable farmers in the eThekweni Municipality. The study, therefore, recommends investing in transportation infrastructure, promoting climate-resilient agriculture, facilitating market access, providing financial support, and urgently strengthening extension services to reduce postharvest losses in the agricultural sector. The need for strengthening extension services is particularly urgent, as it can provide farmers with the necessary knowledge and skills to adopt new technologies and farming practices, thereby reducing postharvest losses.

KEYWORDS

agribusiness investments, financial support, ordinary least square regression, postharvest losses, smallholder vegetable farmers

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 do not only reduce the income of farmers but also represent a concerning waste of precious resources like water, land, and agricultural inputs, making investors reluctant to invest in agribusiness (Melembe et al., 2021; Nkansah-Dwamena, 2023).

The significance of smallholder vegetable farmers cannot be overstated. Smallholder farmers constitute the backbone of agricultural production in many developing economies (Akanmu et al., 2023). Moreover, compared to large-scale commercial farms, smallholder vegetable farmers often cultivate a wider variety of vegetables, catering to diverse local dietary needs (Hendriks et al., 2020). Additionally, Serote et al. (2021) highlighted that smallholder farmers tend to be 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). Investing in smallholder vegetable production, therefore, has the potential to 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 factors such as 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, 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 hold the potential to address the challenges faced by smallholder vegetable farmers regarding PHL. Improved access to technology, training, and infrastructure can equip farmers with the tools necessary for proper handling and storage of their produce, 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 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).

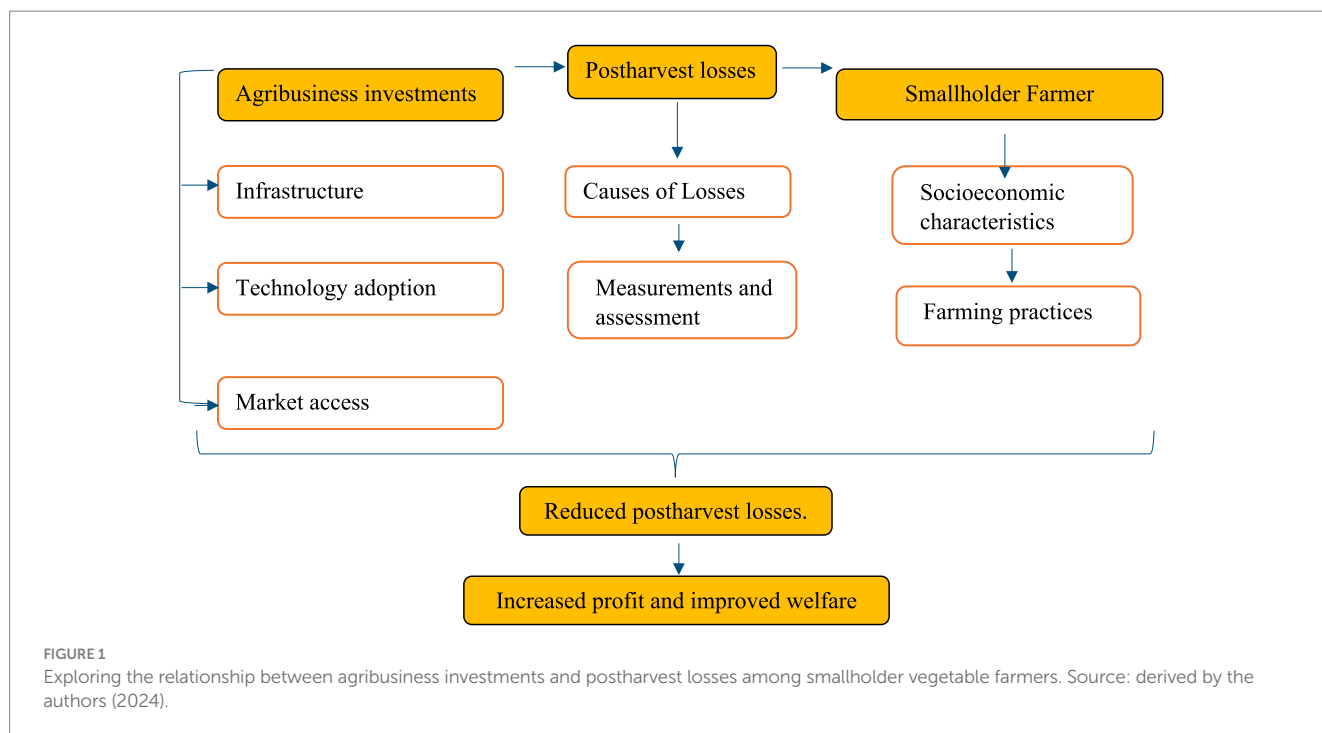
Given the potential benefits and unforeseen consequences of agribusiness investments, a deeper understanding of the relationship between these investments and PHL among smallholder vegetable farmers is essential. Therefore, this study aims to explore the relationship between agribusiness investments and postharvest losses among smallholder vegetable farmers, with a specific focus on the eThekweni Municipality. The study will look at how agribusiness investments influence postharvest handling practices among smallholder vegetable farmers and the extent to which agribusiness investments contribute to the reduction of postharvest losses.

