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EFFECT OF POST-HARVEST LOSSES ON THE INCOME OF AVOCADO FARMERS IN MURANG'A COUNTY, KENYA

DAVID KARIMIRE MUITA

A Thesis Submitted to the Graduate School in Partial Fulfillment for the Requirements of the Award of Master's Degree in Agribusiness Management of Egerton University

EGERTON UNIVERSITY

OCTOBER, 2025

DECLARATION AND RECOMMENDATION

Declaration

I declare that this research thesis is my original work and has not been presented in any other University for the award of a degree.

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This research thesis has been submitted with our approval as University supervisors

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Dr. Dickson Otieno Okello (PhD)

Department of Agricultural Economics and Agribusiness Management

Egerton University

Signature: ……. Date: 18/09/2025

Dr. Florence A. Opondo (PhD)

Department of Commerce

Laikipia University

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DEDICATION

I dedicate this thesis to my dear family: Parents and siblings. The best motivation I have received has come from your unflinching support, your sacrifices, your endless love, your prayers, and your faith. As I travel on this journey, I feel your presence in every step of my life. May the Almighty God bless you abundantly.

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ABSTRACT

All over sub-Saharan Africa and Kenya, enhancing avocado post-harvest losses (PHL) throughout the value chain is an essential avenue to increase commercialization, income for farmers and food and nutrition security. In Murang'a County, where avocado farming is the main source of cash livelihood for farmers, significant quantities of harvested fruits are PHL. Because we know very little about the extent of losses caused by disease, their determinants, and income effect, effective mitigation policy cannot be enunciated. The purpose of the study was to determine the effect of PHL on the income of smallholder avocado farmers in Gatanga Sub-County in Murang'a County. The specific objectives were to: (i) characterize avocado post-harvest losses (PHL) at farm and market level; (ii) identify factors responsible for PHL; and (iii) assess impact of PHL on farmers' earnings. To collect data for the study, a quantitative research design was used where a sample of 187 (one hundred eighty seven) farmers was selected through multistage sampling. Details were gathered using well-organized surveys and evaluated using explanation and deduction statistics, a fractional reaction model, and a multinomial endogenous switching survey (MESR) model. The study revealed that 33.16% of the farmers were affected by quality damage or total loss. This damage mainly occurred during harvesting because of diseases and mechanical damage (abrasion, bruising, splitting). Other causes were pest infestation, theft and poor infrastructure and weather conditions. Older farmers with smaller fields that lacked credit access engaged off-farm and had longer distances to market. Sociodemographic factors like education gender household size, farm size, and farming experience had significant effect on income according to MERS model. Male farmers were less likely to lose produce than female farmers. Farmers who were educated had adopted improved practices that caused them to have less PHL. Larger households and larger farm sizes, especially those with labour and infrastructure advantages, were less likely to lose produce. More experienced farmers, however, often incurred greater losses from risky practices. The research calls for stronger measures on pest and disease management, harvesting and handling, storage infrastructure, transport infrastructure, and finance and training access. Reducing PHL will benefit not just farmers but also consumers and other stakeholders along the chain. It will boost the incomes of farmers and also be significant to Kenya's food security aspirations and commercialisation of avocado farming on a sustainable basis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

92

LIST OF ABBREVIATIONS AND ACRONYMS

CIDP	County Integrated Development Plan
FAO	Food and Agriculture Organization
HCD	Horticultural Crops Directorate
KALRO	Kenya Agricultural and Livestock Research Organization
PHL	Post-Harvest Losses

turnitin Page 27 of 106 - Integrity Submission Submission ID trn:oid:::1:3392023203

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

The horticulture subsector in Kenya is very important; it provides income, food security, and foreign exchange (HCD, 2018). The horticulture subsector comprises avocado farming which is one of its pillar's accountings for 17 percent of the total horticultural export value. Avocado farming is very significant fetching high returns in both local and export markets (HCD, 2018). Avocado is an important commercial fruit in Kenya and it is produced mainly by small-scale farmers who grow for subsistence, local markets, and export (Oduol *et al.,* 2017) as well as a few large-scale farmers.

Avocado is considered a complete food as it is highly nutritious and rich in protein (Tabeshpour *et al.,* 2017) with other benefits in the cosmetic industry (Hakizimana & May, 2018). Although Kenya is the third largest exporter of avocado to Europe (FAO, 2017; Karuiru, 2018) it still exports a lower share compared to what it is producing. This could be attributed to factors such as; poor quality, high regulatory standards, and inadequate capacity for coordination (Amare *et al.,* 2019).

Many of these factors that lead to the rejection of avocados in the local market and especially the export market is highly contributed by post-harvest losses (PHL) hence influencing the income of farmers negatively (Kimiywe, 2015; Ramirez-Gil *et al.,* 2019). PHL are food losses and waste that emerge as a result of immature harvesting, poor harvesting and handling techniques as well as poor post-harvesting practices (Bantayehu *et al.,* 2019; Kasso & Bekele, 2018; Omolo *et al.,* 2019) like; storage, sorting and grading, packaging, transportation, and processing.

Post-harvest activities contribute highly to the final value of agricultural products like avocados (Hansen *et al.,* 2017) whereby the adoption of better innovative post-harvest handling practices that reduce PHL leads to high-valued products that fetch good prices hence increasing farmer's profit margin (Bustos, 2016). According to Rijpkema *et al.* (2014), PHL leads to a reduction in income generation, hunger, and reduced economic growth in many developing nations.

The total food losses in Sub-Saharan Africa arising from PHL is very high, about 40-50%, reducing the income generation and food security of many smallholder farmers (Abass *et al.,* 2014; Datta *et al.,* 2015). Post-harvest losses in developing regions are typically greater than in developed

regions. The PHL could be caused by; early harvesting resulting in loss of quality, nutritive value, and profit (Azebagaoglu, 2018), harvesting of fruits by poor traditional methods like the use of forked sticks causing damages (Kasso & Bekele, 2018; Omolo *et al* 2019).

After harvest food loss also occurs due to the poor storage facilities, lack of proper means of transportation, poor road condition, and insufficient market facilities that provide acceptable storage and retail conditions (Kasso & Bekele, 2018). The high post-harvest losses are a hindrance to farmers maximizing their returns and increasing their growth levels since most of their produce is lost before being consumed, reducing the quantity to be sold (Bekele, 2018).

PHL has been agreed by many researchers to have negative effects on income for both local traders and exporters (Snel *et al.,* 2021). In that case, farmers need to be vigilant and understand the causes of PHL and how it influences the quality, price as well as choice of market. Preference of avocados by consumers depends on different quality attributes (Migliore *et al.,* 2018). Thus, farmers need to understand them accordingly to satisfy their customers hence increasing their income levels. PHL leads to quality deterioration making farmers incur huge losses, especially in export markets where there is greater quality selectivity (Colbert & Stuart, 2015; Kimiywe, 2015; Mishra *et al.,* 2022).

The price received by farmers from selling their produce also influences the income level. High prices for avocados benefit farmers by increasing their profit margin hence increased income (Omolo *et al.,* 2019). Prices are determined by the quality of a product and for avocados post-harvest activities will influence the quality, poor harvesting criteria and handling of avocados lead to poor quality which fetches low prices in the local market and total rejection in export market hence resulting to PHL (Bill *et al.,* 2014; Ramirez-Gil *et al*., 2019).

High prices received act as an incentive for farmers to reduce PHL leading to a supply of high-quality produce at a higher profit margin increasing their income, but the incentive could decrease as prices stabilize indicating that quality is not the only determinant of prices but also market forces (Bustos, 2016); Omolo *et al.,* 2019).

The smallholder farmers especially in Murang'a County which leads in the production of avocados in Kenya heavily depend on it for their income (HCD, 2018). The smallholder farmers in Murang'a County are subsistence farmers and many engage in commercial farming. Commercialization of avocado farming is vital as it contributes to economic development through

increased income of rural households depending highly on it, creation of employment in the supply chain of avocados, and diversification of export products (FAO, 2017).

Mwambi *et al.* (2016), stated that the lack of post-harvest facilities led to PHL hindering the supply of quality produce to the markets that offer profitable returns hence obtaining low income. To reap the benefits arising from the commercialization of avocado farming, like increased yields and income, farmers need to find ways of reducing the PHL (Hansen *et al.,* 2017).

According to Hansen *et al.* (2017), the adoption of post-harvest strategies that minimize PHL is important in increasing the value of farmers' produce hence increasing returns. Most avocado post-harvest losses are related to improper post-harvest handling techniques (Kesse & Bekele, 2018; Ouma *et al.,* 2018). Extension service providers may help farmers access new technologies and demonstrate on how to apply various guidelines when harvesting avocados and post-harvesting practices (Ndour, 2017). Coordination and management of post-harvest stages as well as the adoption of appropriate innovations and technologies also reduces PHL (Elik *et al.,* 2019).

Farmers can also engage in value addition by making avocado oil which is highly valued in the cosmetic industry with their ripe or overripe avocados to avoid wastage hence increasing their income (Hakizima & May, 2018). Having empirical literature on the benefits of avocado farming, what consumers demand, causes and effects of PHL, and how to reduce PHL to achieve maximum returns this study sought to add to the body of knowledge on the effects of PHL on income of avocado farmers in Murang'a County.

1.2 Statement of the Problem

In Kenya, most research on avocado farming has focused on marketing aspects and the factors influencing farmers' participation in markets, while relatively little attention has been given to post-harvest handling practices and their effects on fruit quality, price, and market choice. This gap is critical because poor post-harvest management contributes significantly to post-harvest losses (PHL), which in turn reduce farmers' income. Murang'a County, a leading producer of avocado in Kenya, relies heavily on the crop for household income, employment, and food security. As demand for avocado increases globally and locally due to its nutritional and economic value, there is a big opportunity for smallholder farmers to benefit from supplying quality fruit. Ramping up production does not necessarily translate to higher sales and income since the quantity and quality of avocadoes put to the market by PHL will be lower. Though important, little evidence

exists the extent, causes and income effect of avocado PHL in Kenya. This gap has been filled by the study which seeks to examine the effect of PHL on the income of smallholder avocado farmers in Gatanga Sub-County, Murang'a County.

1.3 Objectives of the Study

1.3.1 General Objective

To contribute towards the improvement of income levels of avocado farmers by determining the extent of the effect of post-harvest losses on income and how to reduce them in Murang'a County.

1.3.2 Specific Objectives

i. To characterize the post-harvest losses of avocado at the farm level and market level in Gatanga Sub-County, Murang'a County.
ii. To determine factors influencing post-harvest losses among avocado farmers in Gatanga Sub-County, Murang'a County.
iii. To determine the effect of post-harvest losses on the income of avocado farmers in Gatanga Sub-County, Murang'a County.

1.4 Research Questions

i. What are the post-harvest losses of avocado that occur at the farm level and market level in Gatanga Sub-County, Murang'a County?
ii. What are the factors that lead to post-harvest losses among avocado farmers in Gatanga Sub-County, Murang'a County?
iii. What are the effects of post-harvest losses on affect income of avocado farmers in Gatanga Sub-County, Murang'a County?

1.5 Justification of the Study

This study is in line with global and national development priorities. The goal is to promote the implementation of sustainable and environmentally sound agriculture, which contributes to the overall achievement of the key SDG's that is Zero Hunger & Food Security (SDG 02), Good Health & Well- being (SDG 03), and Responsible Consumption & Production (SDG 12) and so on. These objectives underline the need to strengthen agribusiness enterprises in order to raise producers' incomes, strengthen food security, and facilitate the sustainable commercialization of agricultural products.

Results of this study will assist avocado farmers and potential entrants to the avocado sector by equipping them with knowledge of post-harvest losses (PHL), factors causing PHL, and techniques to reduce them. In the end, this will raise income level and improve livelihoods. The study is relevant to National and County Government as the results will inform the implementation of CIDPs commercializing Avocado farming. They study aimed to provide evidence on the avocado production and postharvest losses (PHL) status in Murang'a County, Kenya.

It will also help to enhance extension service and support systems for the farmer. The research will benefit traders, distributors, packagers, investors, extension agents, policymakers, and other value chain actors beyond government institutions. It will provide the producers with chances to cut down on losses and enhance value addition. Further, the study is aligned to the Big Four Agenda of Kenya and Vision 2030 on food security and manufacturing. In conclusion, the study will enhance the existing academic literature on post-harvest loss and provide a reference for future research in Kenya and beyond.

1.6 Scope and Limitations of the Study

The study was limited to the effect of post-harvest losses on the income of avocado farmers in Murang'a County focusing only on smallholder commercial avocado farmers. Specifically, it sought to determine the types of post-harvest losses that occur at the farm level and market level, factors influencing post-harvest losses, and the extent of the effect of post-harvest losses on the income of avocado farmers.

The sample was drawn from Gatanga Sub-County where the majority of smallholder avocado farmers engage in commercial farming and depend highly on it for their income. The research instrument that was used in the study was structured questionnaires whereby respondents were required to fill in. The study was conducted in October 2023. The main limitation that is likely to be experienced in the study is that some agripreneurs were not able to give accurate information, limited time, and financial constraints. This was countered by probing the respondents to give more details.

1.7 Operational Definitions of Terms

Income – this refers to revenue that the smallholder agripreneurs receive from selling avocado and its products minus their production costs.

Post-harvest – this is the stage of avocado production immediately following harvest, including cleaning, sorting, storing, packing, and marketing.

Post-harvest losses – this is the degradation/damages in both quantity and quality of avocado from harvest to consumption; regarding this study, they include immaturity, mechanical damages, chilling injury, over-ripening, and pathogenic attacks.

Smallholder farmers – a smallholder avocado farmer is an individual or household cultivating avocados on less than 2 acres, relying mainly on family labour, limited inputs, and producing for both household use and market, often through cooperatives or contract farming arrangements.

Sources of post-harvest losses – these include rotting, mechanical damage, poor handling, improper management of temperature and relative humidity, and hygiene problems during handling in storage and marketing.

CHAPTER TWO

LITERATURE REVIEW

2.1 Avocado Farming in Kenya and Murang'a County

Avocado (*Persea america*) originates from Mexico and is cultivated worldwide in tropic and subtropical areas (Schaffer *et al.,* 2013). Avocado is one of the most economically important fruits in the world and it is a fruit that lies under the horticultural subsector in Kenya contributing a significant value to the subsector ((Bost *et al.,* 2013; HCD, 2018). The total land area under avocado farming is about 11,000 ha (FAO, 2017), and production is mainly dominated by small-scale farmers, having 5-20 trees, who grow for subsistence, local market, and export too (Oduol *et al.,* 2017).

Kenya produces more than 40 varieties (KALRO, 2018) local varieties dominate comprising about 70% of the total production (HCD, 2015). Hass is the main export variety followed by Fuerte (KALRO, 2018). Other varieties like Puebla, Duke, and G6 are traded mainly in the local market (HCD, 2017). Kenya is considered the third-largest producer of avocados in the world and the largest exporter in Africa (Amare *et al.,* 2019).

Kenya exports 10% of its total production and the rest is traded in the local market, with Hass variety accounting for 20% of exports to Europe and Fuerte (10%) which is not popular in Europe has found its way to the Russian market where its demand is high (Amare *et al.,* 2019; HCD, 2017). There is also a substantial export market in the Middle East as well as a high probability of a new market in China (Wamucii, 2020; Yanyan, 2018). In Kenya, the main season for avocado is March to September, with Fuerte being available from March and Hass from May, and available in smaller quantities outside the main season (Wamucii, 2020).

Eastern and Central regions are the leading producers of avocado in Kenya contributing around 70% of total production majoring in Hass and Fuerte varieties for export (HCD, 2014). Murang'a County falls under the Central region and it is one of the leading counties in avocado production contributing the highest value of 53% to the total value of avocado in Kenya (HCD, 2017). Production in Murang'a County is undertaken mainly by small-scale farmers due to limited land sizes of 1.4 acres on average per household, producing majorly Hass and Fuerte varieties (Mwambi *et al.,* 2016). Gatanga Sub-County leads in avocado production with two fruit industries (Murang'a CIDP 2013-2017).

Avocado farming is essential agricultural activity for not only ensuring food and nutrition security, generation of income for farmers and value chain stakeholders, improve standard of living as well as for economic growth and development of the country (Amare *et al.,* 2019; FAO, 2017 and HCD, 2015) but also its expansion will lead to reduction of natural degradation, regulation of climate change, increased export earnings, and emergence and development of fruit processing industries in Kenya (Bantayehu *et al.,* 2018).

The realization of avocado's nutritional benefits that contribute to solving many health problems and other benefits associated with avocado oil like in the cosmetic industry has led to an increase in demand for avocado both locally and globally (Hakizimana & May 2018; Tabeshpour *et al.,* 2017). For instance, the opening of a new market in Russia for the Fuerte variety (HCD, 2017) and the growing demand for Hass variety in the European market presents an opportunity for Murang'a farmers to shift from producing Fuerte to Hass to meet the increasing demand (Jonny *et al.,* 2019).

With the increasing demand especially in the export market Kenya has the potential to meet them as well as the domestic market since it has a high rate of production, however, its exporting share is still low (Amare *et al.,* 2019). According to Amare *et al.* (2019), low export share could be attributed to factors like poor quality, high regulation standards in export markets, weak institutional capacity of small-scale farmers, and poor coordination.

The inability to meet market demand as a result of post-harvest losses leads to loss of or reduced income farmers receive (Abass *et al.,* 2014; Cobert & Stuart, 2015; Johnson *et al.,* 2019; Kikulwe *et al.,* 2018) as most of the avocado produced is never consumed demotivating farmers to increase production (Bustos, 2019). Therefore, for Murang'a and Kenyan avocado farmers as a whole to benefit from increased incomes, as a result of marketing their products either locally or internationally through exports, they need to know to what extent PHL affects their income, the causes of losses and where they occur to reduce them hence making this study significant.

2.2 Concept of Post-Harvest Losses in Avocados

Post-harvest losses (food losses) can be defined as measurable quantity and quality of food that occur during harvesting, after harvesting, and throughout the supply chain till it reaches the consumers. According to Waudo (2015), she referred PHL is harvested produce intended for human consumption but they are not ultimately consumed by people. Quality losses include losses of nutrient or caloric composition leading to unacceptability and inedibility of a given product,

common in developed countries, while quantity losses are those that result in a reduction in the total amount of product, common in developing countries (AUC, 2018; Kiaya, 2014). Post-harvest losses in developing countries are greater than in developed countries due to differences in the usage of advanced technology and infrastructure (Gaona-Forero *et al.,* 2018).

PHL is a global concern as it not only affects the developing countries but also the whole world (AUC, 2018). It has negative effects on farmers' income (Kikulwe *et al.,* 2018; Ouma *et al.,* 2018; Sokoto *et al.,* 2016), and it also leads to food and nutrition insecurity, as well as reduced economic growth (Abass *et al.,* 2014; AUC, 2018; Rijpkema *et al.,* 2014). PHL in avocados may be; physical losses, where avocados will have no residual value or alternative use resulting in total loss of income or economic losses, where avocados are partially damaged or spoiled (deteriorated quality) and can be sold at a discounted price since it has residual value and can have alternative use (Kikulwe *et al.,* 2018).

Deterioration of quality may cause losses to a lower extent in the local market, especially in cases where the edibility of a product is not affected (Johnson *et al.,* 2019). But to a higher extent in the export market where there is greater quality selectivity as well as adherence to high quality and food safety standards (Lanfoarchi *et al.,* 2016).

In Kenya, PHL is estimated at 20-30% reducing the amount of income generated from avocado farming (AUC, 2018). Therefore, after understanding the concept of PHL and its impact it is necessary to identify where PHL occurs mostly in the supply chain and what factors contribute to PHL to address them at the point of origin with the right strategies hence reducing PHL and increase incomes (Kikulwe *et al.,* 2018; Waudo, 2015).

2.3 Farm Level and Market Level Post-Harvest Losses

Post-harvest losses occur from harvesting, after harvesting, and along the supply chain till it reaches the consumer (Kiaya, 2014). Identification of the nature of losses at each point in the supply chain is very important to employ strategies for reducing them effectively hence minimizing the total impact of PHL (Sokoto *et al.,* 2016; Waudo, 2015)).

According to Lipinski *et al.* (2016), the PHL is a result of unintentional agricultural processes or technical limitations in storage, infrastructure, packing, and marketing since no business farmer is willing to lose income intentionally as the main objective of every agribusiness farmer is to maximize profit and minimize losses. Therefore, for suitable prevention and

minimization strategies to be adopted, PHL should be identified at the exact point of occurrence as well as their causes (Muriana, 2017).

PHL is highly influenced by the supply chain (Kiaya, 2014), long supply chain of perishable products like avocado will result in high PHL as well as an unsustainable supply chain (Gardas *et al.,* 2018; Kiaya, 2014; Kikulwe *et al.,* 2018). Muranga farmers participate in both domestic marketing and export of avocado which have different supply chains. For domestic marketing, smallholder farmers sell their products to wholesalers and retailers who deliver them to final consumers (Waudo, 2015).

