ASSESSMENT OF DRIVERS OF POSTHARVEST LOSSES AND FACTORS INFLUENCING ADOPTION OF LOSS REDUCTION PRACTICES ALONG THE MANGO VALUE CHAIN IN EMBU, MACHAKOS AND NAIROBI COUNTIES, KENYA

BY

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DECLARATION

This thesis is my original work and has not been presented for examination in any university.

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DEDICATION

This thesis is dedicated to my husband (Isaac Karanu), children (John, Peter, and Arthur), parents (Mr & Mrs Peter Githumbi), and my siblings (Joyce, Tabitha, Esther, and Nancy).

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LIST OF ACRONYMS

Ag-GDP	Agricultural Gross Domestic Product
AU	African Union
CAADP	Collaborative African Agriculture Development Program
FAO	Food and Agriculture Organisation (of the United Nation)
FSD	Financing Sector Deepening (Kenya)
HELP	High Level Panel of Experts
ICT	Information Communication Technology
KALRO	Kenya Agricultural and Livestock Research Organisation
KBS	Kenya Bureau of Statistics
KII	Key Informant Interviews
MC	Marginal Cost
MR	Marginal Revenue
PHLs	Post-harvest Losses
PHM	Post-harvest Management
SDGs	Sustainable Development Goals
USAID	United States Agency for International Development

ABSTRACT

Fruits and vegetable value chains form a crucial part of the food system. However, the chains have been faced with a major challenge of PHLs that has been estimated at about 40%-50%. Developing countries have been characterised by poor production and market linkages. They have also been employing traditional production and marketing systems which have not been efficient in actualising losses, their causes, as well as means to reducing them. The current study was thus conducted in Embu, Machakos, and Nairobi following a value chain perspective to estimate the level of losses, model the drivers of losses, as well as assess the factors that influence adoption of loss reduction practices.

Survey data was collected from a total of 74 wholesalers, 98 retailers, and 70 farmers making use of a multistage sampling procedure. Household Interviews and trader's checklists were used to gather data which was then analysed using descriptive statistics, multiple regression model and heck-Poisson model. Data was collected during the month of May, 2018, and focused on grafted mango varieties including Tommy, Apple, Vandyke, Ngowe, and Kent.

The descriptive results revealed that major losses were occurring at the farm level with Embu having higher losses compared to Machakos. Loss levels were also high at retail level with major perceived reasons being low prices, poor quality from farmers (infected) and physical injuries. With regards to adoption of loss reduction practices, the actors preferred use of stick and bag as well as hand picking at the farm level, use of cartons at wholesale level, and peeling at retail level. However, actors complained of time wastage, reduced quantities, and high labour requirements as major limiting factors to adoption of low reduction practices.

The regression analysis results at the farm level indicated that age, and output affected the level of PHLs negatively. Schooling, inadequate storage, ICT, and county type affected PHLs positively. At the wholesale level, age, county type, and experience had a negative effect, while purchased quantity, inadequate labour, inadequate transport, and ICT had a positive effect.

Retail level results indicated a negative relation with respect to experience, and county type, while a positive influence with respect to income and purchased quantities.

The Heck-Poisson model at the farm level showed that credit was a major hindrance to adoption, but there was higher adoption in Machakos than Embu. At wholesale level, actors with organised selling were more likely to adopt loss reduction practices, but PHLs reduced the likelihood of adopting multiple practices. At the retail level, diversification limited adoption of the practices, while those with higher incomes adopted multiple practices.

The study concluded that PHLs was evident at all nodes of the post-harvest chain. Thus, at the farm level recommended for farmers to grow the varieties most suitable for the regions and the government should make the varieties available at low cost. At the market level where handling, storage and transportation were key causes of losses, the study recommended for adoption of loss reduction practices to ensure proper handling and improvement of fruit shelf life.

KEYWORDS: Post-harvest losses, Mango value chain, post-harvest loss reduction practices, and drivers

CHAPTER ONE

1.0: INTRODUCTION

1.1: Background Information

Agriculture accounts for about 70% of employment in most African countries and also provides industrial raw materials and food (Admassu, 2001; *Agricultural Sector Development Strategy, 2010;* Ngowi & Selejio, 2019). In East Africa, tea, coffee, fruits and vegetables are the main agricultural products traded. In Kenya, the horticultural subsector is one of the most vibrant sectors that account for about 33% of the agricultural GDP (ITC, 2014; *Agricultural Sector Development Strategy, 2010;* Tarekegn & Kelem, 2022). Vegetables, fruits and cut flowers dominate the horticultural sector making it a major foreign exchange earner that contributes up to US $ 1.6 billion annually. In 2019, the sub-sector contributed about 2% to the national GDP (KBS, 2019). Therefore, it has the potential to alleviate poverty, provide employment, improve the country food and nutritional security and earn foreign exchange (HLPE, 2014). Among the fruits, mangoes rank second in terms of production with about 20% after bananas which accounts for about 38% (ITC, 2014). In addition, mangoes in Africa contributes up to 10% of the world mangoes production, 1.7 % coming from Kenya (FSD Kenya, 2015).

Food products on a broad spectrum can be grouped into perishable and non-perishable commodities. Mangoes (Mangifera Indica) which is a perishable commodity is suitable for most agro-ecological zones. In Kenya, most mangoes are sold in the local market (97%) and the rest (3%) exported (FSD Kenya, 2015). Major export destinations include United Arab Emirates which takes up 56% share of the volumes, Saudi Arabia, Bahrain and Qatar. In the recent past, agricultural production has been boosted by the high technological advances that have seen use of irrigation, high breed varieties, and good crop husbandry in practice. Producers engaging in this lucrative venture are moving towards exploiting its potentials

(Wakholi et al., 2015). It has been estimated that demand for mango fruits will grow twice and export market expand in five folds by 2023 (USAID-KAVE, 2014). However, the Mango value chain has been faced with a lot of challenges one being losses along the value chain. It has been estimated that about 40%-60% of produced mangoes are lost before getting to the end consumer (Kiaya, 2014 and HLPE, 2014).

Mango production in Kenya can be categorised into three production systems including: small scale, medium scale and large scale. The sector is dominated by the small scale and medium scale farmers who account for 45% and 46% respectively of the total production *(*FSD Kenya, 2015). The production is done under two major seasons, from October to March and a low season from May to July. The varieties grown include: Tommy Atkins, Kent, Van Dyke, Kensington, Sensation, Haden, Apple, Ngowe, Boribo, Batawi, Pears, Sabro, Dodo, and Sabine. Kenya mainly trade in apples, Kent, Ngowe, Vandyke, and Tommy (FSD Kenya, 2015).

Different counties are engaged in mango production including; Kilifi (18%), Kwale (16%), Machakos (8%), Meru (8%), Makueni (8%), Embu (7%), Migori (5%), Bungoma (4%), Tana River (4%) and Lamu (4%). Tharaka Nithi, Nyeri and Elgeyo Marakwet account for less than 4% of the produce (ITC, 2014). In Machakos, production volume and area under production increased by about 24% and 16% respectively between the year 2012 and 2014. As of 2021, the production area had increased by 2%, and volume decreased by 3%. This could be due to changes in weather patterns which has resulted to lack of rains and poor flowering. Consequently, reducing volumes. On the other hand, increased production was as due to increased plantation of the apple mangoes, since most other crops did not do well in the region (Techno serve, 2021). Embu decreased the area under production by 3% and volume by 1% between the same period (International & Development, 2014). The area under production and volumes was seen to decrease even more in 2021 with about 5% and 2% respectively (Techno serve, 2021). This trend was mainly due to changes in crops planted in the region as a lot of farmers were changing to other agricultural produces like rice, tomatoes, and Macadamia.

Mango production in Kenya has been improving over the years. For instance, from 1960 to 2016, production increased from 400 thousand metric tonnes to 735 thousand metric tonnes (FAO, 2016). However, it is estimated that a third of what is produced does not reach the end consumer (Adebamiji, 2011 and HLPE, 2014). In addition, it is has been reported that as production increases, postharvest losses increase (Kitinoja et al., 2011). This leads to wastage of resources and an ever-widening gap to satisfy demand despite the increased production. This necessitate proper management of the already produced mangoes to help increase the marketable supply, putting into perspective that developing countries including Kenya are characterized by; low technology adoption, poor storage, prevalence of diseases and poor infrastructure as the major causes of losses (Admassu, 2001; Kitinoja et al., 2011; HLPE, 2014 and Wakholi et al., 2015).

The discourse on PHLs has increasingly gained importance with time. The issue gained momentum in 1974 when the first world food summit agreed to have a 50% food loss reduction by 1985. In the year 1977 a special programme for postharvest reduction was established, and the scope was initially on grains but from 1980s the scope widened to cover roots, tubers, fruits and vegetables. On average, in the year 1978 postharvest losses in fruits were about 20%, 30% in 2001 and about 40%-60% in 2015 (Affognon et al., 2015).

Postharvest studies are increasingly becoming important. This is as a result of increased pressure on productive resources caused by rising population, increased food demand and urbanisation. Therefore, making loss reduction a crucial component of ensuring food availability.

Postharvest losses vary depending on crop, area and season. Research has provided postharvest loss estimates of 30 to 40% and in some instances up to 80% in horticultural produce due to perishability (Aulakh and Regmi, 2013 and Wakholi et al., 2015). Different studies have been undertaken to estimate the level of losses. For instance, FAO estimated that about 33% of food produced is wasted. Roots and tubers losses have been estimated at 40%, while cereals have been estimated to have a loss of 20% (Rockefeller Foundation, 2015). Adebamiji (2011) found a loss of 40% in citrus fruits, while Nigeria recorded a 60% loss in tomatoes (Wakholi et al., 2015). The lower eastern region of Kenya accounted for 37% of the total mango produced in Kenya of which 13% was reported to be lost in the year 2015 (Wakholi et al., 2015). Techno-serve (2021) reported that eastern region has high mango fruit production and is also characterised by high losses. For instance, they reported that Embu farmers loss about 30% of their fruit products, while Machakos losses about 25%. Mujuka et al (2019) reported that losses in Embu are estimated at 38%. Nairobi is a major fruit market in Kenya, and Techno serve (2021) reported that a lot of trader's loss fruits due to problems carried forward from the farm, as well as poor handling. All these reports have been based at the farm level with no estimates at the other nodes of the chain which makes the current study important.

1.2: Statement of the Research Problem

The United Nations Sustainable Development Goals (SDG12.3) as well as African Union Agenda 2063 has committed to reducing PHLs by half from the current levels by 2030 and 2026 respectively. However, attempts to move this agenda has been threatened by lack of reliable data and estimates on the magnitude of the losses as well as the causal factors. In addition, there has been lack of empirical data supporting use of loss reduction practices, and especially assessing the factors that influence adoption of loss reduction technologies like; processing machines, solar driers, evaporative coolers (charcoal coolers, brick coolers and sand cool chamber), plastic crates, storage bags, ripening chambers and field packing, which besides being used, the losses have been increasing (Imaita, 2013 and Affognon et al., 2015). Also, a lot of PHL research have been focused at farm level with little attention on what happens at the other nodes of the chain (Bari, 2004; Kumar et.al. 2006; Gangwar, Singh & Singh, 2007; Aulakh and Regmi, 2013; Hegazy, 2013; Bantayehu et.al, 2018 & Amentae, 2017; Anna et al, 2020; Ahmad et al., 2020; Baltazari et al, 2020; Mengistie et al, 2020). Recently, Rockefeller Foundation in conjunction with the University of Nairobi have been working on projects to reduce postharvest losses. Techno-Serve Kenya through the yield wise project has been helping farmers to endorse good agronomic practices and to scale up awareness on loss reduction practices that would result in reduced postharvest losses. The project has moved on to setting up aggregation centres that would assist farmers in aggregating their fruits for marketing in order to achieve better prices, adoption of PHL reduction technologies, packaging, and processing of dry and wet fruit products with the main aim of reducing losses. However, the projects have widely relied on subjective loss estimates and thus making it difficult to evaluate effectiveness as well as sustainability. In addition, the actual causes of the losses as well as the impact of the technologies to reducing losses have not been evaluated.

Most research in loss estimation has widely been limited by sparse information on the actual losses, impact of these losses on the actors returns and their causes especially along the value chain. This has led to most estimates documented being based to anecdotal stories without actual empirical research (Aulakh and Regmi, 2013). They have also been subjective due to unavailable data on losses especially on perishable produce (Ramaswamy, 2014 and HLPE, 2014). National estimates have been based on samples from selected regions despite the fact that losses and their causes are site specific (HLPE, 2014; FAO, 2016; Amentae, 2017). In addition, despite the great contribution fruits and vegetables play in promoting farmers income, country earnings, and food and nutrition security, they have not received considerable attention in quantifying the actual losses particularly from a value chain perspective (Chandra and Lontoh, 2010 and Affognon et al., 2015; Tarekegn & Kelem, 2022).

Postharvest losses reduce farmers earnings from the enterprises substantially, government earnings and pose threats to a country's food security (Wakholi et al., 2015). In an attempt to reduce the losses, technologies such as the crates, cartons, charcoal coolers, cool bot cold storage, solar driers, brick coolers, field packing, plastic bags, pole pickers, nets, pallets, and hand picking have been recommended. However, they have gained limited success in adoption, less attention by the chain actors and have remained largely underutilised (HLPE, 2014 and Wakholi et al., 2015). In addition, most production and marketing of fruits in Kenya is undertaken by small scale actors employing traditional farming and marketing methods which has hindered adoption of the practices. Besides, there has been little research work assessing the socio-economic and institutional factors that influence adoption of this practices, especially from a value chain perspective. The current study therefore focused on estimating the level of losses, report on the major causes of the losses, as well as identify factors influencing adoption of loss reduction technologies from a value chain perspective.

1.3: Objectives of the Study

The main objective of the study was to assess drivers of postharvest losses and factors influencing adoption of loss-reduction practices along the mango value chain in Embu, Machakos, and Nairobi counties in Kenya.

1.3.1: Specific Objectives

1. To quantify the level of post-harvest losses along the mango value chain in Embu, Machakos, and Nairobi counties of Kenya.
2. To model the drivers of postharvest losses along the mango value chain in Embu, Machakos, and Nairobi counties.

3. To determine factors influencing adoption of post-harvest loss reduction practices along the mango value chain in Embu, Machakos, and Nairobi counties.

1.3.2: Research Question

1. What are the postharvest loss levels at each stage of the mango value chain in Embu, Machakos, and Nairobi counties?

1.3.3: Research Hypotheses

1. Socio-economic and institutional factors have no significant influence on Postharvest losses along the mango value chain in Embu, Machakos, and Nairobi counties.
2. Socio-economic and institutional factors have no significant influence on adoption of postharvest loss reduction practices along the mango value chain in Embu, Machakos, and Nairobi counties.

1.4: Justification of the Study

Farmers engaging in horticultural production suffer a lot of economic losses affiliated to postharvest handling. This is mainly due to the perishability nature of the produce and lack of appropriate technologies (Ngowi & Selejio, 2019). Therefore, the main objective of postharvest research, is to ensure loss reduction and proper food transition between production and consumption, and hence the results from the current study will be of use to different stakeholders including:

Rockefeller foundation, Techno-serve and the University of Nairobi will need the results from the current study. In attempt to reduce postharvest losses, aggregation centres will be constructed to help farmers. Therefore, results on losses, causes and factors influencing adoption will help guide on the approach to be taken to ensure the aggregation centres sustainability.

Farmers and traders including wholesalers and retailers will also benefit from the current study results. Especially results on the level of losses and the causal factors will be useful as they will work towards managing them. In addition, on identification of factors to consider while adopting the practices, the actors will pay attention to the crucial factors to ensure they meet the goal of loss reduction. The research will guide them on the best technologies for use and factors to consider in adoption of those technologies.

Results on the causes of postharvest losses and the levels of the losses for specific crops are important sources of information. The information is needed to identify priority areas for investment and financing by donors and government. These is because loss leads to lack of market, reduced income and nutrition which has an impact on growers, consumers and governments. Technology developers will be able to improve on approaches used and technologies delivered to these areas. They will also be able to follow a multi ministerial approach in development where the necessary sectors will be involved as guided by the significant drivers, factors and loss levels.

The research will build on current literature and create a path for future developments. Therefore, will be useful to Kenya Agricultural & Livestock Research Organisation (KALRO), World Agroforestry (ICRAF) and different universities engaged in postharvest research. Few research has been conducted with a postharvest component. Hence the current research will give insight for further engagement in these kinds of research. Especially insight directed towards assessments of loss levels and causes of the losses for each and every crop.

1.5: Organisation of the Thesis

This thesis is broken into seven chapters. Chapter 1 provides background information, the problem being addressed, objectives, and justification of the study. Chapter 2 provides detailed literature related to the issue of PHL, drivers, loss reduction technologies and factors influencing adoption. Chapter 3 provides the general study methodology. Results are discussed in chapters four, five, and six following the paper format which is targeted at addressing each specific objective. Finally, chapter seven provides a summary to the key findings of the study, conclusion, policy implications, and suggestions for further research.

CHAPTER TWO

2.0: LITERATURE REVIEW

2.1: Mango Production in Kenya

Mango (*Mangifera indica L.)* is a native to the South Asia. It is an important fruit tree grown in over 90 countries all over the world. It is grown in the tropical and subtropical regions and is consumed in both fresh and processed forms. It is an important source of nutrients (fibre, vitamin A and vitamin C) and income to farmers (Kassahun, 2014). It is the second most important fruit in Kenya accounting for about 20% of the total fruit production (Musyimi, 2013; Kitinoja et al, 2018). By 2013, the lower Eastern Kenya comprising of Makueni, Machakos and Kitui constituted about 37% of the total country mango production (FSD Kenya, 2015). Production is mainly in areas 0-1500m above sea. According to FAO (2016) statistics, production area and volumes have been increasing over the years. Production volumes reached 735 thousand metric tonnes in the year 2016 from 513 thousand metric tonnes in the year 2000 and 400 thousand metric tonnes in the year 1961. Production area has also increased reaching 255 thousand hectares in the year 2016 from 165 thousand hectares in the year 2000 and 150 thousand hectares in the year 1961 (USAID, 2016).

Mango is a seasonal fruit with 97% of the marketable produce being consumed domestically. 3% is exported to Middle East (54%), Tanzania (34%), Uganda (10%), and other regions (2%) (FSD Kenya, 2015). Due to changes in consumer preferences, population growth and income differences, demand for the fruit has gone high. Nutritional awareness among consumers has also fuelled demand which is expected to grow by about 30% by year 2022. More international opportunities for participation in the world market have also grown. It has been estimated that by 2023 the demand for mangoes will have grown twice and export market expanded by five folds (USAID-KAVES, 2014). This necessitate postharvest loss reduction in order to increase the level of marketable supply (Kassahun, 2014).

FSD Kenya (2015) categorised mango farmers with respect to land area under production. They argued that as production area increase, the level of mangoes produced increase and the losses increases. Therefore, losses are assumed to increase with the level of production. The farmers have been categorised as follows:

1. Small scale farmers with less than 50 trees, low yield of less than 58 fruits per tree, receive low prices of about 5-6 Kenya shilling and are least commercial.
2. Medium scale framers with between 50 and 300 trees, low yield of about 69 fruits per tree, receive prices of about 7 Kenyan shillings and are semi-commercial.
3. Large scale and very large scale with more than 300 trees, yields between 78 to 189 fruits per tree, receive prices of around 10 Kenya shillings per fruit and are highly commercial.

In terms of production regions, mango is produced in over 10 counties across Kenya. Different parts of the country are engaged in mango production including Kilifi (18%), Kwale (16%), Machakos (8%), Meru (8%), Makueni (8%), Embu (7%), Migori (5%), Bungoma (4%), Tana River (4%) and Lamu (4%). Tharaka Nithi, Nyeri and Elgeyo Marakwet account for less than 4% of the produce (ITC, 2014). The production is done under two major seasons; from October to March and a low season from May to July. Eastern region major production is between November and April, Coastal region production is between October and January with another low season in May to July. Central produces between December and March with North Eastern producing between October and December with a low season in April and May. The Rift valley region produces between October to March with Nyanza and Western regions producing between January to February and June to July. The varieties grown include: Tommy Atkins, Kent, Van Dyke, Kensignton, Sensation, Haden, Apple, Ngowe, Boribo, Batawi, Pears, Sabro, Dodo, and Sabine. Kenya mainly trade in Apples, Tommy, Vandyke, Kent, and Ngowe (FSD Kenya, 2015).

2.2: Trends of Postharvest Losses in the Commodity Value Chain

2.2.1: Definition of PHLs

Postharvest is the separation from the site of immediate growth. Postharvest losses are losses occurring from the time the crop is harvested to the time it is consumed (Harris & Lindblad, 2011). Kiaya (2014) defined postharvest losses to be the losses from the time a crop is harvested to processing, marketing until it gets to the end consumer. However, Rockefeller Foundation (2015) separated food losses and waste along the supply chain. They argued that losses take place during production, postharvest and processing stages. On the other hand, food waste refers to losses occurring at the end of the supply chain including losses at the retail and consumption levels. Therefore, any part of the food that was meant for human consumption and is then directed to other uses that are not intended for human use constitute the loss and waste. Gangwar & Singh, (2007) in the context of citrus fruits production defined farm level PHL as all fruits left on the ground hence not taken to the market and are already picked. Kumar et.al, (2006) defined PHLs as losses from production to consumption of a good. HLPE (2014) described losses to occur at any point before consumption and waste to occur at consumption level. The current study borrowed from these arguments and made a loss assessment from the time of harvest to the retail level as was used by Komuro (2007) in a study carried out in Australia on assessment of postharvest losses in mangoes that after in-depth review showed that major losses occur at the farm, wholesale, and retail levels.