2 Conceptual framework

The conceptual framework presented by Figure 1 provides a holistic perspective on the relationship between agribusiness investments and postharvest losses among smallholder vegetable farmers, integrating key concepts and variables to guide research, policy development, and practical interventions in this critical area of agricultural development.

Figure 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 the adoption of 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 for them 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 (Nzeyimana, 2020; 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). Techniques such as postharvest loss audits, quality assessments, and monitoring systems help in tracking losses and evaluating the effectiveness of interventions 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 and Moelets, 2020). Additionally, farming practices such as harvesting techniques, storage methods, and pest management strategies play a significant role in determining the extent of postharvest losses (Ngwenyama et al., 2023). Understanding the unique context of smallholder farmers is crucial for designing interventions that are tailored to their needs and circumstances, ultimately 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 by minimizing food losses along the supply chain, more food reaches consumers, contributing to food security and reducing pressure on natural resources. Additionally, reduced 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 the environmental footprint of agriculture by decreasing the resources wasted in production and transportation, thereby promoting sustainability and resilience in food systems.

While several studies have examined the impact of agribusiness investments on agricultural productivity, there is a limited understanding of how these investments affect postharvest losses (PHL) among smallholder vegetable farmers. For instance, Mujuka et al. (2021) noted significant PHL in developing countries but did not explore the role of agribusiness investments. Furthermore, existing literature often focuses on large-scale farming operations (Hendriks et al., 2020), leaving a gap in understanding the unique challenges smallholder farmers face. This study aims to fill these gaps by exploring the relationship between agribusiness investments and postharvest losses among smallholder vegetable farmers in the eThekweni Municipality, thus contributing to the literature and providing practical insights for policymakers and stakeholders.

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 greater 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 aimed at addressing postharvest losses contribute to poverty alleviation and socio-economic development, fostering inclusive growth and prosperity within rural communities (Assan, 2023).

3 Description of the study area

KwaZulu-Natal has a diverse landscape, abundant resources, and favorable natural conditions, creating a prime opportunity for poverty reduction (Cooperative Governance and Traditional Affairs, 2020), and significant hurdles impede progress. These challenges include economic

difficulties, inadequate infrastructure, and slow land reform, as highlighted by both the Department of Cooperative Governance and Traditional Affairs (Cooperative Governance and Traditional Affairs, 2020) and the eThekweni Municipality. Overcoming these obstacles necessitates improvements in government initiatives and agricultural policies to ensure sustainable agricultural development and poverty reduction. Despite these hurdles, KwaZulu-Natal boasts significant advantages. The province's fertile land, reliable rainfall, and expertise across various agricultural fields contribute to its reputation for high productivity (KwaZulu Natal Department of Agriculture and Rural Development, 2019). With a substantial portion of land suitable for both livestock and crop production, the potential for agricultural advancement is undeniable. This potential is further underscored by the prioritization of agriculture in municipal development plans and the eThekweni Agribusiness Master Plan of 2022, which envisions economic growth through surplus food production, job creation, and targeted agricultural programs within the eThekweni Metro. By capitalizing on these strengths and addressing the identified challenges, KwaZulu-Natal can unlock the full potential of its agricultural sector and contribute significantly to broader socioeconomic development and poverty reduction efforts (Figure 2).

4 Research design

The study employed a comprehensive mixed methods approach to understand the relationships between various factors affecting postharvest losses in the vegetable supply chain. This approach combined the strengths of both qualitative and quantitative data collection and analysis (surveys, interviews, etc.), allowing for both

the exploration of complex relationships and the statistical testing of hypotheses. The study utilized a cross-sectional design for its cost-effectiveness, gathering data at a single point in time. While this design does not capture changes over time, it offers a cost-effective way to collect relevant information. The study used a combination of descriptive and inferential analysis, with descriptive analysis providing a clear picture of the data and inferential analysis allowing researchers to test hypotheses and draw broader conclusions applicable to the entire population. Additionally, regression analysis was employed to pinpoint the key factors causing postharvest losses and understand the strength of their influence. This comprehensive approach ensured a thorough and robust investigation of the research questions.