Although smallholder farmers' avocados end up in the export market, they do not participate directly in exportation rather, they sell them to companies or firms that finally export the produce (Amare *et al.,* 2019). Therefore, the supply chain in this case will start from smallholder farmers to exporter companies or firms and finally to the export market. Understanding the concept of supply chain and the time taken to transfer products will enable easy identification of possible losses that will occur at each point and the consequences it will have on farmers' income (Kiaya, 2014).

The PHL that has a high effect on farmers' income has been considered to originate from the farm level as a result of immature harvesting, harvesting techniques, post-harvest handling practices, poor market information and coordination leading to mechanical and friction damages like bruising and splitting, chilling injury, fungal damages, physical weight loss, diseases, over-ripening, rotting and decaying (Bantayehu *et al.,* 2019; Bekele, 2018; Johnson *et al.,* 2019; Kasso & Bekele, 2018; Kikulwe *et al.,* 2018; Omolo *et al.,* 2019; Sokoto *et al.,* 2016) hence total loss of the product (physical loss) with little remaining fetching discounted price (economic loss). PHL at the farm level has the greatest effect on farmers' income since they have not shifted the responsibility to third parties like the wholesalers or retailers, the product is still under their care and any loss that arises directly affects their income.

At the market level losses that impact directly farmers' income arise mostly when they involve themselves in direct marketing to final consumers, when there is variability in demand, or when there is poor infrastructure like roads that affect the transportation of avocados to the market (Muriana, 2017; Kikulwe *et al.,* 2018). Low demand for produce, which is not for the case of quality avocados, results in low purchase prices that cannot pay for the cost of production causing farmers to hold back their products (Gunders *et al.,* 2018; Johnson *et al.,* 2019). Quality

deterioration as a result of poor handling and storage facilities at market level determines the price which may be discounted hence economic losses (Dunning *et al.,* 2019; Kikulwe *et al.,* 2018; Omolo *et al.,* 2019).

2.4 Factors that Cause Post-Harvest Losses

Time of harvesting, harvesting, and post-harvesting are critical stages of agricultural systems especially when dealing with avocado which has a short shelf life they contribute significantly to the final value of the product (Hansen *et al.,* 2017). Globally researchers are in agreement that studies on factors contributing to losses need to be conducted to enable easy identification of appropriate measures to be taken in minimizing those losses hence maximizing profits earned as well as utility of the product (Eli *et al.,* 2019; Gunders *et al.,* 2017; Muriana, 2017). The factors that cause PHL if not properly dealt with, drains and demotivates farmers from producing leading to scarcity and loss of income (Bustos, 2019).

Several studies have been conducted and factors resulting to PHL identified. The factors range from activities that occur from harvesting, and after harvesting like storage, packing transportation, and marketing to factors like policies and institutional (AUC, 2018; Hansen *et al.,* 2017). According to Kikulwe *et al.* (2018), a lack of clear and empirical information on determinants and distribution of PHL strategies placed to reduce them ends up being ineffective. Therefore, it is important to find out the causes of PHL that greatly affect the farmer's income to take effective courses of action (Affognon *et al.,* 2015; FAO, 2014).

The main cause of PHL has been attributed to harvesting and post-harvesting handling techniques (Bantayehu *et al.,* 2019; Omolo *et al.,* 2019). Early harvesting reduces the nutritional and economic value and sometimes may lead to total loss of the whole product due to immaturity (Azabagaoglu, 2018; Sokoto *et al.,* 2016). Harvesting criteria determines the quality of product which will eventually determine market price, for instance use of traditional methods contributes highly to PHL as most of the fruits will be damaged when raw and even when ripen due to internal damages (Bill *et al*., 2014; Omolo *et al*., 2019; Ramirez-Gil *et al.,* 2020).

Lack of good practices in packaging and proper technologies for storage and cooling of avocados also causes PHL (AUC, 2018; Gardas *et al*., 2018). The use of unadvisable and unsuitable equipment in the storage of avocados may lead to losses in early ripening and rotting either at the farm level or market level (Kasso & Bekele, 2018).

Avocados are fruits that can start ripening after harvesting therefore cooling and refrigeration are very important at the farm level at the right temperatures before identification of ready market as it lengthens it shelf life hence minimizing PHL, but lack of these storage facilities results in PHL because high temperatures of tropical environment like in Muranga County will lead to high respiration rates increasing metabolic activity of avocado hence fast ripening deteriorating the quality of avocado and making it highly perishable (AUC, 2018; Gardars *et al.,* 2018; Sokoto *et al.,* 2016).

Poorly developed infrastructure like roads is another factor contributing to PHL before the product reaches the market. Transportation of avocados may take a long time to arrive in the market which may lead to mechanical injury or damages reducing the quality or resulting in total loss of the product (Gardars *et al.,* 2018; Kasso & Bekele, 2018; Kiaya, 2014).

Marketing problems with demand fluctuation and price contribute to PHL (Rahiel *et al.,* 2018). Availability of buyers directly influences the price and if the demand is low purchase price will be low since supply will be higher than demand, farmers will be forced to hold back their products or sell at a throw-away price which eventually results in economic losses (Gunders *et al.,* 2017; Johnson *et al.,* 2019; Muriana, 2017).

Poor policy formulation and implementation with inefficient institutions to handle PHL contributes to the increase in PHL. These policies that aren't formulated to tackle PHL at critical source points are not beneficial to farmers hindering the goal of reducing PHL (AUC, 2018). Institutions that formulate the laws and statutes mostly tend to support the production and supply of products but rarely focus on PHL (AUC, 2018; Kikulwe *et al.,* 2018).

This is evident in Muranga County as the leaders mostly focus on increasing the production of avocados by issuing seedlings to farmers and enhancing their husbandry practices through training with little attention on providing ways to deal with PHL (ADP, 2018-2019).

Lack of processing facilities like industries that promote the value addition of avocado by extraction of avocado oil which has numerous benefits and can also be used in the cosmetic industry contributes greatly to PHL (Bill *et al.*, 2014; Omolo *et al.,* 2019; Ramirez-Gil *et al.,* 2020). Processing avocados can significantly reduce losses associated with surplus production and losses associated with deteriorated quality since high-quality standards in processing are not a necessity (Yanyan, 2018).

Other factors causing and contributing to PHL are; limited extension services provided to avocado farmers' and lack of education and training for farmers in dealing with PHL (Bantayehu *et al.,* 2018; Bantayehu *et al.,* 2019; Ndour 2017), inadequate market information and linkages (Rahiel *et al.,* 2018), poor access to financing for PHL reduction initiatives (Etana *et al.,* 2019; Gardas *et al.,* 2017) and insufficient research and development in PHL (AUC, 2018), also causes and contributes to PHL. From the analysis, most authors have adopted the use of descriptive statistics to assess the causes of post-harvest losses. However, there has been scanty information and very few researchers have modeled the drivers of PHL based on the intensity of losses which this study sought to fill the knowledge gap.

2.5 Effect of Post-Harvest Losses on Income of Avocado Farmers

Post-harvest losses have been identified as a major challenge to food security and income generation for many smallholder farmers especially in Sub-Saharan Africa (Abass *et al.,* 2014) and globally as well (Kikulwe *et al.,* 2018). Although it is a major challenge and poses a threat to smallholder farmers' income generation, most farmers don't know how much is lost at each step in the supply chain thus having problems in evaluating potential returns or how much they lose (Waudo, 2015).

This is a major problem especially in avocado farming since much attention has been placed on cereal and grains whereby PHL has been estimated and its impact on income measured (Beune, 2018; FAO, 2018). But in general, the total effect of PHL on income is negative, as it tends to reduce potential income to be earned by farmers (Colbert & Stuart, 2015; Kimiywe, 2015; Sokoto *et al.,* 2016).

According to Kasso and Bekele (2018), PHL arising from poor harvesting and post harvesting handling techniques contribute a significant higher percentage of total PHL, implying that these causes affect income of avocado farmers to a greater extent. These findings were in line with the findings of Kikulwe *et al.* (2018), Ouma *et al.* (2018) and Sokoto *et al.* (2016). Although all these factors contribute to PHL which reduces the income of most farmers, there are strategies and management practices that can be adopted to reduce PHL at various stages in the supply chain (Elik *et al.,* 2019; Hansen *et al.,* 2017; Omolo *et al.,* 2019).

Therefore, reduction of PHL is necessary for farmers to enjoy the benefits of increased incomes, and for this to be achieved major causes of PHL should be identified for proper strategies to be employed (Waudo, 2015). In that case, this study sought the causes and effects of PHL on

the income of avocado farmers thereby providing empirical evidence to all stakeholders and helping in the efficient administration of strategies and management practices to reduce PHL and eventually improve the income of smallholder avocado farmers in Murang'a County, Gatanga Sub-County.

2.6 Theoretical Framework

This study was guided by the Diffusion of innovations Theory, which was developed by (Rogers, 1976). The diffusion of innovation theory is concerned with how a new technological idea, artifact or technique, or a new use of an old one, migrates from creation to use (Arnie, 2012). According to the theory, technological innovation is communicated through particular channels over time and among the members of a social system, which defines diffusion (Apperson & Wikstrom, 1997). Rogers further identified five stages to the process of decision to adopt an innovation.

The first stage is knowledge, in which an individual becomes aware of an innovation, but has no information about it. Next is persuasion, in which the individual becomes actively interested in seeking knowledge about innovation. The third stage is decision making where the individual weighs the advantages and disadvantages of the innovation and decides whether or not to adopt it. After the decision is implemented, in which the individual adopts and uses the innovation. Confirmation is the final stage. After adopting the innovation, the individual makes a final decision about whether or not to continue using it based on his personal experience with it.

In relation to this study, several farm level, socio-economic, institutional and market-level factors have been identified as influencing the loss of avocados after harvest. Farmers' adoption of new knowledge and innovation on avocado loss will be increased if they perceive that the better practice has an advantage over previous methods. This can be promoted through extension services, agricultural financing, market access, education, training and sensitization of farmers on factors that lead to avocado loss.

Farmers with knowledge and skills about the market and proper infrastructures are likely to make decisions to adopt proper practices that reduce post-harvest losses (immaturity, mechanical damages, chilling injury, over-ripening, and pathogenic attacks) thus increasing their incomes. In addition, farmers' characteristics such as age, gender, experience, and education level could affect their decisions on whether to uptake an innovation that could reduce post-harvest losses or not. Therefore, based on the five stages of Rogers's innovation theory, the study will base

this as a framework to understand the factors that lead to avocado loss and its effect on avocado income.

2.7 Conceptual Framework

In this study, post-harvest losses (which included damages as a result of immaturity, mechanical damages, chilling injury, over-ripening, and pathogenic attacks) of avocado farming were assumed to be caused and influenced by factors emerging from demographic and socioeconomic characteristics (age, sex of the household head, household size, average years of education, experience, source of livelihood), farm-specific attributes (total landholding size in acres, insect/pests' infestation, availability of storage, handling techniques) and institutional and marketing characteristics (extension support services, training received on PHL, group membership, use of credit, market information, distance to all weathered road, distance to nearest main market) along the different levels such as harvesting, sorting, cleaning, handling and packing, transportation, storage, distribution or marketing. These factors interlinked to influence the PHL of avocado, forming the independent variables, which in turn affected the avocado farmer's income, which was the dependent variable.

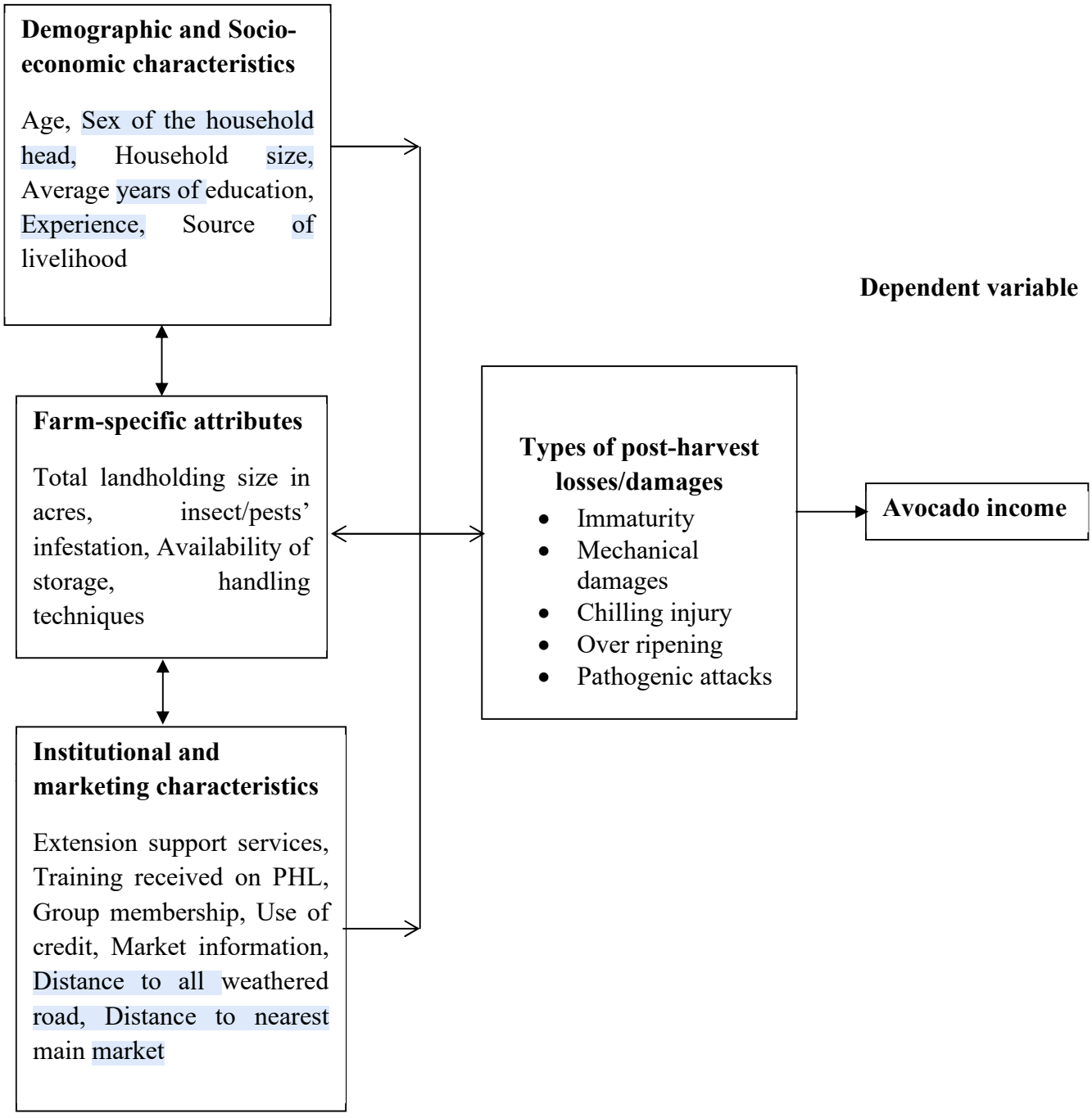

Figure 2.1: Conceptual framework

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Study Area

Murang'a County was selected as the study area because it is the leading producer and exporter of avocado in Kenya. The County mainly grows the Hass and Fuerte varieties (HCD, 2018). The county is found in the Central region of Kenya and borders Nyeri to the north Kiambu to the south Nyandarua to the west and Kirinyaga Embu and Machakos to the east (CIDP 2018). The eastern part is at an altitude of 914 meters above sea level; the western slopes of the Aberdare Mountain range are 3,353 meters high.

The area of Murang'a County is 2,452 km² and has a rural population of 138,213 (KHPC, 2019). The county has rich soils and climatic conditions that favour production of the main cash crops of tea, coffee, avocado, mangoes and macadamia (MCIDP, 2018). The area is governed by 7 sub-counties (Kiharu, Maragua, Kigumo, Kangema, Kandara, Gatanga, Mathioya). The respondent area for this study was Gatanga Sub-County which is among the two most important avocado producing zones in Murang'a County thus a representative area in the county. Farmers in Gatanga diversify their income through avocado farming (Mwambi et al., 2016).

With an area of 531 km² and a population of 187,989, it has 94,437 males and 93,548 females (KHPC, 2019). Gatanga has six wards namely Ithanga, Kakuzi/Mitubiri, Mugumo-Ini, Kihumbu-Ini, Gatanga and Kariara. The farmers in this Sub-County are involved in avocado commercialization for domestic and export markets and thus are an important source of information on post-harvest losses and their impact on household income.

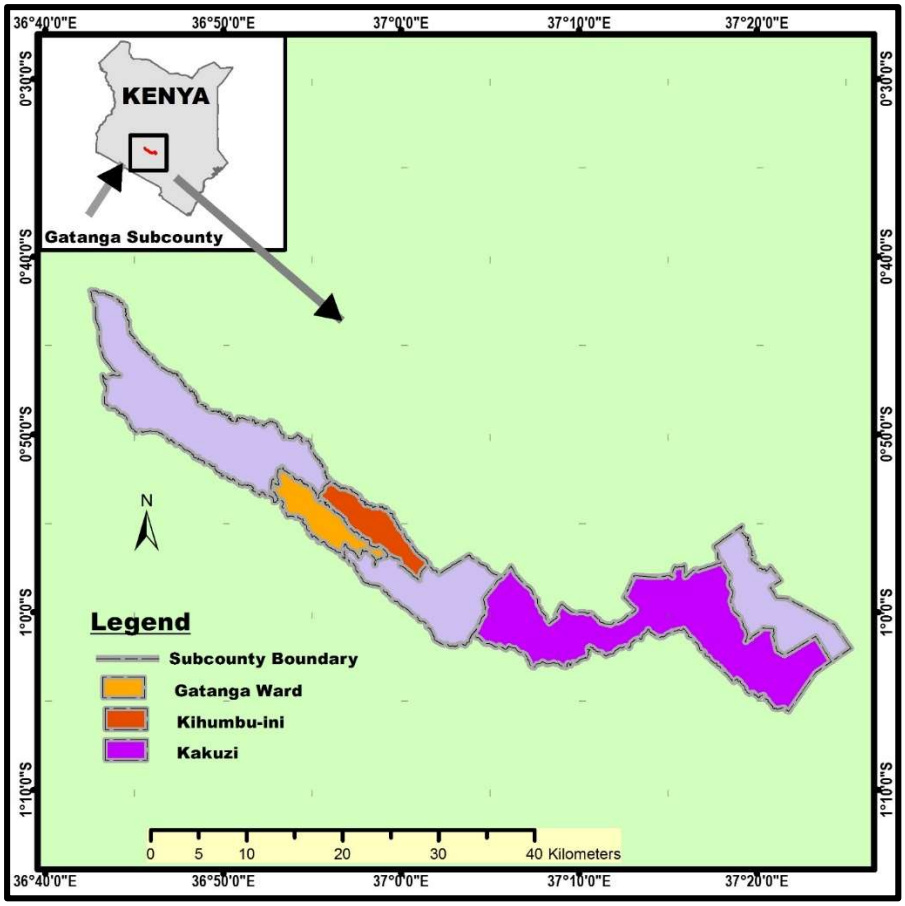

Figure 3.1: Map of study area

3.2 Target Population

The small-scale avocado agripreneurs in Gatanga sub-county in Murang'a county defined the target population.

3.3 Sample and Sampling Procedure

3.3.1 Sampling

Sampling is the process of selecting a subset of respondents from a larger population in such a way that the sample will be representative of the entire population (Bartlett *et al.,* 2001). A sample thus refers to a fraction or percentage of the total population and often is referred to as the sample size. A sample cannot measure every unit of the population. So, the use of a sample always involves some uncertainty. This is known as sampling error. We determine the magnitude of this error using a measure called a confidence interval, which relates to the precision of the estimates realised from the sample.

A confidence interval is expressed at a given confidence level, such as 90% or 95%. For example, a 90% confidence level implies that if the same survey were repeated multiple times

under similar conditions, the results would fall within the stated interval in 90 out of 100 cases. Thus, although sampling involves some inherent uncertainty, it remains a powerful and practical approach that allows researchers to draw valid inferences and make generalizations about a larger population based on data obtained from a representative subset.