2.2.2: Level of PHLs along the Commodity Value Chain

Food waste and losses has become an increasingly urgent problem**.** For instance, Nigeria recorded a 40% loss in grains which led to more food importation in 2015. Across Africa, fruits and vegetables experience the highest losses of about 50% of the total production, roots and tubers account for 40% and cereals contribute about 20% (Rockefeller Foundation, 2015). Adebamiji (2011) in a study on the effect of postharvest losses on citrus farmers income, revealed that harvesting, transportation and marketing losses constituted 14% loss on potential total revenue.

It is estimated that 30% of produced food is lost before it gets to the end user (Wakholi et al., 2015 and Rockefeller Foundation, 2015). This is because postharvest losses have been estimated at 45% during peak season with those of mangoes estimated at 30% 2010 (Mada et al., 2014). In the year 2015, estimates showed the losses in the lower eastern region of Kenya to be 13% of the total production and the country overall to be 30% to 60% (Affognon et al., 2015). In other instances, loss estimates have been 30 to 40% and in some cases up to 80% (Aulakh & Regmi, 2013 and Wakholi et al., 2015). Vilas et al. (2006) reported a loss of 50% in mangoes, FSD Kenya (2015) reported a loss of 25% and Affognon et al., (2015) estimated losses of 30% to 60%.

Different studies have been conducted for different agricultural commodities around the world. Most of these studies have estimated losses at the farm level. For instance, in Pakistan loss levels for citrus fruit were estimated at 35% by Leghari (2001), 40% by Srivastava (2002), 39% by Bari (2004), and 22% by Gangwar & Singh, (2007). Murthy et.al. (2008) in Tanzania reported a 29% loss in tomatoes. In Bangladesh, grain losses were estimated at 15% (FAO, 2006). Kumar et.al, (2006) estimated a loss level of 60% in onions in Karnataka-India and 56.6% in potatoes. Kummu et al. (2012) estimated a global food loss of 25% while Godfray et al. (2010) estimated a global loss of about 30%-40% for maize. In Kenya, fruits PHLs has been estimated at 40%-50%. KBS, (2019) reported that growers lost about 1.9 million tonnes of food due to PHL. Worst hit was maize, where the country had to import maize worth 42 billion yet 24 billion worth of maize had been lost due to poor PH handling. The 2018 economic survey report showed that potatoes worth 19.7 billion, beans of 11.5 billion, bananas of 5.6 billion, tomatoes of 2.4 billion and pineapples of 2.4 billion were lost (KBS, 2018).

Few studies have been able to make consideration of losses occurring along the value chain. For instance, Amentae (2016) estimated milk loss at 3.35%, 2.45% and 0.95% at farm, wholesale, and retail levels. Cereals losses (teff) were estimated at 8.18%, 1.67% and 2.85% at the farm, wholesale and retail levels. McKencie et.al (2017) quantified loss in tomatoes and found it to be 40.3% to 55.9% of the total harvestable produce. At the farm, loses were 28.7%, 0 at wholesale and 5.4% at retail. Amentae (2009) used simple averages to estimate losses at different stages. The study assumed that losses for all mango varieties were the same hence used one variety for the study. Total PHL was 29.73% (farm=15.59%, 8.89% = wholesale and 5.25% =retail), for grapes, losses were 7.31% at the farm, 4.24% at wholesale and 2.85% at retail level, and bananas was 5.53% at the farm, 6.65% at wholesale and 16.66% at retail level. Umar et.al (2015) estimated Kinnow fruit losses in Pakistan and reported a loss of 32.4%, 25% and 3% at farm, wholesale and retail levels respectively. From the literature assessment, the studies have been consistent in their methodology, where researchers make use of simple averages to estimate the level of losses. A similar approach will be adopted for the current analysis. However, there is limited information with regards to assessments following a value chain approach which the current study will adopt.

2.2.3: Impact of PHLs along the Commodity Value Chain

Postharvest losses in grains has been estimated at 10-38% where about 8% of the losses occurs at the farm level (Hodges, 2013). In the same study, the researcher estimated that an increase in production to take care of the loss would lead to increase in losses rather than reducing them. Therefore, advocated for loss reduction instead of increased production. It was estimated that losses in grains became huge as they continued to be stored for long periods having 15% at three months, 30% at six months and 55% at nine months. In perishable produce like mangoes more losses are expected during the same periods. However, their study was on wheat, maize, rice, sorghum and millet with little attention on losses occurring in fruits which the current study will give focus to.

With interventions, it is hoped that by 2050 postharvest losses will have reduced by 50% (HLPE, 2014 and Affognon et al., 2015). However, currently less than 5% of horticultural funding are directed towards postharvest management practices (Kitinoja et al., 2011). Throughout history, donor and government funding towards agriculture has been minimal. Most of the African countries make less than 5% agricultural investment. Out of these, only about 1% of the funding are directed to horticultural production with less than a third of the projects having a postharvest management component (Kitinoja et al., 2011). Improved production is not sufficient and thus postharvest management is necessary to assure a sustained future development in food security. It is also necessary to have research developments with respect to loss levels in order to probe for investments on loss reduction.

Postharvest losses entail losses in quality and quantity. Quality losses are prevalent in developed countries (Kader, 2001 and Kiaya, 2014) while quantity loss are prevalent in developing countries (Kitinoja et al., 2011 and Kiaya, 2014). The losses have impacts on both framers and consumers. Farmers' income is compromised and there is loss of factors of production. Consumers are faced with reduced food availability, price hicks, and low nutrition content. Crop grains taken together constitute of 88% losses (grains, fruits, vegetables, tubers, pulses and dairy), 8% losses is from meat and the rest 4% from fish (Rockefeller Foundation, 2015).

Postharvest stages include activities during harvesting, aggregation, storage, package and transportation (Vilas et al., 2006). There are different supply chains through which mangoes can move from production to consumption (FSD Kenya, 2015). The chains include: rural market chain (farmer-rural – wholesaler - rural retailer), urban market chain (farmers- brokers- traders- wholesale- retail), supermarket channel (farmer- traders- central procurements- supermarkets) and export channel (framer- brokers- exporters- export agents- foreign markets). Due to lack of a holistic approach in developing countries, the extent of the loss is not usually understood. The chain actors at each stage take the losses to be normal and are normally compensated by increased production/quantity handled. Abimbola (2014) in a study on the effect of postharvest losses on famers welfare in Nigeria, found that the losses have a negative significant impact on farmers' income. Rockefeller Foundation (2015) also estimated that the losses would reduce farmers' income by about 12%. Similarly, FSD Kenya (2015) in an assessment of opportunities for financing along the mango value chain, found the losses to have led to a drastic reduction in farmers income. Using these arguments, the current study will estimate the level of losses in the mango value chain in order to provide a holistic approach and estimation figures that will give a clear picture of how much is lost.

2.3: Empirical Review on the Causes of Postharvest Losses

Causes of losses along the food value chain can be broadly classified into primary and secondary causes. The primary causes include: damage by pests, animals and bacteria (microbial or biological), bruises and crushing (mechanical), poor storage and environmental conditions (physical). The secondary causes include poor harvesting, handling, storage, transportation, inadequate marketing system and lack of refrigeration (Komuro, 2007).

Different studies have made use of modelling as well as descriptive methods to assessing the causes of the losses. For instance, Kassahun (2014) made use of a descriptive approach in a study on mango value chain in Ethiopia and identified the major drivers to losses in mango production as water scarcity, pests and diseases, lack of technologies, limited access to mango varieties, limited postharvest research, poor means of transport which were by use of donkeys and human back, and lack of information and market transparency. Kiaya (2014) found that the losses were due to low adoption of technologies, harvesting of immature fruits, poor weather, employment of poor harvesting methods like shaking of fruits and improper harvesting containers, poor road networks, poor modes of transport, overloading, lack of bridges to connect to the market and lack of refrigerated transport, pests, diseases, lack of cleanliness, poor ventilation and poorly constructed storage area. Vilas et al., (2006) found Poor facilities, lack of know-how, poor management and improper market facilities to be the causes of losses in vegetable production. HLPE (2014) argued that poor transport, poor storage, poor temperature management, lighting, humidity and careless handling to be the major causes of losses along a food value chain.

Rockefeller Foundation (2015) argued that poor distribution channels, lack of technical knowledge by farmers, gender inequality, limited credit access and lack of cost effectiveness in linking farmers to the market, poor extension services, inefficient postharvest storage facilities, lack of well-structured markets and poor market access were the main hindrances to reducing losses along the food value chain. Mada et al.,(2014) suggested the causes to be financial problems, low technical ability in harvesting, storage and handling techniques. Lack of appropriate storage and handling facilities were reported to be the main cause of losses in Ethiopia (Kassahun, 2014). In addition, excess supply, large number of middlemen, weak institutions, lack of coordination between the chain actors, lack of information, poor handling and packing, low prices and lack of contracts were not significant causes of losses along the mango value chain in Ethiopia. Kiaya (2014) found food losses to be mainly due to poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of supply chain actors, and lack to markets. In a study on the causes of postharvest losses in wheat, Amentae et al., (2017) found transport, distance to market, storage, family size and sex to be significant. Credit access, age and education were not significant. However, the factors were not evaluated at each stage of the value chain. It is clear that different factor in different places and on different commodities were seen to cause losses. Coker & Ninalowo, (2016) on a study on the effects of PHL on rice income using different postharvest loss parameters like harvest losses, threshing losses, drying losses, storage losses and winnowing losses found household size and threshing losses to be the factors influencing income.

The studies discussed had been limited in their modelling capabilities which pushed other researchers to work around and model the drivers of the losses. This was in attempt to identifying the most critical factors with regards to their effect on PHLs. For instance, Murthy et.al (2015) used a double log multiple regression model to assess the factors causing losses along the citrus value chain. The author found existence of a negative relationship with experience (22%), picking time (28%) and picking method (48%). The author also found a positive relation with respect to orchard size (21%). At wholesale level expertise (27%), loading methods (56%) and storage place (56%) had a negative association. At retail level unsold quantity (26%) and type of retailer (1%) had a negative association with the number of citrus fruits lost. Begum (2012) used factor analysis where multiple regression for rice and wheat at the farm level were analysed. The author found a negative relation with respect to area under cultivation (64% for rice and 57% for wheat), and labour 30% in rice). Kumar (2006) at farm level used factor analysis multiple regression to assess factor influencing PHLs in onions and potatoes. The author with regards to onions found a positive relation with regards to area under production (2%), weather (43%), storage (73%), and transportation (57%). On the other hand, the author found the same factors to influence PHL in potatoes (5%), (132%), (85%) apart from transport.

Amentae (2016) used a Tobit model for milk and cereals and found distance to the market as the major cause of losses (43%). Liker scale was used to assess severity of the causal factors by different stakeholders. Sex (9%) and distance to market (11%) had negative effect while output (4%), storage facility (7%) and weather (2%) had a positive effect on the level of losses. Kassahun (2014) used descriptive statistics where averages and frequencies were presented on the major loss causing factors in grapes. The author found education (40%), farm size (13%), age (28%), sex (9%), and experience (39%) to be the major loss causing factors. On the other hand, Adebamiji, (2011) made use of a multiple regression model and combined all factors along the chain and found time spent before collection (76%) and quantities handled (112%) to have a positive influence on the level of losses.

Murthy et.al, (2009) used simple averages and frequencies and found that the major cause of losses in mangoes were injuries during harvest (8%), immature fruits (66%) and diseases (23%). Transit losses were negligible. At wholesale and storage problems, bruises and diseases were the major problems while at retail physical injuries (51%) and diseases (31%) were the major problems. Adepoju, (2014) used frequencies and found the major problems for tomato farmers in Nigeria due PHL to be lack of storage (30%), poor infrastructure (49%), theft (23%), and long distance to market (15%).

From the analysis, a lot of authors have adopted use of descriptive statistics to assessing the causes of the losses. However, there has been scanty information and only a few researchers have modelled the drivers especially following a value chain approach. The current study will thus combine use of descriptive analysis as well as use of a multiple regression and follow a value chain perspective.

2.4: Postharvest Loss Reduction Interventions

2.4.1: Loss Reduction Interventions and their Impact

Loss reduction intervention have helped actors in different ways. For instance, Cowpeas storage project by Purdue University led to improved farmers income. AGRA through a yam improvement project moved towards an objective to double farmers' incomes and ensure food security. USAID project on hybrid seeds and postharvest storage programme was expected to lead to 50% increase in yields and 20% decrease in losses (Rockefeller Foundation, 2015). Rockefeller Foundation has established an initiative to reduce post harvest losses even with the existen of green revolution. This is because it is projected that postharvest loss reduction during harvesting, storage and trasportaion together with the production iniative will see Africa food secure despite the high population growth. It is estimated that reduction in postharvest losses would lead to a 15% increase in farmers' income. Loss reduction by 1% is also estimated to result to an increase in income by about $40 million US dollars annually (Mada et al., 2014). More recently is the yield wise project by Rockefeller Foundation, University and Nairobi, and Techno-Serve Kenya that aims at reducing PHLs in mangoes through harvesting initiatives, storage facilities, and value addition through processing.

However, such initiatives have been limited especially for perisahble crops due to lack of information which the current study will help build. In addition, most postharvest interventions have concentrated on specific parts of the value chain. For example, on-farm storage using sealed bags, use of solar coolers for fruits and vegetables, refrigeration and use of mobile drying systems for grain. These has resulted to lack of a clear picture on the extent of the losses especially along the value chain.

Different technologies have been advanced to help reduce losses along the mango value chain. They include: crates, cartons, charcoal coolers, cool bot cold storage, solar driers, field packing, plastic bags, pole pickers and hand picking (Imaita, 2013 and Affognon et al., 2015). However, the level of estimated losses has remained relatively high despite the documented literature on potential loss reduction abilities of these technologies. For instance, Vilas et al., (2006) assumed a positive relationship between inadequate storage and losses. Lipinskiet al., (2013) argued that use of coolers during storage would improve the shelf life of mangoes by 50%. Similarly, use of plastic storage bags reduces infestation by pests and diseases hence reduce losses by 20%. In addition, use of plastic crates in Afghanistan for package of tomatoes was seen to reduce losses from 50% to 5% (Lipinskiet al., 2013). Mix of products during storage stimulates ripening in some crops and quality deterioration in some and therefore lead to more losses and was seen to be reduced by use of seal bags (Ramaswamy, 2014). The technologies despite proving to have a positive effect, they have remained widely underutilised. This calls for further research into the technologies and especially on socio-economic and institutional factors that influence their use.

2.4.2: Empirical Review on Factors Influencing Adoption of Loss Reduction Technologies

Technological adoption is measured by how much farmers are using the technologies. It can be through assessing the rate of adoption or the extent of adoption. The rate of adoption is measured by the time required for a give number of people to have adopted. The extent of adoption is measured by the number of technologies adopted and the number of people who have adopted the technologies (Bonabana-wabbi and Taylor, 2002). However in developing countries, technology adoption is slow mainly due to: lack of proper land policy, lack of farm machinery, lack of skills to use the technologies, lack of credit and poor means of communication (Imaita, 2013).

Different studies have employed different modelling capabilities in attempt to assessing the factors that influence adoption. For instance, Abimbola (2014) made use of a binary logit model and revelled that market participation (2%), gender (8%), farm size (21%), household size (31%), time spent on the farm (11%), and occupation (1%) influence adoption of loss reduction technologies in tomatoes production. Marital status, education, age and farm experience were found not to influence adoption of loss reduction technologies in tomatoes production. Coker et al., (2016) used descriptive statistics and reported that poor handling (30%) and inadequate agro-processing (13%) caused 40% loss in fruits.

Imaita (2013) used a double handle model with probit and Poisson at the first and second stage respectively and identified training at production (12%), storage (31%) and, handling (51%) to have a significant positive influenced on adoption of technologies. In addition, training had a positive association with technology adoption at traders and exporters' level (11% & 21%) but the association was insignificant. Affognon et al., (2015) used a binary logit model in onions and revealed that gender issues in postharvest research was under estimated. They pointed out that female households had a low rate of adoption and experienced high rates of losses since they had less access to productive resources and postharvest technologies access. Hodges (2013) estimated an 87.5% reduction in losses due to training on loss reduction strategies employing a Poisson regression model.

Mariano et al. (2012) made use of binary logit and Poisson model to assess adoption of certified seeds and use of integrated management practices. From their analysis they found both models to provide similar results in terms of significant variables. Education (9%), household size (3%), other income sources (1%), credit access (21%), participation in farm demonstrations

(15%), training (23%) and extension services (13%) were significant at 1% indicating that farmers with those characteristics were more likely to adopt technologies.

In most of the reviewed studies, adoption rates were seen to be low and most of the interventions remained widely underutilized. The actors associated the low adoption to high initial costs, low technical knowledge on the use of the technologies and lack of proper reward for storage from the market (Affognon et al., 2015). In addition, there appear to be a mix of methodology applied to assessing the factors. The studies that have made use of count model have recognised that the interventions are count in nature, and thus to be able to assess the rate as well as the extent of adoption, a double handle model would be most appropriate. Thus, the current analysis thus adopted the hypothesised factors and employ a double handle model. Therefore, a probit model was applied at the first stage and Poisson model at the second stage (Heck-Poisson model). The model is advanced after Heckman two stage model, where with count data, most studies have not been able to solve for selection bias that comes about due to use of the steps independently. The current study was specifically interested in adoption of loss reduction intervention which is a two-stage process: that is adopt or fail to adopt the intervention, and the number of interventions adopted. Moreover, a sample selection bias already exist since the persons in the first stage are the ones in the second stage. Besides, the studies have been limited in scope, with little attention to assessment of the factors that influence adoption along the value chain which the current study will attempt to bridge.

2.5: Theoretical Framework

The current study is anchored on the theory of expected utility maximization theory (Liedtke, 2006). The theory was used to assess the producer as well as the consumer side. Profit maximisation theory was used to assess the producer side as it alleges that in the short and long-run actors determine inputs, prices, and output levels that lead to high profits. In a perfectly competitive market, prices will be equated to quantity. The neoclassical economist allege that all actors are rational and thus profit maximisers. Thus, at each node of the chain, the actor will mind about their profits. Thus, loss reduction will be ultimate to reducing costs, and increasing revenue. The current study will measure the level of losses and express them as a proportion at each stage along the mango value chain. It is assumed that at each stage, the participants will maximize their profits thus will reduce the proportions lost by handling high volumes of the product since prices are set by the forces of demand and supply. Consequently, earning high revenue with lower costs and thus all actors will equate MR=MC, handling Q level of mangoes that maximizes their profit.

The theory of utility maximisation from a consumer side will be used to assess the level of satisfaction for adopters of loss reduction practices. Adoption of agricultural technologies as well as reduction of PHLs is mainly based on optimization of the outcome, in this case minimization of postharvest losses. The adopter is faced with a budget constraint and competition of technologies for use in other enterprises and hence need to maximize their utility function subject to the constraints (Cragg, 2016).

CHAPTER THREE

3.1: Conceptual Framework

Postharvest losses hinder attainment of food security, nutritional security and leads to low economic development (HLPE, 2014). A critical analysis of factors influencing PHLs has been shown to be one way towards dealing with the problem that has remained unchanged along the value chain (Wakholi et al., 2015). As shown in Figure 3.1 relationships are built between the factors hypothesised to be the major drivers of PHLs. Demographic factors, resource and assets, institutional factors, and farm characteristics were hypothesised to have an influence on the level of PHLs which in turn influences technology adoption and mango supply chain actors' livelihood.