Agribusiness investments were measured as a continuous variable, quantified by the amount of money invested in various aspects of farming, including technology, infrastructure, and training. Postharvest losses were assessed using both physical and economic measures. Physical loss was quantified by the percentage of produce lost from harvest to market, while economic loss was calculated based on the market value of the lost produce. Data on PHL were collected at multiple stages of the supply chain, including harvesting, handling, storage, transportation, and marketing. This comprehensive approach allowed us to capture the full extent of postharvest losses and their determinants.

5 Sampling procedure, frame, and sample size

The study was conducted within the eThekweni Municipality, which was purposefully chosen due to its high concentration of smallholder vegetable farmers. A multi-stratified random sampling

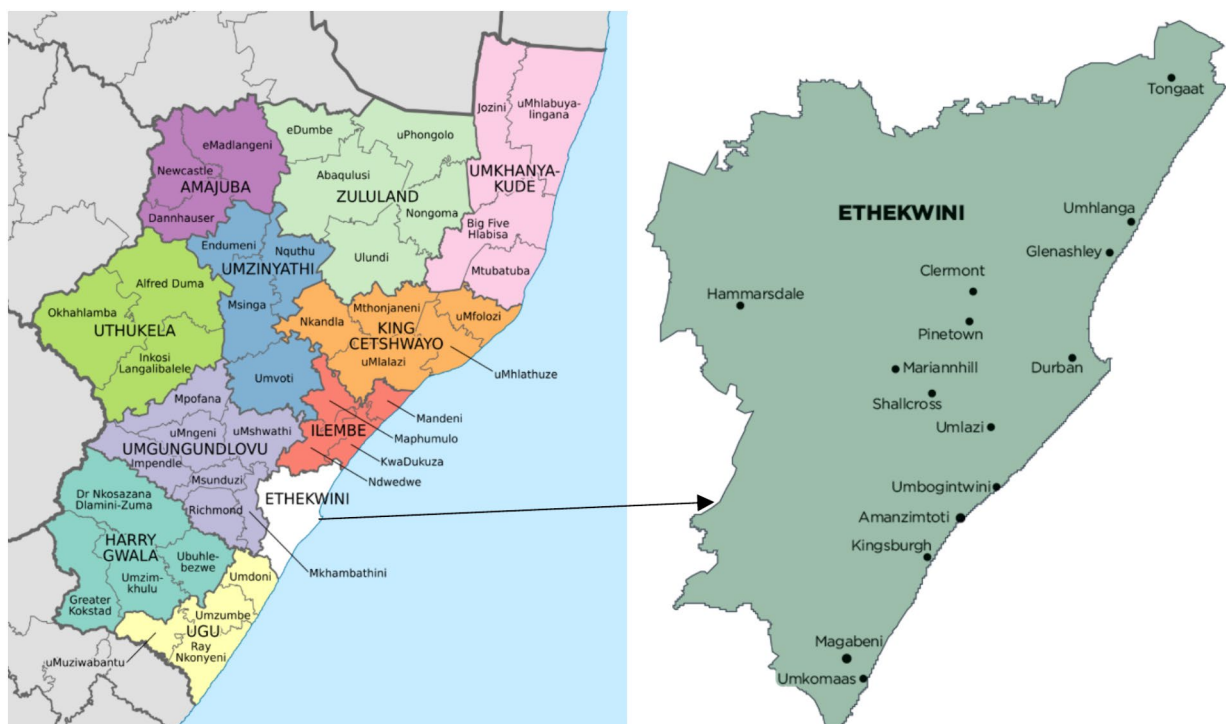


FIGURE 2
Map showing eThekweni Municipality. Source: Cooperative Governance and Traditional Affairs (Cogta) (2020).

approach was employed to achieve a representative sample. To start, the approach encompassed multiple steps. Initially, we carefully chose specific districts within the municipality based on their significance to agricultural activity. Our study concentrated on wards and villages known for their thriving agricultural pursuits. Within these areas, we meticulously stratified the farmers based on the particular types of crops they cultivated, with a specific emphasis on those engaged in vegetable farming. Lastly, through a random selection process, we identified individual smallholder vegetable farmers as the primary unit of analysis for the study.