In this study, to find the appropriate sample size formula by Anderson *et al.* (2007) was employed to get a representative sample of the whole population. The formula allowed calculation of an ideal sample size given the desired level of precision, desired confidence level, and the estimated proportion of the attribute present in the population when the target population was unknown. It is highly considered in situations with large population; therefore, it was suitable in identifying the right number of respondents in Gatanga Sub County. The formula is as follows:

$$n= (pqz^2)/e^2 \quad (1)$$

Where: n Sample size, z. is the value found in a z table given the desired confidence level, p. is estimated proportion of the population which has the attribute in question, q. is 1-p, e. is the desired level of precision (margin of error) (Bartlett *et al*., 2001). For this study the following assumption was applicable: Confidence level of 95%, which gives a Z value of 1.96, the proportion (prevalence) of the households practicing avocado farming to be 90%, and the margin of error to be 5%. Therefore, to get the sample size using Cochran's formula will be as follows;

$$= (1.96^2 \times 0.5 \times 0.5)/ 0.08^2$$

$$= 150.06$$

= 150 respondents

According to generalization of scientific results, guidelines for sample size estimation indicate that sample size large than 30 and less than 500 is appropriate for most research (Hair *et al*., 2006). Therefore, a sample of 150 respondents was justifiable.

3.3.2 Sampling Procedure

This study employed a combination of probability and non-probability sampling techniques, specifically purposive sampling and simple random sampling. At the first stage, Murang'a County and Gatanga Sub-County were purposively selected because they are among the leading areas in Kenya in avocado production and commercialization. Within Gatanga Sub-County, three wards, Kakuzi/Mitubiri, Kihumbu-Ini, and Gatanga, were further purposively chosen due to their high levels of avocado production compared to other wards in the county.

The second stage had simple random sampling used in a proportionate-to-size manner to select respondents from the villages in the wards selected for the study. By selecting farmers through systematic random sampling according to the two sampling procedures, farmers of the three wards were represented in the ratio of one-third each forward A, B and C. This multi-stage process improved the sample's relevance and representativeness, which in turn improved the reliability of the findings.

3.4 Data Collection Method

Data was collected from both primary and secondary sources. The primary data was collected by use of semi-structured questionnaires that was administered to the respondents. The questionnaire was developed in line with specific research objectives and were made simple and easy for the respondents to understand and answer. The questionnaires had questions related to factors contributing to avocado PHL at farm level and market level as well as those related to institutions. Questions about market price for both quality avocados and those that have deteriorated but still edible were administered too. Secondary data was collected by use of journals, county reports, publications, relevant websites, books and County Integrated Development plans.

3.5 Analytical Framework

3.5.1 To Characterize the Post-Harvest Losses of Avocado at Farm Level and Market Level in Gatanga Sub-County, Murang'a County

To establish the post-harvest losses of avocado at farm level and market level, this study used the following descriptive statistics: mean percentage, standard deviation, tabulation and frequency distribution. These descriptive statistics explained, described, compared, and contrasted the different losses due to harvesting, handling, transportation to storage, storage, transportation to market, and marketing.

3.5.2 To Determine Factors Influencing Post-Harvest Losses in Avocado Farming in Gatanga Sub-County, Murang'a County

Understanding the factors that influence multiple post-harvest losses is crucial in reducing losses along the different levels of marketing avocado. The identified post-harvest losses included: immature avocados, mechanical damages (abrasion, bruising, splitting), physical damages (injuries, scarring and discoloration), over ripening and infestation (pathogenic attacks). The losses were measured as binary, whether a farmer experiences this loss or not. However, it is most likely

1 there was a selection of one or more than one loss. To answer this research question, the fractional response model was used.

3 This is because the extent of post-harvest losses in avocado farming was measured as a percentage of the marketed surplus that was a proportion of the total amount of the marketed produce. The values of the dependent variable ranged between 0 and 1. Ordinary Least Squares would have been used to estimate the proportional dependent variable but the bounded explained variable would exhibit inconsistent slopes in the explanatory variables also, the linear models produce predictions outside the interval. Other models that could have been used to estimate bounded dependent variables were truncated and censored regressions such as Tobit but, the values in the interval would not be feasible since the values would not be censored (Baum, 2008).

The fractional response model is an extension of the generalized linear models (GLM) and other conventional models that are used to explain the bounded dependent variable. The model accounts for the nature of a continuous and bounded dependent variable, predicts values within the limit of the dependent variable interval and produces a good fit for linear models by capturing the non-linearity effect (Gallani *et al.,* 2015). The conditional prospect for the fractional response model is inscribed as;

$$\boldsymbol{\varepsilon(y_i/x_i) = G(x_i, \emptyset), i = 1, 2, \ldots N \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)}$$

Whereby $\boldsymbol{y_i}$ is the dependent variable and $\boldsymbol{x_i}$ are the exogenous explanatory variables and G is a cumulative distribution function obtained using non-linear methods particularly the quasi-maximum likelihood method (QML) grounded on the Bernoulli log- like function, given as;

$$\boldsymbol{LL_i(\theta) = y_i log[G(x_i, \theta)] + (1 - y)[1 - G(x_i, \theta)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)}$$

1 The Bernoulli function is an affiliate of a linear exponential family (LEF), an estimator of QML denoted as θ defined as;

$$\boldsymbol{\theta = arg_{\theta} max \sum_{n=1}^{N} LL_i \theta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)}$$

Table 3.1: Description of variables and expected signs that will be used in the fractional response model

Dependent Variable	Code	Description	Unit	Hypothesized sign
Proportion	Prop	Percentage of marketed surplus	Continuous	
Demographic and socio-economic characteristics				
Household size	Hhsize	Number of adults in household	Number	+/-
Gender	Sex	Sex of agripreneur	Dummy 1= male, 0=female	+
Age	Age	Age of agripreneur	Number of years	+/-
Land size	Fsize	Area in avocado production	Acres	+
Education	Educ	Highest level of education of agripreneur	Years of schooling	+/-
Experience in farming	Expfarm	Years in farming	Number of years	+/-
Engagement in other businesses	Otherbs	Other businesses	Categorical	+
Availability of storage	AvaiStore	1 if the household has storage facility; 0 otherwise	Dummy	+/-
Insect/pests infestation	Infestation	1 if insect/pest cause PHl; 0 otherwise	Dummy	+/-
Institutional Factors				
Extension contacts	ExtCont	Number of contacts with extension agent	Number	+
Credit	Credt	Amount of credit Borrowed credit	KES	+

Distance to nearest market	DistMkt	Distance to nearest output market.	Km	+/-
Distance to all weathered road	DistWeRd	Distance to all weathered road	Km	+/-
Group	Grp	Group membership yes=1, 0= otherwise	Dummy	+
Post-harvest lsses training	PHLtrg	Received training on PHL yes=1, 0= otherwise		+/-
Market information	MktInf	Receive information on markets yes=1, 0= otherwise	Dummy	+/-

3.5.3 To Determine the Effect of Post-Harvest Losses on Income of Avocado Farmers in Gatanga Sub-County, Murang'a County

The harms suffered by avocado farmers at postharvest level (PPH) can be classified into various types. Depending on the prevailing conditions and unobservable characteristics, farmers may incur a single or combination of losses attributable to post-harvest losses (PHL). As a result, a simple analysis of the income earned under PHL would likely lead to a biased or misleading outcome. We usually use endogenous switching regression (ESR) or propensity score matching (PSM) to tackle issues of endogeneity and sample selection bias where treatment and control variables are binary in nature. Since smallholder farmers usually experience various types of post-harvest losses in combination at the same time, binary modeling approaches ESR and PSM will not be suitable.

The study uses a Multinomial Endogenous Switching Regression (MESR) framework to overcome this shortcoming. This approach that captures the treatment-effect of pairs, triples and quads, designed by Bourguignon *et al.* (2007) and based on Durbin and McFadden (1984), was applied to the combinations of PHL and income. The second step involved the use of OLS (with a selectivity correction term from stage 1) to estimate the impact that each PHL combination had on farmer income.

The underlying assumption was that commercial avocado farmers seek to maximize income while minimizing losses. Since PHL directly reduce household earnings, farmers experiencing fewer losses are expected to earn higher incomes compared to those facing multiple combined losses. It can be concluded that avocado farmer's income (Y) is affected by PHL, m. The expected income (Y) of avocado farmer i incurring loss j from m other combination of losses, which is a latent variable, determined by observed characteristics (Xi) and unobserved characteristics (∈ij):

$$\boldsymbol{Y}^*_{ij} = X_i\beta j + \in_{ij} \quad (4)$$

Where, Xi is a vector of observed exogenous variables, (household characteristics, farm and market level characteristics as well as farm, market and institutional factors).

Let *I* be an index that denotes the PHL that avocado farmer suffers such that;

$$I=\begin{cases} \mathbf{1}\ \boldsymbol{if}\ \boldsymbol{Y^*_{i1} > max(Y^*_{im})\ or\ \eta_{i1} < 0} \\ \qquad\qquad \boldsymbol{m \neq j} \\ \boldsymbol{j\ if\ Y^*_{ij} > \max(Y^*_{im})\ or\ \eta_{ij} < 0} \\ \qquad\qquad \boldsymbol{m \neq j} \end{cases} \quad \text{for all } m \neq \boldsymbol{j} \quad (5)$$

Where $\boldsymbol{\eta_{ij}} = \underset{m \neq j}{\max}(\boldsymbol{Y^*_{im} - Y^*_{ij}}) < \mathbf{0}$ (Bourguignon *et al.* 2007). Eq. (7) implies that the ith avocado farmer would rather incur loss *J* if he will yield more income rather than any other PHL or its combination $m \neq j$, that is, if $\boldsymbol{\eta_{ij}} = \underset{m \neq j}{\max}(\boldsymbol{Y^*_{ij} - Y^*_{im}}) > \mathbf{0}$ Assuming that ε are identically and independently Gumbel distributed, the probability that avocado farmer *i* with characteristics *Xi* would rather incur PHL *j* can be specified by a multinomial logit model (McFadden, 1973):

$$\boldsymbol{P_{ij} = \Pr(\eta_{ij} < 0 / X_i)} = \frac{\boldsymbol{exp\ (Xi\beta j)}}{\sum_{m=I}^{J} \boldsymbol{exp\ (Xi\beta m)}} \quad (6)$$

A maximum likelihood function can estimate the parameters of the latent variable model. In the second stage of the MESR, the relationship between the outcome variable (income) and a set of exogenous variables Z (household characteristics, farm and market level characteristics as well as farm, market and institutional factors) will be estimated for the identified PHL. The outcome equation for each possible regime j will be as:

$$\begin{cases} \boldsymbol{Regime\ 1: Q_{i1} = Z_i\alpha_1 + \mu_{i1}\ if\ I = 1} \\ \boldsymbol{Regime\ J: Q_{ij} = Z_i\alpha_j + \mu_{ij}\ if\ I = J} \end{cases} \quad \text{J= other combinations of PHL} \quad (7)$$

Where Q_{ij} 's is the income of the *ith* avocado farmer in regime *j*, and the error terms (μ's) are distributed with $E(u_{ij} \mid X, Z) = 0$ and $var(u_{ij} X, Z) = \sigma^2 j$. Q_{ij} will be observed if, and only if, PHL *j* will be suffered, which occurs when $\boldsymbol{Y^*_{ij} > \max_{m \neq j}(Y^*_{im})}$. if the ε's and *u*'s are not independent, OLS estimates obtained from Eq. (9) will be biased. A consistent estimation of αj requires inclusion of the selection bias correction terms of the other PHL in Eq. (8). The DM model assumes the following linearity assumption:

$$E\,(Uij \mid \boldsymbol{\epsilon_{Ii}} \ldots \boldsymbol{\epsilon ij}) = \sigma j \sum_{m \neq j}^{j} \boldsymbol{rj(\epsilon im - E(\epsilon im))} \quad (8)$$

With $\Sigma jm = 1rj = 0$ (by construction, the correlation between the *u*'s and $\boldsymbol{\epsilon}$'s sums to zero). Using this assumption, the equation of the MESR in Eq. (10) is specified as:

$$\begin{cases} \boldsymbol{Regime\ 1: Qi1 = Zi\alpha 1 + \sigma i\lambda 1 + \omega i1 \quad if\ I = 1} \\ \boldsymbol{Regime\ J: Qij = Zi\alpha j + \sigma i\lambda j + \omega ij \quad if\ I = J} \end{cases} \quad (9)$$

Where, σj is the covariance between the *u*'s and ε's. Whereas, ω's are the error terms with an expected value of zero and λj is the Inverse Mill Ratio computed from the estimated probabilities in Eq. (10) as follows:

$$\lambda_j = \sum_{m \neq j}^{j} \mathbf{p_j} \left[\frac{\widehat{\mathbf{p_{im}}} \ln(\widehat{p_{im}})}{1 - \mathbf{p_{im}}} + \ln(\widehat{\mathbf{p_{ij}}}) \right] \quad (10)$$

Estimation of average treatment effects

The above framework was used to examine the average treatment effects of the treated (ATT) by comparing the expected outcomes of each PHL. The challenge of impact evaluation using observational data is to estimate the counterfactual outcome, which is the outcome avocado farmers could have achieved had they not incurred the PHL they did. Following Di Falco and Veronesi (2013) and Carter and Milon (2005) the ATT was computed in the actual and counterfactual scenarios as follows:

Avocado farmers with PHL (actual PHL observed in the sample)

$$\begin{cases} \boldsymbol{E(Q_{i2} \mid I = 2) = Z_i\alpha_2 + \sigma_2\lambda_2} & (\boldsymbol{a}) \\ \boldsymbol{E(Q_{ij} \mid I = J) = Z_i\alpha_j + \sigma_j\lambda_j} & (\boldsymbol{b}) \end{cases} \quad (12)$$

$$\begin{cases} \boldsymbol{E(Q_{i1} \mid I = 1) = Z_i\alpha_1 + \sigma_1\lambda_1} & (\boldsymbol{a}) \\ \boldsymbol{E(Q_{ij} \mid I = 3) = Z_i\alpha_3 + \sigma_3\lambda_3} & (\boldsymbol{b}) \end{cases} \quad (13)$$

Avocado farmers if they were not to incur PHL (counterfactual):

$$\begin{cases} \boldsymbol{E(Q_{i1} \mid I = 2) = Z_i\alpha_1 + \sigma_1\lambda_2} & (\boldsymbol{a}) \\ \boldsymbol{E(Q_{ij} \mid I = J) = Z_i\alpha_1 + \sigma_1\lambda_j} & (b) \end{cases} \quad (14)$$

$$\begin{cases} E(Q_{i2}|I=1) = Z_2\alpha_2 + \sigma_2\lambda_1 & (a) \\ E(Q_{ij}|I=3) = Z_2\alpha_3 + \sigma_3\lambda_3 & (b) \end{cases} \quad (15)$$

These expected values were used to derive unbiased estimates of the ATT. The ATT is defined as the difference between Eqs. (12a) and (14a) or Eqs. (12b) and (14b). For instance, the difference between Eqs. (12a) and (14a) is given as:

$$ATT = E\,[Q_{i2}|I=2)] - E\,(Q_{i1}|\,I=2) = Z_i\,(\alpha_2 - \alpha_1) + \lambda_2\,(\alpha_2 - \alpha_1) \quad (16)$$

The first term on the right-hand side of Eq. (16) represents the expected change in the mean outcome if the characteristics and the factors of avocado farmers incurring PHL will have equal returns to those without. The second term (λj) is the selection term that captures all potential effects of differences in unobserved variables. On the other hand, the average treatment effect on the untreated (ATU) is the difference between equation (13a) and (15a) and can be specified as:

$$ATU = E\,[Q_{i1}|I=1)] - E\,(Q_{12}|\,I=1) = Z_i(\alpha_2 - \alpha_1) + \lambda_2(\alpha_2 - \alpha_1) \quad (17)$$

Table 3.2: Description of variables and expected signs that will be used in the multinomial endogenous switching regression model

Dependent Variable	Code	Description	Unit	Hypothesized sign
Avocado income	IncAvo	Gross income from selling avocado	KES	
Treatment variable				
Number of PHL experienced	PHLloss	PHL due to immaturity, mechanical damages, physical damages, over ripening, pathogenic attacks	Dummy	
Socio-economic Characteristics				
Household size	Hhsize	Number of adults in household	Number	+/-
Gender	Sex	Sex of agripreneur	Dummy 1= male, 0=female	+

Age	Age	Age of agripreneur	Number of years	+/-
Land size	Fsize	Area in avocado production	Acres	+
Education	Educ	Highest level of education of agripreneur	Years of schooling	+/-
Experience in farming	Expfarm	Years in farming	Number of years	+/-
Engagement in other business	Otherbs	Other businesses	Categorical	+
Availability of storage	AvaiStore	1 if the household has storage facility; 0 otherwise	Dummy	+/-
Institutional Factors				
Extension service	ExtService	Access to extension services	Dummy	+
Credit access	Credit	Access to credit	Dummy	+
Distance to nearest market	DistMkt	Distance to nearest output market.	Km	+/-
Distance to all weathered road	DistWeRd	Distance to all weathered road	Km	+/-
Group	Grp	Group membership yes=1, 0= otherwise	Dummy	+
Post-harvest losses training	PHLtrg	Received training on PHL yes=1, 0= otherwise		+/-
Market information	MktInf	Receive information on markets yes=1, 0= otherwise	Dummy	+/-

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Descriptive Statistics

4.1.1 Socio-economic Characteristics

Results in Table 4.1 below presents socio-economic characteristics of the respondents. According to the results, the age distribution of the surveyed population is predominantly middle-aged with a significant portion (31.55%) of the respondents being over 60 years old followed closely by those aged 41 to 50 years old (31.02%). The average age of 53.92 years highlighting a mature demographic of the population. As pertains education level, the majority of the respondents, 48.66%, have managed to complete primary education level with only a small fraction (1.6%) having no formal education. With an average of 9.60 years of education, individuals generally have a foundational to intermediate level of formal education.

Sixty-eight-point four five percent (68.45%), of the respondents are male and 31.55% are female. Hence, the female to male ratio is skewed. This imbalance may be associated with the broader social and cultural context, wherein greater access to, or involvement in, avocado production activities might be likely among men. This could also indicate disparities based on sex when it comes to accessing resources, making decisions, and taking part in economic activities. Moreover, farming methods and management actions with avocado (grafting, pruning, harvesting—climbing avocado trees) may be perceived as masculine roles, as well as the utilisation of IPV. The study by Muriithi and Kabubo-Mariara (2022) also noted that most of the avocado farmers were males.

Most (93.58%) of respondents are engaged in other businesses than avocado production thus indicating a high level of entrepreneurial activity and diversification of income sources. The high engagement indicates that not only one source of income is there. This possibly has a strong impact on their economic strength. The population has a diversified source of income with livestock keeping and other incomes with 41.45 % and 40.73 % reported as the major means respectively. Business activities are 15.27% while formal employment is the least common source of revenue at 2.55%. To put it another way, it has a mainly farming and business economy with hardly any formal jobs.

Household sizes average 4.35 members, reflecting a typical family structure presenting a likelihood of labor availability and economic needs. The average total land size is 1.80 hectares, with 1.10 hectares dedicated to avocado production, indicating that a significant portion of land is utilized for agricultural productivity.

Table 4.1: Socio-economic characteristics

Variable	Description	Frequency	Percentage (%)
Age	5_years_up_to_30_years	6	3.21
	31_years_up_to_40_years	22	11.76
	41_years_up_to_50_years	58	31.02
	51_years_up_to_60_years	42	22.46
	over_60_years	59	31.55
Education level	No schooling	3	1.6
	Primary education level	91	48.66
	Secondary education level	62	33.16
	Tertiary education level	31	16.58
Gender	Female	59	31.55
	Male	128	68.45
Engagement in other businesses	No	12	6.42
	Yes	175	93.58
Income sources	Other income source	112	40.73
	Livestock keeping	114	41.45
	Formal employment	7	2.55
	Business	42	15.27
Continuous Variables	Mean	Std. Dev.	
Age in years	53.92	0.9955	
Education in years	9.60	0.3001	
Household size	4.35	1.1731	
Total land size (ha)	1.80	0.1080	
Land under avocado production (ha)	1.10	1.1820	

4.1.2 Social Participation

The respondents were further probed into gaining knowledge on their levels of social participations such as credit access, extension service provisions and group memberships as presented in Table 4.2. As presented in the results, a significant majority of the population (80.75%) do not have access to credit, while only 19.25% have accessed credit. This alludes to a considerable gap in financial inclusion and accessibility to credit services, which could have a potential of limiting the ability of many individuals to invest in their agricultural or business activities.

Among those who have access to credit and credit services, the main primary purpose of accessing the credit is for household consumption (58.82%) followed by purchase of inputs (21.57%). Only, 19.61% use the credit accessed for avocado marketing. The high percentage of credit used for household consumption indicates that the majority of the respondents in Murang'a county prioritize immediate living needs over investment in business and agricultural inputs. These results correspond to those of Kwizerimana (2023), who found out that majority of the avocado farmers in Kenya did not have access to credit explaining their low-income levels thus limiting their productivity.

In terms of sources of credit, most respondents (61.36 %) said they take loans from informal groups (chamas) with the second being financial institutions (25 %), friends or family (11.36 %), and others (2.27 %). The average household borrowed KES 46,057.14, with a standard deviation of 5205.84 in the amount borrowed from credit access method. Farmers have become greatly reliant on Chamas as a source of credit.