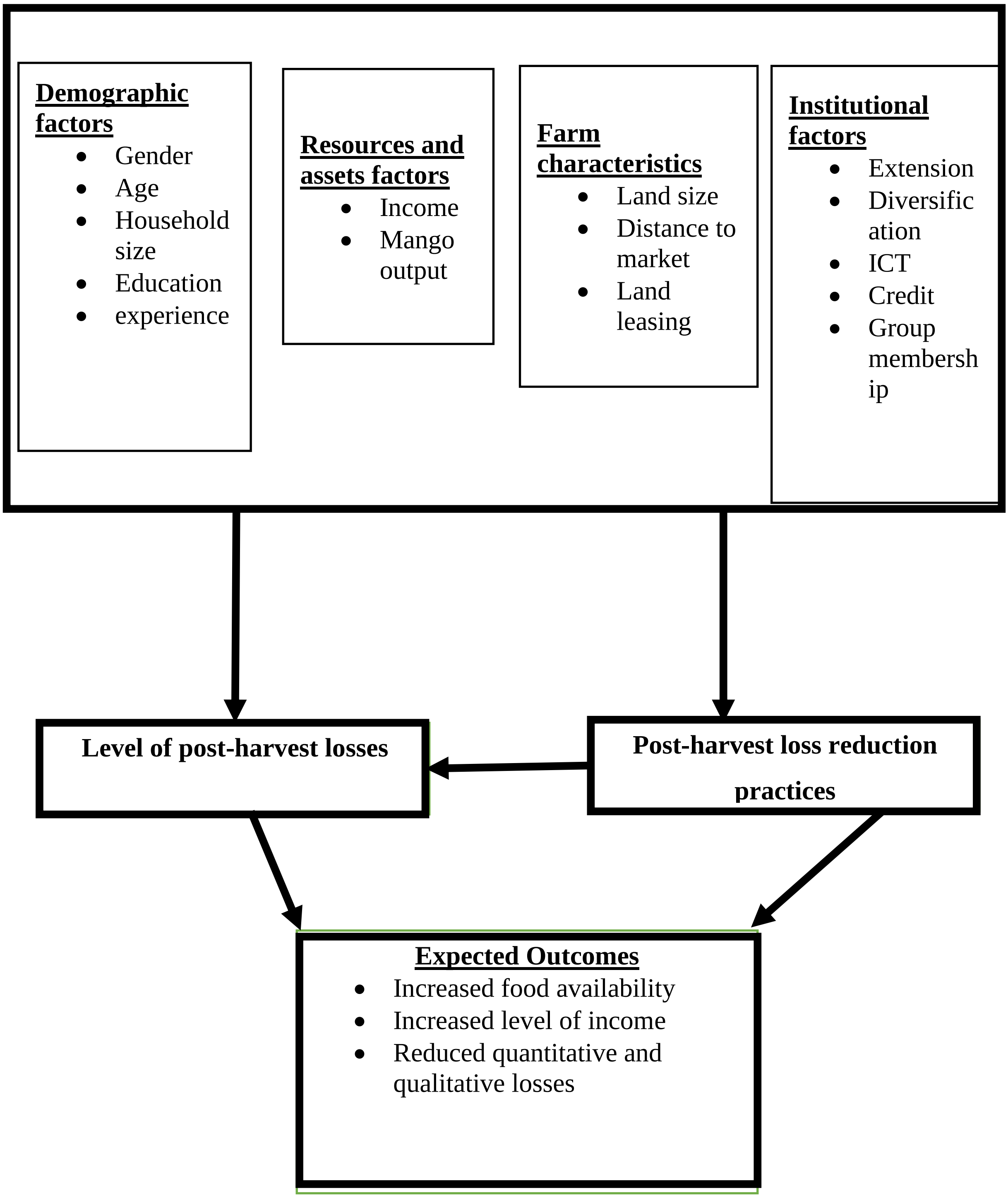

Figure 3.1: conceptual framework on factors influencing the level of PHL

Source: own schematic representation (2020)

Food losses can occur at different points of the value chain starting from harvest to consumption. Postharvest losses occurs from harvest until the retail level (Rockefeller Foundation, 2015). The losses can be attributed to factors that can be viewed from three levels based on scope (HLPE, 2014). The levels include a micro level which entails characteristics attributed to the chain actor like farm size, education, age, technologies, mode of transport and household size. The second level is the meso level that view the drivers from an institutional perspective like land tenure rights, transport network and market arrangements. The third perspective is on a macro level where the losses would be due to national, international and global forces like trade policies, taxes and global prices. These drivers influence the magnitude of losses occurring at different stages of the value chain. Therefore, different actors in attempt to reduce the losses will adopt loss reduction technologies based on their effectiveness and sustainability. They will also be influenced by individual characteristics and other forces beyond their control like government regulations. Adoption of technologies is expected to have a negative effect on the level of the losses and hence improved food availability, income and overall economic growth.

The current study thus hypothesises individual characteristics, institutional factors, assets and resources, as well as risk averseness to have significant influence on reduction of PHL as well as adoption of loss reduction practices. As shown on figure 3.1, appropriate handling of ICT tools, and loss reduction practices, as well as diversification will help support reduction of losses significantly. The actors will also be able to enjoy the benefits of loss reduction since they will be able to preserve their fruits longer, attract higher prices, incomes, and ensure food security.

3.2: Study Area

The current study was undertaken in Machakos, Embu and Nairobi counties of Kenya. The two main areas (Embu and Machakos) were chosen for their high production with Machakos being the third and Embu the fifth best producers of mangoes in Kenya. Besides, they have a large area coverage under mango production, which is the basic source of income controlling about 40% of their income.

Machakos especially areas of Mwala and Masii where the study was undertaken are semi-arid receiving rainfall of 250- 650 mm per annum and is in the upper eastern region. They are in the lower parts of Machakos county as shown on Figure 3.2 below. They were selected as they have high production of varieties considered in the study including apple, Tommy, and Ngowe. Has high temperatures and infertile soils. Approximately 95% of people living in Machakos are Akamba since this is predominantly their mother land. The dominant vegetation are dry bushes and trees. Fruits, vegetables, maize and drought-resistant crops such as sorghum and millet are also grown. Machakos lies in the latitude of 0º 45’ south to 1º 31’ South and longitudes 36° 45’ east to 37° 45’ east. The county has an altitude of 1000 - 1600 meters above sea level.

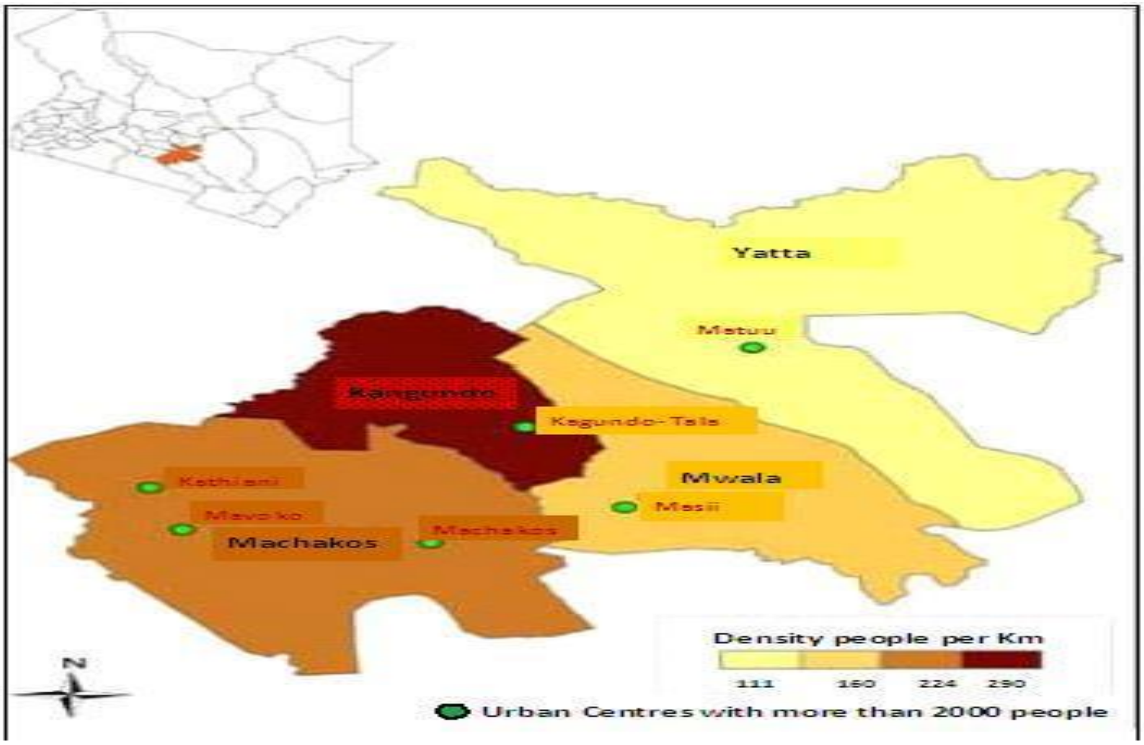

Figure 3.2: Machakos County Map showing the study sites (Mwala and Masii)

Embu is a well-watered region especially regions of Runyenjes where the study was undertaken and in the lower eastern region. The ward is in the upper region of Embu County as shown on figure 3.3 below. The area was selected for its high production level of major fruit varieties including Kent, Tommy and VanDyke that were considered in the current study. The main ethic group in the area is Aembu since this is their indigenous home, with other tribes like Akamba, Ambeere and Agikuyu. Major crops grown by Aembu are tea, coffee, millet, cassava, dairy and horticultural crops since their soils are fertile. Temperatures are estimated at 9°C - 28°C receiving rainfall of about 1206mm per annum.

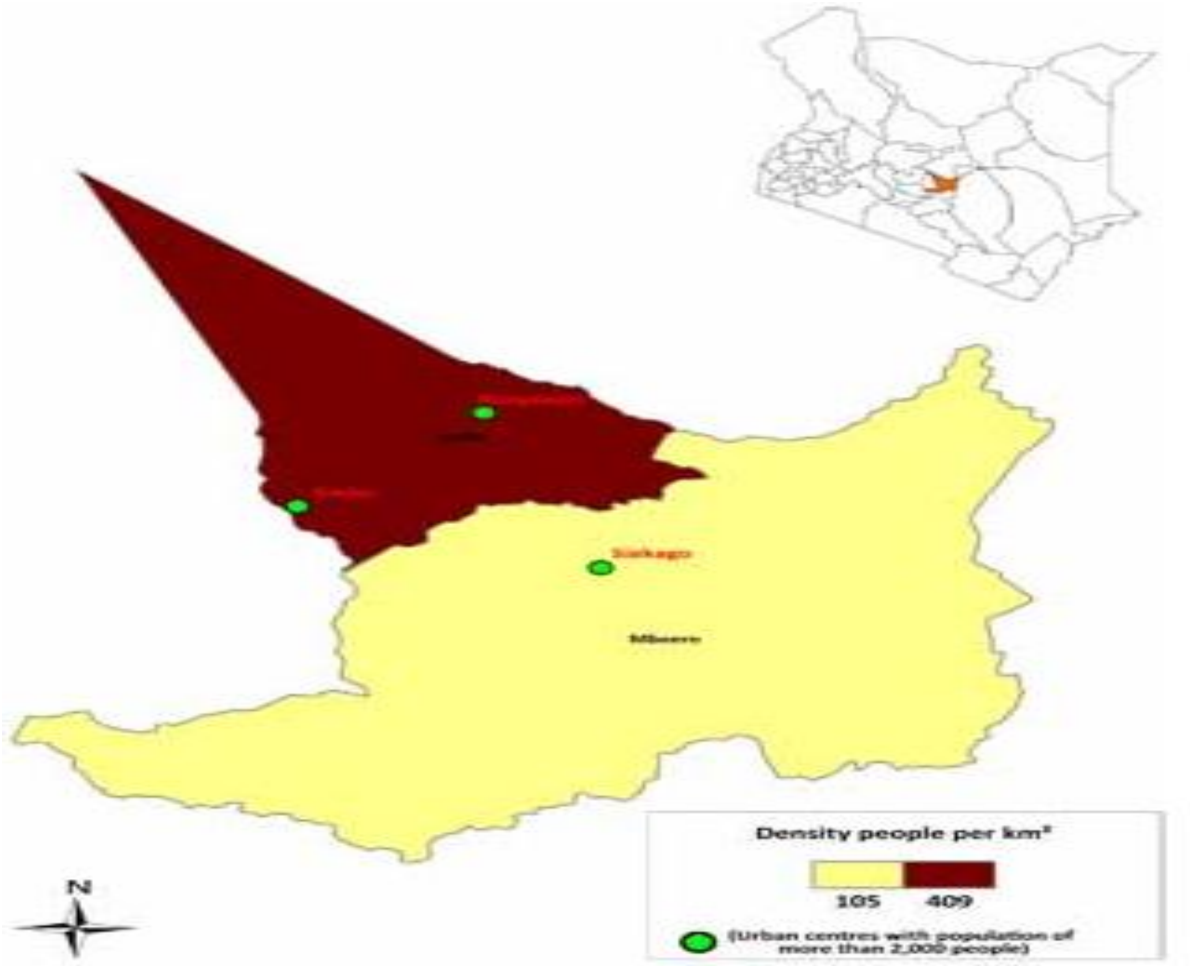

Figure 3.3: Embu County Map showing the study site (Runyenjes)

Nairobi County was chosen as the main market of mangoes that are locally sold in Kenya from different regions. From the farm level either from Machakos and Embu, the chain would end at the main markets in Nairobi County. As shown on Figure 3.4, there are different markets where the mangoes would be sold both at the wholesale and retail level. Nairobi is a metropolitan area with all tribes represented and lies in the latitude of 1° 17' 11.0004" S and longitude of 36° 49' 2.0028" E.

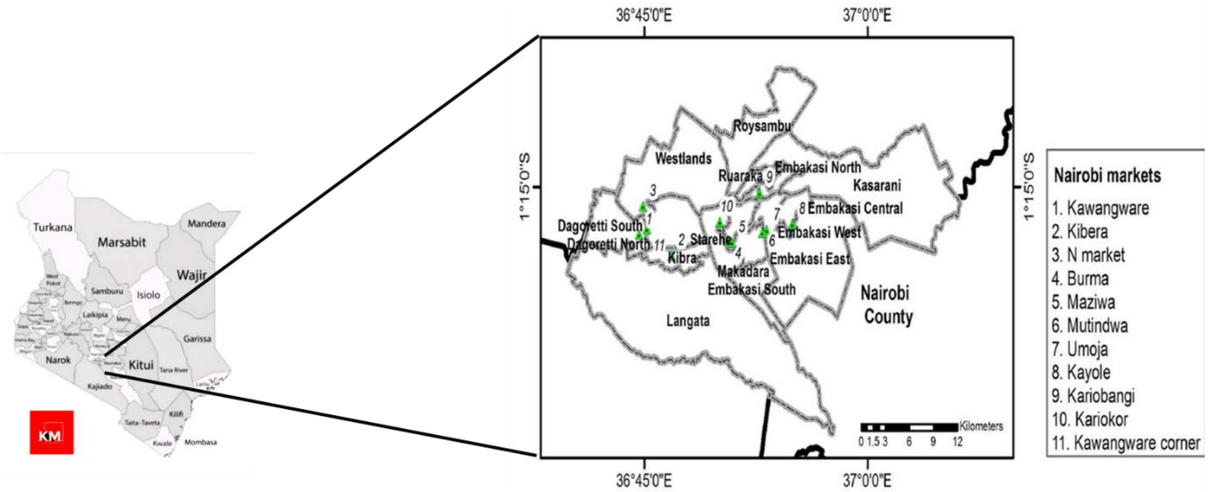

Figure 3.4***: Nairobi County Map showing the major markets***

3.3: Research design and sampling procedure

The research made use of quantitative research design. Survey procedure from a value chain perspective was employed to collect data from the respondents. The current study was conducted along Embu and Machakos Mango value chain which were purposively selected under Rockefeller Foundation project development. They were also selected as they are among the best mango producing areas in Kenya. The study made use of a multistage sampling technique. To map the mango value chain, Nairobi was selected purposively since it is the major market for mangoes in Kenya. Selection of wholesalers and retailers used in the sample was through snowball sampling technique in order to be able to trace only traders selling fruits from these two counties. The value chain evaluation began at the wholesale level where the wholesaler would make reference and provide contact of the farmers or brokers that helped them get fruits from the two counties. A total of 48 wholesalers were interviewed. They gave reference to 60 retailers and thirteen brokers. The traders were distributed within Marikiti market, Muthurwa, Kangemi, and Ngara. From the 60, the researcher was able to complete questionnaires from 48 retailers since 12 were non-responsive. The thirteen brokers were distributed as; 7 from Embu, and 6 from Machakos.

Key informant interviews were conducted with all the brokers on the issue of PHLs, prices, and challenges. Later they were all asked to provide a list with names of farmers from whom they purchased fruits from, which was used as the sampling frame. A random sample of 35 framers was selected from each county. The study extended to assessing losses within the county market where Embu market (Marikiti), and Machakos market (Uhuru) were used for the survey. A total of 26 wholesalers were fully interviewed (11 from Embu and 15 from Machakos), and a total of 50 retailers were interviewed from both markets (25 each market).

3.4: Analytical Framework

The current study was anchored on expected utility maximization theory. The utility difference between adopting and not adopting can be denoted as (U_{iA}- U_{iN}) and can be represented by U_i. Therefore, an actor will choose to adopt a technology only if the utility of adoption is greater than not adopting, in this case getting the least losses due to adoption of a loss reduction practices. The theory has been applied widely in research analysing decision making behaviour of respondents (Ouma and Abdulai, 2009; Awotide et.al, 2015). The decision of chain actors to adopt a loss reduction practice as well as the number to take up is based on expected utility. Since the utility is not observable, it can be expressed as a latent variable (Wooldridge, 2010). The decision to adopt or not can be expressed in a double hurdle model as expressed below:

$D_i^* = X_i\beta_i + U_i,\ U_i \sim N\ (0,1)$ ………………………………….. (1)

Where D_i^* is unobserved and is influenced by a range of X independent variables. U_i is the error term. Assuming a normal distribution, the model begins from a probit model that expresses the probability of adoption as:

$P(E_t) = \int_{-\infty}^{Xt\beta} (2\pi)^{-1/2} \exp\ (-Z^2/2)\ dz$ …………………………….. (2)

Where X_t are the values of the independent variables observed at t and β the coefficient. The cumulative distribution function will then be presented as:

$C(Z) = \int_{-\infty}^{z} (2\pi)^{-1/2} \exp(-t/2)\, dt$ …………………………………. (3)

The expression can be simplified further and presented in a density function that resembles a probit model. Hence from equation 2, the probability to adopt shall be expressed as:

$P(Y_t=0|X_t) = C(-X_t'\beta|\delta)$ ……………………………………………. (4)

Where $P(Y_t=0|X_t)$ is the probability that the outcome variable Y is zero (a non-adopter), C is the cumulative distribution function with X_t independent variables and β the coefficients.

The decision to adopt is influenced by a wide range of social-economic, institutional, and farm characteristics and thus the expected utility on the decision to adopt the practices can be denoted as:

$EU_{ad} = \beta_a X_d + \mathcal{E}_{ad}$ …………………………………………………….. (5)

Where EU_{ad} denotes expected utility of adopting loss reduction practices, X represent vector of factors influencing adoption and Ɛ the disturbance term.

The decision not to adopt can be denoted as:

$EU_{nd} = \beta_n X_d + \mathcal{E}_{nd}$ …………………………………………………….. (5)

Where EU_{nd} denotes expected utility of non-adopting loss reduction practices, X represent vector of factors influencing adoption and Ɛ the disturbance term. The error term is assumed to be distributed around zero mean (Green, 2011). And thus, an actor's decision to adopt a loss reduction practice is reliant on $EU_{ad} - EU_{nd} > 0$.

Therefore, the difference in utility is:

$EU_{ad} - EU_{nd} = (\beta_a X_d + \mathcal{E}_{ad}) – (\beta_n X_d + \mathcal{E}_{nd})$

Thus, the difference in expected utility of adoption and non-adoption is the potential factor influencing an actor decision.

3.5: Model Diagnostics

3.5.1: Multicollinearity

Variance inflation factors (VIF) according to Gujarati (2004) should be below 10 in cases where multicollinearity does not persist. The test was undertaken for variables included in both the multiple regression and heck-Poisson models. The mean VIF was 1.40 and 1.39 (see appendix 1 and 2) which was less than the threshold of 10. This suggested absence of multicollinearity and showed suitability of the variables included in both models.

3.5.2: Heteroscedasticity

For a model to meet the basic assumptions of ordinary least squares, the variance should be constant. The Breusch-Pagan test was undertaken making use of "hettest" command in STATA 14 on the multiple regression model to check whether it was statistically significant. If significant this would lead to the use of robust multiple regression with robust standard errors to correct for the problem.

The Breusch-Pagan test for the probit model was conducted to check whether it was statically not significant which would mean that the model was not suffering from heteroscedasticity and hence BLUE.

CHAPTER FOUR

4.0: QUANTIFYING LEVELS OF POST-HARVEST LOSSES ALONG THE MANGO VALUE CHAIN IN EMBU, MACHAKOS AND NAIROBI COUNTIES OF KENYA

4.1: Abstract

Horticulture sector forms a major source of livelihood for many Kenyans and its potential to elevating poverty cannot be underestimated. However, it has continually been threatened by high levels of post-harvest losses estimated at 40%-50% in fruits and vegetables. Losses have been attributed to different causal factors along the chain, although the poor link between production and marketing has made the impact of post-harvest losses (PHLs) not to be fully recognised. Consequently, PH information has remained scarce and unreliable leading to most estimates being based on anecdotal stories. It is thus imperative that information on PHLs is documented based on empirical research, and thus the objective of the current analysis was to quantify the level of PHLs along the mango value chain as well as identify the causes of the losses. The study was conducted along Embu and Machakos mango value chain of Kenya for major mango fruit varieties in Kenya including Apple, Ngowe, Tommy, Kent, and Vandyke. A multistage sampling procedure was employed where total of 98 retailers, 74 wholesalers, 13 brokers, and 70 farmers were interviewed. Primary data was collected using questionnaires and analysed using descriptive statistics in STATA version 14.

Results revealed that major losses were occurring at the farm level (42.1%). The percentage response results revealed that high losses at the farm were due to low price (80%), while at the trader's level, major losses were due to physical injuries (35%). Thus, the study concluded that PHLs is indeed real at all stages of the value chain and reduces welfare of value chain actors. At the farm level, the study recommended that farmers embrace varieties that are best suited in terms of the climatic condition, has less disease prevalence, and best market timing to fetch higher prices and reduce the level of PHLs. The government should make suited improved varieties available to farmers at large quantities and also provide pest and disease control chemicals at affordable prices. At the trader's level, the study recommended adoption of loss reduction technologies to ensure fruits are transported and stored properly including use of bread crates, nestable crates, waxing, and coolers.

KEYWORDS: Post-harvest losses, Mango value chain.