Cochran's formula determined the sample size, aiming for a 95% confidence level with a margin of error of $\pm 5\%$. Assuming the most diverse scenario ($p=0.5$), the formula suggested a sample size of 384. However, a meticulous data cleaning process, eliminating inconsistencies, inaccuracies, and missing values, resulted in a final sample size of 238 completed questionnaires deemed suitable for analysis. This data-cleaning step ensured the dataset's reliability and integrity, leading to more robust research findings. The subsequent study, conducted on this refined dataset of $n_0=238$, allowed for the extraction of meaningful insights and conclusions from the collected information.

6 Data collection

The study relied on local enumerators fluent in IsiZulu, the dominant language in the research area. These enumerators received thorough training to ensure a uniform understanding of the questionnaire. Initially written in English, the questionnaire was translated into IsiZulu during data collection to improve respondents' comprehension. To validate the questionnaire's consistency, reliability, and relevance, a pre-test was conducted with 10% of the intended sample size in a location outside the main study area (Inchanga). This pre-test helped identify missing variables or translation errors, allowing adjustments before full-scale data collection. In addition to the quantitative data collected through structured questionnaires, this study employed qualitative methods to gain deeper insights into the challenges and perceptions of smallholder vegetable farmers. Specifically, we conducted semi-structured interviews to complement the quantitative data and provide a more nuanced understanding of the factors influencing postharvest losses. Additionally, enumerators underwent rigorous training in understanding and accurately translating the questionnaire. The researcher then reviewed the completed questionnaires for completeness and accuracy before data entry and analysis. Furthermore, the study adhered to ethical research standards. The Human and Social Sciences Research Ethics Committee (HSSREC) of the University of KwaZulu-Natal granted ethical approval (Reference No.: HSSREC/00005449/2023). This approval ensures the research was conducted following established ethical guidelines and upholds the rights and well-being of participants. The meticulous data collection procedures and ethical considerations employed in this study contribute to its findings' overall validity, reliability, and trustworthiness within the academic community.

7 Data analysis

The study employed descriptive and inferential statistics, alongside Ordinary Least Squares Regression, to thoroughly analyze

the collected data. Data collection, coding, and cleaning were conducted using Microsoft Excel. Outliers and incomplete questionnaires were subsequently excluded. The data was then exported to Stata 18 for analysis. Descriptive statistics were utilized to summarize the characteristics of the population under study through measures like mean and standard deviation, simplifying the data and facilitating a clearer understanding of the findings. Meanwhile, inferential statistics enabled 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. Ordinary Least Squares Regression, a statistical technique, was used to model the relationship between one or more independent variables (predictors) and an ordinary dependent variable. Together, these statistical techniques provided a robust framework for analyzing the data and addressing the research objectives effectively. Agribusiness investments were measured as a continuous variable, quantified by the amount of money invested in various aspects of farming, including technology, infrastructure, and training. Postharvest losses were assessed using both physical and economic measures. Physical loss was quantified by the percentage of produce lost from harvest to market, while economic loss was calculated based on the market value of the lost produce.

8 A priori expectation

"A Priori Expectation Table" was compiled to provide a clear framework for our analysis and establish theoretical expectations for the study. This table outlines each variable utilized in the Ordinary Least Squares regression model, delineating whether a positive or negative impact is anticipated based on prior literature and theoretical considerations. The table briefly justifies each expected relationship, supported by relevant citations from existing research. This methodological approach enhances the transparency of our analysis and aligns our empirical investigation with established economic theories concerning agribusiness investments and postharvest losses. The following table guides the interpretation of our regression results, ensuring that our findings are evaluated within well-grounded expectations (Table 1).

9 Analytical tool

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 ordinary variable exhibits a natural order, although the intervals between categories may not be uniform (Tutz, 2022). In essence, OLS regression extends the principles of linear regression to accommodate ordinary dependent variables. It assumes a linear relationship between the independent variables and the ordinal dependent variable. Equation 1 below illustrates the OLS regression:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + \epsilon \quad (1)$$

Where:

TABLE 1 A priori expectation table.