People seem to prefer borrowing from groups rather than from institutions. Groups are more accessible in addition to being trusted. Besides that, they also provide a flexible repayment mechanism. Formal financial institutions, in contrast, require collateral and impose strong conditions that smallholders' avocado farmers cannot meet. Access to them is constrained as a result. These findings demonstrate that farmers should have access to credit that is inexpensive and not informal. Thus, informal credit mechanisms must be strengthened while inclusive financial products must be designed.

Regarding extension services, 74.19% of respondents do not receive these services while 25.81% do receive extension services. This indicates that most people may not have the ability to reach critical agricultural advice which can boost productivity and efficiency. Most extension

service users are advised on avocado production (57.5%). The extension service agents also give other services such as marketing and marketing outlets (27.5%), value addition of avocado (12.5%), and advise on avocado processing (2.5%). The production practices are highly emphasized as compared to processing, value addition and post production which are less attended.

On average, there were three extension visits per year which is not a lot of visits. Most Avocado extension services were made available by either farmer organizations/cooperatives (35.59%) or County government agents (28.81%). Agents in the private sector also engage in activities worth 28.81% of ASK Shows (27.74%). The variation in the types of service providers indicates public, private and community extension efforts.

As per the finding of the study, most of the farmers (70.43%) do not belong to any farmer group while only 29.57% belong to a farmer group. This means many farmers do not find it useful to sell their produce jointly. Collective marketing definitely helps the farmers but many do not find it useful. Most common benefits of belonging to groups members reported are information access, collective marketing and access to credit in group with 39.25, 29.91 and 27.1% respectively.

Despite the benefits, our findings show low uptake in group membership. In contrast to above, Kwizerimana *et al.* (2023), state that in their area, most avocado farmers are group members and benefited from collective marketing and bargaining power. The difference in the experience of farmer groups suggests that their role and effectiveness are context specific. This underlines the need for intervention that promotes group membership and strengthens the capacity of existing groups in Murang'a County.

Most of the respondents (84.15%) did not receive any training on post-harvest losses. The failure to conduct training may lead to bigger losses and inefficiencies in the avocado value chain. Over half of the respondents sampled (54.35%) do not have information about the market for where to sell avocados while 45.65% have information. The absence of this marketing intelligence may limit the marketing and sales of many avocado producers. Results by Kwizerimana (2023), show contrasting finding since it shows that most of the farmers who had avocado farming jointly have access to market information.

The road conditions to the markets are tarmacked 55.61% and murramed 44.39%. Just over 50% have transport access while just under 50% do not. Easy access to regular transport for produce to the market helps with effective marketing and profitability. Of those with transport access, the main mode of transport is pick-up/trucks (85.58%) followed by motorbike (7.69%) and

lorry (6.73%). Farmers like pick-up trucks. Pick-up trucks can move avocado produce fallen off the tree or either damaged. The average distance from homestead to the nearest market is 2.69 Km which shows that they are not far from the local markets. The distance from the homesteads to avocado produce market is on average 3.26 Kms which shows that they are reasonably close to larger markets.

Table 4.2: Social participation descriptive statistics

Variable	Description	Frequency	Percentage (%)
Credit access	No	151	80.75
	Yes	36	19.25
Purpose of credit	Purchase of inputs	11	21.57
	Avocado marketing	10	19.61
	Household consumption	30	58.82
Sources of credit	Financial institutions	11	25
	Chamas	27	61.36
	Friends and family	5	11.36
	Other sources	1	2.27
Extension service provision	No	139	74.19
	Yes	48	25.81
Types of services provided	Advise on avocado production	46	57.5
	Advise on avocado processing	2	2.5
	Marketing and marketing outlets	22	27.5
	Avocado value addition	10	12.5
Extension service providers	County governments agents	17	28.81
	Private agents	17	28.81
	ASK shows	4	6.78
	Farmer organizations/cooperatives	21	35.59

Group membership	No	131	70.43
	Yes	55	29.57
Benefits derived from the group	Market together	32	29.91
	Input access	2	1.87
	Group credit access	29	27.1
	Information access	42	39.25
	Value addition services	2	1.87
Training on post-harvest losses	No	154	84.15
	Yes	29	15.85
Market information on where to sell the avocado	No	100	54.35
	Yes	84	45.65
Type of road condition	Tarmac	104	55.61
	Murram	83	44.39
Access to transport	No	88	47.06
	Yes	99	52.94
Means of transport from farm to nearest market	Motorbike	8	7.69
	Pick_up	89	85.58
	Lorry	7	6.73
Average cash credit received (Kes)	46,057.14	5,205.84	
Number of extensions visits in a year	3	0.3906	
Distance from homestead to nearest market (Kms)	2.69	0.2001	
Distance to produce market (Kms)	3.26	0.1869	

4.1.3 Avocado Production Characteristics

Results presented in Table 4.3 present avocado production characteristics in Murang'a county. Hass avocado variety was the most grown by 60.86% of the population. The variety known for its high demand and export potential and takes a shorter time (2.5 years) to be productive compared to other varieties is largely preferred by the farmers. Fuerte variety is also popular, grown by 32.57% of the respondents.

A smaller percentage (6.58%) cultivates local avocado varieties. The high preference for the Hass variety among the farmers indicates that the farmers are likely targeting commercial markets where this variety is favored. Kwizerimana *et al.* (2023) and Muriithi and (2022) established similar findings on the Hass avocado preference among farmers citing that the variety is more productive and highly resistant to temperature variations.

On average, avocado farmers in Murang'a county have a farming experience of 14 years with a standard deviation of 0.7713 years. With this great amount of experience, it can be assumed that most farmers are a long-term avocado producer and, therefore, are well acquainted with the ways of avocado farming.

The average avocado trees per farmer are 80.46, which is highly variable since it has a standard deviation of 34.3584 trees. Some orchards have been revealed to exceed 125 citrus trees. Others have six or even fewer. There are on average 29.37 and a standard deviation of 3.0560 which are productive avocado trees. Some of the trees may not be fully matured or may be having diseases or poor management or external factors affecting them.

Table 4.3: Avocado production characteristics

Variable	Description	Frequency	Percentage (%)
Avocado variety grown	Hass	185	60.86
	Fuerte	99	32.57
	Local	20	6.58
Experience in avocado farming (years)	14.27	0.7713	
Total number of avocado trees	80.46	34.36	
Total number of avocado productive trees	29.37	3.06	

Table 4.4 below outlines the cost of production and input of avocado. Seedlings cost a total of KES 10,164.18. Each seedling costs KES 130.31. It's essential to start with quality seedlings to develop a good avocado orchard. The total farmyard manure of all sites was 1778.84 kg, which cost KES 24,779.24. FYM is significant for improving soil fertility as well as structure. Moreover, it helps the plant growth with higher yields. Only 2.08 kg of NPK fertilizer was used, which KES 17.66 is not a lot compared to other inputs. Even though it is in small quantity, the NPK fertilizer is very important as it provides nutrients that may not be present sufficiently in the soil.

The highest cost will be the labor cost. The project shall employ 142 laborers at 800 KES per laborer. This shall cost a total of 113,600 KES. This research shows that farming avocados requires a lot of hard work and manpower. This tells us that a labour force is needed for planting, weeding, pest control, and harvesting. The cost of pesticides for use with 1.89 liters is KES 128.52.

This is not a huge cost but pesticides are important to keep the crop protected against pest and diseases which may reduce yield. The total production cost per season is KES 148,689.60, which includes all the essential inputs for successful avocado farming. It is essential to control these costs while maximizing output for the farming business to be profitable and sustainable.

Table 4.4: Cost of avocado production per season

Inputs	Quantity	Price per unit (Kes)	Total cost (Kes)
Seedlings	78	130.31	10,164.18
FYM (Kgs)	1778.84	13.93	24,779.24
NPK (Kgs)	2.08	8.49	17.66
Laborers	142	800	113,600
Pesticide (Liters)	1.89	68	128.52
Total cost of production per season			148,689.60

According to Dolaso and Shano (2023), the harvesting stages of avocados are essential for extending their storage life. Most avocados (90.91%) are harvested when they are not yet ripe. Only 9.09% of avocados are harvested just ripe. In order for avocados to be harvested, they must be picked 'green,' on average between six and 20 months after the flower sets. According to study by Dolaso and Shano (2023), majority of the people in the area studied often harvest their avocado when they are just ripe contrary to previous findings.

About 81.82% of respondents loosen avocados in trees by climbing and picking them by hand. This old-fashioned way works well even though it is tedious and involves picking them directly. It also makes sure that not much damage/loss such as cuts and bruising occurs. Most farmers (98.4%) have a market for their avocado after harvest. Also, this indicates that they (most farmers) have the market link. This also indicates that people want to buy the produce and sellers benefit from an organized market. But the 1.6% may not have a market readily available to sell their avocados. This could lead to losses as well as waste unless they have another marketing strategy in place.

Table 4.5: Avocado harvesting

Variable	Description	Frequency	Percentage (%)
Harvesting stage of avocado	Just ripe	17	9.09
	Unripe	170	90.91
Main method used for harvesting avocado	Climbing on tree/hand picking	153	81.82
	Improved integrated with picking pole/s	31	16.58
	Improved integrated with picking pole/s	3	1.6
Ready market for avocado once harvested	No	3	1.6
	Yes	184	98.4

The figure below (Figure 4.1) illustrates the number of avocados at three stages: harvested, damaged/lost, and sold. A total of 14,293 avocados were harvested, out of this, 998 were either damaged or lost accounting for approximately 6.98% of the total harvested avocados. The loss can be attributed to factors related to poor handling, pest and disease infestation and poor storage conditions. The number of avocados sold stands at 11,804 indicating that a substantial portion of the harvested avocados (82.59%) successfully reached the market and were sold.

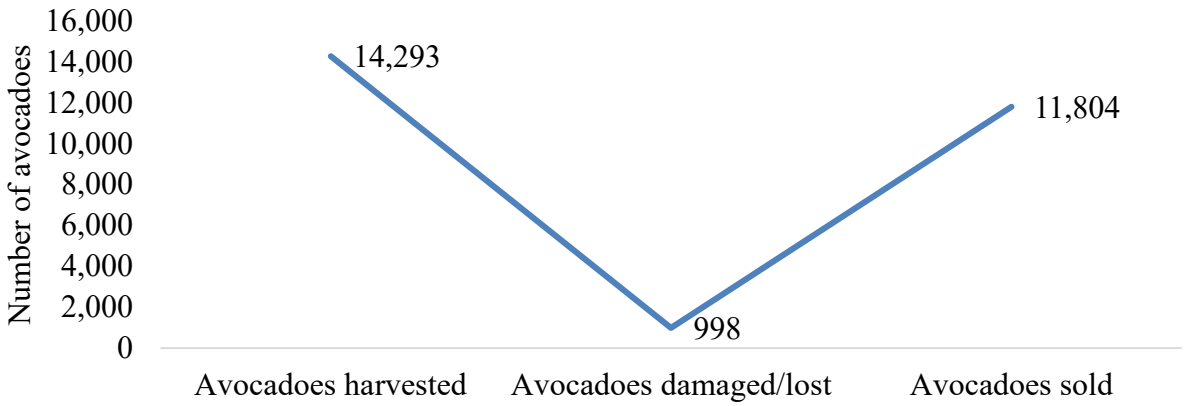

Figure 4.1: Number of avocadoes harvested, damaged/lost and sold

According to the results of the study presented in Figure 4.2 below, it is found that a large majority of the avocados, 71%, are sold in the export market. Many of the avocados are made for export. Also, often better prices and the chance to meet global demand makes selling to export markets attractive. Only 29% of avocados are sold in the local market. Even though it's a smaller part than the export business, it still means a significant share of sales. Most respondents prefer to sell in export markets. Although, selling in local markets are important as they help in getting close to consumers but they can also provide stability when export offers drop.

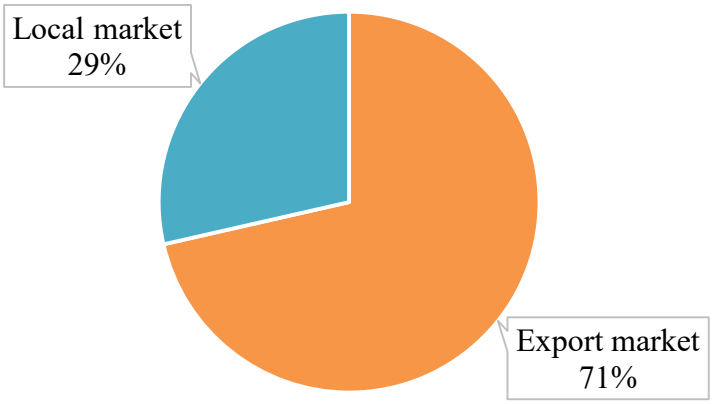

Figure 4.2: Market participation

The average price for avocados in export markets is KES 11.7, with a standard deviation of 0.6378 (Table 4.6). It is a relatively high price as international buyers are willing to pay more for quality avocados. This export market option may be appealing to producers enabling them to maximize revenues. In contrast, local markets sell avocados at an average price of KES 7.18.

The local price is not as high as the export price, but it does send a message to local growers that there is demand for avocados in the local region. For producers that cannot export, the local market provides an opportunity. The average price of avocados failing to meet standards is KES 3.78. If quality is maintained, if the product is affordable, any producer would have sold steel at Rs 5000.

In the avocado market, some respondents said that avocado prices are standard. Therefore, it is inferred that avocado prices are marked consistently in some markets/conditions. Hence, it offers better predictability for both traders and producers. This means that some markets or conditions have stable prices so sellers and traders won't worry as much. However, a greater share of 76.47% said prices vary. Friction can cause volatility in food prices, as can seasonally factors, supply and demand shocks, and market access issues.

Table 4.6: Avocado market price information

Avocado prices	Mean	Std. Dev
Export markets	11.7	0.6378
Local markets	7.18	0.7717
Selling price of unmet avocado quality	3.78	0.2406

Table 4.7 shows how the respondents were further probed into their avocado storage capacity. Almost 90% of the producers do not access any sort of storage facility. This induces extreme amounts of post-harvest losses and low-quality products. Consequently, this affects the sales and the profits overall. Two storage methods were the principal storage one which was crates (1.60%) and barrels/containers and sacks 1.07%. Karuiru (2018) and Malekela (2022) found similar results. Specifically, they indicated that in the avocado value chain, facilities for storage are inadequate which make them lose the quality of avocado after harvest.

Those who store avocados, do so in a mean maximum quantity of 11,764 units, with a standard deviation of 6,668.359. This high degree of variation indicates that there are certain producers capable of storing much larger quantities than others who store much less. On average, they only have 1 day of storage. So, avocados need to be moved to the market quickly as they are perishable and there are no adequate facilities to store them.

Table 4.7: Avocado storage characteristics

Variable	Description	Frequency	Percentage (%)
Availability of storage facility	No	152	90.48
	Yes	16	9.52
Principal avocado storage method	Barrels/containers	2	1.07
	Crates	3	1.60
	Not in any storage unit	27	14.44
	Sacks	2	1.07
Mean maximum quantity stored		11,764	
Average number of storage days		1	0.0610

4.2 Characterizing Post-Harvest Losses of Avocado at Farm Level and Market Level in Gatanga Sub-County, Murang'a County

Table 4.8 below indicates whether or not avocado farmers were faced with loss in quality or total loss of the avocado fruits. According to the results of the study, most of the respondents or 66.84% experienced no loss in quality or complete loss of avocado fruits while 33.16% of respondents experienced such a case. This means that although a lot of people can keep the quality of those products in that condition, a significant minority are having challenges that lead to some losses. The results are consistent with Arpaia et al. (2018) and Ramirez-Gil et al. (2019) who found that most avocado farmers experience avocado losses that lead to frequent market rejections. The losses arise from the preharvest, harvest and post-harvest-handling value chains.

Table 4.8: Losses in avocado quality/complete loss

Variable	Description	Frequency	Percentage (%)
Losses in quality/complete loss	No	125	66.84
	Yes	62	33.16

The number of avocados that were damaged or lost at different points along the value chain is shown in a line graph (Figure 4.3). Harvesting stage has the maximum losses with 544 affected avocado fruits. Then, insect damage affects a total of 121 avocados. After that, there are storage-

related losses with 53 damaged avocados. Then loading (20), packing (14), marketing (90), and transportation (22). Perkins *et al.* (2019) and Ramirez-Gil *et al.* (2019) observed similar losses during harvesting due to poor harvesting methods which result in huge quantities of avocado fruits being lost throughout the harvesting process.

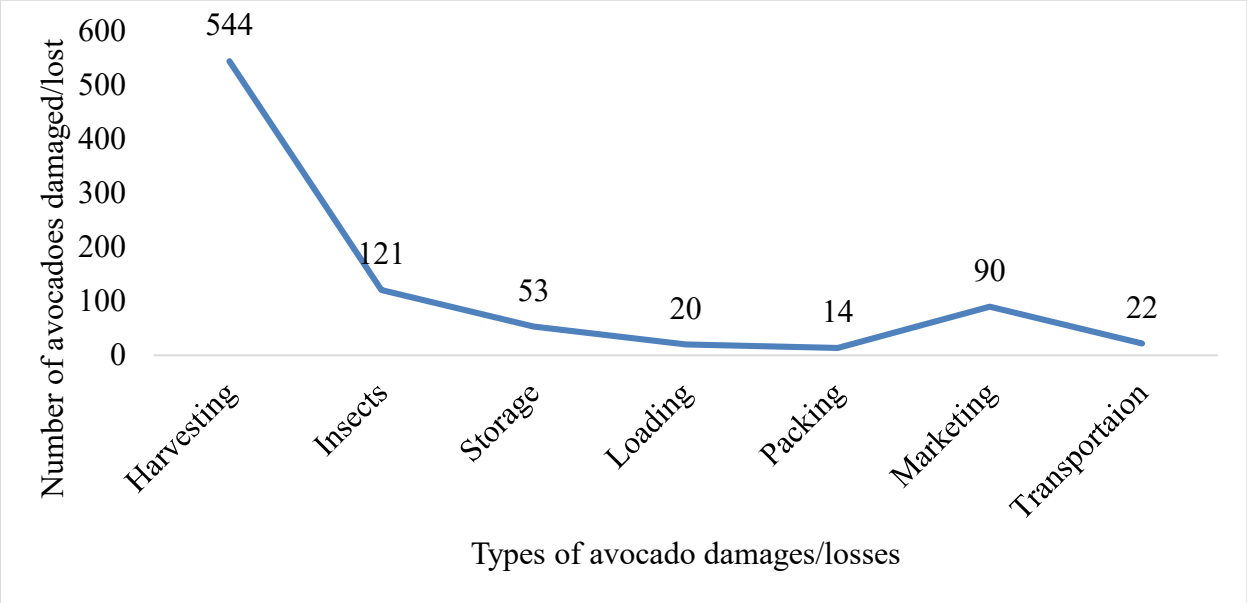

Figure 4.3: Number of avocado damages/losses by type of loss

4.2.1 Causes of Avocado Loss During Harvesting

Avocados can be lost for many reasons (Table 4.9) The most important reason is mechanical damage which includes abrasion bruising and splitting responsible for the 47.96% loss. The second most common cause of losses is handlers losing the product, which causes 21.94% of the losses. Timing of harvesting, immaturity of the avocado's contribution to 11.22% and 10.2% of losses respectively. 8.67% of the losses are contributed by the weather conditions at the time of harvesting or transporting. The reduction of avocado losses at harvest will result from improvement of handling practices and reduction of mechanical damage.

Table 4.9: Causes of avocado loss during harvesting

Description	Frequency	Percentage (%)
Handlers lost the product	43	21.94
Weather at the time of harvesting/transporting	17	8.67
Timing of harvesting	22	11.22
Mechanical damages (abrasion, bruising, splitting)	94	47.96

Immaturity	20	10.2

4.2.2. Causes of Avocado Loss During Post-Harvest Handling and Storage

The table presents the reasons for losses in avocado during post-harvest handling and storage. Most major reason being theft with 56.95% of the losses attributed to it Next comes infestation at 17.22%. Other losses caused by rodent/animal and heat accounted for 8.61% each. Moisture or humidity-related losses are 5.96%, while poorly packed avocados (in sack/silo) account for the least at 2.65%. According to these contractions there should be increased security and improved pest control to prevent post-harvest loss.