4.2: INTRODUCTION

4.2.1: Background

Horticultural subsector is one of the most vibrant sectors in Kenya and accounts for about 33% of the agricultural GDP (ITC, 2014; KBS, 2019). Vegetables, fruits and cut flowers dominate horticultural sector making it a major foreign exchange earner that contributes up to US $ 1 billion annually (KBS, 2019). However, commodities in the sector face a major challenge of high post-harvest losses both qualitative and quantitative losses due to their perishability nature and disease infestation (Anna et al, 2020; Ahmad et al., 2020; Baltazari et al, 2020; Mengistie et al, 2020; Abayneh and Awoke; 2021). It has been estimated that about 30% of produced fruits are lost before they get to the end consumer (ITC, 2014). With an ultimate goal and attempt to achieve Sustainable Development Goals (SDGs) on poverty reduction, zero hunger, and sustainable production and consumption, a lot has been advanced mainly targeting at increased production. In addition, Collaborative African Agriculture Development program (CAADP) requires a 10% improvement in agriculture. Thus, adoption of different technologies including use of irrigation, high yield varieties, and improved crop husbandry has been on rise. Consequently, over the last 10 years a steady increase in mango production has been witnessed (ITC, 2014; FSD Kenya, 2015; validate report ,2016). However, economic resources are scarce and inelastic, thus considerable attention need to be placed on post-harvest stages to ensure conservation of the food system bearing in mind that PHLs in fruits have been estimated at 40%-50% (McKencie et.al, 2017; Baltazari et al., 2020; Mengistie et al, 2021; Yebirzaf and Esubalew; 2021)

The high level of PHLs have been attributed to poor handling, poor harvesting, lack of appropriate storage, lack of markets, and lack of value addition (Admassu, 2001). In Kenya, high losses have been attributed to poor linkage between production and markets, as well as continued use of traditional production and marketing strategies. Lack of chain actor's awareness on the magnitude as well as ways to reducing the losses has been a major hindrance to reducing losses (Aulakh and Regmi, 2013; HLPE, 2014 and Wakholi et al., 2015; Yebirzaf and Esubalew; 2021). Thus, in order to lower the losses, it is important that the chain actors are fully aware of the magnitude of the losses and their causal factors.

In 2016, fruits in Kenya had a value of KSh 58.7 billion, which accounted for about 27% of the horticultural produce (validate report ,2016). In Kenya, mango ranks second (21%) in terms of production after bananas (ITC, 2014; FSD Kenya, 2015; validate report ,2016). As of 2016, production was recorded at 779 thousand metric tonnes with Machakos and Embu accounting for about 23% and 15% of the total value respectively (validated report, 2016). According to Techno-Serve Kenya (2019), production in Machakos and Embu has increased by about 2% over the years. Mango is produced in about 10 counties within Kenya majorly by small scale farmers and the major varieties include Tommy Atkins, Kent, Van Dyke, Kensignton, Sensation, Haden, Apple, Ngowe, Boribo, Batawi, Pears, Sabro, Dodo, and Sabine (FSD Kenya, 2015). Most of the fruits produced in Kenya are sold in the local market (97%) and the rest (3%) exported (FSD Kenya, 2015). Major export destinations include United Arab Emirates which takes up 56% of the volumes, Saudi Arabia, Bahrain and Qatar. It has been estimated that local demand is likely to double between 2013 and 2022, while export would grow by a fivefold within the same period (Ridolfi et.al, 2018).

In Kenya PHLs have been estimated at 20-30% for cereals and 40%-60% for fruits (validated report, 2016; AU, 2018). It has been estimated that reduction in PHLs alone would raise domestic revenue by 17% (Hegazy, 2013; Amentae, 2017). With an estimated population of 50 million Kenyans and an average per capita consumption of 400 grams of fruit per day (150kg per year), the loss is enough to feed 1 million Kenyans (World Bank, 2017). Reduction in losses would raise food reserves and enhance global good security which is in line with Kenya blueprint Vision 2030. It will also fuel achievement of United Nations Sustainable Development Goal (SDG.12.3) and African Union Agenda 2063 that are both committed to halving PHLs by 2030 and 2023 respectively (FAO, 2019; Tarekegn & Kelem, 2022).

4.2.2: PHL Estimates along the Value Chain

The attempts by different governments to meet food requirement needs and to be able to increase production by 70% to feed the 9 billion population by 2050 requires improved food systems. This will only be realised with reduced losses of the already produced food (Amentae, 2016; McKencie et.al, 2017, AU, 2018; Baltazari et al., 2020). Postharvest losses vary depending on crop, area and season. Research has provided postharvest loss estimates of 30 to 40% and in some instances up to 80% in horticultural produce due to perishability (Aulakh and Regmi, 2013 and Wakholi et al., 2015; Ahmad et al., 2020; Baltazari et al, 2020; Mengistie et al, 2021; Yebirzaf and Esubalew; 2021). Surveys for different crops have been undertaken. For instance, at the farm level, studies by Gangwar, Singh & Singh, (2007) in Pakistan estimated PHLs of 22% in citrus, Leghari (2001), reported that 35% of fruits and vegetables are lost in Pakistan while Srivastava (2002) reported a 40% loss. Bari (2004) recorded a 37% loss at the farm and 36% at marketing. Murthy et.al., 2008 reported a 29% loss level, while Kumar et.al., 2006 estimated a loss level of 60% in onions in Karnataka-India and 57% in potatoes. Umar et.al (2015) estimated Kinnow fruit losses in Pakistan and reported a loss of 32%, 25% and 3% at farm, wholesale and retail levels respectively. Baltazari et al. (2020) in Tanzania reported a loss of 48-60% in fresh mangoes. In Kenya fruit losses have been estimated at 40%-60%. The lower eastern region of Kenya accounted for 37% of the total mango produced of which 13% was reported to be lost in the year 2016 (validated report, 2016).

Most research in loss estimation has widely been limited by sparse information on the actual losses, impact of this losses and their causes especially along the value chain. This has led to most estimates documented being based to anecdotal stories without actual empirical research (Aulakh and Regmi, 2013). They have also been subjective due to unavailable data on losses especially on perishable produce (Ramaswamy, 2014 and HLPE, 2014). National estimates have been based on samples from selected regions despite the fact that losses and their causes are site specific (HLPE, 2014; FAO, 2016; Amentae, 2017). In addition, despite the great contribution fruits and vegetables play in promoting farmers income, country earnings and food and nutrition security, they have not received considerable attention in quantifying the actual losses particularly from the value chain perspective (Chandra and Lontoh, 2010 and Affognon et al., 2015). Traders since buy at the farm gate have not had specialised storage, transport, and packaging technologies which has accelerated PHLs. According to Baltazari et al., (2020) major mango losses occur at harvest, packaging, transport, wholesaling, and retailing stages. These necessitates a need for interventions to lower losses. The current study hence attempts to fill in this knowledge gap by estimating actors perceives quantitative postharvest losses and their causes at each stage of the value chain. Hence assist policy makers, administrators, donors and researcher to move towards loss reduction, improved efficiency, improved food availability, less resource wastage and development of a loss reduction strategy which Kenya lacks.

Hypothesis:

1. Post-harvest losses of mango fruit are high and vary with the stages and regions

4.3: METHODOLOGY

4.3.1: Theoretical Framework

The current study is anchored on the theory of profit maximisation (Liedtke, 2006). The theory alleges that in the short and long-run actors determine inputs, prices, and output levels that lead to high profits. In a perfectly competitive market, prices will be equated to quantity. The neoclassical economics posit that all actors are rational and thus profit maximisers. Thus, at each node of the chain, the actor will mind about their profits. Thus, loss reduction will be ultimate to reducing costs, and increasing revenue. The current study will measure the level of losses and express them as a proportion at each stage along the mango value chain. It is assumed that at each stage, the participants will maximize their profits thus will reduce the proportions lost by handling high volumes of the product since prices are set by the forces of demand and supply. Consequently, earning high revenue with lower costs which increases their profit. All actors will equate MR=MC, handling Q level of mangoes that maximizes their profit.

4.3.2: Study Area

The current study was undertaken in Machakos, Embu and Nairobi counties, Kenya. The two production areas were chosen for their high production with Machakos being the third and Embu the fifth best producers of mangoes in Kenya. Besides, they have a large area coverage under mango production, which is the basic source of income controlling about 40% of their income. Nairobi was chosen as the main mango market in the country.

4.3.3: Research Design and Sampling Procedure

The research made use of quantitative research design. Survey procedure from a value chain perspective was employed to collect data from the respondents. The current study was conducted along Embu, Machakos and Nairobi Mango value chain which were purposively selected under Rockefeller Foundation project development. The study made use of a multistage sampling technique. Respondent at the market level were identified through snowballing, and at the farm level random sampling was applied. This led to a total of 74 wholesalers, 98 retailers, and 70 farmers.

4.3.4: Data Analysis

Negazy (2013) and Ridolfi et.al (2018), in the context of citrus fruits and tomatoes production defined farm level PHL as all fruits left on the ground hence not taken to the market and are already picked. Kumar et.al (2006), defined PHL as losses from production to consumption of a good. HLPE (2014) differentiated food loss and waste with losses along the chain being from production to retail revel. Combining these insights, the current study estimated losses at the farm, wholesale and retail levels. The study made use of averages and percentages to make the estimation with an intent of identifying the stage with the highest level of losses.

The estimation method was adopted from FAO measurements, used by Buyukbay et.al (2011) in their working paper on reducing food losses and wastage, Muchiri (2012) in estimation of economic losses due to fruit fly, Amentae (2016) in estimation of losses in selected crops in Ethiopia and Baltazari et al., (2020) in estimation of losses in mango supply chain in Tanzania. The losses are estimated as shown in equation 1.

$$PHloss\ (Yi) = \frac{total\ quantity\ rejected\ (Yr)}{total\ quantity\ hunlded\ (Yh)}$$ …………………….. Equation 1

Y_i will be the level of PHLs at each stage. It is important to assess for significant differences in loss levels among chain actors of the same level but in different region. Thus, the author made use of T-test analysis to assess for differences in loses at the farm level, and one way ANOVA analysis was adopted to assess for differences at the market as was used by Baltazari et al (2020).

To be able to assess the causes of the losses as depicted by the respondents, they were provided with a list of possible causes including; poor harvest methods, low prices, lack of market, rains, diseases, pests at the farm level. At the wholesale level factors considered included lack of market, poor transport, physical injuries, diseases, and poor harvest timing while at the retail level inadequate storage, lack of value addition together with factors considered at the wholesale level were used (Amentae, 2016; Baltazari et al., 2020). from which they would tick what they perceived to have caused the losses in their fruits. The approach was borrowed from the work of Amentae, (2016) who used it to report the causes of losses, with the most reported becoming the major cause of loss.

4.4: RESULTS AND DISCUSSION

4.4.1: Post-harvest Losses among Farmers in Embu and Machakos Value Chain

As shown on Table 4.1 below, the average total losses in Embu were estimated at 46%. In Machakos, the average loss was 30%. A test of comparison showed that Embu has a significantly high level of losses compared to Machakos ($P<0.01$). In Embu Tommy had the highest loss while Ngowe had the highest loss in Machakos. Kent has lowest level of losses in Embu (35%) which is an indication that it should be embraced. A study by Techno-serve (2018) recommended Kent for Embu for its characteristics based on the climate of the region, and late maturity which means less market flooding. For the case of Machakos, Apple has the highest production and lowest relative losses. This was due to its high demand since it is favoured by the hot climatic conditions that makes it sweet compared to fruits of the other regions. In addition, a study by FSD Kenya (2015) revealed that the timing of apple fruit from Machakos is favourable which reduces its level of losses.

Table 4.1: Losses at the farm level

	Embu(n=35)				**Machakos(n=35)**			
Variety	Average pieces harvest	Average pieces lost	PHL percent (A.L/A.H)		Variety	Average pieces harvest	Average pieces lost	PHL percent (A.L/A.H)
Tommy	18,720	9,106	48.6		Tommy	3,431	848	24.7
Kent	61,705	21,515	34.9		Apple	14,429	3,801	26.3
Vandyke	3,049	1,701	55.8		Ngowe	2,080	793	38.1
Total	83,534	32,321	**46.4**		Total	19,940	5,441	**29.7**
Two-sample t-test comparing means at 99.9% N= 70 $H_o= PHL_E - PHL_M = 0$ T= 3.6 p-value (diff !=0) = 0.003***, p-value (diff > 0) = 0.001***								

Different studies have been conducted for different agricultural commodities around the world. They have indicated a loss level above 30% which is consistent with the current results. For instance, in Pakistan loss levels for citrus fruit has been estimated at 35% by Timmermans et.al (2014), 40% by Kitinoja & Kader (2015), 39% by Bayakchay et.al (2011), and 29% by Murthy et.al. 2008. In India mango losses have been estimated at 45% by Negazy (2013). Kumar et.al (2006) estimated a loss level of 60% in onions at the farm level in Karnataka-India and 57% in potatoes. Kumar et al. (2012) estimated a global food loss of 25% while Ridolfi et al. (2018) estimated a loss of about 30%-40%. McKenzie, 2017 estimated a loss of 40-55% in tomatoes, in a study conducted in India. Umar et.al (2015) estimated Kinnow fruit losses in Pakistan and reported a loss of 32%. Neyazy (2013) indicated that losses in fruits and vegetables were about 25%-40%. Murthay et al. (2007) estimated 58% mango losses in Tanzania at the farm level. Basavaraja et al. (2007) reported 75% losses at the farm level while Sarkar (2011) estimated average losses of 34% in Bangladesh and Baltazari et al., (2020) in Tanzania reported losses in mangoes to be 49% in 2016, and 42% in 2017. In addition, Tarekegn & Kelem, (2022) estimated a farm level mango loss of 40.7% in Ethiopia.

4.4.2: Post-Harvest Losses among Traders along Embu, Machakos and Nairobi Value Chain

Wholesale level

The study revealed as shown on Table 4.2, that losses in Nairobi was highest (10.9%) at the wholesale level, followed by Embu (9.2%), and last was Machakos (8%). However, the losses were not significantly different from each other ($P>0.05$). This is consistent with the work of Ramchandra (2015) who revealed that losses at the trader's level are relatively the same irrespective of the market. In Machakos, Apple has the highest loss levels (10%). This was because of the high production as it is the highly preferred variety. In Embu major losses were on Vandyke (19%) which was due to the low preference by customers compared to other varieties. In Nairobi, Ngowe was less preferred since its less sweet compared to other varieties which led to high losses (17.5%). The farmers have higher losses compared to the traders mainly because the traders will leave the fruits after harvesting for about 3 days, and any fruit showing symptoms of disease will be loss incurred by the farmers. This is owing to the fact that some fruits at harvest will appear good, but after 2 to 3 days those infected will show symptoms mainly of rotting. Therefore, keeping the produce at the farm reduces traders' losses as it increases farmers losses.

Table 4.2: Losses at Wholesalers level

	Nairobi (n=48)				Embu(11)				Machakos (n=15)		
Variety	Average pieces purchase	Average pieces lost	PHL percent (A.L/A.P)		Average pieces purchase	Average pieces lost	PHL percent (A.L/A.P)		Average pieces purchase	Average piece lost	PHL percent (A.L/A.P)
Apple	10,152	924	9.1		4,059	218	5.3		9,040	904	10.0
Tommy	13,454	1,406	10.5		4,285	322	7.5		5,780	340	5.9
Ngowe	4,690	820	17.5		0	0	0.0		3,300	263	8.0
Kent	6,956	449	6.5		6,621	322	4.9		0	0	0.0
Vandyke	0	0	0.0		3,997	764	19.1		0	0	0.0
Total	35,252	3,600	**10.9**		18,962	1,507	**9.2**		18,120	1,510	**8.0**
Test that the means are the same 95% confidence level F(2,71) = 2.19 Prob > F = 0.119											

The results were consistent with the work of Murthy et.al (2009), who found a loss level of 14% in grapes. For bananas, the loss levels were estimated at 17% which again leads to a general estimation level of 5% to 20% losses at the wholesale level. Similarly, Kumar (2012) estimated a loss of 18% and 17% in onions and potatoes in India. Also, Baltazari et al., (2020) reported a loss level of 7.7% in apples in Tanzania.

Retail level

The results revealed as indicated on Table 4.3 that there is a significant difference in losses estimated in the three markets (*P<0.1*). Nairobi has the highest level of losses (18.4%), followed by Embu with 18.3%, and Machakos last with 17.4%. The losses in Nairobi were high due to physical injuries resulting from poor handling as the fruits are offloaded from the truck, they are poorly transported to the retailer shops mainly using sucks, and trolleys, and are poorly packaged in crates. A study by Muchiri (2012) reported that fruits consumption in Kenya is still low. The author argued that consumers have not placed considerable attention to fruits due to the low awareness on their nutritional value. This leads to loss of purchasing attention, which could explain the high level of PHLs. Besides, most of the fruits reaches the retailer shop when they have deteriorated in quality and shape which makes the fruits less appealing to customers. Consequently, they fail to buy the fruits leading to high loss levels.

In the three markets, Apple is highly preferred in Nairobi due to its sweetness but due to high volumes and poor handling still experience high level of losses. Also, it is delicate and spoils fast which fuels the level of PHLs with 18%, 21%, and 10% in Nairobi, Embu and Machakos respectively. Embu has higher losses for the variety as it is less sweet and less appealing which leads to low purchases. Kent although having good characteristics and easy to store, it is less preferred which leads to extensive storage and less buying which also fuel losses with 19% in Nairobi and 21% in Embu. In Embu, Tommy is highly infected by diseases, and pests which leads to high level of losses at the market level (16%). Similar cases were witnessed in Machakos where Tommy was found to be highly infected (21%). It is also less preferred by customers which increases its level of losses.

Table 4.3: Losses at Retail level

	Nairobi (n=48)				**Embu(n=25)**				**Machakos (n=25)**		
Variety	Ave. pieces purchase	Ave pieces lost	PHL percent (A.L/A.P)		Average pieces purchase	Average pieces lost	PHL percent (A.L/A.P)		Average pieces purchase	Average piece lost	PHL percent (A.L/A.P)
Apple	927	171	18.4		235	50	21.3		443	46	10.4
Tommy	1,550	173	11.1		388	63	16.2		245	52	21.2
Ngowe	1,440	363	25.2		0	0	0.0		522	107	20.5
Kent	3,147	591	18.8		406	86	21.2		0	0	0.0
Vandyke	0	0	0.0		554	79	14.3		0	0	0.0
Total	7,064	1388	**18.4**		1,434	278	**18.3**		1,210	205	**17.4**
Test that the means are the same at 90% confidence level F(2,95) = 2.38 Prob > F = 0.098*											

Murthy (2009) estimated a loss of 14% in grapes at this level, and 17% for bananas. Kurmar (2006) found a loss level of 23% and 26% in onions and potatoes respectively. It is evident that at this level losses are between 15% and 20%. However, these results contradict the work of McKencie et.al (2017) who found a loss level of 5% in tomatoes. Baltazari et al., (2020) reported a loss of 19% in apples in 2016, and 25% in 2017 in a study conducted in Tanzania.

4.4.3: Mapping Price Differentials along the Mango Value Chain

The study was extended to the prices along the value chain to give a picture of how much is lost in monetary terms. The study revealed as indicated on Table 4.4 that prices increased as you move along the chain from farm to retail level. Embu has a best price on Kent which could explain the low level of losses on the variety and the high level of losses on Vandyke. In Machakos, apple has the best price (Kenya shillings 5) which could also explain the low loss level at the farm as farmers are able to sell and take care of the variety due to the high compensation. In Nairobi apple sells high at the whole sale and retail level due to their high market demand (KSh 15 and KSh 30 respectively). In Embu Kent is most preferred since it is less infected and has less spoilage level. It also gets to the market a time when there is less competition with other varieties which could explain the high price (KSh 12 and KSh 20 at the wholesale and retail level respectively). In Machakos, apple is the most preferred variety and gets to the market a time when most varieties are not yet ready for sale which gives it a high price (KSh 12 and KSh 20 at wholesale and retail respectively).

Table 4.4: Mean Price differentials at different levels in Kenya shillings (KSh.)

	Farm level		Wholesale level			Retail level		
Variety	***Embu***	***Machakos***	***Nairobi***	***Embu***	***Machakos***	***Nairobi***	***Embu***	***Machakos***
Tommy	3.7	2.5	10.0	8.4	10.0	20.0	15.0	15.0
Kent	4.6	0.0	14.4	11.5	0.0	25.0	20.0	0.0
Vandyke	2.2	0.0	0.0	6.9	0.0	0.0	10.0	0.0
Apple	3.4	5.3	15.9	7.9	12.3	30.0	10.0	20.0
Ngowe	0.0	2.2	12.4	0.0	9.4	20.0	0.0	15.0
Averagep	***3.5***	***3.3***	***13.2***	***8.7***	***10.6***	***23.8***	***13.8***	***16.7***

4.4.4: Mapping Total Post-harvest Losses along the Mango Value Chain

From the analysis it is evident that Kent is best for Embu farmers, and apple for Machakos farmers. Apple and Kent are best for Nairobi market. From figure 4.1 below, in Embu, about 46.4% of mangoes are lost due to PHLs. That translates to a loss of 41,257 mango fruits. This leads to a loss of KSh 142,750 at the farm level in Embu, and if they were to be sold in Nairobi a loss of KSh 543,767 at the wholesale, and KSh 979,854 at the retail level. This would transpire if the same fraction is lost at the different nodes. However, at each node, losses at getting bigger reaching a loss of more than 60% in the different channels. In Machakos about 6,953 fruits are lost at the farm level. This translates to a loss of KSh 23,154 at the farm level, KSh 91,640 at the wholesales and KSh 165,134 at the retail level in Nairobi.