Variable	Expected sign	Justification	Source
Agribusiness investment	+	Higher investment in agribusiness should lead to better infrastructure and technology, reducing postharvest losses.	Johnson and Brown (2021), "Agribusiness and Sustainable Farming," <i>Journal of Agricultural Economics</i>
Transport infrastructure	+	Improved transport facilities reduce the time production takes to reach markets, minimizing decay and losses.	Smith et al. (2020), "Impact of Infrastructure on Agricultural Efficiency," <i>Agricultural Science Review</i>
Financial support	+	Greater financial support allows farmers to access better storage and processing facilities, reducing losses.	Davis and Lee (2019), "Financial Investments in Agriculture and Postharvest Losses," <i>Food Policy</i>
Market demand	-	Higher market demand reduces the amount of time produce remains unsold, thereby reducing opportunities for loss.	Kim and Park (2018), "Market Dynamics and Food Security," <i>Food Economics</i>
Weather conditions	-	Adverse weather conditions, such as excessive rainfall or drought, can exacerbate postharvest losses.	Green et al. (2017), "Weather Impact on Crop Production and Losses," <i>Journal of Climate and Agriculture</i>
Adoption of new farming practices	+	Adopting improved farming practices, such as better harvesting techniques, is expected to reduce losses.	Allen and Wright (2016), "Innovations in Farming and Postharvest Loss," <i>Agricultural Innovations Review</i>
Market access	+	Better access to markets allows for quicker sales and reduces the risk of loss through spoilage.	Carter (2022), "Market Access and Its Role in Reducing Agricultural Waste," <i>Journal of Rural Development</i>

- 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 ordinary 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:

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

Where Y_i represents the observed value of the ordinary 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 ordinary 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.

10 Results and discussion

This section primarily focuses on analyzing the acquired findings. First, it explores the demographic characteristics of smallholder vegetable farmers in the eThekweni Municipality. Subsequently, it examines the relationship between agribusiness investments and postharvest losses within this demographic group. The qualitative findings revealed several key themes influencing postharvest losses among smallholder vegetable farmers. Farmers reported that inadequate storage facilities, poor transportation infrastructure, and limited market access were significant challenges. For example, one farmer noted, "We often lose much of our produce during transportation because the roads are in bad condition, and we do not have proper vehicles." Another recurring theme was the lack of financial support, with farmers highlighting the difficulties in accessing loans and credit facilities necessary for improving their operations.

10.1 Demographic characteristics of smallholder vegetable farmers in eThekweni Municipality

The study conducted within eThekweni Municipality sheds light on the demographics and socio-economic realities of smallholder vegetable farmers in the region. The average age of 45 suggests a relatively middle-aged group, potentially receptive to adopting new farming techniques and skills. A study by Obi and Maya (2021) found that farmers in their middle years often exhibit a balance between experience and willingness to explore new methods, making them more receptive to adopting innovative practices. However, the average of 11 years of education, aligning with the national secondary school completion rate, highlights a potential barrier to implementing innovative practices like climate-smart agriculture (Setshedi and Modirwa, 2020). Farming appears to be a critical source of income, with an average household size of six and

monthly earnings of ZAR8,568.37, though significant income disparities exist. [Hardadi et al. \(2021\)](#) supported the findings highlighting that agricultural activities do not only provide direct employment opportunities for farmers but also support various downstream industries and value chains, contributing to overall economic growth and development. Females comprise 56% of the farmers, highlighting their central role in agricultural activities. Yet, research by [Maziya et al. \(2020\)](#) and [Mthethwa and Wale \(2020\)](#) suggests female-headed households in rural areas face greater risks of poverty and food insecurity. Marital status also seems to play a part, with 77% of farmers being unmarried could potentially impact farm operations. Marriage often plays a significant role in agricultural households, as it can influence labor availability, decision-making processes, and resource allocation within the farm ([Kom et al., 2022](#)). Furthermore, the high proportion (76%) of unemployed farmers highlights their reliance on farming for income ([Table 2](#)).

These findings emphasize the need for targeted interventions to address limited education, income disparities, gender gaps, and market access. Such interventions are crucial for enhancing the long-term sustainability and profitability of smallholder vegetable farming in eThekweni Municipality. Additionally, strategic agribusiness investments focusing on infrastructure development, access to finance, technology adoption, and value chain integration could further bolster the resilience and competitiveness of smallholder farmers in the region, fostering economic growth and food security ([Langyintuo, 2020](#)).

10.2 Factors contributing to smallholder farmers' reluctance in investing in farming activities

[Figure 3](#) indicates reasons why smallholder farmers are not investing in their farming activities.