Table 4.10: Losses in avocado during post-harvest handling and storage

Description	Frequency	Percentage (%)
Infestations	26	17.22
Rodents/animals	13	8.61
Heat	13	8.61
Humidity/moisture	9	5.96
Theft	86	56.95
Poorly packaged in sacks/silos	4	2.65

4.2.3 Causes of Avocado Loss During Transportation

The table shows the causes of avocado losses of transportation. The predominant cause of these losses, 49.4%, is the type of transport mode used. When transporting, weather conditions would contribute with 26.51% while type of road would contribute with 15.66%. The timing of transporting is the least significant cause of accidents accounting for 8.43%. The current study results indicate that the optimization of transport mode and improvement of weather-related strategies could help to minimize avocado losses during transportation.

Table 4.11: Losses in avocado during transporting

Description	Frequency	Percentage (%)
Weather at the time of transporting	22	26.51
Type of transport mode used	41	49.4
Type of road	13	15.66
Timing of transporting	7	8.43

4.2.4 Primary Causes of Avocado Losses During Harvesting

Table 4.12 outlines the main factors that cause avocado loss in harvesting bruises and cuts caused by physical damage contribute to 45.6% of the loss. The second most common source of damage accounted for 33.68% of the cases were pest and disease damage. Inefficient management practices are responsible for 14.51% of the losses and spoilage due to climatic condition for 5.18%. Insufficient storage space is the least contributing factor, accounting for only 1.04% of the total loss. The results show that controlling damage by pests and diseases may help to lessen losses during harvesting of avocado.

Table 4.12: Primary causes of avocado losses during harvesting

Description	Frequency	Percentage (%)
Physical damages e.g. bruising, cuts	88	45.6
Inadequate storage facilities	2	1.04
Pests and diseases damage	65	33.68
Poor handling practices	28	14.51
Spoilage due to climatic conditions	10	5.18

4.2.5 Measures Taken to Reduce Avocado Post-Harvest Losses

The table shows actions taken to reduce post-harvest losses of avocados. The measure that has been implemented most frequently is the use of a trap tin, insect spray and pesticide (38.52% response). 31.15% of respondents adopt timely harvesting. 19.67% of respondents used fencing as an improvement measure for security. Post-harvest related trainings have the least commonly adopted measure, with only 10.66% respondents attending the trainings. As per the findings pest control and timely harvesting are seen as the most effective measure for reducing of post-harvest loss.

Table 4.13: Measures taken to reduce post-harvest losses

Description	Frequency	Percentage (%)
Attending post-harvest related trainings	13	10.66
Improvement in security measures e.g. fencing	24	19.67
Timely harvesting of the avocadoes	38	31.15
Use of trap tins, insect sprays and pesticides to avoid the risk of avocado loss and damages	47	38.52

4.2.6 Challenges when implementing PHL reduction measures

Table 4.14 presents the difficulties encountered in implementing measures related to avocado post-harvest loss reduction. According to 38.55% of respondents, the most serious money-related was a limited access to markets and domination by brokers. Many people (21.69%) are also insecure due to theft or because of animals like monkeys attacking them. 18.07% of the respondents' state that they do not have enough money or credit. 10.84% of respondents say selling MFPs is a challenge due to lack of training and extension services. 8.43% of respondents say that inaccessibility of inputs and level of input prices interfere with their selling of MFPs. Only 2.41% of the respondents reported pests and diseases as a challenge. The challenges of market access and security, financial support and training need to be better addressed to reduce post-harvest losses.

Table 4.14: Challenges faced when implementing the reduction measures

Description	Frequency	Percentage (%)
Insecurity emanating from theft and animal attacks (monkeys)	18	21.69
Pests and diseases	2	2.41
Financial constraints/limited access to credit	15	18.07
Inaccessibility of inputs/high input prices	7	8.43
Lack of training and extension service provision	9	10.84
Limited access to markets/domination by brokers	32	38.55

4.3 Factors Influencing Post-Harvest Losses Among Avocado Farmers in Gatanga Sub-County, Murang'a County

Before executing the fractional regression model, multicollinearity was tested for independent variables (Table 4.15) The average VIF was 1.87, indicating that the independent variables to be included in the model were not multicollinear. Because of this, the independent variables are not too correlated, leading to consistent and stable values of coefficients. This strengthens the overall robustness of the model, guaranteeing that the links discovered between the independent variables and the dependent variable are reasonable.

Table 4.15: Multicollinearity tests for independent variables used in the fractional equation model

Variable	VIF	1/VIF
Distance from home to nearest market (Kms)	4.68	0.2136
Distance to produce market (Kms)	4.62	0.2165
Number of extension contacts	2.24	0.4459

Infestations	1.92	0.5202
Education of respondent (years)	1.66	0.6006
Household size	1.57	0.6358
Training on post-harvest losses	1.53	0.6519
Market information on where to sell avocadoes	1.42	0.7064
Amount of credit in cash received	1.35	0.7423
Gender	1.34	0.7460
Engagement in other businesses	1.31	0.7605
Experience in avocado farming (years)	1.31	0.7644
Storage facility availability	1.29	0.7740
Age	1.28	0.7813
Group membership	1.25	0.8002
Land size under avocado farming (ha)	1.17	0.8547
Mean VIF	**1.87**	

The factors (demographic, socio-economic, and institutional) influencing post-harvest losses among avocado farmers were achieved using Fractional Response Model. Logit regression was used to determine factors influencing the post-harvest losses. Sixteen independent variables were used in the model, out of which only five were significant. These significant variables were the age of the respondent (years), land size under avocado farming, engagement in other businesses, amount of credit received in cash (Kes), and distance to the produce market (Kms) as indicated in

In Table 4.16, the results indicate diagnostic statistics, and the Wald chi-square (44.59) was significant at 1% level suggesting that independent variables in fractional response model jointly had an influence on post-harvest losses affecting avocado farmers in Murang'a county. The Pseudo R^2 of 0.1494 indicated that about 15% of the avocado farmers were affected by post-harvest losses.

The results show a significant negative relationship between age of the avocado farmers and their post-harvest losses with a coefficient of -0.0472 and p-value of 0.020. Elderly farmers have a lower post-harvest loss than younger farmers, the evidence suggests. An important reason could be the enhanced learning acquired by older farmers to use better management practices and take more informed decisions regarding post-harvest management. Also, older farmers may have

networks and ties in the supply chain that allow them to better market their produce. This may reduce the chances of post-harvest losses.

There was a statistically significant positive association between land size of avocado farming and post-harvest losses. Bigger farms incur more losses after crop harvesting which is likely due to logistical problems of operating large agriculture. The problems may involve difficulty in harvesting on time, post-harvest management becoming more complex and higher risks in storage and transport.

Larger farms may have inefficient labor. If the farmer manages a larger crew, the labor management will become inefficient. Snel *et al*. (2023) found that most avocado farmers own small acreages which are easier to manage than larger land sizes. Similar findings were reported by Snel *et al.* (2023). Farmers can easily prevent post-harvest losses due to their income levels. In contrast, larger farms having low-income levels will find it challenging in avoiding post-harvest losses.

If farmers are engaged in other businesses, then their post-harvest losses are low (coefficient = -0930, $p<0.01$). Farmers may be able to gather new financial resources, increased income diversity and greater skills' base from participating in other enterprises which may help in post-harvest management. If farmers diversify into other businesses, it will relieve their economic pressure to sell their produce quickly. As a result, they will be able to manage and market avocados more judiciously.

Results show that the amount of credit received in cash (Kes) has a significant and negative effect on post-harvest losses. Getting access to credit is important to enable farmers to invest in better post-harvest technologies, which include facilities for storage, transport and packaging. Credit may also inject the necessary money to engage skilled labour and apply good post-harvest practices. By giving farmers financial assistance so that they are able to manage their produce better and hence lower post-harvest losses.

The distance from the produce market significantly affects post-harvest damages, with a coefficient that is positive at 1 percent significance. Post-harvest losses are higher for avocados expected to cover greater distances to the market. This is due to the cost of and time involved in the delivery of avocados over long distances. If shipping takes too long, the food might spoil, get hurt, or become low grade. Handling errors and delays may be more likely with increased distances that require more extensive logistics procedures. Dolaso and Shano (2023) found that as farmers

moved farther away from the produce market, their post-harvest loss also increased. This was especially true for avocados. This study agrees with their findings.

Table 4.16: Factors influencing post-harvest losses among avocado farmers using fractional regression

Variables	Coefficient	Standard error	P>z
Demographic and socio-economic characteristics			
Gender	0.1017	0.4856	0.834
Age (years)	-0.0472	0.0203	0.020**
Education of respondent (years)	-0.0711	0.0603	0.238
Household size	0.0012	0.1070	0.991
Land size under avocado farming (ha)	0.1317	0.0621	0.034**
Experience in avocado farming (years)	0.0070	0.0238	0.768
Engagement in other businesses	-2.1664	1.2397	0.081*
Storage facility availability	-0.2974	0.6676	0.656
Infestations	0.6064	0.6400	0.343
Institutional characteristics			
Number of extension contacts	0.0234	0.0993	0.814
Amount of credit received in cash	-0.0879	0.0495	0.076*
Distance from home to nearest market (Kms)	-0.2099	0.2033	0.302
Distance to produce market (Kms)	0.6618	0.2077	0.001***
Group membership	0.0226	0.5596	0.968
Training on post-harvest losses	-1.0726	0.7172	0.135
Market information on where to sell avocadoes	0.0076	0.3907	0.984
_cons	5.9684	1.8099	0.001***

Note: *** 1% significance level; **5% significance level; *10% significance level.

4.4 Effect of Post-Harvest Losses on Income of Avocado Farmers in Gatanga Sub-County, Murang'a County

4.4.1 Alternative Combinations of Post-harvest Losses (PHL)

Table 4.17 shows the in-depth study of the different combinations of post-harvest losses (PHL) by avocado farmers in Murang'a County. A few farmers (10.16%) reported end harvest losses (M0Im0In0Ov0P0). Mechanical damages were reported most often and were also reported

along with other types of damages. The combination M1Im0In0Ov0P0, which forbids damage of only mechanical nature, reported by 21.39% of the, is the second most common. Similarly, it was found that most of the famers (31.02%), were affected by mechanical & physical damages (M1Im0In0Ov0P1). Thus, it shows mass effect of these PHLs on avocado quality.

Another key combo was mechanical damages and infestations (M1Im0In1Ov0P0), reported by 28 farmers (14.97%). According to this research, infestation is the least common damage reported after mechanical and physical damage however, it causes considerable damage when associated with mechanical damage. The farmers who sustained damages due to immaturity and physical damages (M0Im1In0Ov0P1) were 4.28%. Likewise, thirteen farmers (6.95%) indicated combination M1Im1In0Ov0P1 for mechanical, immature and physical damage. A small group of 10 farmers (5.35%) also suffered from A damages not including over-ripening (M1 Im1 In1 Ov0 P1)

Table 4.17: Alternative combinations of post-harvest losses (n=187 avocado farmers)

PHL Combinations	Frequency	Percentage (%)
$M_0Im_0In_0Ov_0P_0$	19	10.16
$M_0Im_0In_0Ov_0P_1$	11	5.88
$M_1Im_0In_0Ov_0P_0$	40	21.39
$M_1Im_0In_0Ov_0P_1$	58	31.02
$M_1Im_0In_1Ov_0P_0$	28	14.97
$M_0Im_1In_0Ov_0P_1$	8	4.28
$M_1Im_1In_0Ov_0P_1$	13	6.95
$M_1Im_1In_1Ov_0P_1$	10	5.35

Note: M=Mechanical damages, Im=Immaturity, In=Infestations, Ov=Over ripening, P=Physical damages

4.3.2 Associations Between Independent Variables and Post-harvest Losses

As indicated by the multinomial regression estimates presented in Table 4.18, the results of the associations between the socioeconomic and institutional characteristics and different PHL (post-harvest losses) is as follows. Farmers with no post-harvest losses M0Im0In0Ov0P0. The effect of gender was negative with mechanical damages only (M1Im0In0Ov0P0) at 5% level of significance. This shows that men are less likely to cause any mechanical damages in the avocado

losses. This indicates that men are most probably more careful when handling the avocadoes during harvesting thus reducing the damages.

Likewise, the combination of mechanical, immaturity, and physical damages (M1Im1In0Ov0P1) had a negative effect. This means that men are less likely than women to be involved in and/or experience avocado losses due to post-harvest that combines combination mechanical damages, immaturity, and physical damages. People of the male gender are more likely than members of the female gender to be engaged in an association. This means that men get more exposure to training and resources that help them reduce the types of post-harvest loss. Contrary to the findings of Gill and De Silva (2020), Dolaso and Shano (2023), Papaioannou and Vassiliou (2019), and others. As per the results, male avocado farmers face lower odds of post-harvest loss than female led households.

The avocado farmers' level of education had a significant and negative effect on mechanical damages (M1Im0In0Ov0P0) at 1% level of significance indicating that farmers with a higher level of education had lower mechanical damages to their avocados. As a person studies more, he also gets a better understanding of the harvesting and post-harvest management techniques suitable for avocado which will reduce the chances of experiencing mechanical damages.

As noted by Dolaso and Shano (2023), with the increase in education level there is a decrease in PHL among avocado farmers. A study by Sina et al. (2023), revealed similar findings indicating that as years of education increases, chances of facing PHL losses decreases as the farmers tend to be more knowledgeable in handling pre-harvesting, harvesting and post-harvesting avocado stages. The number of people living in a particular house is very important especially when it comes to harvesting of avocados as it helps in provision of labour. Having a larger house hold size does not do well on the physical damages (M1Im0In0Ov0P0) and combination of physical, immaturity and mechanical damages (M1Im1In0Ov0P1). This has an effect of 10% level of significance. Hence, there is bigger PHL coming from the combinations.

Large families are more likely to augment labour availability and may therefore enhance the efficiency of harvesting and post-harvesting practices. Households that have a bigger family size are at an advantage according to Kwizerimana *et al.* (2023) and Samuel (2023) as they provide constant labour especially at harvest times. The ability of the family members to participate in

activities such as harvesting avocado together can help reduce PHLs due to mechanical, immaturity, and physical damages.

The size of the avocado farm affects mechanical damages (M1Im0In0Ov0P0), mechanically interpreted to mean as the size of the farm increases, mechanical damages is reduced. Generally, bigger farms probably benefit from having better farm infrastructure, using better modern harvesting equipment, having better storage, and management practice.

Moreover, efficient management of large farms is likely to employ skilled personnel due to economies of scale. This will result in better post-harvest management practices hence reduced PHL from mechanical damages. A 2019 study by Amare and associates found that avocado farmers with bigger farms were more likely to adopt technologies to reduce these losses. Similarly, a 2023 study by Mosé et al. showed that the use of improved avocado bags resulted in less losses from chilling, bruising and mechanical damage at harvest.

Having farmed avocadoes for a long time will negatively impact any combination of PHL. More experienced farmers are thus expected to experience lower PHLs. However, the study results contradict this expectation. Long years of experience had a positive effect on physical damages (M0Im0In0Ov0P1) and a combination of mechanical damages and infestations (M1Im0In1Ov0P0) at 10 and 1% respectively.

It means the farmers with increased years of experience in avocado farming are more likely to suffer PHL because of physical damages and a combination of mechanical damages and infestations. Surprisingly, experienced farmers, despite acquiring a lot of knowledge, become risk-taking or complacent in their practices. In this way, they are more likely to inflict these damages types.

Having a storage facility caused spoilage of seed resulting in mechanical damage, immaturity and physical damage. Like PHL, a storage facility can reduce the likelihood of this happening because of this combination. Availability of proper storage facilities provides a good environment to maintain the quality of avocadoes by reducing PHL. Along with that, sufficient storage helps manage and time sales of avocados to ensure their sale at peak quality to prevent PHL risks.

The facilities lacked by the majority of avocado farmers in Murang'a county have an effect on the quality of avocadoes. According to Dolaso and Shano (2023), Shivachi *et al.* (2023), and Sina *et al.* (2024), the absence of adequate storage facilities is a major cause of post-harvest losses

(PHLs) among the farmers. In other words, storage facilities mean low chances of PHL due to mechanical damage, immaturity and physical damages.

With the help of extension services, farmers gain access to the latest and best agricultural technologies that help reduce PHL through proper handling, storage, and processing. Also, these services provide continuous education and support to help farmers quickly adopt innovations and effectively avert potential losses. The findings of this study show that the extension service has a positive effect at 5% significance level on PHL combination: mechanical, immaturity and physical damage (M1Im1In0Ov0P1). Access to extension services is likely to increase the expiry of their PHL combinations. The extension services we have now may not be suitable to deal with issues on PHL.

This could be since 74% of avocado farmers did not have regular access to extension services, and those who did only received them twice a year, which is insufficient to provide comprehensive support. Additionally, the focus of extension services may not align with the specific needs of reducing mechanical, immaturity, and physical damages, as they might prioritize other farming aspects like production techniques or pest control.

The distance to the produce market is positively and significantly associated with mechanical damages only, as well as mechanical damages, immaturity, and physical damages. Thus, it signifies that as distance to produce market increases the chances of suffering PHL from these combination increases. Delays in transportation due to farther distances from the produce market might have led to such PHLs.

Alternatively, the PHL combination for mechanical damages and infestations (M1Im0In1Ov0P0) was found to have a negative marginal effect on distance to produce market. This means that greater distance to the produce market reduces PHL for this combination. This could be due to better handling and pest management with longer transport times becoming a practice in such cases. Similar results were obtained by Dolaso and Shano (2023), who indicated that as distance (in Kms) to the produce market increased, postharvest loss of avocado increased and this is consistent with the findings of the study undertaken.

Avocado farmers benefit from group membership because it provides them with better access to collective resources and support networks, which can lower individual costs and risks, strengthen bargaining power, and allow information sharing, thereby reducing post-harvest losses. The positive marginal effect at 10% significance level suggests that being a member of a group

increases the likelihood of experiencing physical damages ($M_0Im_0In_0Ov_0P_1$). Group membership might be associated with practices that inadvertently increase physical damages. A high proportion of avocado farmers also do not belong to groups.

It could be that groups majorly concentrate on collective harvesting and handling methods hence may not really prioritize on proper handling during harvesting leading to increased PHL. Furthermore, a high proportion of avocado farmers do not belong to groups, which might limit their exposure to both the benefits and the risks associated with group activities. Kwizerimana *et al.* (2023), findings indicate that the active participation in collective groups is key in enhancing production of avocado farmers which is contrary to the findings of this study.

Training on post-harvest losses is critical for educating farmers with optimum practices for post-harvest losses. Training programs can drastically reduce post-harvest losses by giving farmers with the knowledge and skills they need to effectively manage, store, and transport their crops. The study's findings demonstrated that PHL training has a negative influence on mechanical, immaturity, and physical damages ($M_1Im_1In_0Ov_0P_1$), implying that PHL training aids in the reduction of PHL losses caused by this combination.

By providing training on PHL to avocado farmers, there is a reduction in PHL especially in cases of physical damages and when farmers are not aware about the right time to harvest the fruits. Findings by Abebe *et al.* (2022), concur with these findings by indicating that increasing training access on avocado PHL led to a decrease in avocado post-harvest losses by a great extent.

Having access to market information on where to sell avocados minimizes post-harvest losses (PHL) through discovering good selling places and market conditions, hence reducing delays and inefficiencies. Market intelligence about potential selling points of avocado is affecting PHL negatively. It caused immaturity and physical damage. Gebru *et al.* (2022), identified avocado market information as being scanty which led to majority of the farmers to experience PHLs. However, linking of these farmers to market information on where to sell the avocado ensures timely harvest and coordination in the marketplace thus reducing PHLs among avocado farmers. Similar findings have also been documented by Abebe *et al.* (2022) indicating that for farmers and producers to increase their incomes and prevent PHLs, then a well-organized market system is mandatory.

Table 4.18: Parameter estimates of alternative post-harvest losses– using a multinomial logit selection model

Base category ($M_0Im_0In_0Ov_0P_0$)	$M_0Im_0In_0Ov_0$ P_1 n=11	$M_1Im_0In_0Ov_0$ P_0 n=40	$M_1Im_0In_0Ov_0$ P_1 n=58	$M_1Im_0In_1Ov_0$ P_0 n=28	$M_0Im_1In_0Ov_0$ P_1 n=8	$M_1Im_1In_0Ov_0$ P_1 n=13	$M_1Im_1In_1Ov_0$ P_1 n=10
Demographic characteristics							
Gender	-29.5348*	-30.6640*	-32.6092**	-32.5461**	-31.0082*	-33.0997**	-35.3091*
Age	-0.2350	-0.2937	-0.3413	-0.3682	-0.2570	-0.3299	-0.5805
Educ	0.6087	-0.7732	0.7614	0.9245*	0.7615	0.7311	2.0923
Household size	-1.4777	-4.7726**	-2.3821*	-2.5078*	-1.8702	-2.8901**	-3.3162
Farm size under avocado production	-1.5917*	-2.6306***	-1.5522*	-1.7372**	-1.5291*	-1.4832*	-1.7355
Engagement in other businesses	-5.2938	-12.2758	5.8278	-3.8682	3.2277	-0.5471	-15.3276
Experience in avocado farming (Years)	0.3542	-0.0523	0.2666	0.3548	0.2469	0.2393	0.3586
Availability of a storage facility	-1.5189	-6.2201	0.0945	-0.7831	-7.6765	-0.8043	-6.1254
Extension service	8.3931	4.7988	8.2913	11.2952**	8.3554	9.1098*	15.7721
Credit access	-23.4541	-7.4370	-15.8680***	-15.2880**	-20.6568	-14.1788*	-15.0525
Distance to produce market	-0.78081	0.0635	-1.4564**	-3.5929**	-1.5154**	-1.5519**	-2.4337
Group membership	12.4096	11.7109	9.4770	11.1094	11.7920	8.2211	17.2208
Training on post-harvest losses	-2.74089	-12.2769*	-4.5094	-2.1902	-3.0533	-10.1247	-4.5099

Market information on avocado sales	-3.18375	2.2403	-0.9631	-2.5322	-2.2797	0.8162	-4.9615
_constant	67.48898*	108.1028**	-32.6092	83.8392**	65.0397	78.7022	83.7406

Note: M=Mechanical damages, Im=Immaturity, In=Infestations, Ov=Over ripening, P=Physical damages; *** 1% significance level; **5% significance level; *10% significance level.