Thus, at the farm level the loss of 4,257 fruits in Embu and 6,953 in Machakos. This translates to a loss of KSh 142, 750 and KSh 23,154 in Embu and Machakos respectively. At the wholesale level about 4,914 fruits are lost in Nairobi, 1,686 in Embu, and 3,037 in Machakos. This translates to KSh 64,767 in Nairobi, KSh 14,618 in Embu, and KSh 32,070 in Machakos. At the retail level about 1,558 pieces are lost in Nairobi, 257 in Embu, and 205 in Machakos. This translates to a loss of KSh 37,003, KSh 3534, and KSh 3417 in Nairobi, Embu and Machakos respectively. This transpires to a total value loss of KSh 2.1 million. We have more than 20 mango producing regions which means that about KSh 40 million are lost each season due to PHLs. In most regions, there are two mango seasons which translates to about KSh 80 million each year which could be used in development strategies as well as help achieve major policies like Kenya big four agenda and vision 2030 goal on food security.

Past reviews have shown that high losses are experienced at the farm level (Kumar, 2006; Murthy, 2015 & McKencie et.al., 2017; Tarekegn & Kelem, 2022). This is consistent with the results of current analysis, where farmers were found to experience the highest level of PHLs. The losses are extending to the other nodes of the chain which calls for policy attention directed at the specific nodes to help deal with the issue of PHLs.

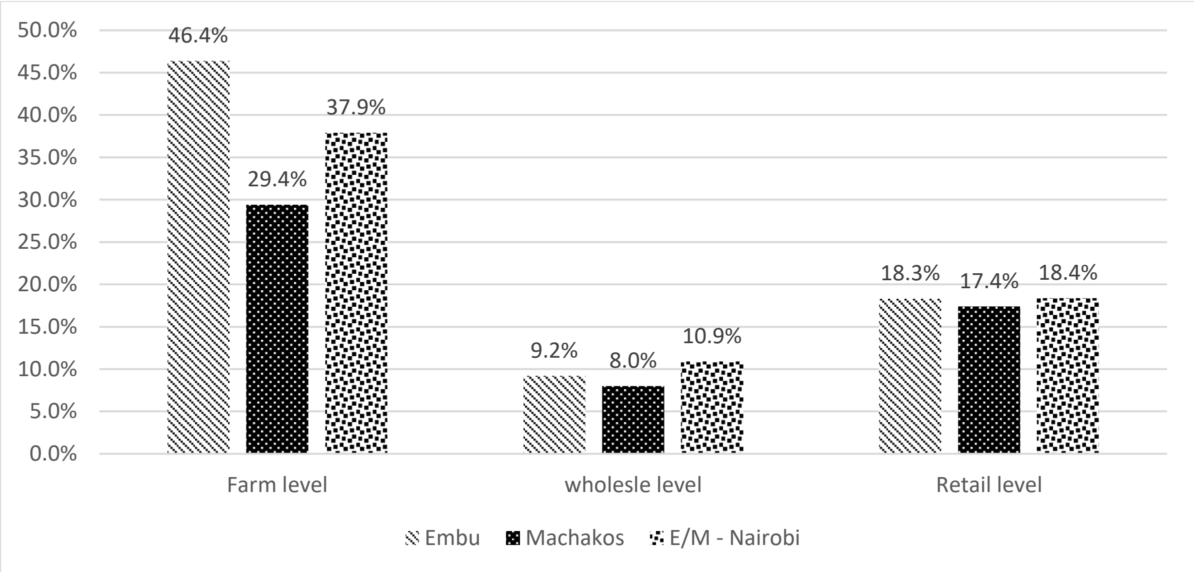

Figure 4.1: Mapping Total PHLs (%) along the chain (author, 2020)

The 80 million value loss to the Kenyan economy could be used to the advantage of development. For instance, this amount could be used to feeding the poor, increasing the actor's income, and they could use the money to adopt loss reduction practices. In addition, PHL reduction increases food availability which would be an essential element to dealing with food insecurity as well as ensuring poverty elevation.

4.4.5: Causes of losses

4.4.5.1: Farm Level

The study following the percentage response analysis presented the results of major causes of the losses as perceived by the farmers. With results on the very high in terms of causing post-harvest losses to the very least was documented. The results showed that in Embu, the major cause of the loss was due to low prices (80%) while in Machakos it was attributed to diseases (77%) as shown on Figure 4.2 below. Further probing to the respondent on to the question showed that the low prices were due to brokers in the chain and thus they were not able to reach to the market. Market flooding also led to the low prices and production of les preferred varieties in Embu as affected by the weather patterns. The high disease incidence was majorly due to fruit fly and black moth. Disease control was a major challenge for the farmers due to the expensive control measures, and the low revenues from the enterprise. The results on diseases as a major causal factor concurs to the work of Tarekegn & Kelem, (2022) who reported diseases and lack of good harvesting technologies as the main causes of loss at farm level.

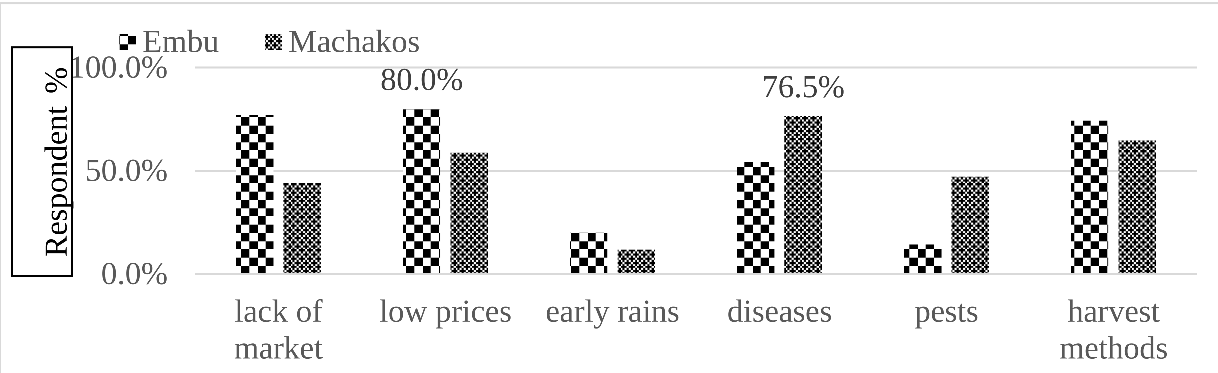

Figure 4.2: Major loss causing factors as perceived by farmers at the farm level

4.4.5.2: Trader's Level

The percentage response results showed that most traders in Nairobi were concerned about physical injuries as shown on Figure 4.3. Of the respondents sampled, 40% of them felt that physical injury was the major cause of the losses that they experienced at this stage. Further review to the question showed that most traders used lorries, pickups, and personal car ('probox') to transport the fruits. They did not use any loss reduction measure, like use of cartons or crates, which made the magnitude of losses escalate. The main method was pouring the fruits on the vehicle which made exposure to injury quite high. Similar cases were with traders from Embu, where about 31% of the respondents attributed their losses to physical injuries which concurs to the work of Baltazari et al., (2020). For Machakos, diseases was a major concern (31%). Most traders were not able to detect infected fruits at the point of purchase mainly as a result of black moth and fruit fly. This was realised at the market which increased the level of losses.

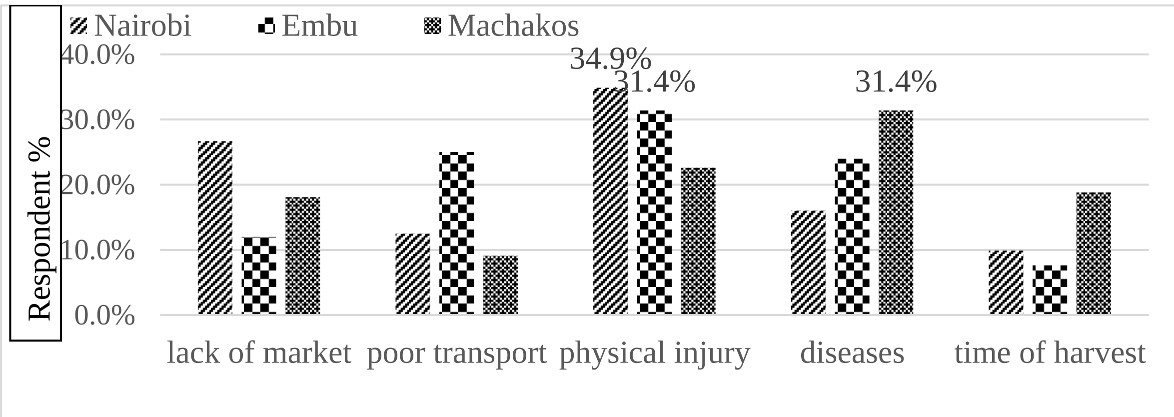

Figure 4.3: Major loss causing factors as perceived by traders at the wholesale level

From the three markets, physical injury was the main concern among retailers as indicated on Figure 4.4. Of the sampled traders 32% from Nairobi, 35% from Embu and 38% from Machakos attributed loses to physical injury. Further investigation to the question revelled that most retailers use carts, wheelbarrows, public vehicles, sacks, and baskets to transport their fruits from the point of purchase. This led to high bruises on the fruits making them less attractive to customers and thus leading to increased loses.

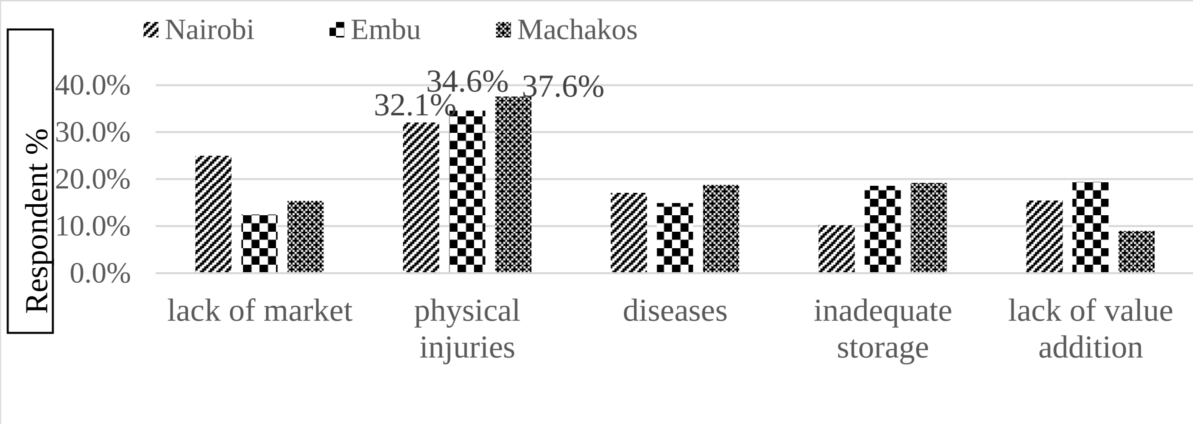

Figure 4.4: Major loss causing factors as perceived by traders at the retail level

CHAPTER FIVE

5.0: ANALYSIS OF DRIVERS OF POSTHARVEST LOSSES ALONG THE MANGO VALUE CHAIN IN EMBU, MACHAKOS AND NAIROBI COUNTIES OF KENYA

5.1: Abstract

In Kenya, the horticultural subsector is one of the most vibrant sectors and account for about 33% of the agricultural GDP. However, the chain has been faced with a lot of challenges among them losses along the value chain estimated at 30% -40%. There has been attempts to reducing losses. However, attempts to move this agenda has been threatened by lack of reliable data on the magnitude of the losses as well as the causal factors. There has been limited empirical data in relation to losses and their causes since they are site and crop specific. Thus, the current study was undertaken with an aim of modelling the driver of PHLs following a value chain perspective.

For the current study, three levels of the value chain were examined: farm, wholesale, and retail levels. A semi-structured questionnaire was used to collect data. The sampling method was multistage in nature resulting to a sample of 70 farmers, 74 wholesalers, and 98 retailers. Data was collected within 8 days, entered into SPSS and analysed using STATA version 14.

The regression analysis results at the farm level indicated that schooling, inadequate storage, ICT, and county type affected PHLs positively. At the wholesale level purchased quantity, inadequate labour, inadequate transport, and ICT had a positive effect while at retail level income and purchased quantities had positive effect.

From the results it was concluded that there are factors that drive PHLs. The major drivers of PHL at the farm include inadequate storage and inappropriate use of ICT. From the results, the study recommended for massive training to farmers so that they can be able to store fruits properly, use appropriate storage technologies as well as be able to use ICT to reduce losses. At the market level, major drivers included inadequate transport, inadequate storage, and

quantities purchased. Thus, recommended for adoption of loss reduction techniques to ensure fruits are transported properly, properly stored and in handled in ample quantities.

5.2: Introduction

Horticultural sector in Kenya is a major foreign exchange earner that contributes up to US $1 billion annually. In 2015, the sub-sector contributed about 2% to the national GDP, about 1% in 2018 and 1.6% in 2020 (Chikez et al, 2021). Therefore, it has the potential to alleviate poverty, provide employment, improve the country food and nutritional security and earn high foreign exchange (HLPE, 2014; Tarekegn & Kelem, 2022). Among the fruits, mangoes rank second in production with 20% after bananas which accounts for 38% (ITC, 2014).

Mango is a highly valued crop in Kenya both in value and production. It ranks second after bananas, and third within East Africa. However, its importance has not been fully actualised due to the high level of postharvest losses along its chain mainly by diseases, perishability, and poor handling (Tarekegn & Kelem, 2022). Different organisations have been calling for conservation of food systems through reduction of PHLs which would increase food availability (HLPE, 2014; Baltazari et al, 2020). In addition, Kenya has been guided by the constitution, CAADP objectives, vision 2030, and big four agenda to ensuring losses are reduced significantly.

FAO (2019) estimates a steady increase in mangoes production in future. For instance, since 1960, production has increased from 400 metric tonnes to 735 thousand metric tonnes in 2016 and 980 metric tonnes in 2019. However, it is estimated that a third of what is produced does not reach the intended user (Adebamiji, 2011 and HLPE, 2014). It is thus important that postharvest practices are given much equal importance as production practices. In addition, it is articulated that as production increases, postharvest losses increase (Kitinoja et al., 2011; Mengistie et al, 2021; Yebirzaf and Esubalew; 2021). This leads to wastage of resources and an ever-widening gap to satisfy demand despite the increased production. Thus, necessitate for proper management of the already produced mangoes to help increase the marketable supply, putting into perspective that developing countries including Kenya are characterized by low technology adoption, poor storage, prevalence of diseases and poor infrastructure as the major causes of losses (Admassu, 2001; Kitinoja et al., 2011; HLPE, 2014, Wakholi et al., 2015; Tarekegn & Kelem, 2022).

Producers engaging in this lucrative venture are moving towards exploiting its potentials (Wakholi et al., 2015). However, the venture has been faced with a lot of challenges. Losses along the value chain are becoming the biggest challenge and therefore, loss reduction could be a strategy to realisation of agricultural potential to meeting the world food and energy needs. In addition, the reduction in PHLs would not only increase food access but would also help in adjusting prices at the market (Mujuka et al., 2020). It will also have positive environmental impacts and will help bridge the production gap of the expectation to feed the 9 billion people by 2050 (HLPE, 2014; Weber & Labaste, 2017; Chala et al., 2019; Farm Africa, 2020). Interventions through the determinants of PHLs would help increase production and food security without production costs (Bart et al., 2021; Tarekegn & Kelem, 2022). Besides, efficiency of the chain is needed making improvements through postharvest research paramount.

Mango is exposed to postharvest losses during harvesting, handling, transportation, storage and marketing (Anna et al, 2020; Ahmad et al., 2020; Baltazari et al, 2020; Yebirzaf and Esubalew; 2021; Tarekegn & Kelem, 2022). However, in most developing countries, the level and the causes have not been fully examined due to the weak linkage between production and marketing systems. PHLs, have been taken as part of the chain thus importance of curtailing it has not been evaluated. According to Amentae (2016) about 20-50% of fruit is lost from production to the table.

Past studies have been limited in scope. They have also been subjective due to unavailable data on losses especially on perishable produce (Ramaswamy, 2014 and HLPE, 2014). National estimates have been based on samples from selected regions despite the fact that losses and their causes are site specific (HLPE, 2014). Besides, the relevance and importance of the factors causing losses vary across different regions, season and commodities (Aulakh and Regmi, 2013; HLPE, 2014, Wakholi et al., 2015; Tarekegn & Kelem, 2022). Therefore, identification of the causes of the losses with regards to specific commodities is a predominant move towards dealing with food losses (HLPE, 2014).

Different studies have been undertaken in different areas to assessing the causes, as well as the magnitude of the losses. However, most studies have concentrated on farm level estimation and ignored what happens in other stages of the value chain. In Kenya there are studies that have been taken to evaluate PHLs (Ambuko et al, 2017; Chikez et al, 2021; Amwoka et al, 2021). However, they have been limited as they have focused on farm level. There has been scanty information with regards to modelling of the factors taking the value chain perspective. There has also been lack of consistency on the methods applied which could lead to differences in the factors that drive the magnitudes of losses. Consequently, this has made policy development to loss reduction difficult. The past studies have been limited in scope with most of them undertaken in mangoes using qualitative factors and thus necessitating use of experiments. In addition, the studies have mostly made use of simple averages with limited modelling capabilities. For instance, Chala et al., (2019) and Tarekegn & Kelem, (2022) although followed the value chain approach, used descriptive statistics. Thus, the current study was undertaken with an objective of modelling the driver of PHL from a value chain perspective.

5.3: Methodology

5.3.1: Conceptual Framework Analysis

Postharvest losses hinder attainment of food security, nutritional security and leads to low economic development (HLPE, 2014). A critical analysis of factors influencing PHLs has been shown to be one way towards dealing with the problem that has remained unchanged along the value chain (Wakholi et al., 2015). Demographic factors, resource and assets, institutional factors, and farm characteristics were hypothesised to have an influence on the level of PHLs which in turn influences technology adoption and mango supply chain actors' livelihood.

The current study thus hypothesises individual characteristics, institutional factors, assets and resources, as well as risk averseness to have significant influence on reduction of PHL as well as adoption of loss reduction practices. Appropriate handling of ICT tools, and loss reduction practices, as well as diversification would help support reduction of losses significantly. The actors would enjoy the benefits of loss reduction since they would be able to preserve their fruits longer, attract higher prices, incomes, and ensure food security.

5.3.2: Description of Variables in the Analysis and their Expected Signs

Choice of hypothesised factors was guided by extensive research into the factors that are associated with causing losses along the value chain. The current study hypothesised that the level of losses was influenced by individual characteristics, institutional factors, assets owned factors, extension factors, and respondent behaviour characteristics.

Age (age of household head) was expected to have a negative sign with respect to influencing the level of losses. Age has been used extensively in literature to depict one experience in production and marketing. A negative association has been found with respect to the level of losses by different researchers (Mariano et.al, 2012; Affognon et al., 2015). A person older is expected to be more experienced in mango production as well as marketing. Consequently, expected to have lower level of losses, The variable was measured in number of years and was expected to have a negative sign with losses.

Level of education: most studies have found level of schooling to have an influence on the loss levels along the commodity value chain. The elite have been found to be more conscious as well as market oriented when it comes to agricultural production. Studies have found a negative association with respect to loss reduction (Imaita, 2013 and Affognon et al., 2015). The variable was measured in the number of years one has been in school and a negative sign was expected with respect to losses.

Household size: the number of persons in a household has widely been used to measure labour supply coming from the family. However, there has been a mix of finding with respect to household size. For instance, Kumur (2006) found a negative association with respect to the level of losses, while Amentae (2017), and found a positive relation. In the current study, it is expected that household size would have a positive or negative sign with respect to loss reduction.

Income: the variable has been used to depict capability. It has thus been associated with ability to undertake interventions as well as ensure losses are minimised. Past studies have found no impact on the level of losses (Harris, 2011; Kassahun, 2014). Howevre, Coker et.al, (2016) and Tarekegn & Kelem, (2022) reported a negative association between one’s endowment and level of PHLs since those with higher incomes are expected to mitigate loss levels. The variable was measured in Kenya Shilling and was expected to have a positive sign.

Land size: the variable was captured in terms of the number of acres one owned as well as cultivated. This variable depicts a household assets ownership and was thus expected to influence loss levels. Past studies have depicted land ownership to have a negative relation to loss reduction (Adepoju, 2014; Imaita, 2013; Tarekegn & Kelem, 2022). This is because as land cultivated increases, production increases and PHLs are expected to increase. The current study thus hypothesised land size to have a positive relation to adoption of loss reduction practices.

Distance: the variable was measured in kilometres from the point of production to the market as well as point of sale. It referred to the respondent's ability to access markets and thus participate in them. It was thus a proxy of endowment and capabilities. Past studies have associate longer distance with increased level of losses (Ramaswamy, 2014; Coker et.al, 2016). The current study thus expected a positive relation with respect to the level of losses.

Sex: most studies have reported that gender influence loss levels. In addition, there has been reported lower women participation on production as well as marketing thus poor handling of produce has been witnessed. Studies have reported a positive association with respect to losses levels taking a dummy variable of 1=male (Vilas et al., 2006; Kiaya, 2014). Thus the current study will hypotheise that when one is a male the level of PHLs are expected to increase.

Information communication technology (ICT): access to information is one of the key elements of reducing transaction costs. Economists have associated transaction cost reduction with efficient resourse allocation as well as need for optimisation. Research has reported a mix results with some studies showing a postive effect on loss while other reporting negative effect (Kumur et.al, 2006; Murthy et.al, 2009). Thus the current study hypothesied ICT to have an indetreminate effect.