The majority (90%) of the smallholder vegetable farmers indicated that being unaware of the market demand has resulted in their produce being wasted hence they become reluctant to invest more in their farming activities. The study conducted by [Slayi et al. \(2023\)](#) agreed that without accurate information about market preferences, seasonal demand fluctuations, and quality standards, smallholder farmers may struggle to plan their production and marketing strategies effectively, leading to wastage along the supply chain. Moreover, a significant number of smallholder farmers (88%) indicated that the cost of inputs and other farming resources is quite high, resulting in them being unable to purchase high-quality inputs and postharvest handling equipment. [Dube et al. \(2020\)](#) supported the findings, highlighting that high input costs, including seeds, fertilizers, pesticides, and machinery, significantly impact farmers' production costs and profitability, limiting their ability to invest in essential inputs and technologies that could improve productivity and reduce postharvest losses. Furthermore, the limited markets that farmers have access to, 79% of the farmers indicated that there is high competition, which results in some of their products getting rejected or wasted. [Barrett et al. \(2022\)](#) also found that limited market access restricts farmers' ability to reach a diverse customer base. This often leads to concentration within a few local or regional markets, resulting in heightened competition among producers and increased possibility of postharvest losses. Moreover, 70% of the farmers indicated that adverse weather conditions had threatened their farming activities, making them reluctant to invest

TABLE 2 The demographic and socioeconomic characteristics of smallholder farmers in eThekweni Municipality.

Variable description	Mean (n = 238)	Standard deviation
Age	45.11	9.54
Years in school	11.66	2.85
Household size	5.96	2.00
Total income	8,568.37	6,004.39
Categorical variables	Frequency	Percentage
Gender		
Male	104	43.7%
Female	134	56.3%
Marital Status		
Single	184	77.31%
Married	45	18.91%
Widowed	7	2.94%
Divorced	2	0.84%
Employment status		
Unemployed	180	75.63%
Employed	41	17.23%
Pension	13	5.46%
Other	4	1.68%
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%

Source: field survey, 2023.

more. [Kumar et al. \(2022\)](#) highlighted that rising temperatures, changes in precipitation patterns, and increased frequency of droughts, floods, storms, and other extreme events pose significant challenges to farmers worldwide, disrupting cropping patterns, reducing yields, and threatening food security and rural livelihoods. Lastly, 69% of the farmers struggle to adopt new farming practices that potentially reduce postharvest losses. Smallholder vegetable farmers' attitudes toward farming new practices, their perceptions of the benefits and risks involved, and their ability to overcome barriers such as financial constraints, lack of technical knowledge, and social norms play a critical role in shaping their adoption decisions ([Damalas, 2021](#)). Thus, adopting new farming practices holds great potential for smallholder farmers to improve their productivity and profitability and attract agribusiness investments.

10.3 The relationship between agribusiness investments and postharvest losses

[Table 3](#) demonstrates the relationship between agribusiness investments and postharvest losses. This analysis examines how

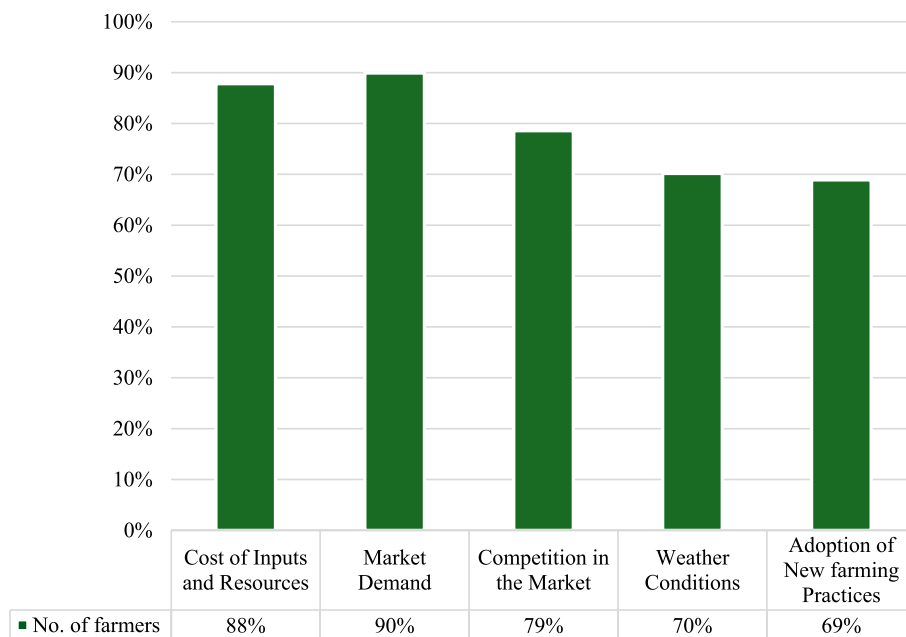


FIGURE 3 Factors Contributing to smallholder farmers' reluctance in investing in farming activities. Source: field survey (2023).