Table 4.19: Marginal effects of alternative post-harvest losses

Base category ($M_0Im_0In_0Ov_0P_0$)	$M_0Im_0In_0Ov_0$ P_1 n=11	$M_1Im_0In_0Ov_0$ P_0 n=40	$M_1Im_0In_0Ov_0$ P_1 n=58	$M_1Im_0In_1Ov_0$ P_0 n=28	$M_0Im_1In_0Ov_0$ P_1 n=8	$M_1Im_1In_0Ov_0$ P_1 n=13	$M_1Im_1In_1Ov_0$ P_1 n=10
Demographic characteristics							
Gender	-0.0451	0.0104	-0.4303**	-0.0531	-0.0030	-0.1950*	-0.0119
Age	0.0018	0.0003	-0.0074	-0.0024	0.0023	-0.0009	-0.0009
Educ	-0.0010	-0.0290***	0.0200	0.0083	0.0039	0.0083	0.0051
Household size	0.0239	-0.0473*	0.0059	-0.0097	0.0176	-0.0405*	-0.0035
Farm size under avocado production	-0.0058	-0.0224*	-0.0040	-0.0126	0.0011	0.0075	-0.0001
Engagement in other businesses	-0.2709	-0.2839	1.2255	-0.3705	0.0833	-0.3004	-0.0546

Experience in avocado farming (Years)	0.0046*	-0.0060	0.0033	0.0054***	-0.0010	-0.0001	0.0001
Availability of a storage facility	0.0210	-0.1036	0.3594	0.0231	-0.3086	0.0064	-0.0231
Extension service	0.0257	-0.0689	-0.0459	0.1633*	0.0018	0.0973	0.0212
Credit access	-0.3301	0.1607	-0.1429	0.0590	-0.1909	0.0542	0.0016
Distance to produce market	0.0299**	0.0294**	0.0470	-0.1338*	-0.0027	-0.0058	0.0035
Group membership	0.1193*	0.0490	-0.0072	0.0664	0.0854	-0.1093	0.0273
Training on post-harvest losses	0.0384	-0.1272	0.2140	0.1702	0.0683	-0.4737	-0.0079
Market information on avocado sales	-0.0732	0.0573	-0.0213	-0.0807	-0.0459**	0.1491	-0.0116

Note: M=Mechanical damages, Im=Immaturity, In=Infestations, Ov=Over ripening, P=Physical damages; *** 1% significance level; **5% significance level; *10% significance level.

4.3.3 Effects of Post-harvest Losses Combinations on Income of Avocado Farmers

The results of effects of post-harvest losses on income of avocado farmers are presented in Table 4.20. The estimated effects on avocado income from the post-harvest losses were calculated from the MESRM model for both the ATT and ATU effects. Thus, the results in Table 4.20 were viewed as two settings: (1) avocado farmers' income were affected by single PHLs (mechanical damages, immaturity, infestations, over ripening and physical damages) and (2) avocado farmers' income were affected by single PHLs either two, three, four or five combinations. The results show that the farmers who suffer losses as a result of mechanical damage, immaturity, infestations, without over-ripening, however, with physical damage suffer the maximum loss in gross income. The treatment effect of 101,873.4 is significant at 1%. When these kinds of damages occur, it causes a serious economic harm with a high value. Damage and infestation are important at the harvesting stage or post-harvest stage. This causes the quality to deteriorate badly and causes damage or economic loss.

The occurrence of post-harvest losses in this M1Im0In1Ov0P0 strategy affects the gross income of farmers negatively, showing a treatment effect of 115,454.4 significant at the 5%. This means even if there is no physical damage, the combination of mechanical damage combined with immaturity and infestations reduce income markedly. This indicates that we ought to manage better and use pest management practices to cut down on our losses.For this combination (M0Im1In0Ov0P1) of losses, treatment effect is -455773.39 which is significant at 5% level. This indicates that the presence of over-ripening and physical damage and additionally mechanical damage are affecting the farmers' income severely. Delays in harvesting or poor storage conditions causes over-ripening during transport or handling. Physical damage can occur during transport and handling.

A mechanical damage, immaturity, infestations, over ripening and physical damage (M1Im1In0Ov0P1) have a treatment effect of -86,364.32, significant at the 10% level. Thus, showing that the loss due to the effect of those damages cause a big reduction in gross income. For farmers who do not endure post-harvest loss (PHL) from these combinations, the results indicate that the treatment effect is -68,217.49, significant at the 1% level, reinforcing the serious economic consequence of PHL.The combination of these losses reflects the problem of system failures in the processes of postharvest handling and storage. Thus, there is a need for a strategy for minimizing such losses. The absence of post-harvest losses, caused by mechanical damage,

immaturity, and physical damage, results in a treatment effect of -209,756.9 for the gross income, which is statistically significant at the 1% level. The fact that this value is negative even tells us that the prospect for such losses is enough to adversely affect the income of farmers.

Table 4.20: The average treatment effect of post-harvest losses on gross income: Multinomial Endogenous switching regression estimation

Post-harvest Losses (PHL)		Gross Income		
		Associated with PHL	Not associated with any PHL	Treatment effect: ATT/ATU
$M_0Im_0In_0Ov_0P_1$	Associated	125,580.4	64,320.78	61,259.66
	Not associated	56,073.11	109,486.4	-53,413.3
	Heterogeneity effect	69,507.29	-45,165.62	114,672.96
$M_1Im_0In_0Ov_0P_0$	Associated	84,361.11	84,361.11	0.00
	Not associated	128,628.90	115,122.8	13,506.13
	Heterogeneity effect	-44,267.79	-30,761.69	-13,506.13
$M_1Im_0In_0Ov_0P_1$	Associated	134,292.5	87,248.47	47,044.05
	Not associated	208,463.20	106,589.9	101,873.4***
	Heterogeneity effect	-74,170.70	-19,341.43	-54,829.35
$M_1Im_0In_1Ov_0P_0$	Associated	179,672.2	64,217.79	115,454.4**
	Not associated	-50,821.97	104,304.8	-155,126.8***
	Heterogeneity effect	230,494.17	-40,087.01	270,581.20
$M_0Im_1In_0Ov_0P_1$	Associated	70,898.78	86,620.88	-15,722.10
	Not associated	67,276.31	113,049.70	-45,773.39**
	Heterogeneity effect	3,622.47	-26,428.82	30,051.29
$M_1Im_1In_0Ov_0P_1$	Associated	73,748.72	160,113	-86,364.32*
	Not associated	67,852.99	136,070.5	-68,217.49***
	Heterogeneity effect	5,895.73	24,042.5	-18,146.83
$M_1Im_1In_1Ov_0P_1$	Associated	96,714.05	133,531.5	-36,817.45
	Not associated	25,099.07	234,856	-209,756.9***
	Heterogeneity effect	71,614.98	-101,324.50	172,939.45

Note: M=Mechanical damages, Im=Immaturity, In=Infestations, Ov=Over ripening, P=Physical damages; *** 1% significance level; **5% significance level; *10% significance level.

turnitin Page 84 of 106 - Integrity Submission Submission ID trn:oid:::1:3392023203

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.0 Introduction

In this chapter a summary, conclusion and recommendation of the research study is presented. The key findings related to the objectives of the study, will be presented on this page along with the conclusions from each of the research questions. After that, the recommendations of the study are discussed and the areas for further research are detailed.

5.2 Conclusions

i. The research found that post-harvest losses (PHL) in the avocado value chain remain a major challenge. 33.16% of farmers reported losing quality or losing their fruit. During the harvest stage, there were unexpected losses that caused a high level of damage usually caused by mechanical damage like abrasion, bruising and splitting. The losses were largely caused by theft, pest damage, storage damage, transportation damage and so on. Even though farmers were using pest control and harvesting on time but this was not enough, which showed the necessity of improving the value chain.

ii. Analysis of determinants of PHL revealed that five factors, farmer age, farm size, credit access, market distance, and engagement in other enterprises, significantly influenced outcomes. Older farmers and those with access to credit reported fewer losses, while larger farm sizes and greater distances to market increased PHL due to logistical constraints.

iii. The results of the MESR model showed that gender, education, household size, and farm size significantly affected farmer income through PHL. Men and educated farmers incurred lower losses while larger households and small plots benefited from additional labour and infrastructure. In contrast, it seems like experienced farmers suffered more losses because they took on risks. Importantly, there was a large amount of PHL arising from the combined effects of different factors- mechanical damage, immaturity, pest, overripening which led to large reductions in gross income.

5.3 Recommendations

i. The research notes that an essential improvement in the situation will require a comprehensive strategy including better pest control, improved harvesting and handling practices, worker training and investment in advanced post-harvest technologies. To

enhance the avocado value chain efficiency, enhancing farmer capacity through targeted training and provision of facilities is also vital.

ii. Next, collection centers exist in important production zones to enhance transport and marketing infrastructure. This will minimize losses during transit and shorten market distances. It is equally important to promote the formation of farmers' groups so that they have better negotiation power, access to funds and invest in new post-harvest technologies and techniques.

iii. Finally, to minimize PHL and increase farmer incomes, priority should be placed on effective pest control, improved harvesting methods, and investment in innovative storage and transportation systems. These interventions will reduce losses, raise farmer earnings, and contribute to the sustainable commercialization of avocado farming in Murang'a County and beyond.

5.4 Areas for Further Studies

Other studies could possibly explore the following areas for their studies:

i. A study analyzing the economic feasibility of various government interventions in the avocado value chain in Kenya. This includes the evaluation of the costs and benefits of advanced storage technology, improved handling systems, and effective pest management techniques.

ii. How farmers' trainings and knowledge transfers affected post-harvest losses. Assessing the effectiveness of training programs that teach farmers the correct methods for handling, storing, and transporting their product may render useful insight on how to improve such programs.

iii. Technology has a significant role in reduction of post-harvest losses. Further research advisable. It is important to look into ways like mobile applications with real-time monitoring, spoilage sensors, and automated handling and processing systems that can help lessen PHL, thanks to technology.

REFERENCES

Abass, A., Ndunguru, G., Mamiro, P., Alenkhe, B., Mlingi, N., & Bekunda, M., 2014. Post- harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. *Journal of Stored Products Research, 57*(2014), 49- 57.

Abebe, A., Kuma, B., & Zemedu, L. (2022). Assessment of postharvest loss of Avocado at producers' level (case of Wolaita and KembataTembaro zones). *Journal of Agriculture and Crops*, *8*(4), 364-374.

Affognon, H., Mutungi, C., Sanginga, P., & Borgemeister, C. (2015). Unpacking post-harvest losses in sub-Saharan Africa: a meta-analysis. *World Development*, *66*(2015), 49-68.

African Union Commission (AUC). (2018). *Post-Harvest Loss Management Strategy*. AUC.

Amare, M. (2020). *Avocados in Kenya: What's holding back smallholder farmers?* International Food Policy Research Institute.

Amare, M., Mariara, J., Oostendorp, R., & Pradhan, M. (2019). The impact of smallholder farmers' participation in avocado export markets on the labor market, farm yields, sales prices, and incomes in Kenya. *Land Use Policy*, *88*(2019), 104168.

Arpaia, M. L., Collin, S., Sievert, J., & Obenland, D. (2018). 'Hass' avocado quality as influenced by temperature and ethylene prior to and during final ripening. *Post-harvest Biology and Technology*, *140*, 76-84.

Azabağaoğlu, M. Ö. (2018). Investigating fresh fruit and vegetables losses at contemporary food retailers. *Sosyal Bilimler Araştırma Dergisi, 7*(4), 55-62.

Bantayehu, M., Alemayehu, M., Abera, M., & Bizuayehu, S. (2019). 'Estimation of pre and post-harvest losses of tropical fruits in Ethiopia'. *International Journal of Post-harvest Technology and Innovation, 6*(1), 46–56.

Bekele, D. (2018). Review on Factors Affecting Post-harvest Quality of Fruits. *Journal of Plant Science & Research, 5*(2), 1-5.

Beune, R. (2018). *Income intervention quick scan: post-harvest loss prevention measures: Farmer Income Lab Intervention Quick Scan* (No. 18-033). Wageningen Centre for Development Innovation.

Bill, M., Sivakumar, D., Thompson, A.K., & Korsten, L. (2014). Avocado fruit quality management during the post-harvest supply chain. *Food Reviews International, 30(*3), 169-202.

Bost, J.B., Smith, N.J., & Crane, J.H. (2013). History, distribution and uses. In *The Avocado: Botany, Production and Uses* (2nd ed.). CABI Publications.

Bourguignon, F., Ferreira, F. H., & Walton, M. (2007). Equity, efficiency and inequality traps: A research agenda. *The Journal of Economic Inequality*, *5*(2007), 235-256.

Bustos, C. A. (2016). *Towards sustainable food supply chains. Reducing post-harvest losses in the avocado supply chain through innovative collaboration*. (Master's thesis, Utrecht University).

Carter, D.W., & Milon, J.W. (2005). Price knowledge in household demand for utility services. *Land Economics, 81*(2), 256–283.

Cochran, W. G. (1977). *Sampling techniques*. John Wiley & Sons.

Colbert, E. (2015). Food waste in Kenya: uncovering food waste in the horticultural export supply chain. In *Envisioning a future without food waste and food poverty: Societal challenges* (pp. 103-108). Wageningen Academic Publishers.

Datta, S., Das, A., Basfore, S., & Seth, T. (2015). Value addition of fruits and vegetables through drying and dehydration. *Value Addition of Horticultural Crops: Recent Trends and Future Directions*, 179-189. Springer.

Davidson, R., & MacKinnon, J. G. (2003). *Econometric theory and methods*. Oxford University Press.

Di Falco, S., & Veronesi, M. (2013). How can African agriculture adapt to climate change? A counterfactual analysis from Ethiopia. *Land Economics, 89*(4), 743–766.

Dolaso, A. A., & Shano, B. K. (2023). Assessment of Post-harvest Loss of Avocado at Producers Level (Case of Wolaita and KembataTembaro Zones).

Dubin, J.A. & McFadden, D. (1984). An econometric analysis of residential electric appliance holdings and consumption. *Econometrica, 52*(2), 345–362.

Dunning, R. D., Johnson, L. K., & Boys, K. A. (2019). Putting Dollars to Waste. *Choices*, *34*(1), 1-9.

Elik, A., Yanik, D. K., Istanbullu, Y., Guzelsoy, N. A., Yavuz, A., & Gogus, F. (2019). Strategies to reduce post-harvest losses for fruits and vegetables. *Strategies*, *5*(3), 29-39.

Etana, M. B., Fufa, B. O., & Aga, M. C. (2019). A detailed review on common causes of post-harvest loss and quality deterioration of fruits and vegetables in Ethiopia. *Journal of Biology, Agriculture and Healthcare*, *9*(7), 48-52.

FAO. (2014). *Global Initiative on food loss and waste reduction*. FAO.

FAO. (2017). *Statistics*. FAOSTAT.

Gades, B. B., Raut, R. D., & Narkhede, B. (2018). Evaluating critical causal factors for post-harvest losses (PHL) in the fruit and vegetables supply chain in India using the DEMATEL approach. *Journal of Cleaner Production*, *199*(2018), 47-61.

Gaona-Forero, A., Agudelo-Rodríguez, G., Herrera, A. O., & Castellanos, D. A. (2018). Modeling and simulation of an active packaging system with moisture adsorption for fresh produce. Application in 'Hass' avocado. *Food Packaging and Shelf Life*, *17*(2018), 187-195.

Gebru, M., Baye, K., Demissie, M., Bogala, S., & Ekesa, B. (2022). Incorporating Avocado production in agri-food systems: Benefits, opportunities, and challenges: Lemo Woreda's experience in Hadiya Zone, Southern Ethiopia.

Gunders, D., & Bloom, J. (2017). *Wasted: How America is losing up to 40 percent of its food from farm to fork to landfill*. Natural Resources Defense Council.

Hakizimana, C., & May, J. (2018). Can smallholder avocado production reduce poverty and improve food security through internal markets? The case of Giheta, Burundi. *Forests, Trees and Livelihoods*, *27*(4), 203-216.

Hansen, H., Durkee, L., Fulwider, W. M., Diaz, C., Christiansen, A. N., Hansen, C. P., & Prag, E. (2017). *Factors influencing choice of post-harvest handling strategies for a horticulture and cash crop in Kibugu, Kenya*. University of Copenhagen.

Horticultural Crops Directorate (HCD). (2015). *Validation report of 2015-2016 on the performance of the horticulture subsector*. HCD.

Horticultural Crops Directorate (HCD). (2017). *Validation report of 2016-2017 on the performance of the horticulture subsector*. HCD

Horticultural Crops Directorate (HCD). (2018). *Validation report of 2017-2018 on the performance of the horticulture subsector*. HCD.

Hussein, Z., Fawole, O. A., & Opara, U. L. (2018). Pre-harvest factors influencing bruise damage of fresh fruits–a review. *Scientia Horticulturae*, *229*(2018), 45-58.

Johnny, E. G., Mariara, J. K., Mulwa, R., & Ruigu, G. M. (2019). Smallholder avocado contract farming in Kenya: determinants and differentials in outcomes. *African Journal of Economic Review*, *7*(2), 91-112.

Johnson, L. K., Bloom, J. D., Dunning, R. D., Gunter, C. C., Boyette, M. D., & Creamer, N. G. (2019). Farmer harvest decisions and vegetable loss in primary production. *Agricultural systems*, *176*(2019), 102672.

Johnson, L. K., Dunning, R. D., Bloom, J. D., Gunter, C. C., Boyette, M. D., & Creamer, N. G. (2018). Estimating on-farm food loss at the field level: A methodology and applied case study on a North Carolina farm. *Resources, Conservation and Recycling*, *137*(2018), 243-250.

Karuiru, M. (2018). Value Chain Management and the Performance of Avocado fruit small scale farmers in Kandara Sub-county, Murang'a County, Kenya. *International Journal of Physical and Social Science, 8*(10), 24-40.

Kasso, M., & Bekele, A. (2018). Post-harvest loss and quality deterioration of horticultural crops in Dire Dawa Region, Ethiopia. *Journal of the Saudi Society of Agricultural Sciences*, *17*(1), 88-96.

Kenya Agricultural & Livestock Research Organization (KALRO). (2018). *Avocado cultivation*. KALRO.

Kiaya, V. (2014). Post-harvest losses and strategies to reduce them. *Technical Paper on Post-harvest Losses, Action Contre la Faim (ACF)*, *25*(2), 1-25.

Kikulwe, E. M., Okurut, S., Ajambo, S., Nowakunda, K., Stoian, D., & Naziri, D. (2018). Post-harvest losses and their determinants: A challenge to creating a sustainable cooking banana value chain in Uganda. *Sustainability*, *10*(7), 2381.

Kimiywe, J. (2015). Food and nutrition security: challenges of post-harvest handling in Kenya. *Proceedings of the Nutrition Society*, *74*(4), 487-495.

KPHC (2019). *Kenya Population and Housing Census. Volume II: Distribution of Population by Administrative units*. KPHC.

Kwizerimana, S. (2023). *Impact of Collective Marketing Participation on Smallholder Avocado Farmers' Income in Murang'a County, Kenya* (Doctoral dissertation, Kenyatta University).

Kwizerimana, S., Mugwe, J., & Nigat, B. (2023). Impact of collective marketing participation on farmers' income: Evidence from smallholder avocado farmers of Murang'a County, Kenya. *Social Sciences & Humanities Open*, *8*(1), 100614.

Lanfranchi, M., Giannetto, C., & De Pascale, A. (2016). Information Asymmetry on Rfid System in the Agrifood Sector: A Study of Consumer Behavior. *Quality-Access to Success, 17*(151), 73-77.