Output: the variable was measured as the number of mango pieces the actor handled in the past season. Research has shown that there is a positive relationship between the output produced and handled with the level of PHLs (Coker et.al, 2016; Imaita, 2013; Tarekegn & Kelem, 2022). Most of the studies have reported that as output increase, the level of PHLs increases. Thus, the current study hypothesized that the level of output will have a positive influence on the level of PHLs.

Weather conditions: According to Kassahum (2014) mango harvesting and trading is bets when the weather conditions are favourable. The author defined favourable weather conditions as warm climatic conditions that would allow proper harvesting and increase consumptions. Kiaya (2014) looking at the favourable weather conditions for transportation and storage, reported that warm temperatures of 20^{o}cc to 30^{o}cc are favourable for fruit trading. In the study the author reported that unfavourable weather conditions resulted into high PHL. Thus, the current study borrowing form the findings hypothesised that there would be a positive relationship between unfavourable weather conditions and level of PHLs. The variable was measured as a dummy variable where 1 was unfavourable weather condition during harvest and marketing, 0 otherwise.

Availability of Labour: Labour is a critical factor in facilitating production and marketing. According to Technoserve (2018) lack of labour limits agricultural production and marketing. Amentae (2016) reported that inadequate labour during harvesting and marketing contributes to about 10% to 20% of PHLs. Thus, the current analyses hypothesised that there would be a positive relationship and measured the variable as a dummy variable where 1 would be inadequate labour, 0 otherwise.

Storage adequacy: According to Amentae et al., (2017) inadequate transport and inadequate storage are detrimental to causing high PHLs. In a study undertaken in Ethiopia, the authors reported that due to lack of storage at the farmer level about 10% to 15% of commodity were not taken to the market. In addition, Murthy et al., (2015) reported that storage of fruits and vegetables increases shelf life and improves quality. Thus, the author concluded that lack of storage leads to produce deterioration. Consequently, resulting to increased PHLs. Therefore, the current study hypothesised that there would be a positive relationship between storage inadequacy and level of PHLs.

Experience: the number of years one has been engaged with an enterprice has been related to loss reduction. Thus, for farmers and traders that have been in the enterprice for long are expected to lower their losses significantly. Studies have found a negative relation on experience with respect to loss reduction (Mada et.al, 2014; Adepoju, 2014. The variable was measured in number of years one has been engaged in production or marketing of mangoes and was expected to have a negative sign.

Diversification: studies have shown that diversification has a significant effect on loss levels (Murthy et.al, 2009). In addition, they have been seen to be less careful with the different enterprises which has resulted to higher losses. Thus, the current study expected a positive relation with respect to PHLs.

5.3.3: Study Area

The current research was undertaken in Embu, Machakos, and Nairobi counties of Kenya following a value chain perspective. Specifically, the study was undertaken in Kyeni South ward (Embu) and Masii and Mwala wards (Machakos). The regions were selected as part of yield wise project under Rockefeller Foundation. They were also the best producing areas within the eastern region. In addition, mango production is a basic source of income for people in these areas. Nairobi was selected as the major fruit market in the country.

5.3.4: Research Design

The study made use of quantitative research design and employed the survey strategy. A value chain approach to data collection was employed and a survey technique of farmer household questionnaire was used to collect data from farmers while trader's checklist used at the market level.

5.3.5: Sampling Procedure

The study made use of a multistage sampling technique. Respondent at the market level were identified through snowballing, and at the farm level random sampling was applied. This led to a total of 74 wholesalers, 98 retailers, and 70 farmers.

5.3.6: Data Collection

Data was collected making use of a semi-structured household questionnaire, and traders' checklist. The data was collected through direct personal interviews by the researcher. Pre-test was undertaken with 10 farmers, and 5 wholesalers to assess the appropriateness of the tools and appropriate modifications undertaken before the formal data collection. Although there were difficulties getting all information as some respondents were reluctant, the researcher made efforts to collect real and factual information.

5.3.7: Data Analysis

To assess the drivers of PHLs, a multiple regression analysis was used. Most studies have used descriptive statistics (Murthy et.al, 2007; Murthy et.al, 2009; Mada et.al, 2014 & Ahamed et.al, 2015; Baltazari et al, 2020). They were not able to estimate the influence each single factor would have on PHLs; thus, severity assessment was difficult. Other studies although have used a modelling approach, they have only modelled drivers at the farm level (Timmermans et.al, 2014 and Weber & Labaste, 2017). Only a few studies have made use of the value chain perspective to modelling the drivers in fruits (Umar, 2015 & Amentae, 2016; Tarekegn & Kelem, 2022). The estimation by Umar however was in Kinnow fruit, while Amentae modelled drivers in milk and cereals. Tarekegn & Kelem (2022) although focused on mangoes, the study was in Ethiopia. In this study, an effort was made to model the driver at three major stages including farm, wholesale and retail levels. A multiple regression model was used as shown on equation 2;

$Q_1 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 LnX_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 LnX_8 + \beta_9 LnX_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14} X_{14} + \varepsilon$ ……………...Equation 2

Q_1 = PHLs in Mangoes at the different stages of the value chain

X_1 = dummy variable for gender; (1= male, 0 = female), X_2 = age of respondent in years, X_3 = monthly household income in Kenya shillings, X_4 = age squared of the respondent in years, X_5 = household size, X_6 = distance to the market in kilometres, X_7 = education in years, X_8 = operational landholding in acres, X_9 = total harvested mangoes in pieces, X_{10} = dummy variable for weather (1= unfavourable weather condition during harvest/distribution, 0 = favourable), X_{11}= dummy variable for labour (1= inadequate labour during harvest/distribution, 0 = adequate labour), X_{12} = dummy variable for storage (1= inadequate storage, 0 = adequate storage), X_{13} = dummy for ICT (1= use ICT, 0= no use, X_{14} = dummy for county type (1 Embu County, 2 Machakos County), ε = the disturbance term, β_0 the constant term and β_1 ...... β_{14} the coefficients of the estimates in the model.

5.4: Results and Discussion

5.4.1: Descriptive Statistics

5.4.1.1: Farm Characteristics

As shown in Table 5.1, the average age of the respondent was 59 years in Embu and 57 years in Machakos. Farmers in Machakos and Embu were not different in terms of education attained with 7 years in Embu and 8 years in Machakos. This is an indication that in both regions, most mango grower have attained formal education, with most of them having gone through the primary education. In addition, the study revealed that on average, most families have about 4 members. This is relevant since most heads are above 55 years an indication that most of their children have their own households. The two regions showed a lot of similarities on bases of experience in mango production. Farmers in Embu had an average of 12 years with those in Machakos having an average of 13 years. Both regions were endowed in terms of resources, and Machakos farmers were found to have higher incomes (KSh. 27,236) especially during the mango season compared to those in Embu (KSh. 25,478). This could be attributed to the low prices of mangoes in Embu as compared to Machakos. Besides, Embu has higher level of losses compared to Machakos, which could explain the low level of income. The survey revealed that Machakos had higher adoption of post-harvest loss reduction practices (3) which could explain the low level of loses, and the high fruit prices. Farmers in Machakos have higher land sizes (6 acres) as compared to Embu. This could be attributed to the population sizes since this is a semi-arid region thus less populated as compared to Embu.

Table 5.1: Descriptive statistics of variables used in modelling drivers of PHL at farm level

	Embu	Machakos
Socio-economic characteristics	**Mean (standard deviation)**	**Mean (standard deviation)**
Age of the respondent in years	58.7(14.3)	57.3(13.2)
Number of years in school	7.0(3.1)	8.1(3.7)
Number of household members	4.3(1.9)	4.7(2.1)
Mango production experience in years	11.9(7.0)	12.5(8.0)
Assets/resources		
Monthly household income in Kenya shillings	25,478(2,144)	27,236(2,801)
Average harvest in pieces	83,534(23,264)	19,940(1,937)
Average lost in pieces	32,321(4,170)	5,442(4,215)
Post-harvest practices used	2.4(1.7)	2.8(1.7)
Institutional factors		
Operational landholding cultivated and owned in acres	3.8(1.5)	6.4(1.5)
Distance to the nearest market in kilometres	4.1(2.0)	5.4(2.1)
Total number of mango trees planted	232.8(72.3)	135(85.4)
Number of mango varieties produced/sold	3.3(0.9)	2.9(1.1)
	%	**%**
Gender (1=Male, 0=Female)	68.6	74.3
Post-harvest losses in percentage	46.4	29.4
Access to credit (1=Yes, 0=No)	57.1	34.3
Land leasing (1=Yes, 0=No)	14.3	40.0
Membership to mango production group (1=Yes, 0=No)	85.7	34.3
Inadequate labour (1=Yes, 0=No)	71.4	75.4
Favourable weather conditions (1=Yes, 0=No)	68.6	42.9
Inadequate storage (1=Yes, 0=No)	62.9	57.1
Hired labour (1=Yes, 0=No)	82.9	60.0
Inadequate transport (1=Yes, 0=No)	71.4	65.7
Integrated pest management (1=Yes, 0=No)	34.3	31.4
Extension		
ICT use (1=Yes, 0=No)	74.3	65.7
Attends on-farm demonstrations (1=Yes, 0=No)	54.3	68.6
Respondent behaviour		
Level of diversification in production (1=Yes, 0=No)	62.9	60.0
Organized selling arrangements (1=Yes, 0=No)	8.6	57.1

The two regions were found to have differences with regards to the number of productive trees with Embu farmers having more trees (233). This could be due to the favourable weather conditions in the region. However, they were found to experience higher level of postharvest losses which were due to high disease incidence as the area favours diseases causing organisms like fruit fly. In both regions, a high percentage of the respondents were males with 69% in Embu and 74% in Machakos. Besides, most households were headed by males, and the land tenure rights associated with customary relations would help explain their high representation. Most farmers in Embu had access to credit, but did not get involved in land leasing which could be due to the high population and small parcels of land. Inadequate labour and lack of adequate storage were the major problems faced by farmers. Besides, they also had issues with the transport network. Although most of them were involved in fruit diversification (63% and 60% for Embu and Machakos respectively), and used ICT tools, they were less engaged in organised selling. This would help explain the high postharvest loses due to lack of market access. The results especially on high use of hired labour, low education, and respondents aged more than 40 years concurs with the work of Tarekegn & Kelem, (2022).

5.4.1.2: Trader's Characteristics

The results revealed as indicated on Table 5.2 that most traders in the local market aged of 44 years while in Nairobi the average age was 41years. It was also revealed that most traders have acquired formal education with those in the local market and Nairobi having reached an average primary and secondary education respectively. Nairobi traders were found to be more experienced in mango trading with an average of 11 years in business while those in the local county had an average of 7 years. This is indicative of a fair experience to be able to understand major issues in the mango value chain. On average, traders in the local market were able to make Kenya shillings KSh. 163,990 compared to Kenya shillings KSh. 464,428 that was earned by traders in Nairobi. This is indicative of price differentials in the two markets. In addition, it could be due to the high number of purchases made by Nairobi traders with an average of

35,252 pieces and an average PHL of 13%. Both areas have an average adopted practices of 3 loss reduction strategies which could explain the lower loss levels compared to farmers.

Traders in the local market were mainly involved with 3 mango varieties while those in Nairobi were engaged with 4 varieties. While most traders in the local market were females (69%), most traders in Nairobi were males accounting 58%. It was also revealed that most respondents did not have access to credit with only 35% and 38% in local and Nairobi counties respectively having access. The study revealed that most respondents were not satisfied with the weather conditions during the mango season and attributed the poor weather, inadequate storage and inadequate labour to the high losses. In addition, most of them claimed that transport was a major concern with 50% and 83% having a negative response in the local and Nairobi market respectively. However, most traders like would be expected did not diversify with only 31% and 35% from local and Nairobi being engaged with more than one fruit.

Table 5.2: Descriptive statistics of variables used in modelling drivers of PHL at wholesale level

	Embu/Machakos (n=26)	Nairobi (n=48)
Socio-economic characteristics	**Mean (standard deviation)**	**Mean (standard deviation)**
Age of the respondent in years	43.8(10.0)	40.6(10.5)
Number of years in school	7.9(3.8)	9.4(4.4)
Mango trading experience in years	7.0(5.2)	10.6(4.4)
Assets/resources		
Monthly household income in Kenya shillings	163,990(159,222)	464,428(709,604)
Average purchase in pieces	18,477(17,411)	35,252(21,668)
Average lost in pieces	1,501(887)	3,600(1,941)
Post-harvest practices used	2.7(2.0)	2.8(2.4)
Institutional factors		
Distance to the nearest market in kilometres	7.3(3.1)	143.4(109.9)
Number of mango varieties sold	3.1(1.1)	3.6(1.5)
	%	**%**
Gender (1=Male, 0=Female)	30.8	58.3
County	35.1	64.9
Post-harvest loss in percentage	8.6	10.9
Access to credit (1=Yes, 0=No)	34.6	37.5
Membership to mango marketing group (1=Yes, 0=No)	73.1	83.3
Inadequate labour (1=Yes, 0=No)	88.5	75.0
Favourable weather conditions (1=Yes, 0=No)	61.5	72.9
Inadequate storage (1=Yes, 0=No)	88.5	60.4
Hired labour (1=Yes, 0=No)	84.6	72.9
Inadequate transport (1=Yes, 0=No)	50.0	83.3
Integrated pest management (1=Yes, 0=No)	30.8	33.3
Extension		
ICT use (1=Yes, 0=No)	80.8	39.6
Respondent behaviour		
Diversification in fruit trading (1=Yes, 0=No)	30.8	35.4
Organized selling arrangements (1=Yes, 0=No)	50.0	77.1

The study revealed that most retailers have acquired a formal education with an average of primary school education (4 years of schooling) as shown on Table 5.3. They have trading experience of 10 years in the county level and 9 years in Nairobi. In Nairobi, retailers earn higher income (KSh. 20,609) which could be due to the higher prices and more fruit demand in the area. In addition, they make purchases of more fruits, with an average of 7,064 pieces. Besides, they have been able to adopt more PHL reduction practices with an average of 2 practices, which would explain the lower losses and the higher incomes.

Table 5.3: Descriptive statistics of variables used in modelling drivers of PHL at Retail level

	Embu/Machakos (n=50)	Nairobi (n=48)
Socio-economic characteristics	**Mean (standard deviation)**	**Mean (standard deviation)**
Age of the respondent in years	38.8(10.3)	35.6(7.0)
Number of years in school	4.1(1.7)	4.3(2.4)
Mango trading experience in years	9.9(3.5)	8.6(3.6)
Assets/resources		
Monthly household income in Kenya shillings	15,073(18,155)	20,609(22,347)
Average purchase in pieces	1,323(915)	7,064(2,453)
Average lost in pieces	242(330)	1,388(661)
Post-harvest practices used	1.9(2.3)	2.8(2.3)
Institutional factors		
Distance to the nearest market in kilometres	0.5(0.2)	0.7(0.9)
Number of mango varieties sold	2.6(1.1)	3.0(2.0)
	%	**%**
Gender (1=Male, 0=Female)	38.0	39.2
County	51.0	49.0
Post-harvest loss in percentage	17.9	18.4
Access to credit (1=Yes, 0=No)	44.6	53.2
Membership to mango marketing group (1=Yes, 0=No)	36.1	22.2
Inadequate labour (1=Yes, 0=No)	64.6	52.9
Favourable weather conditions (1=Yes, 0=No)	58.3	46.2
Inadequate storage (1=Yes, 0=No)	50.2	56.9
Hired labour (1=Yes, 0=No)	82.0	88.2
Inadequate transport (1=Yes, 0=No)	48.0	69.8
Integrated pest management (1=Yes, 0=No)	8.6	11.8
Extension		
ICT use (1=Yes, 0=No)	54.0	43.1
Respondent behaviour		
Diversification in production (1=Yes, 0=No)	70.3	74.1
Organized selling arrangements (1=Yes, 0=No)	22.6	39.8

Most of the retailers in the local market do not have access to credit (55%). In both markets, there is little engagement in organised selling (23% at the county level and 40% in Nairobi). Most of the respondents especially in Nairobi claimed that transport was inadequate (70%), storage was inadequate (57%), and labour was not adequate (53%) which they attributed to have cost them a lot in terms of increased level of losses.

5.4.2: Modelling Drivers of Post-harvest Losses at Different Value Chain Stages

5.4.2.1: At Farmer Level

Results from the model as shown on Table 5.4 indicated that there are different drivers that could be attributed to losses in the two regions. In Embu, as the size of the household increase, losses would increase by 5%. This would be so because most families have concentrated on child education and thus, they would not be used to reduce PHL. In Machakos, as the farmer distance to the market increases, losses would increase by 3%. This would be attributed to lack of buyers due to the high cost of getting the fruits.

Table 5.4: Multiple regression results at the farmer level

OLS estimates using robust standard errors	Pooled	Embu	Machakos
Explanatory variable			
Intercept	0.905 (0.564)	-0.308 (0.987)	1.101 (0.739)
Sex; 1=Male, 0=Female (x_1)	-0.037 (0.061)	-0.116 (0.141)	-0.053 (0.088)
Age of the respondent in years (x_2)	0.009 (0.013)	0.038 (0.033)	0.008 (0.013)
Log monthly household income in KSh. (x_3)	-0.015 (0.024)	-0.032 (0.036)	-0.065 (0.050)
Age squared of the respondent in years (x_4)	-0.023** (0.011)	-0.056* (0.030)	-0.006 (0.011)
House hold size (x_5)	0.003 (0.012)	0.054* (0.031)	-0.020 (0.014)
Distance to the nearest market in KMs (x_6)	0.010 (0.016)	0.001 (0.026)	0.031** (0.015)
Respondent number of years in school (x_7)	0.016** (0.007)	0.028* (0.015)	0.003 (0.010)
Log land holding in acres (x_8)	-0.009 (0.028)	-0.099 (0.559)	0.021 (0.032)
Log output in pieces (x_9)	-0.096*** (0.023)	-0.082* (0.047)	-0.069* (0.036)
Unfavourable weather; 1=Yes, 0=No (x_{10})	0.026 (0.054)	0.241** (0.122)	0.030 (0.049)
Inadequate labour; 1=Yes, 0=No (x_{11})	0.022 (0.057)	0.130* (0.092)	0.009 (0.601)
Inadequate storage; 1=Yes, 0=No (x_{12})	0.076* (0.044)	0.212** (0.104)	0.104** (0.046)
ICT use; 1=Yes, 0=No (x_{13})	0.081* (0.048)	0.042 (0.116)	0.131** (0.058)
County type; 1=Embu, 2=Machakos (x_{14})	0.354*** (0.070)	0.000 (0.000)	0.000 (0.000)
R^2	0.524	0.554	0.613
F-value	5.8***	5.9***	5.7***
N	70	35	35
***1% level, **5% level, *10% level			

The study revealed on Table 5.4 that as the years of schooling increase, PHL would increase by 2% in the pooled data and by 3% in Embu. This was because, most people did not concentrate on agricultural production. The study results are contrary to the work of Amentae (2016) who revealed that as the production increases, the level of PHLs increases. Wholly, for the two regions, it would be by 10%, in Embu it would reduce by 8%, and in Machakos by 7%.

The reduction was attributed to higher technological adoption by farmers with higher output levels. In addition, brokers tend to visit more to farmers with higher production to meet their output levels, which leads to lower loses. Embu farmers were affected by the rains that led to high losses. Harvesting when weather is unfavourable would lead to a 24% more increase in losses compared to production and marketing during favourable weather condition. Labour was also a major issue in Embu and would lead to a 16% more loss if it was inadequate compared to when there is adequate labour during harvesting. As alleged by Techno Serve (2018), Embu fruits come in late when most other areas are productive, thus competition for labour is high. Storage was a major issue in both regions. Inadequate storage would lead to increased PHLs by 8% for both, 21% in Embu and 10% in Machakos. Besides, farmers were found to make use of ICT tools for other social and economic activities which were not related to PHL reduction. Thus, although there is high use of ICT tools, the level of losses would be expected to increase by 8% for both, and by 13% in Machakos. The results indicated that Embu has higher losses and if a farmer was from Embu, they would experience losses of 35% more.

5.4.2.2: At the Traders Level

Wholesale level

The regression results as shown o Table 5.5 indicated that the overall model was fit with ability to explaining 67% of variability in PHLs. The results indicated that as the age of the respondent increased, PHLs would reduce by 1%. According to Umar (2015) as the age of a respondent increases, they get more experienced and are able to reduce losses. However, squaring the age variable would lead to increase in PHLs by 7%. This means that in the future as people age grow in twofold, their PHL levels will increase. According to Murthy (2015), as one ages, to a certain level, they start exhibiting diminishing scales and thus will incur higher losses. According to HELP (2014), the more the fruits that are being handled at each stage of the value chain, the more the portion of lost fruits increases. The results indicate that as one increased the amount purchased, PHLs would increase by 14%. Similar results to the work of Wakholi et. al (2015), were reported with respect to labour adequacy. The study revealed that in cases labour was inadequate, losses would increase by 3%, while inadequate transport would lead to increased losses by 2%. In addition, Mada et.al (2014) argued that distance was a major factor in determining the magnitude of losses traders experienced. Making use of the county variable, the current analysis revealed that being a trader in the local market would reduce losses by 8%. This would be related to the distances as well as the lower level of fruits that they handle.