TABLE 3 OLS estimating the relationship between agribusiness investments and postharvest losses in eThekweni Municipality.

Variables	Coefficient	Std. err.	t-value	p > t
Poor transport infrastructure	0.610	0.220	-2.73	0.007*
Financial support	-0.540	0.166	3.01	0.003*
Cost of inputs	0.230	0.101	2.00	0.046*
Market demand	-0.120	0.120	-1.00	0.037*
Weather conditions	0.141	0.150	0.67	0.004*
Adoption new farming practices	-0.151	0.110	-1.50	0.065*
Market access	-0.242	0.140	-2.00	0.046*
Cons	0.712	0.156	4.47	0.000*

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.

*Significant at 5% level.

Source: empirical results estimated using STATA (18).

factors affecting agribusiness investment are linked to postharvest losses among smallholder vegetable farmers, using data from 238 observations. The overall model is statistically significant (p -value = 0.0433) at 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 analyzed. 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.

Agribusiness investment has been quantified as the total annual expenditure by farmers on inputs directly related to agricultural production. This includes, but is not limited to, spending on seeds, fertilizers, pesticides, irrigation systems, and farm machinery. This measurement is collected through detailed farmer surveys where respondents provide expenditure data for the last agricultural year. Moreover, Postharvest losses are measured both in terms of physical and economic losses. Physical losses refer to the percentage of total harvested produce that is lost from harvest up to the market due to spoilage, pests, or damage during handling and transportation. Economic losses are calculated as the cost equivalent of the lost produce, factoring in the market prices at the time of sale. Loss assessments are conducted at various stages of the supply chain,

including post-harvest, during storage, during transportation, and at the market, to accurately capture the multifaceted nature of postharvest losses.

Poor transport infrastructure shows a positive coefficient and is statistically significant at a 5% level. This implies that lack of transport is associated with increased postharvest losses by 61%. These results underscore the importance of investing in transport infrastructure to ensure effective agricultural supply chains. The study by [Parimia and Chakraborty \(2022\)](#) supported 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 that there is a 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, ultimately contributing to the sustainability and resilience of the agribusiness sector.

Financial support has a negative coefficient and is statistically significant at a 5% level. This implies that increased financial support is associated with a decrease in postharvest losses of 54%. 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 Rejikumar \(2023\)](#) agreed 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 cost of inputs 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 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.

Market demand has a negative coefficient and is statistically significant at a 5% level. This implies that an increase in market demand for the produce is associated with a decrease in postharvest losses of 12%. Therefore, the high demand for agricultural products stimulates more efficient supply chain management practices, as producers are compelled to meet market demand promptly and capitalize on lucrative opportunities. [Sibanda and Workneh \(2020\)](#)

supported the findings highlighting that meeting the market demand increases profitability along the value chain, attracting more investors seeking to capitalize on the promising prospects offered by the agricultural sector. Moreover, the research by [Barrett et al. \(2022\)](#) highlighted the significance of market responsiveness in driving agricultural investment, as businesses that effectively meet consumer demand are better positioned to generate higher returns and attract capital. Similarly, studies by [Santa et al. \(2022\)](#) and [Rahman et al. \(2022\)](#) emphasize the role of market-oriented strategies in enhancing competitiveness and financial sustainability in agricultural enterprises, appealing to investors seeking profitable opportunities.

Weather conditions have a positive coefficient and is statistically significant at 5% level. This indicates that adverse weather conditions increase postharvest losses by 14.10%. The impact of weather conditions on postharvest losses suggests the importance of incorporating climate resilience considerations into agribusiness investment decisions. [Casey et al. \(2021\)](#) supported the findings, indicating that by understanding and mitigating climate-related risks, investors can help ensure the long-term viability and profitability of their investments in the agricultural sector. Moreover, [Ali et al. \(2023\)](#) also emphasized the importance of implementing risk management strategies to enhance the resilience of agribusiness investments. This includes adopting improved storage facilities, crop diversification, water management techniques, and weather insurance to mitigate losses associated with adverse weather conditions. Furthermore, governments and financial institutions are crucial in providing incentives, technical assistance, and infrastructure support to encourage investments in climate-smart agriculture ([Mungai et al., 2021](#)).