Li, Z., & Thomas, C. (2014). Quantitative evaluation of mechanical damage to fresh fruits. *Trends in Food Science & Technology*, *35*(2), 138-150.

Lipinski, B., Hanson, C., Robertson, K., Dias, D., Gavilan, I., Gréverath, P., ... & Quested, T. (2016). *Food Loss and Waste Accounting and Reporting Standard Food Loss and Waste Protocol*. World Resources Institute.

Malekela, A. A. (2022). Value Chain Challenges: Experiences from Avocado Farmers and Traders in Njombe Town, Tanzania. *East African Journal of Education and Social Sciences (EAJESS)*, *3*(2), 17-25.

McKelvey, R. D., & Zavoina, W. (1975). A statistical model for the analysis of ordinal level dependent variables. *Journal of Mathematical Sociology*, *4*(1), 103-120.

Migliore, G., Farina, V., Guccione, G. D., & Schifani, G. (2018). Quality determinants of avocado fruit consumption in Italy. Implications for small farms. *Calitatea*, *19*(163), 148-153.

Mishra, P., Paillart, M., Meesters, L., Woltering, E., & Chauhan, A. (2022). Avocado dehydration negatively affects the performance of visible and near-infrared spectroscopy models for dry matter prediction. *Post-harvest Biology and Technology*, *183*(2022), 111739.

Mose, D. N. N., Maobe, S. N., & Basweti, E. A. (2023). Influence of Farm Size and Access to Funds on Uptake of Improved Production Technologies in Avocado (Persea Americana). *International Online Journal of Education & Teaching*, *10*(2).

Muriana, C. (2017). A focus on the state of the art of food waste/losses issue and suggestions for future researches. *Waste Management*, *68*(2017), 557-570.

Muriithi, B., & Kabubo-Mariara, J. (2022). The Dynamics and Role of Gender in High-Value Avocado Farming in Kenya. *The European Journal of Development Research*, *34*(5), 2272-2304.

Mwambi, M. M.; Oduol, J.; Mshenga, P. and Saidi, M. (2016). Does contract farming improve smallholder income? The case of avocado farmers in Kenya. *Journal of Agribusiness in Developing and Emerging Economies, 6*(1), 2-20.

Ndour, C. T. (2017). *Effects of human capital on agricultural productivity in Senegal*. World Scientific News.

Oduol, J. B. A., Mithöfer, D., Place, F., Nang'ole, E., Olwande, J., Kirimi, L., & Mathenge, M. (2017). Women's participation in high value agricultural commodity chains in Kenya: Strategies for closing the gender gap. *Journal of Rural Studies*, *50*(2017), 228-239.

Omolo, P., Tana, P., Mutebi, C., Okwach, E., Onyango, H. & Okach K. O. (2019). Analysis of avocado marketing in Trans-Nzoia district, Kenya. *African Journal of Agricultural Marketing, 7*(2), 001-006.

Perkins, M. L., Joyce, D. C., & Coates, L. M. (2019). Possible contribution of impact injury at harvest to anthracnose expression in ripening avocado: A review. *Scientia Horticulturae*, *246*, 785-790.

Rahiel, H. A., Zenebe, A. K., Leake, G. W., & Gebremedhin, B. W. (2018). Assessment of production potential and post-harvest losses of fruits and vegetables in northern region of Ethiopia. *Agriculture & Food Security*, *7*(2018), 1-13.

Ramírez-Gil, J. G., López, J. H., & Henao-Rojas, J. C. (2019). Causes of Hass avocado fruit rejection in preharvest, harvest, and packinghouse: economic losses and associated variables. *Agronomy*, *10*(1), 8-20.

Rijpkema, W., Rossi, R., & GAJ van der Vorst, J. (2014). Effective sourcing strategies for perishable product supply chains. *International Journal of Physical Distribution & Logistics Management, 44*(6), 494-510.

Samuel, K. (2023). *Impact of Collective Marketing Participation on Smallholder Avocado Farmers' Income in Murang'a County, Kenya* (Doctoral Dissertation, Kenyatta University).

Schaffer, B., Wolstenholme, B. N., Whiley, A.W. (2013). *The avocado botany, production and uses*. CABI Publishing.

Selina, W. (2020). Buy Mount Kenya avocado directly from exporters and suppliers, best of 2020 market prices. Retievd March 16, 2022 from https://www.selinawamucii.com/produce/fruits-and-vegetables/mtkenyaavocadofarms/

Sina, B., Demissie, H., & Rezene, Y. (2023). Evaluation of smallholder farmers' use of indigenous knowledge in Ethiopian avocado (Persea americana Mill.) production and fruit preference criteria. CABI Agriculture and Bioscience, 4(1), 57.

Snel, H., Broeze, J., Kremer, F., Osena, E., Muyela, J., Erick, J., ... & van Spronsen, A. (2021). *A food system analysis of Kenya's mango, avocado and poultry sectors: Assessing*

opportunities to reduce food losses (No. WCDI-21-185). Wageningen Centre for Development Innovation.

Sunir, K., Kannaujia, P. K., Guru, P. N., Kale, S., Dukare, A., Mahawar, M., & Kumar, R. (2019). *Processing and Value Addition of Vegetable Crops: Challenges and Opportunities*. ICAR-CIPHET

Tabeshpour, J., Razavi, B. M., & Hosseinzadeh, H. (2017). Effects of avocado (Persea americana) on metabolic syndrome: A comprehensive systematic review. *Phytotherapy Research*, *31*(6), 819-837.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.

Yanyan, G. (2018). *Diversification and reduction of loss of food: a business plan for production of avocado oil in Kenya for the Chinese market*. (Doctoral dissertation, ISCTE-Instituto Universitario de Lisboa (Portugal).

APPENDICES

Appendix I: Questionnaire

Introduction

My name is David Karimire Muita, a student at Egerton University pursuing a Master of Science in Agribusiness Management. This survey is aimed at determining the "***Determining the Effect of Post-Harvest Losses on The Income of Avocado Farmers in Gatanga Sub-County, Murang'a County in Kenya"***. This questionnaire is meant for academic purposes only and information obtained therein will be treated with utmost confidentiality. I take this opportunity to request for your time to run through this interview. Thank you.

Questionnaire identification

Questionnaire Number _____ County _____

Sub-County _____ Ward _____

Name of Respondent_____

Date_____ Starting time_____ Finishing time_____

Instructions: Tick [√] in the appropriate cell or give the answer in the space provided.

Section A: Household demographic characteristics

A1: Provide the following details about the household head

Sex: 1 = Male, 2 = Female	Age (years)	Highest education level (years)
[___]	[__ _]	[___]

Education Level

1=No formal education 2= Adult education 3= Primary education 4= Secondary education

5= College education 6= University education

A2: Provide the following details about the household size

Number of adults that usually live in the household	Number of children in household	Occupation
Male [__] Females [__] Total [___]	Males [__] Females [__]	1=employed, 2=unemployed

A3. Apart from avocado farming do you have any source of income?

☐ Yes ☐ No

A4. If yes, where do you get it from?

(i) Crop farming [ ]

(ii) Livestock & poultry keeping [ ]

(iii) Employment (e.g. civil servant, domestic work) [ ]

(iv) Business – trade / services (non-agric.) [ ]

(v) Other (specify) _____

SECTION B. Farm-specific attributes

B1. Total land holding size ……. Hectares

B2. Land under avocado farming …….

SECTION C: Institutional and Market Characteristics

I. Access to credit

C1. Have you ever had access to credit? □ Yes □ No

C2. If yes in **C1** above, what was the purpose of the credit? (*Tick where appropriate*)

CODE C1: 1= Purchase of inputs, 2= Avocado marketing, 3=Household consumption, 4= Renting income, 5=Others (specify)

C3. How much cash credit did you receive (Kes) _____

C4. From where do you access/ obtain credit?

1= financial institutions 2= chamas 3= government support

4= friends and family 5= NGOs 6= private organizations

7= Others (specify)

II. Extension services

C5. Have you ever accessed/received extension services/visits to avocado farming and management of PHL in the past twelve months?

□ Yes □ No

C6. If yes, how many times in the past 12 months?

C7. What services are provided by extension officers?

CODE C2: *1=advise on avocado production, 2=advise on avocado processing, 3=marketing and marketing outlets services, 4=avocado value addition services, 5=Others (specify)*

C8. If yes in **C5** above, who provided the extension services?

i) County government agents [ ] ii) Private agents [ ]

iii) ASK Shows [ ] iv) Farmer organizations/cooperatives [ ]

C9. What challenges do you encounter when contacting extension officers?

……

……

……

III. Group membership

C10. Are you a member of any cooperative or out-grower group? □ Yes □ No

C11. If Yes, what benefits do you get from the group?

CODE C3: *1=market together, 2= input access, 3=credit access, 4=information access, 5=value addition activities, 6=others (specify)*

C12. If yes C**10** above, which group do you belong to?

(i) Producer cooperatives [ ]

(ii) Multi-purpose cooperative [ ]

(iii) Savings & credit cooperatives [ ]

(iv) Informal/self-help groups [ ]

C13. In what conditions are the roads from farmstead to the market place?

(i) Tarmacked [ ]

(ii) Murram [ ]

C14. What is the distance from your homestead to the nearest market place for farm produce in kilometers?.....

C15. Have you received any training on post-harvest losses?

□ Yes □ No

C16. Do you receive market information on where to sell the avocados?

□ Yes □ No

Section D: Avocado Farming

D1. Experience in avocado farming ……. years

D2. Which variety do you produce?

(i) Hass variety [ ]

(ii) Fuerte variety [ ]

(iii) Local variety [ ]

D3. Variable costs incurred per season

Variables	Unit	Unit price	Quantity
i. Avocado seedlings			
ii. FYM			
iii. NPK			
iv. Labour			
v. Pesticide			
vi. Others (Specify).....			

Section E: Effect of Post-Harvest Losses (Prices Should Be Given in Kenyan Shillings)

E1. Which method do you use to harvest your avocados?

(i) Hand picking [ ]

(ii) Use of sticks [ ]

(iii)Use of secateurs [ ]

E2. What kind of market do you participate in?

1. Export market [ ] 2. Local market [ ] 3. Both market [ ]

E3. Do you have ready market immediately after harvesting?

☐ Yes ☐ No

E4. If no, approximately how long does it take to get buyers? _____

E5. Approximately, how many kilograms of avocados do you harvest per season? _____

E6. What is the selling price per Kilogram?

in the export market? _____ in the local market for? _____

E7. Are those prices standard or they keep on fluctuating based on market forces?

(i) Standard [ ] (ii) Fluctuate [ ]

E8. If they do fluctuate what is the percentage per kilogram when?

(i) Demand is high in the export market _____, local market _____

(ii) Demand is low in the export market _____, local market _____

E9. What is the selling price per kilogram of partially damaged or unmet quality avocado?

E10. How did you store this product?

CODE E1: *1. House 2. Open air 3. Outside the home, in a granary 4. Outside the home, in the shade 5. Warehouse 6. Other, specify*

E11. What was the maximum quantity of avocado that was stored during this period?

E12. What was the average storage period (in days) during the last harvest for avocado?

E13. What was the principal method of storage you used for avocado?

CODE E2: *1. Sacks 2. Crates 3. Barrels/containers 4. Not in any storage unit 5. Other, specify*

E14. In the last harvest season, were there any losses in quality or complete loss of avocado?

☐ Yes ☐ No

E15. For each of the activity in the table below, indicate how much quantity of avocado was lost in percentages:

Activities	**Harvesting**	**Storage**	**Transportation**
Total quantity during			
Total physical loss quantity			
Value of quantity affected			

E16. In your opinion, what could have caused the loss in quality?

i. Harvesting

CODE E3: *1. Handlers lost the product 2. Weather at the time of harvest/transport 3. Timing of harvesting 4. Mechanical damages (*abrasion, bruising, splitting*) 5. Immaturity 6. Other, specify*

ii. Post-harvest handling and Storage

CODE E4: *1. Infestations 2. Rodents/animals 3. Heat 4. Humidity/Moisture 5. Theft 6. Poorly packaged in sacks/silo 7. Over-ripening 8. Other, specify*

iii. Transporting

CODE E5: *1. Weather at the time of transporting 2. Type of transport mode used 3. Type of road 4. Timing of transporting*

E17. Do you have market for overripe avocados?

☐ Yes ☐ No

E18. If yes in **E17** above, where do you sell them? _____

E19. At what price do you sell each overripe avocado? _____

E20. Is there any avocado processing industry within the Sub-County?

☐ Yes ☐ No

THANK YOU!

Appendix II: Fractional regression model results

Fractional logistic regression

Number of obs = 81
Wald chi2(16) = 44.59
Prob > chi2 = 0.0002
Log pseudolikelihood = -20.068074 Pseudo R2 = 0.1494

Market_Surplus	Coefficient	Robust std. err.	z	P>|z|	[95% conf.	interval]
Gender	.101676	.4856395	0.21	0.834	-.85016	1.053512
Age	-.0471647	.0202715	-2.33	0.020	-.086896	-.0074333
Educ	-.0710532	.0602661	-1.18	0.238	-.1891726	.0470662
HHSize	.0012065	.1069687	0.01	0.991	-.2084483	.2108613
LandSize	.1316678	.0621196	2.12	0.034	.0099157	.25342
Years_Exp	.0070026	.0237868	0.29	0.768	-.0396186	.0536239
Engagement_in_other_businesses	-2.166423	1.239673	-1.75	0.081	-4.596137	.2632908
Storage_facility	-.2974489	.6676309	-0.45	0.656	-1.605981	1.011084
Infestations	.6064255	.6399554	0.95	0.343	-.647864	1.860715
Extension_Contacts	.0233622	.0993391	0.24	0.814	-.1713389	.2180632
Cash	-.0878597	.0494631	-1.78	0.076	-.1848056	.0090862
Dist_home	-.2099337	.2033165	-1.03	0.302	-.6084267	.1885593
Dist_produce	.6617924	.207697	3.19	0.001	.2547137	1.068871
Group_member	.0226115	.5596125	0.04	0.968	-1.074209	1.119432
Training_on_postharvest_losses	-1.072565	.7172023	-1.50	0.135	-2.478256	.3331257
Market_info_on_where_sell_the_av	.0075973	.3907394	0.02	0.984	-.7582379	.7734325
_cons	5.968436	1.809948	3.30	0.001	2.421002	9.515869

Appendix III: Multinomial logit results

38

Multinomial logistic regression — Number of obs = 99
LR chi2(98) = 214.76
Prob > chi2 = 0.0000
Log likelihood = -71.193195 — Pseudo R2 = 0.6013

PHL	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
0	(base outcome)					
1						
Gender	-29.53478	16.52681	-1.79	0.074	-61.92673	2.857175
Age	-.2349588	.2352018	-1.00	0.318	-.6959458	.2260283
Educ	.6086786	.5303034	1.15	0.251	-.430697	1.648054
HHSize	-1.477683	1.243297	-1.19	0.235	-3.914499	.9591338
LandSize	-1.591741	.8662303	-1.84	0.066	-3.289522	.1060389
Engagement_in_other_businesses	-5.293826	9.568113	-0.55	0.580	-24.04698	13.45933
Years_Exp	.3542185	.2251664	1.57	0.116	-.0870995	.7955366
Storage_facility	-1.518923	15.96204	-0.10	0.924	-32.80394	29.7661
Extension_service	8.393102	5.527316	1.52	0.129	-2.440238	19.22644
Credit_access	-23.45413	14.29042	-1.64	0.101	-51.46284	4.554572
Dist_produce	-.7808063	.6690666	-1.17	0.243	-2.092153	.5305403
Group_member	12.4096	7.767914	1.60	0.110	-2.815229	27.63443
Training_on_postharvest_losses	-2.740892	4.342779	-0.63	0.528	-11.25258	5.770798
Market_info_on_where_sell_the_av	-3.183754	3.319777	-0.96	0.338	-9.690397	3.322889
_cons	67.48898	37.67553	1.79	0.073	-6.3537	141.3317
2						
Gender	-30.66404	17.19792	-1.78	0.075	-64.37135	3.043271
Age	-.293711	.3114334	-0.94	0.346	-.9041093	.3166874
Educ	-.7732041	.9368007	-0.83	0.409	-2.6093	1.062892
HHSize	-4.772589	2.077466	-2.30	0.022	-8.844348	-.70083
LandSize	-2.630571	1.128466	-2.33	0.020	-4.842324	-.4188174
Engagement_in_other_businesses	-12.27577	13.87769	-0.88	0.376	-39.47554	14.924
Years_Exp	-.0522523	.4700555	-0.11	0.911	-.9735442	.8690396
Storage_facility	-6.220097	22.58745	-0.28	0.783	-50.49069	38.05049
Extension_service	4.798807	7.555078	0.64	0.525	-10.00887	19.60649
Credit_access	-7.436998	9.430789	-0.79	0.430	-25.92101	11.04701
Dist_produce	.0634555	1.044371	0.06	0.952	-1.983474	2.110385
Group_member	11.71087	8.407288	1.39	0.164	-4.767111	28.18885
Training_on_postharvest_losses	-12.2769	6.578991	-1.87	0.062	-25.17149	.6176798
Market_info_on_where_sell_the_av	2.240338	4.367046	0.51	0.608	-6.318914	10.79959
_cons	108.1028	44.85665	2.41	0.016	20.18533	196.0202
3						
Gender	-32.60922	16.69759	-1.95	0.051	-65.3359	.1174633
Age	-.3412872	.2362009	-1.44	0.148	-.8042325	.1216581
Educ	.7613927	.4920831	1.55	0.122	-.2030725	1.725858
HHSize	-2.382065	1.323597	-1.80	0.072	-4.976267	.2121375
LandSize	-1.552153	.8521937	-1.82	0.069	-3.222422	.1181154
Engagement_in_other_businesses	5.827848	27.52708	0.21	0.832	-48.12424	59.77994
Years_Exp	.2666054	.2234513	1.19	0.233	-.1713511	.7045619
Storage_facility	.0945396	15.71105	0.01	0.995	-30.69856	30.88764
Extension_service	8.291338	5.228046	1.59	0.113	-1.955444	18.53812
Credit_access	-15.86799	7.325162	-2.17	0.030	-30.22504	-1.510937
Dist_produce	-1.456371	.7019586	-2.07	0.038	-2.832184	-.0805571
Group_member	9.477035	7.749494	1.22	0.221	-5.711695	24.66576
Training_on_postharvest_losses	-4.509449	4.108881	-1.10	0.272	-12.56271	3.54381
Market_info_on_where_sell_the_av	-.9630972	3.090848	-0.31	0.755	-7.021048	5.094854
_cons	72.78771	44.31246	1.64	0.100	-14.06312	159.6385