Table 5.5: Multiple regression results at the Wholesale level

OLS estimates using robust standard errors	**Coefficient**	**Standard error**	**t-value**
Explanatory variable			
Intercept	0.641***	0.127	5.1
Age of the respondent in years (x_1)	-0.007**	0.003	-2.1
Log monthly household income in KSh. (x_2)	-0.003	0.006	-0.6
Age squared of the respondent (x_3)	0.066**	0.032	2.1
Experience in years (x_4)	-0.019*	0.011	-1.7
Fruits diversification; 1=Yes, 0=No (x_5)	0.008	0.013	0.6
Log pieces purchased (x_6)	0.137***	0.012	11.1
Favourable weather; 1=Yes, 0=No (x_7)	-0.013	0.010	-0.7
Inadequate labour 1=Yes, 0=No (x_8)	0.030*	0.018	1.7
Inadequate storage; 1=Yes, 0=No (x_9)	0.009	0.013	0.7
Inadequate transport; 1=Yes, 0=No (x_{10})	0.024*	0.013	1.9
ICT use 1=Yes, 0=No (x_{11})	0.019*	0.010	1.9
County type; 1=Machakos/Embu, 2=Nairobi (x_{12})	-0.080***	0.015	-5.3
R^2	0.670		
F-value	21.8***		
N	74		

Retail Level

The results from the retailers as shown on Table 5.6 indicted that the model was fit and was able to explain about 52% of the variability in PHLs. The estimation showed that as the income of the trader's increases, the level of PHLs would increase by 2%. This was contrary to the work of Mada et.al (2016). Further probing revealed that the traders did not make efforts towards loss reduction. Thus, their income was for other activities apart from reducing losses, which led to high losses. The study also revealed that as the traders got more experienced, their losses would reduce by 4%. This was because as they got more experienced, they were handling the fruits better, and were also able to select quality fruits at the purchase point. The traders who purchased more fruits would increase PHL by 9% mainly because as the purchased produce increased, there was a tendency of the traders poorly handling the commodity that let to physical injuries. This result concurs to the work of Umar (2015) who reported an increase in losses as purchases increased. The results also revealed that storage was a major issue, and if it was inadequate PHL would increase by 10%. According to Amentae (2017) storage of fruits and vegetable is critical as it influences the fruit deterioration rate as well as its shelf life. Thus, poor storage made fruits exposed to deterioration and rotting. If a trader was in the local county, their losses would reduce by 19%.

Table 5.6: Multiple regression results at the retail level

OLS estimates using robust standard errors	**Coefficient**	**Standard error**	**t-value**
Explanatory variable			
Intercept	1.203**	0.457	2.6
Age of the respondent in years (x_1)	-0.003	0.007	-0.5
Log monthly household income in KSh. (x_2)	0.015*	0.008	1.9
Age squared of the respondent (x_3)	0.068	0.094	0.7
Trading experience in years (x_4)	-0.040*	0.023	-1.7
Fruits diversification; 1=Yes, 0=No (x5)	0.034	0.028	1.2
Log pieces purchased (x_6)	0.090**	0.040	2.3
Favourable weather; 1=Yes, 0=No (x_7)	-0.040	0.030	-1.1
Inadequate labour; 1=Yes, 0=No (x_8)	0.055*	0.029	1.9
Inadequate storage; 1=Yes, 0=No (x_9)	0.098***	0.036	2.7
Inadequate transport; 1=Yes, 0=No (x_{10})	0.028	0.021	1.3
ICT use; 1=Yes, 0=No (x_{11})	-0.005	0.028	-0.2
County type; 1=Machakos/Embu, 2=Nairobi (x_{12})	-0.189**	0.081	-2.3
R^2	0.524		
F-value	11.9***		
N	98		

CHAPTER SIX

6.0: FACTORS INFLUENCING ADOPTION OF POSTHARVEST LOSS-REDUCTION PRACTICES ALONG THE MANGO VALUE CHAIN IN EMBU, MACHAKOS, AND NAIROBI COUNTIES OF KENYA

6.1: Abstract

Postharvest losses reduce farmers earnings from the enterprises substantially, government earnings and poses threats to a country's food security. In an attempt to reduce the losses, technologies such as the crates, cartons, charcoal coolers, cool bot cold storage, solar driers, brick coolers, field packing, plastic bags, pole pickers, nets, pallets, and hand picking have been advanced. However, they have gained limited success, less attention by the chain actors and have remained largely underutilised. Thus, the current study was undertaken with an aim of assessing the factors that influence adoption of loss reduction practices along the mango value chain in Embu and Machakos counties of Kenya.

The study empirically assessed factors responsible for influencing adoption choices among actors in the mango value chain. A multistage sampling technique was employed, where a total of 74 wholesalers were selected and interviewed, 13 brokers, 98 retailers, and 70 farmers.

The results revealed that in Embu, farmers preferred stick and bag for harvesting while respondents from Machakos preferred hand picking. At the wholesale level, respondents from Nairobi preferred use of cartons, while in Embu and Machakos they preferred use of shades. Retailers preferred use of shades and peeling. The Heckpoisson model at the farm level showed that those with access to credit were less likely to adopt more practices. However, farmers experiencing high PHL were more likely to adopt loss reduction practices, and were more likely to embrace a number of practices. At the wholesale level, traders who were engaged in organized selling were more likely to adopt one or more loss reduction practices. However, PHL increase led to a less likelihood of adopting one or multiple practices. At the retailer's level, the results indicated that retailers in the local market (Embu/Machakos) were less likely to adopt loss reduction practices. On the other hand, those experienced in mango trading were more likely to adopt the practices, and increase in PHLs led to a more likelihood of adopting loss reduction practices. More probing to the low adoption rates with regards to different activities revealed that the major limiting factors to adoption at the farm were lack of involvement in harvesting and high labour requirement. At the trader's level, wholesalers claimed the major limiting factors were reduced quantities, lack of stores, and time wastage. Retailers claimed lack of stores, and reduced quantities handled to be the major limiting factors. Hence, the study concluded that the technologies preferred were those that are cost effective, could reduce PHL, and could help increase the respondent's income. It was evident that as PHL increase, the likelihood of adopting loss reduction practices increased. In addition, with high PHLs, respondents were willing to adopt multiple loss reduction practices at the different levels of the value chain. The study also asserted that most farmers were not involved in harvesting. Wholesalers were majorly involved, and feared of reduced quantities and lack of stores. Similar fears were witnessed at the retail level. Therefore, from the findings, the researcher recommended for detailed research and upgrading of the available loss reduction practices to ensure they allow chain actors meet their objective of profit maximization as well as meet the need for PHL reduction.

Key words: post-harvest loss reduction practices, post-harvest losses, and mango

6.2: Introduction

Agricultural sector has been transforming as preferences and diet needs changes. Rising concerns of nutritional security has led to a shift from staples to fruits and vegetables in developing countries. Thus, making fruit production and marketing a crucial part of chain actor's income, and important for food and nutritional security. It also offers an opportunity to achieving multiple SDGs specifically SDG 1 on no poverty, and SDG 2 on zero hunger. In addition, the changes have led to a changed perception on the importance and need to have fruits in human diet (Bonabana-wabbi & Taylor, 2002; Ali, 2012). Consequently, raised importance of reducing wastes occurring along the fruit value chain, and need for improved technological innovations and adoption to help preserve quantity and quality of the highly perishable product. In addition, greater coordination on how they are produced, marketed and consumed is needed to achieve nutritional needs, market competitiveness and stability of prices. A lot of initiatives have been advanced towards increased production and productivity. However, as the production increases, the levels of PHL have remained relatively high. This calls for a need to manage the food system in order to conserve the already produced fruits which will increase food availability which is in line with the vision 2030 agenda, the constitution of Kenya Cap.318, and SDG 12 on sustainable production and consumption.

This category of products is highly perishable and thus need care and proper coordination from production, marketing, and consumption. Their importance cannot be underestimated for the high contribution to the Kenyan agricultural GDP of about 33% and as a major foreign exchange earner of about US $ 1 billion annually. Unfortunately, high postharvest losses have been one of the major problems along the fruit and vegetable value chains. The losses have been estimated at about 30% which has greatly undermined the food system. This has led to reduced incomes, inability to produce market-oriented produces and reduced safety of fruits appropriate for consumption. To feed the estimated 9 billion persons by 2050 considering that the production systems as well as resources have been challenged by the effect of climate change, better approaches to create a linkage between production and marketing in order to increase food availability, income, and ensure environmental conservation are needed as guided by SDG 12 on sustainable production and consumption (Ali, 2012). This makes loss reduction at the PH stages crucial.

In this regards the government of Kenya has been partnering with different organization to ensure losses are reduced especially in fruits which are characterized by high perishability. For instance, Cowpeas storage project and fruits hub by Purdue University led to improved farmers income. AGRA through a yam improvement project moved towards an objective to double farmers' incomes and ensure food security. USAID project on hybrid seeds and postharvest storage is expected to lead to 50% increase in yields and 20% decrease in losses (Rockefeller Foundation, 2015). Rockefeller Foundation has established an initiative to reduce post harvest losses even with the existence of green revolution. Different technologies have been advanced to help reduce losses along the mango value chain. The technologies have been advanced to assist in different practices including harvesting, after harvest handling, storage, transportation, and sale point handling. They include: crates, cartons, charcoal coolers, cool bot cold storage, solar driers, brick coolers, field packing, plastic bags, pole pickers, nets, pallets, and hand picking (Imaita, 2013 and Affognon et al., 2015)

Fruits production has been receiving increased attention in the recent past. It has been estimated that use of appropriate postharvest practices helps reduce quantitative and qualitative losses (Kader, 2001; Murthy et.al, 2009 & Ali, 2012). Due to increased production practices, mango fruit ranks second in terms of production and as of 2016, production was recorded at 779 thousand metric tons with Machakos and Embu accounting for 23% and 3% of the total production respectively (validated report, 2016). According to Techno-serve Kenya (2019), Machakos and Embu production has increased by about 2%. Domestic consumption has remained high with only about 3% of mangoes being exported. However, it has been estimated that about 25%-45% is lost before it gets to the end user. As a result, a lot has been done in development of harvest, handling, storage and transportation practices that would reduce the losses along the value chain (Mariano et.al, 2012). Adoption of such practices have provided opportunities for farmers and marketers to reduce losses. However, adoption of this practices has been faced with a lot of challenges with some practices failing to be adopted completely and those adopted have not been continually used which deters research and development objectives. This has been so, as most production and marketing of fruits in Kenya is undertaken by small scale actors employing traditional farming and marketing methods (FSD Kenya, 2015 & Techno serve, 2019).

Adoption is more effective in terms of research depending on how much is used. However, social, institutional, environmental and economic factors affect the ability and willingness of people to adopt and use those technologies. Recently, conducted research in the field include the work of Ali, 2012; Mariano et.al, 2012; FSD Kenya, 2015; Amentae, 2016, McKencie et.al. 2017 & Techno serve 2019. Through the developments, the researchers have particularly focused on factors influencing adoption at the farm level with little engagement on other nodes of the value chain. Understanding of challenge actor's face during adoption and use are prerequisite to high adoption. This has not been given attention in literature despite its importance in offering a solution for adoption and loss reduction. They have also made use of binary and poison models in their estimation which results to sample selection bias if undertaken as independent steps. Due to these past limitations in literature, the current study was thus undertaken to determine the factors affecting adoption of loss reduction practices and challenges actors have been facing through the adoption process following a value chain perspective.

6.3: Theoretical Framework

Adoption of agricultural technologies is mainly based on optimization of the outcome, in this case minimization of postharvest losses. The adopter is faced with a budget constraint and competition of technologies for use in other enterprises and hence need to maximize their utility function subject to the constraints (Cragg, 2016). Thus, the current study will be anchored on expected utility maximization theory. The utility difference between adopting and not adopting can be denoted as (U_{iA}- U_{iN}) and can be represented by U_i. Therefore, an actor will choose to adopt a technology only if the utility of adoption is greater than not adopting, in this case getting the least losses due to adoption of a loss reduction practices. The decision to adopt or not can be expressed in a double hurdle model. The decision to adopt is influenced by a wide range of social-economic, institutional, and farm characteristics and thus the expected utility on the decision to adopt the practices can be denoted as:

$EU_{adopt} = \beta_i X_j + \varepsilon_{ij}$ ………………………………………………………….. (1)

Where EU_{adopt} denotes expected utility of adopting loss reduction practices, X represent vector of factors influencing adoption and ε the disturbance term.

Since the actors will first make a decision to adopt the loss reduction practices, and then chose how many practices to use, the model becomes a double handle model. However, at the first stage there is the option of adoption or no adoption, and those people who don’t adopt automatically have a zero as the optimal number of practices they would be using. This makes it impossible to make use of the Heckman double handle model that assumes the number of practices to be continuous since our outcome variable becomes a count. Thus, at the first stage the probit model is used and a Poisson model is adopted at the second stage giving rise to a heck-Poisson model. According to Cameron& Kolstoe (2020) the model estimates the two models simultaneously thus eliminating the bias caused by sample selection. The model was used to assess the factors that influence adoption and the intensity of use of loss reduction practices. The model is estimated in two parts including the selection (probit) and the outcome model (Poisson).

The selection model is specified as

$S_i = \{^{1, \text{ if } X_i\beta + \varepsilon_{1i} > 0, \; 0 \text{ if otherwise}}$

Where S_i is 1 if the actor adopted a loss reduction practice, and 0 if they did not adopt a loss reduction practice. X*i* are the vector variables and the ε_{1i} is the error term.

The number of practices adopted being the count model is estimated making use of the Poisson model specified as

$Y_i = X_i\beta + \varepsilon_{2i}$...(2)

Where Y_i denotes the number of practices taken by the actors, ε_{2i} the error term for the count model, and β the coefficients of the vector variables.

6.4: Methodology

6.4.1: Study Area

The current study was undertaken in Machakos, Embu and Nairobi counties, Kenya. The two production areas were chosen for their high production with Machakos being the third and Embu the fifth best producers of mangoes in Kenya. Besides, they have a large area coverage under mango production, which is the basic source of income controlling about 40% of their income. Nairobi was chosen as the main mango market in the country.

6.4.2: Sampling Procedure and Data Collection

The research made use of quantitative research design. Survey procedure from a value chain perspective was employed to collect data from the respondents. The current study was conducted along Embu, Machakos and Nairobi Mango value chain which were purposively selected under Rockefeller Foundation project development. The study made use of a multistage sampling technique. Respondent at the market level were identified through snowballing, and at the farm level random sampling was applied. This led to a total of 74 wholesalers, 98 retailers, and 70 farmers.

6.4.3: Data Analysis

In order to achieve the objective, an empirical model was applied. The dependent variable was count in nature as it was the number of techniques used at each stage of the value chain. To assess the rate and the intensity of adoption, a two-stage model is required. The social economic factors and institutional factors were the independent variables. This allowed for use of a probit at the first stage and poison model at the second stage to assess probability of adoption. Other methods that have been applied in assessing the determinants of technological adoption include probit, logit and ordinary least squares (Ali, 2012). However, in the current case, the actors had a probability of using more than one technique at a time as proposed and applied by Mariano et.al (2012) & McKencie et.al (2017). Past studies have used the two models separately, thus have not been able to deal with selection bias (Hodges, 2013; Affognon et al., 2015; Coker et al., 2016). Thus, the current study made use of a heck-Poisson model that solves the problem. The model is generally linear and run the selection (probit), and outcome (Poisson) models concurrently using the algorithmic associations following the normal and Poisson distribution respectively. The model makes use of maximum likelihood in estimation and expresses the log of the expected dependent outcome as follows;

$\log \lambda_i = \alpha + \beta_i X_i + \varepsilon_i$

The commonly used model for count data is Poisson Regression Model (PRM). Count data are non-normal and hence not well estimated by OLS regression (Maddala, 2001). The PRM is commonly used where response variables have a non-negative integer with no excess zero counts than would be expected (Greene, 2008). It also assumes that the conditional mean equals the conditional variance of the distribution. The model follows a Poisson distribution density and will be presented as:

$$\mathbf{P}(\boldsymbol{Yi}) = \frac{\mu^{y} e^{-\mu}}{Y!} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where Y is a non-negative integer

μ = E(Y) is the expected value of Y (mean) and is expected to also equal the variance

Log of μ as a function of X is therefore presented as:

$$\mu = e^{\sum_{j=1}^{k} \beta_j X_{ji}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

This equation can be rewritten as:

$$\boldsymbol{ln}(\boldsymbol{\mu}) = \sum_{j=1}^{k} \beta_j X_{ji} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

And further expanded as

$$\boldsymbol{ln}(\boldsymbol{\mu}) = \boldsymbol{\beta_0} + \boldsymbol{\beta_j X_i} + \ldots + \boldsymbol{\beta_k X_K} + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

Where the βs represent the regression coefficients to be estimated, Xs will be the hypothesized explanatory variables and **Ɛ** will be the error term

The model allows for estimation using discrete dependent variable that is non-negative and based on probability of occurrence and results are presented in relative rate. The log linear form allows for expression of the relationship between the dependent and independent variable. However, the model assumes that variance and mean are equal which in most cases does not apply (Woodridge, 2012). To solve the over dispersion problem, negative binomial model is applied. The estimates of both models in the current study were not different and thus the Poisson model was used for the final estimation.

Research has widely made use of dichotomist choice models which requires assessment of whether a technology is adopted or not. This has led to use of logit and probit models for estimation of the probability of influence of the social economic variables on technological adoption. These models are able to give a description of farmers who would use a specific technology as applied by Mariano et.al (2012). Other approaches involve use of count models where the dependent variable is treated as a portfolio selection with a package of items. This has widely been used where farmers have a variety of technologies to choose from. These methods are more encompassing despite the fact that it treats all technologies as equally important which is not the case in reality. Despite having this shortcoming, the models are best for assessing intensity in situations of multiple technologies and thus applied in the current analysis.

6.4.4: Description of variables used in assessing use and intensity of use of loss-reduction practices

Age (age of household head) was expected to have a positive sign with respect to adoption of loss reduction practices. Age has been used extensively in literature to depict one experience in production and marketing. Studies has found a positive relationship in relation to adoption of technologies (Awotide et.al, 2015; Amentae, 2016). A person older is expected to be more experienced in mango production as well as marketing. Consequently, expected to have lower level of losses, as well having more possibility of adopting loss reduction practices. The variable was measured in number of years and was expected to have a positive sign with adoption of loss reduction practices.

Level of education: most studies have found level of schooling to have an influence on adoption of technologies. The elite have been found to be more conscious as well as market oriented when it comes to agricultural production. They have been seen to take up preventive measures with ease due to their flexibility to understanding the technologies (Imaita, 2013 and Affognon et al., 2015). A positive association has been reported with respect to adoption of loss reduction practices (Komuro, 2007; Kassahun, 2014). The variable was measured in the number of years one has been in school and a positive sign with respect to adoption of loss reduction practices.

Household size: the number of persons in a household has widely been used to measure labour supply coming from the family. However, there has been a mix of finding with respect to household size. For instance, Kumur (2006) found a negative association with respect to the level of losses, while Amentae (2017), and found a positive relation. When it comes to adoption of loss reduction practices studies have found a negative association (Bonabana-wabbi and Taylor, 2002; Imaita, 2013). In the current study, it is expected that household size would have a negative sign with respect to adoption of loss reduction practices.

Experience: the number of years one has been engaged with an enterprice has been related to vasteness in undertaking the practice. Thus, for farmers and traders that have been in the enterprice for long are expected to lower their losses significantly as well as adopt practices that would help them maintain the losses at lower level. However, contrary to expection, a lot of studies have found a negative relation with respect to adoption of technologies (Murthy et.al, 2009; Taiwo & Bart-Plange, 2016). The variable was measured in number of years one has been engaged in production or marketing of mangoes and was expected to have a negative sign.

Income: the variable has been used to depict capability. It has thus been associated with ability to undertake interventions as well as ensure losses are minimised. Past studies have found no impact on the level of losses but a positive influence on adoption of agricultural technologies (Harris, 2011; Kassahun, 2014). The variable was measured in Kenya Shilling and was expected to have a positive sign.

Land size: the variable was captured in terms of the number of acres one owned as well as cultivated. This variable depicts a household assets ownership and was thus expected to influence adoption of loss reduction practices. Past studies have depicted land ownership as wealth and thus was expected to have positive relation to adoption of technologies (Adepoju, 2014). The current study thus hypothesised land size to have a positive relation to adoption of loss reduction practices.

Sex: most studies have reported that gender influence adoption of technologies. In addition, there has been reported lower women participation on production as well as marketing. Studies have reported a negative association with respect to adoption and reduction of losses (Vilas et al., 2006; Kiaya, 2014).

Access to credit: finacial support and capabilities are widely seen as an empowernment tool to agricultural participants. However, a lot of studies contrary to the expected, have reported a negative association with respect to adoption of technlogies (Gangwar, Singh & Singh, 2007; Wakholi et.al, 2015). There has been a lot of reports arguing that a lot of financial support is diverted to other practices. Thereofore, there is an expected a negative association with respect to adoption of loss reduction practices.

Group membership: households networks to social groups has been seen as a key element to social capital development that has directly been linked to increased market access. The groups have also been associated with creating a condusive environment that enables people to learn and gain new skills. Thus, has been associated with increased adoption of new practices that have positive efffect on their livelihoods. Thus, households associated with groups are expected to have lowers losses, and a higher incentive to adoption of new practices.

Information communication technology (ICT): access to information is one of the key elements of reducing transaction costs. Economists have associated transaction cost reduction with efficient resourse allocation as well as need for optimisation. Research has reported a mix results with some studies showing a postive effect on adoption while other reporting negative effect (Kumur et.al, 2006; Murthy et.al, 2009). Thus the current study hypothesied ICT to have an indetreminate effect.