The study reveals that there is a negative relationship that exists between the adoption of new farming practices and postharvest losses. This relationship is indicated by a negative coefficient, which is significant at the 5% level. It implies that adopting new farming practices is associated with a decrease in postharvest losses by 15.10%. The study by [Benyam et al. \(2021\)](#) agrees with the findings, highlighting the importance of embracing modern agricultural practices to mitigate postharvest losses and enhance overall efficiency and productivity in the farm sector. Moreover, [Nkansah-Dwamena \(2023\)](#) further suggested that by adopting innovative farming methods, such as precision agriculture, sustainable crop management, or improved storage and handling techniques, farmers can minimize postharvest losses, increasing prospects for profits and attracting agribusiness investors. Additionally, there is a potential benefit in investing in agricultural research, extension services, and technology transfer programs aimed at promoting the adoption of new farming practices, which ultimately contribute to the sustainability and profitability of agribusiness operations ([Binge et al., 2023](#)).

Market access shows a negative coefficient and is statistically significant at a 5% level, suggesting that improved market access is associated with decreased postharvest losses. The negative coefficient implies that as farmers gain improved access to markets, there is a corresponding decrease in postharvest losses by 24%. These findings indicate the crucial role of market access in optimizing the efficiency of agricultural supply chains and reducing postharvest losses. [Mapiye et al. \(2023\)](#) supported the findings, indicating that investments in market information systems, including digital platforms and communication technologies, can help farmers access real-time market data, price information, and

demand forecasts. Moreover, the findings suggest the importance of investments and policies to enhance market access for farmers, such as infrastructure development, market information systems, and trade facilitation initiatives (Singh and Dey, 2023). Therefore, by addressing barriers to market access, policymakers and stakeholders can support the sustainability and competitiveness of the agricultural sector while simultaneously reducing postharvest losses and improving food security and prospects for investments (Mbiakop et al., 2023).

11 Conclusion and recommendations

In conclusion, this study comprehensively analyses the demographics and socio-economic conditions affecting smallholder vegetable farmers in the eThekweni Municipality. It highlights the middle-aged demographic and the reliance on farming as a primary source of income, alongside enduring challenges such as limited education, notable income disparities, and significant gender gaps. These socio-economic factors are critical as they directly impact the farmers' ability to reduce postharvest losses and enhance agricultural productivity.

The research identifies several key factors contributing to postharvest losses, including high input costs, low market demand, intense market competition, adverse weather conditions, and the challenges of adopting new farming practices. Each of these factors underscores the complexities within the agricultural sector that hinder the efficiency and sustainability of smallholder farming operations.

Based on these findings, the study recommends:

- 1 Invest in transportation infrastructure: implement policies to upgrade transportation infrastructure, including roads, railways, and cold chain facilities, to improve the efficiency of transporting agricultural produce from farm to market. This may involve government investment in infrastructure development projects and public-private partnerships to enhance transportation networks.
- 2 Promote climate-resilient agriculture: develop policies that promote adopting climate-smart agricultural practices, such as conservation agriculture, agroforestry, and crop diversification, to enhance resilience to climate change impacts. This could include financial incentives, technical support, and extension services to farmers transitioning to climate-resilient farming methods.
- 3 Facilitate market access: enact policies to facilitate market access for smallholder farmers, including reducing trade barriers, streamlining regulatory processes, and promoting market information systems. Governments can also support establishing market infrastructure, such as wholesale markets and agro-processing facilities, to improve market access and reduce postharvest losses.
- 4 Provide financial support: implement policies to provide financial support to farmers for investments in postharvest management infrastructure and technologies, such as cold storage facilities, packaging materials, and transportation equipment. This may involve establishing subsidy programs, low-interest loans, and grants to improve postharvest handling practices.

- 5 Strengthen extension services: enhance extension services and farmer training programs to build capacity in postharvest management practices, including proper harvesting, handling, and storage techniques. Governments can allocate resources to expand extension services, develop training curricula, and deploy extension agents to provide farmers with technical assistance and advisory support.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by The Human and Social Sciences Research Ethics Committee (HSSREC) of the University of KwaZulu-Natal. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because it was verbal and on the questionnaire.

Author contributions

SQ: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. LM: Supervision, Writing – review & editing. AM: Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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