4						
Gender	-32.54606	16.65814	-1.95	0.051	-65.19541	.1032839
Age	-.3682456	.2397018	-1.54	0.124	-.8380525	.1015613
Educ	.9245241	.5100183	1.81	0.070	-.0750933	1.924142
HHSize	-2.507759	1.347087	-1.86	0.063	-5.148	.1324827
LandSize	-1.737222	.8590258	-2.02	0.043	-3.420882	-.0535623
Engagement_in_other_businesses	-3.868168	10.30556	-0.38	0.707	-24.0667	16.33036
Years_Exp	.3548294	.2251386	1.58	0.115	-.0864341	.7960928
Storage_facility	-.7830858	15.79525	-0.05	0.960	-31.7412	30.17503
Extension_service	11.29524	5.401656	2.09	0.037	.708184	21.88229
Credit_access	-15.28803	7.391455	-2.07	0.039	-29.77501	-.8010428
Dist_produce	-3.592912	1.418839	-2.53	0.011	-6.373784	-.8120392
Group_member	11.10937	7.840109	1.42	0.156	-4.25696	26.4757
Training_on_postharvest_losses	-2.190181	4.288659	-0.51	0.610	-10.5958	6.215437
Market_info_on_where_sell_the_av	-2.532199	3.265236	-0.78	0.438	-8.931943	3.867546
_cons	83.8392	38.91726	2.15	0.031	7.56277	160.1156
5						
Gender	-31.00817	16.74634	-1.85	0.064	-63.83039	1.81405
Age	-.2570261	.236884	-1.09	0.278	-.7213101	.207258
Educ	.7614645	.5122424	1.49	0.137	-.2425122	1.765441
HHSize	-1.870163	1.313725	-1.42	0.155	-4.445017	.7046917
LandSize	-1.529083	.8609135	-1.78	0.076	-3.216443	.1582765
Engagement_in_other_businesses	3.227695	53.69805	0.06	0.952	-102.0185	108.4739
Years_Exp	.2468592	.2357104	1.05	0.295	-.2151246	.708843
Storage_facility	-7.676519	27.1057	-0.28	0.777	-60.80272	45.44968
Extension_service	8.355385	5.485646	1.52	0.128	-2.396284	19.10705
Credit_access	-20.65677	18.41181	-1.12	0.262	-56.74325	15.42971
Dist_produce	-1.515355	.7657263	-1.98	0.048	-3.016151	-.0145594
Group_member	11.792	7.880601	1.50	0.135	-3.653693	27.2377
Training_on_postharvest_losses	-3.053266	4.238284	-0.72	0.471	-11.36015	5.253618
Market_info_on_where_sell_the_av	-2.27971	3.328613	-0.68	0.493	-8.803671	4.244251
_cons	65.03967	65.03933	1.00	0.317	-62.43508	192.5144
6						
Gender	-33.09967	16.70615	-1.98	0.048	-65.84313	-.3562057
Age	-.3298816	.2382603	-1.38	0.166	-.7968632	.1371001
Educ	.731131	.5062397	1.44	0.149	-.2610806	1.723343
HHSize	-2.890068	1.345543	-2.15	0.032	-5.527284	-.2528514
LandSize	-1.483222	.8574538	-1.73	0.084	-3.1638	.1973569
Engagement_in_other_businesses	-.5471156	36.67217	-0.01	0.988	-72.42324	71.32901
Years_Exp	.2392595	.2262307	1.06	0.290	-.2041446	.6826635
Storage_facility	-.8042615	15.78123	-0.05	0.959	-31.73491	30.12638
Extension_service	9.10982	5.255861	1.73	0.083	-1.191479	19.41112
Credit_access	-14.17881	7.349021	-1.93	0.054	-28.58263	.2250028
Dist_produce	-1.551898	.7267014	-2.14	0.033	-2.976207	-.1275896
Group_member	8.22109	7.796622	1.05	0.292	-7.060009	23.50219
Training_on_postharvest_losses	-10.12473	12.02433	-0.84	0.400	-33.69197	13.44252
Market_info_on_where_sell_the_av	.8161837	3.196662	0.26	0.798	-5.449159	7.081526
_cons	78.70223	50.78162	1.55	0.121	-20.82792	178.2324
7						
Gender	-35.30905	19.7296	-1.79	0.074	-73.97837	3.360264
Age	-.5804879	.3842803	-1.51	0.131	-1.333663	.1726876
Educ	2.092309	1.514447	1.38	0.167	-.8759533	5.060571
HHSize	-3.316239	2.573467	-1.29	0.198	-8.360142	1.727665
LandSize	-1.735528	1.614173	-1.08	0.282	-4.899249	1.428193
Engagement_in_other_businesses	-15.32758	16.84959	-0.91	0.363	-48.35218	17.69701
Years_Exp	.3586127	.2267548	1.58	0.114	-.0858185	.8030439
Storage_facility	-6.125403	18.42197	-0.33	0.740	-42.2318	29.98099
Extension_service	15.77212	10.98873	1.44	0.151	-5.765405	37.30964
Credit_access	-15.05248	11.90764	-1.26	0.206	-38.39102	8.286056
Dist_produce	-2.433693	3.264858	-0.75	0.456	-8.832698	3.965312
Group_member	17.22081	11.37526	1.51	0.130	-5.074293	39.51591
Training_on_postharvest_losses	-4.50994	10.96839	-0.41	0.681	-26.0076	16.98771
Market_info_on_where_sell_the_av	-4.961504	6.964576	-0.71	0.476	-18.61182	8.688813
_cons	83.7406	46.97267	1.78	0.075	-8.324148	175.8054

43 Marginal effects

```
. margins, dydx(*) predict (outcome(1))

Average marginal effects                                    Number of obs = 99
Model VCE: OIM

Expression: Pr(PHL==1), predict(outcome(1))
dy/dx wrt:  Gender Age Educ HHSize LandSize Engagement_in_other_businesses Years_Exp Storage_facility
            Extension_service Credit_access Dist_produce Group_member Training_on_postharvest_losses
            Market_info_on_where_sell_the_av
```

7

	dy/dx	Delta-method std. err.	z	P>|z|	[95% conf.	interval]
Gender	-.0451418	.1303587	-0.35	0.729	-.3006402	.2103566
Age	.0018328	.0029041	0.63	0.528	-.0038591	.0075248
Educ	-.0009541	.0088349	-0.11	0.914	-.0182702	.016362
HHSize	.0239206	.0155236	1.54	0.123	-.006505	.0543462
LandSize	-.0057809	.0085113	-0.68	0.497	-.0224627	.0109009
Engagement_in_other_businesses	-.2708843	.6183149	-0.44	0.661	-1.482759	.9409905
Years_Exp	.004571	.0023968	1.91	0.057	-.0001266	.0092686
Storage_facility	.0209745	.2145831	0.10	0.922	-.3996007	.4415497
Extension_service	.0256918	.0789767	0.33	0.745	-.1290996	.1804832
Credit_access	-.3300778	.4732914	-0.70	0.486	-1.257712	.5975564
Dist_produce	.0298589	.0147075	2.03	0.042	.0010328	.058685
Group_member	.1192751	.0672877	1.77	0.076	-.0126065	.2511566
Training_on_postharvest_losses	.0383787	.0680169	0.56	0.573	-.0949319	.1716893
Market_info_on_where_sell_the_av	-.0731748	.0658029	-1.11	0.266	-.2021461	.0557965

14

```
. margins, dydx(*) predict (outcome(2))

Average marginal effects                                    Number of obs = 99
Model VCE: OIM

Expression: Pr(PHL==2), predict(outcome(2))
dy/dx wrt:  Gender Age Educ HHSize LandSize Engagement_in_other_businesses Years_Exp Storage_facility
            Extension_service Credit_access Dist_produce Group_member Training_on_postharvest_losses
            Market_info_on_where_sell_the_av
```

7

	dy/dx	Delta-method std. err.	z	P>|z|	[95% conf.	interval]
Gender	.0103957	.0793219	0.13	0.896	-.1450723	.1658637
Age	.0003476	.0043163	0.08	0.936	-.0081122	.0088073
Educ	-.0290065	.0095221	-3.05	0.002	-.0476695	-.0103434
HHSize	-.0472546	.0258907	-1.83	0.068	-.0979994	.0034903
LandSize	-.0223782	.0131788	-1.70	0.090	-.0482082	.0034519
Engagement_in_other_businesses	-.2839363	.3298675	-0.86	0.389	-.9304646	.362592
Years_Exp	-.0060109	.0070435	-0.85	0.393	-.0198158	.0077941
Storage_facility	-.1035804	.3195723	-0.32	0.746	-.7299306	.5227697
Extension_service	-.068898	.1116233	-0.62	0.537	-.2876757	.1498797
Credit_access	.160744	.1243073	1.29	0.196	-.0828937	.4043817
Dist_produce	.0293918	.0132107	2.22	0.026	.0034994	.0552842
Group_member	.0490296	.0693802	0.71	0.480	-.0869531	.1850122
Training_on_postharvest_losses	-.127151	.1156242	-1.10	0.271	-.3537704	.0994683
Market_info_on_where_sell_the_av	.0572615	.060665	0.94	0.345	-.0616397	.1761628

14

```
. margins, dydx(*) predict (outcome(3))

Average marginal effects                                    Number of obs = 99
Model VCE: OIM

Expression: Pr(PHL==3), predict(outcome(3))
dy/dx wrt:  Gender Age Educ HHSize LandSize Engagement_in_other_businesses Years_Exp Storage_facility
            Extension_service Credit_access Dist_produce Group_member Training_on_postharvest_losses
            Market_info_on_where_sell_the_av
```

7

	dy/dx	Delta-method std. err.	z	P>|z|	[95% conf.	interval]
Gender	-.4302863	.2078158	-2.07	0.038	-.8375978	-.0229749
Age	-.0073826	.0057498	-1.28	0.199	-.0186521	.0038868
Educ	.0199988	.0145873	1.37	0.170	-.0085918	.0485893
HHSize	.0058711	.0328455	0.18	0.858	-.058505	.0702472
LandSize	-.0039743	.0145414	-0.27	0.785	-.0324749	.0245263
Engagement_in_other_businesses	1.225539	4.561791	0.27	0.788	-7.715408	10.16649
Years_Exp	.0032702	.0064581	0.51	0.613	-.0093874	.0159279
Storage_facility	.3593552	.588229	0.61	0.541	-.7935526	1.512263
Extension_service	-.0459149	.1553692	-0.30	0.768	-.3504331	.2586032
Credit_access	-.1429101	.4769902	-0.30	0.764	-1.077794	.7919735
Dist_produce	.0469626	.0489261	0.96	0.337	-.0489307	.142856
Group_member	-.0071766	.1236513	-0.06	0.954	-.2495287	.2351755
Training_on_postharvest_losses	.21397	.6957188	0.31	0.758	-1.149614	1.577554
Market_info_on_where_sell_the_av	-.0213261	.1044385	-0.20	0.838	-.2260218	.1833697

6

```
. margins, dydx(*) predict (outcome(4))

Average marginal effects                                        Number of obs = 99
Model VCE: OIM

Expression: Pr(PHL==4), predict(outcome(4))
dy/dx wrt:  Gender Age Educ HHSize LandSize Engagement_in_other_businesses Years_Exp Storage_facility
            Extension_service Credit_access Dist_produce Group_member Training_on_postharvest_losses
            Market_info_on_where_sell_the_av
```

7

	dy/dx	Delta-method std. err.	z	P>|z|	[95% conf.	interval]
Gender	-.053091	.0989038	-0.54	0.591	-.2469388	.1407568
Age	-.0023812	.0029961	-0.79	0.427	-.0082535	.0034912
Educ	.008298	.0101786	0.82	0.415	-.0116516	.0282477
HHSize	-.0096903	.0154981	-0.63	0.532	-.0400661	.0206855
LandSize	-.0126223	.0092682	-1.36	0.173	-.0307876	.005543
Engagement_in_other_businesses	-.3704886	1.058406	-0.35	0.726	-2.444925	1.703948
Years_Exp	.0054197	.0018733	2.89	0.004	.001748	.0090913
Storage_facility	.023149	.1454752	0.16	0.874	-.2619771	.3082751
Extension_service	.1632703	.0905594	1.80	0.071	-.0142229	.3407635
Credit_access	.0590115	.1234503	0.48	0.633	-.1829465	.3009696
Dist_produce	-.1337591	.0726016	-1.84	0.065	-.2760555	.0085374
Group_member	.0664388	.0762616	0.87	0.384	-.0830312	.2159088
Training_on_postharvest_losses	.1701764	.1235574	1.38	0.168	-.0719916	.4123445
Market_info_on_where_sell_the_av	-.0806721	.0653111	-1.24	0.217	-.2086795	.0473353

11

```
. margins, dydx(*) predict (outcome(5))

Average marginal effects                                        Number of obs = 99
Model VCE: OIM

Expression: Pr(PHL==5), predict(outcome(5))
dy/dx wrt:  Gender Age Educ HHSize LandSize Engagement_in_other_businesses Years_Exp Storage_facility
            Extension_service Credit_access Dist_produce Group_member Training_on_postharvest_losses
            Market_info_on_where_sell_the_av
```

7

	dy/dx	Delta-method std. err.	z	P>|z|	[95% conf.	interval]
Gender	-.002969	.0708045	-0.04	0.967	-.1417432	.1358052
Age	.0023166	.0024664	0.94	0.348	-.0025175	.0071507
Educ	.0038907	.0067735	0.57	0.566	-.0093852	.0171665
HHSize	.0176478	.0148019	1.19	0.233	-.0113634	.0466591
LandSize	.0011302	.0054452	0.21	0.836	-.0095423	.0118027
Engagement_in_other_businesses	.0833171	2.385696	0.03	0.972	-4.592561	4.759195
Years_Exp	-.0010183	.0036383	-0.28	0.780	-.0081492	.0061126
Storage_facility	-.3085521	.9641495	-0.32	0.749	-2.19825	1.581146
Extension_service	.0018109	.0736277	0.02	0.980	-.1424968	.1461186
Credit_access	-.1908508	.7457979	-0.26	0.798	-1.652588	1.270886
Dist_produce	-.0026568	.0152902	-0.17	0.862	-.0326249	.0273114
Group_member	.0853976	.0561628	1.52	0.128	-.0246795	.1954746
Training_on_postharvest_losses	.0682715	.0783769	0.87	0.384	-.0853444	.2218875
Market_info_on_where_sell_the_av	-.0459311	.0592232	-0.78	0.438	-.1620065	.0701442

11

```
. margins, dydx(*) predict (outcome(6))

Average marginal effects                                        Number of obs = 99
Model VCE: OIM

Expression: Pr(PHL==6), predict(outcome(6))
dy/dx wrt:  Gender Age Educ HHSize LandSize Engagement_in_other_businesses Years_Exp Storage_facility
            Extension_service Credit_access Dist_produce Group_member Training_on_postharvest_losses
            Market_info_on_where_sell_the_av
```

7

	dy/dx	Delta-method std. err.	z	P>|z|	[95% conf.	interval]
Gender	-.1949802	.101074	-1.93	0.054	-.3930816	.0031211
Age	-.0009438	.0035998	-0.26	0.793	-.0079992	.0061116
Educ	.0083211	.0108911	0.76	0.445	-.013025	.0296673
HHSize	-.0404644	.024424	-1.66	0.098	-.0883347	.0074058
LandSize	.0074804	.0111812	0.67	0.503	-.0144344	.0293952
Engagement_in_other_businesses	-.3004481	3.241612	-0.09	0.926	-6.653891	6.052995
Years_Exp	-.0000934	.0044993	-0.02	0.983	-.0089119	.0087251
Storage_facility	.0063647	.2028421	0.03	0.975	-.3911986	.4039279
Extension_service	.097276	.1041651	0.93	0.350	-.1068838	.3014357
Credit_access	.0541854	.1190161	0.46	0.649	-.179082	.2874527
Dist_produce	-.0058389	.0188557	-0.31	0.757	-.0427953	.0311175
Group_member	-.1092862	.0805991	-1.36	0.175	-.2672575	.0486851
Training_on_postharvest_losses	-.4736771	.9565393	-0.50	0.620	-2.34846	1.401105
Market_info_on_where_sell_the_av	.149138	.0738812	2.02	0.044	.0043335	.2939426

11

```
. margins, dydx(*) predict (outcome(7))

Average marginal effects                                        Number of obs = 99
Model VCE: OIM

Expression: Pr(PHL==7), predict(outcome(7))
dy/dx wrt:  Gender Age Educ HHSize LandSize Engagement_in_other_businesses Years_Exp Storage_facility
            Extension_service Credit_access Dist_produce Group_member Training_on_postharvest_losses
            Market_info_on_where_sell_the_av
```

7

	dy/dx	Delta-method std. err.	z	P>|z|	[95% conf.	interval]
Gender	-.0119342	.0462918	-0.26	0.797	-.1026644	.0787961
Age	-.0009378	.0015114	-0.62	0.535	-.0039001	.0020245
Educ	.0051362	.0075339	0.68	0.495	-.00963	.0199025
HHSize	-.0035473	.0097155	-0.37	0.715	-.0225894	.0154948
LandSize	-.0001233	.0058534	-0.02	0.983	-.0115958	.0113492
Engagement_in_other_businesses	-.0545653	.0764421	-0.71	0.475	-.2043892	.0952585
Years_Exp	.0000767	.0001992	0.38	0.700	-.0003139	.0004672
Storage_facility	-.0230966	.0459301	-0.50	0.615	-.113118	.0669248
Extension_service	.021155	.0424382	0.50	0.618	-.0620222	.1043323
Credit_access	.0016224	.0398449	0.04	0.968	-.0764721	.0797169
Dist_produce	.0035393	.014398	0.25	0.806	-.0246803	.0317588
Group_member	.0273125	.0410642	0.67	0.506	-.0531718	.1077969
Training_on_postharvest_losses	-.0078924	.0427672	-0.18	0.854	-.0917146	.0759299
Market_info_on_where_sell_the_av	-.0115709	.0281818	-0.41	0.681	-.0668063	.0436644

Appendix IV: Graduate School Approval

EGERTON UNIVERSITY
Tel: Pilot: 254-51-2217620
254-51-2217877
254-51-2217631
Dir.line/Fax: 254-51-2217847
Cell Phone
P.O. Box 536 - 20115
Egerton, Njoro, Kenya
Email: bpgs@egerton.ac.ke
www.egerton.ac.ke

OFFICE OF THE DIRECTOR GRADUATE SCHOOL

Ref: KM19/00316/12 **Date:** 22nd April, 2024

Dr. Dickson Okello
Dept. of AGEC
Egerton University
P.O. Box 536
EGERTON

Dear Dr. Okello

RE: APPOINMENT AS SUPERVISOR

I am pleased to inform you that the Vice-Chancellor acting on behalf of Senate and on recommendation of the Board of Postgraduate Studies has appointed you as the M.Sc. research supervisor for **David K. Muita** research proposal entitled **"Effect of Postharvest Losses on Income of Avocado Farmers in Murang'a County, Kenya."**

As part of the supervision process, you will be expected to:

(i) Keep regular contact with the student (where possible at least twice a month).

(ii) In case of joint supervision, maintain regular consultation with one another, with regard to the progress reports on the student.

(iii) Submit progress reports on the student's work after every three months.

(iv) Fully reflect the student's role as a researcher in any joint publication and show credit to the student's work.

(v) Show dedication to the student's research work as a basis of avoiding delay in communication, or unnecessary misunderstanding between the student and the supervisor.

(vi) Perform any other activity which will help in making the supervision exercise more effective and efficient to enable the student complete his/her thesis without undue delay.

Appendix v: Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **812923**

Date of Issue: **28/September/2024**

RESEARCH LICENSE

This is to Certify that Mr.. Daivid Karimire Muita of Egerton University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Muranga on the topic: EFFECT OF POSTHARVEST LOSSES ON INCOME OF AVOCADO FARMERS IN MURANG'A COUNTY, KENYA for the period ending : 28/September/2025.

License No: **NACOSTI/P/24/40404**

812923

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

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See overleaf for conditions

Appendix VI: Publication

Discover Food

Research

Determinants of post harvest losses in the avocado value chain: insights from farmers in Murang'a County, Kenya

David Muita[1] · Dickson Okello[1] · Florence Opondo[2]

Received: 15 October 2024 / Accepted: 5 March 2025
Published online: 17 March 2025

Abstract
This study investigates the determinants of post-harvest losses among smallholder avocado farmers in Kenya, employing a quantitative approach through a structured questionnaire administered to a sample of 187 farmers in Murang'a County. The fractional response model and descriptive statistics were used to analyze the data. The results indicate a significant negative correlation between farmers' age and post-harvest losses, suggesting that older farmers leverage their experience and knowledge to minimize losses. Conversely, larger land sizes are associated with increased post-harvest losses, attributed to logistical challenges in managing extensive avocado harvests. Notably, farmers engaged in other income-generating activities reported fewer losses, highlighting the importance of income diversification in enhancing resilience against economic pressures. Additionally, better access to credit emerged as a critical factor in reducing post-harvest losses by enabling investments in improved post-harvest technologies. The findings emphasize the need for targeted interventions that support older farmers, enhance access to credit, and promote best practices in post-harvest management to mitigate losses and improve the livelihoods of smallholder avocado farmers.

Keywords Avocado farming · Determinants · Smallholder farmers · Post-harvest losses

1 Background of the study

Avocado farming has become a crucial agricultural activity in Kenya, with Murang'a County emerging as one of the leading production areas. The rise in global demand for avocados, driven by their nutritional value, economic potential, and increasing health consciousness, has elevated the importance of avocado farming for Kenyan farmers [1]. Avocados are renowned for their health benefits, containing high levels of healthy fats, vitamins, and minerals, which make them popular in global markets [2]. Countries in Europe, North America, and Asia, where consumer health awareness is growing, have significantly contributed to the rise in avocado demand. As a result, the global avocado market has expanded considerably in recent years. By 2021, the global avocado market was valued at approximately USD 14.2 billion, and it is projected to continue its upward trajectory, driven by both health trends and the fruit's culinary versatility [3].

Kenya, as a significant avocado producer, has become a key player in this booming global market. The country ranks among the top global exporters of avocados, with production expanding rapidly over the past decade [4]. As of 2023, Kenya was producing an estimated 350,000 metric tons of avocados annually, reflecting a significant increase from approximately 230,000 metric tons in 2019 [5]. The rising production levels underscore the sector's robust growth and its critical role in Kenya's agricultural economy. In 2022, Kenya exported approximately 100,000 metric tons of avocados,

✉ David Muita, dickson.okello@egerton.ac.ke | [1]Department of Agricultural Economics and Agribusiness Management, Egerton University, P. O. Box 536, Njoro, Kenya. [2]Department of Commerce, Laikipia University, P.O. Box 1100, Nyahururu 20300, Kenya.

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turnitin Page 106 of 106 - Integrity Submission Submission ID trn:oid:::1:3392023203