Diversification: studies have shown that diversification has a significant effect on loss reduction. Research has reported that persons engaged in diversification of enterprises, are not good adopter due to the high demand (Murthy et.al, 2009). In addition, they have been seen to be less careful with the different enterprises which has resulted to higher losses. Thus, the current study expected a negative relation with respect to adoption of loss reduction practices.

Organised selling: arrangements and contractual agreements have been cited as the best means of maximizing profits as well as reducing costs. Participants have been able to link to high end markets and thus reducing PHLs significantly. They have also had a need to quality preservation which has been associated with adoption of technologies that ensure proper handling and delivery (Ouma and Abdulai, 2009; Awotide et.al, 2015). Thus, persons engaged in organised selling are expect to have a positive association with adoption of loss reduction practices.

Post-harvest losses: there are different varieties that actors deal with which have differences in their level of perishability and need for handling. Research has shown that most varieties are perishable, and require proper handling for them to reduce losses (Mengistie et al, 2020; Abayneh and Awoke; 2021). According to Anna et al (2020) adoption of loss reduction practices helps in handling and movement of the perishable produce from one point to the other, hence adoption would be associated with lower losses. Thus, the current study hypothesized that there would be a negative association between PHLs and adoption of loss reduction practices.

6.5: Results and Discussion

6.5.1: Analysis of Characteristics of Adopters and Non-adopters

6.5.1.1: Farm Level

At the different nodes of the value chain, actors were classified as adopters and non-adopters. An adopter was a respondent using one or more of the loss reduction techniques while a non-adopter did not make use of any of the loss reduction techniques. Adoption was assessed at different points including farm, wholesale and retail levels.

From the analysis as shown on Table 6.1, Embu farmers showed a significant difference with regards to education acquired by the two groups. Adopters had a significantly higher level of education which could explain their vast advantage in understanding use and need to adopt. It was also found that they had smaller family sizes compared to the non-adopters. According to Ali (2012), as production increases, PHLs increases. With this regard, farmers with more production were expected to adopt more practices. The current study concurred with the results as it was revealed that adopters had more production, lost more fruits on average, and thus adopted about 3 loss reduction practices. The study also revealed that PHLs were significantly high among the non-adopters (59%) compared to the adopters (39%). Adopters were more associated with production groups (66%) which was an opener for increased adoption and loss reduction. Adopters were also seen to embrace use of ICT (60%) and were engaged in diversified production (54%). However, their major complain was on bases of inadequate transport which they associated to the high losses.

Table 6.1: descriptive statistics of factors used in assessing the factors influencing adoption of loss reduction practices for Embu farmers

Variable	Pooled Mean(S.D)	Adopters Mean(S.D)	Non-adopters Mean(S.D)	t-value
Social economic characteristics				
Age of the respondent in years	58.7(14.3)	58.1(15.5)	60.9(9.6)	0.5
Number of years in school	6.9(3.1)	7.6(2.9)	5.0(2.9)	-2.2**
Number of household members	4.3(1.9)	4.11(1.8)	5.1(2.2)	1.7*
Experience of the respondent in years	11.9(6.9)	12(6.9)	11.8(7.4)	-0.1
Assets/resources				
Monthly household income in Kenya shillings	25478(2144)	27991(2403)	16996(1128)	-1.2
Average harvest in pieces	83534(23264)	92497(13769)	53350(4549)	1.8*
Average lost in pieces	32321(4170)	37179(2660)	22675(1384)	1.8*
Post-harvest practices used	2.4(1.7)	2.9(1.8)	0.00(0.00)	-2.4**
Institutional factors				
Operational landholding cultivated in acres	3.8(1.5)	4.0(2.1)	2.9(1.0)	-0.5
Total number of mango trees planted	232.8(72.3)	260.1(99.9)	140.8(16.8)	-1.1
Number of mango varieties produced/sold	3.3(0.9)	3.4(0.9)	3(0.6)	1.2
	Mean(S.D)	**n=27 percentage**	**n=8 percentage**	**z-value**
Gender (1=Male, 0=Female)	0.7(0.3)	48.6 28.6	20 2.9	1.8* 1.7*
Post-harvest loss in percentage	**49.4(22.9)**	39.4(24.2)	59.4(19.4)	2.0**
Access to credit (1=Yes, 0=No)	0.6(0.3)	45.7	11.4	1.3
Land leasing (1=Yes, 0=No)	0.1(0.4)	11.4	2.9	0.3
Membership to mango production group (1=Yes, 0=No)	0.9(0.4)	65.7	30	2.1**
Hired labour (1=Yes, 0=No)	0.8(0.4)	17.1	65.7	-2.1**
Integrated pest management (1=Yes, 0=No)	0.3(0.2)	22.9	11.4	0.5
Extension				
ICT use (1=Yes, 0=No)	0.7(0.4)	60	14.3	1.8*
Attends on-farm demonstrations (1=Yes, 0=No)	0.5(0.5)	40	14.3	1.1
Respondent behaviour				
Diversification in production (1=Yes, 0=No)	0.6(0.5)	54.3	8.6	1.7*
Organized selling arrangements (1=Yes, 0=No)	0.1(0.2)	8.6	0	1.0

The analysis in Machakos contrary to Embu revealed as shown on Table 6.2 that adopter had more household members. In addition, they were found to have been more experienced in mango production (19%). Besides, the adopter took about 3 loss reduction practices. Non-adopters on the other hand were found to loss significantly higher level of mangoes. In addition, they had more productive trees compared to the adopters. This could explain the significantly higher level of PHLs (44%). However, adopters were faced with a major challenge of labor (54%), storage (43%), and transportation (57%) which could explain the high losses despite adopting loss reduction practices. The adopters diversified their production much more than the non-adopters (49%).

Table 6.2: descriptive statistics of factors used in assessing the factors influencing adoption of loss reduction practices for Machakos farmers

	Pooled Mean(S.D)	Adopters Mean(S.D)	Non-adopters Mean(S.D)	t-value
Social economic characteristics				
Age of the respondent in years	57.3(13.2)	57.9(13.9)	54.8(10.2)	-0.5
Number of years in school	8.1(3.7)	7.3(3.6)	9.1(2.9)	0.8
Number of household members	4.7(2.1)	5.0(2.0)	3.2(1.5)	-2.1**
Experience of the respondent in years	12.5(7.9)	18.8(10.2)	11.2(6.8)	2.3**
Assets/resources				
Monthly household income in Kenya shillings	27236(2801)	27838(2310)	24324(1947)	-0.4
Average harvest in pieces	19940(1937)	18196(1435)	28366(3541)	1.2
Average lost in pieces	5442(4215)	4827(3617)	8413(5899)	1.9**
Post-harvest practices used	2.8(1.7)	3.3(1.6)	0(0)	-3.2***
Institutional factors				
Operational landholding cultivated in acres	6.4(1.5)	6.9(2.6)	4.1(1.9)	-0.5
Total number of mango trees planted	135(85.4)	109.1(17.4)	260.3(35.9)	1.9*
Number of mango varieties produced/sold	2.9(1.1)	2.9(1.1)	3(0.9)	0.1
	Pooled Mean(S.D)	**Adopters n=29 Percentage**	**Non' n=6 percentage**	**z-value**
Gender (1=Male, 0=Female)	0.7(0.4)	62.9 20	44.4 5.7	0.7 0.3
Post-harvest loss in percentage	**34.9(19.1)**	32.9(17.9)	44.1(23.2)	1.7*
Access to credit (1=Yes, 0=No)	0.3(0.5)	25.7	8.6	0.6
Land leasing (1=Yes, 0=No)	0.4(0.5)	37.1	2.9	0.7
Membership to mango production group (1=Yes, 0=No)	0.3(0.2)	20	14.3	0.3
Integrated pest management (1=Yes, 0=No)	0.3(0.5)	20	11.4	0.4
Extension				
ICT use (1=Yes, 0=No)	0.7(0.5)	51.4	14.3	1.7*
Respondent behaviour				
Diversification in production (1=Yes, 0=No)	0.6(0.5)	48.6	11.4	1.9*
Organized selling arrangements (1=Yes, 0=No)	0.6(0.5)	45.7	11.4	1.3

6.5.1.2: Wholesale Level

The study revealed as shown on Table 6.3 that traders that had adopted loss reduction technologies had lower incomes which would be attributed to the lower number of pieces handled. According to Mariano et.al (2012), PHL reduction practices reduce quantities handled significantly and do not prevent one from making losses as some are actually pre-harvest related problems. However, their losses were lower (15%) which means that the practices were effective. The study also revealed existence of a significant difference between males and females that had adopted with both categories showing a significantly high adoption and more so among males. In addition, most of the wholesalers made use of hired labour (77%), where about 86% of those using hired labour adopted loss reduction practices to reduce the magnitudes of PHLs.

Table 6.3: descriptive statistics of factors used in assessing the factors influencing adoption of loss reduction practices for wholesalers

Trader characteristics-whole sale	Pooled Mean(S.D)	Adopters Mean(S.D)	Non-adopters Mean(S.D)	t-value
Social-economic characteristics				
Age of the respondent in years	41.7(10.4)	41.5(11.1)	42.7(11.1)	0.4
Number of years in school	8.9(4.2)	8.9(4.3)	8.3(4.1)	0.5
Experience of the respondent in years	9.3(4.9)	9.6(5.1)	7.8(4.1)	-1.2
Assets/resources				
monthly household income in Kenya shillings	358,869(594,753)	259,084(197,441)	827,088(129824)	3.3***
Average purchase in pieces	29,358(21,718)	29,133(20,835)	30,506(26,402)	0.2
Average lost in pieces	2,961(1,944)	2872(1982)	3428(1742)	1.9*
Post-harvest practices used	3.3(2.0)	3.3(2.0)	0(0)	5.9***
Institutional factors				
Number of mango varieties sold	3.4(1.4)	3.4(1.4)	3.3(1.2)	0.3
	% pooled	***Adopters N=61***	***Non-adopter N=13***	
Gender (1=Male, 0=Female)	0.5(0.5)	72.2 57.4	27.8 7.9	2.4** 1.7*
County (1=Local, 0=Nairobi)	0.7(0.5)	81.3	18.8	3.7***
Post-harvest loss in percentage	13.9(10.6)	11.8(9.1)	14.5(7.9)	1.7*
Access to credit (1=Yes, 0=No)	0.4(0.5)	37.8	30.7	0.3
Extension				
ICT use (1=Yes, 0=No)	0.5(0.5)	54.1	53.9	0.01
Respondent behaviour				
diversification in trading (1=Yes, 0=No)	0.3(0.5)	32.8	38.5	0.2
organized selling arrangements (1=Yes, 0=No)	0.7(0.5)	67.2	69.2	0.1

6.5.1.3: Retail Level

At the retail level, the study revealed as shown on Table 6.4 that both groups had formal education. Adopters had about 3 post-harvest loss reduction practices, and thus their losses were significantly lower (20%) compared to the non-adopters (23%). The study also revealed that adoption rate within the local county were significantly lower which could explain the high level of PHLs. In addition, about 71% of the respondents were in social groups, although only about 20% adopted a loss reduction practice. Also, despite having a relatively high number of respondents using ICT tools (49%), use of the tools among the adopters was significantly low (47%). Among the respondents that diversified their fruits, only 42% adopted a practice compared to 51% who failed to adopt. However, most of the people in organized selling adopted loss reduction practices (68%).

Table 6.4: descriptive statistics of factors used in assessing the factors influencing adoption of loss reduction practices for retailers

Trader characteristics-retailers	Pooled Mean(S.D)	Adopters Mean(S.D)	Non-adopters Mean(S.D)	t-value
Social-economic characteristics				
Age of the respondent in years	37.2(8.9)	37.2(8.7)	37.3(10.0)	0.1
Number of years in school	4.2(2.1)	3.9(2.1)	5.1(1.9)	2.1***
Experience of the respondent in years	9.2(3.6)	9.2(3.5)	9.3(4.1)	0.2
Assets/resources				
monthly household income in Kenya shillings	17,868(20,468)	18,056(19,945)	17,111(23,007)	0.3
Average purchase in pieces	4,222(3,426)	4,468(3,501)	3,225(2,982)	1.8*
Average lost in pieces	821(777)	847(797)	714(697)	0.7
Post-harvest practices used	2.4(2.3)	2.9(2.2)	0(0)	5.9***
Institutional factors				
Number of mango varieties sold	2.8(1.6)	2.9(1.7)	2.5(1.3)	1.1
	% pooled	***Adopters (64)***	***Non-adopters (34)***	
Gender (1=Male, 0=Female)	0.4(0.5)	35.8 64.2	25.6 16.1	0.8 0.8
County (1=Local, 0=Nairobi)	0.5(0.5)	45.7	65	1.9*
Post-harvest loss in percentage	19.8(11.6)	18.9(11.1)	22.97(13.37)	1.8*
access to credit (1=Yes, 0=No)	0.2(0.3)	20.4	12.5	0.8
Membership to mango production group (1=Yes, 0=No)	0.7(0.3)	19.6	77.8	2.8***
Extension				
ICT use (1=Yes, 0=No)	0.5(0.5)	46.5	55	1.7*
Respondent behaviour				
diversification in production (1=Yes, 0=No)	0.5(0.4)	41.5	51.3	1.9**
organized selling arrangements (1=Yes, 0=No)	0.7(0.3)	67.8	22.2	3.6***

6.6: Distribution of Loss Reduction Practices

6.6.1: At the Farm Level

The analysis revealed that at different levels, different loss reduction practices were given preference. According to Ali (2012), the practices are better adopted together since each practice has a purpose. Murthy & Naidu (2015) reported that use of at least 5 practices together help reduce PHLs significantly. The current study as shown on Figure 6.1 concurred to the results as it was found that the different practices were used with different level of preference. In Embu, use of stick with a bag was used more while hand picking was the most embraced practice among Machakos farmers. In the sample, about 20% and 17% of the respondents did not adopt any practice from Embu and Machakos respectively.

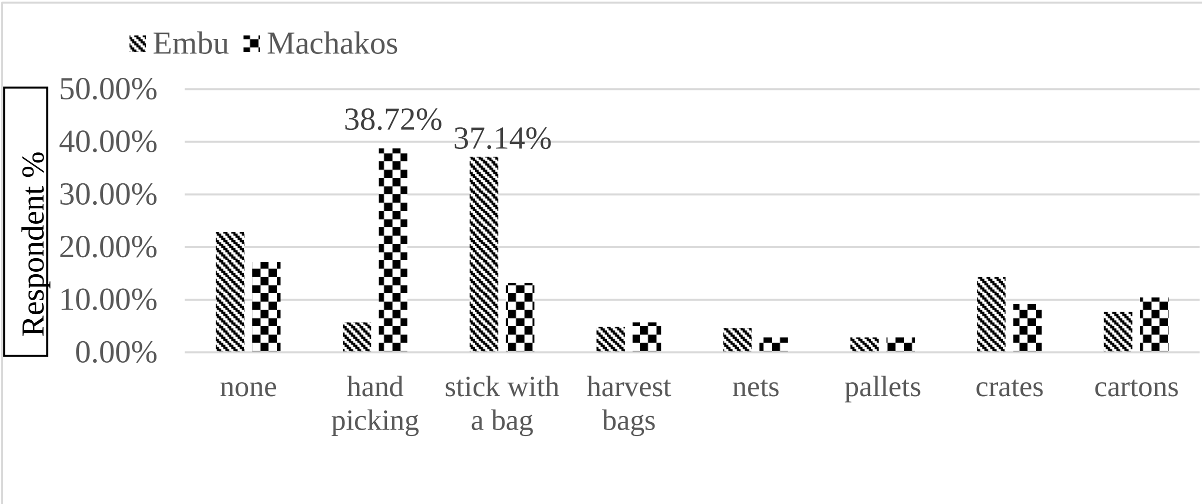

Figure 6.1: Post-harvest loss reduction practices at the farm level

6.6.2: At the Trader's Level

At the wholesale level, the study revealed as shown on Figure 6.2 that use of cartons was in great favour among wholesalers from Nairobi (27%). In machakos and Embu, Shades were used more with 38% of the respondents from embu being in favour of the technlogy while 29% favoured use of the practice in Machakos. About 15%, 10% and 11% did not adopt any loss reduction practice from Nairobi, Embu, and Machakos respectively.

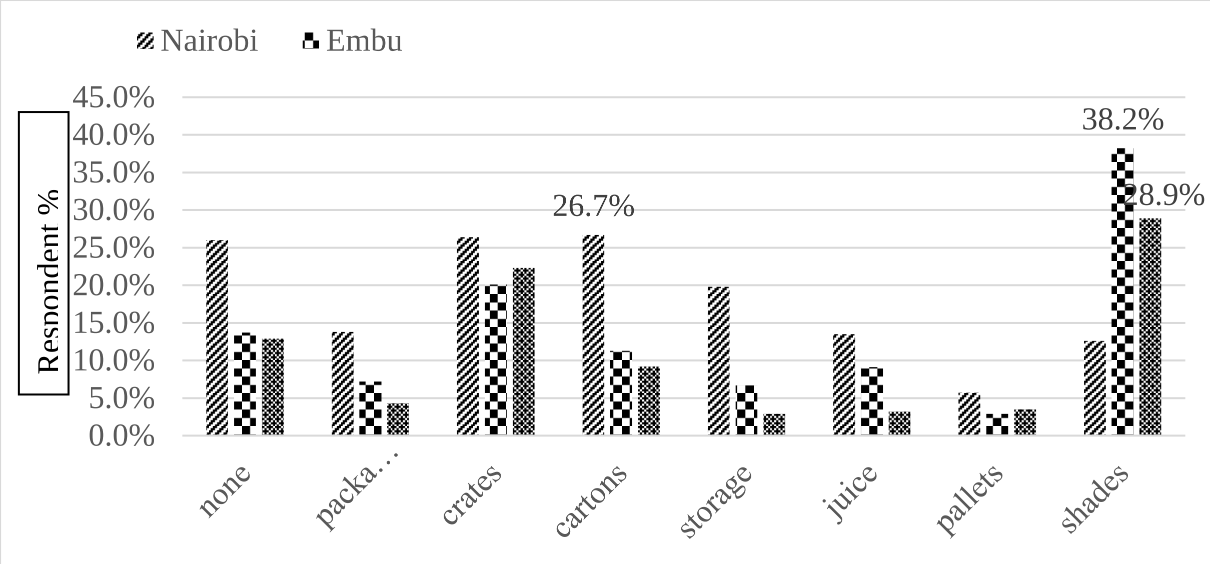

Figure 6.2: Post-harvest loss reduction practices at the wholesale level

At the retail level, the analysis revealed as shown on Figure 6.3 that about 26%, 14%, and 13% from Nairobi, Embu and Machakos did not adopt any of the loss reduction practices. Among the retailers, those from Nairobi and Machakos used peeling as a most preferred loss reduction practice, while in Embu shades were most preferred (38%).

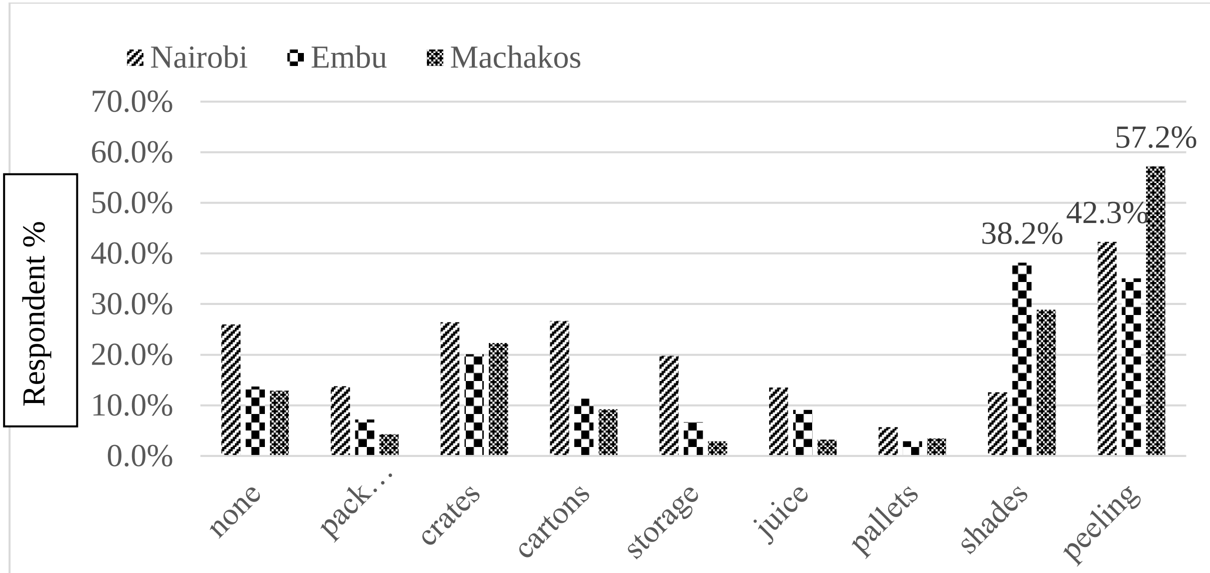

Figure 6.3: Post-harvest loss reduction practices at the retail level

6.7: Factors influencing use and intensity of use of loss reduction practices

6.7.1: At the Farm Level

Model 1 as shown on Table 6.5 indicated that use of integrated pest management increased the probability of adopting postharvest loss reduction practices by 29%. Increased mango types produced increases the likelihood of adoption by 8%. According to Murthy & Naidu (2015), some varieties require more care while handling than others. Techno serve (2019) asserted that apples are a delicate variety, thus required adoption of more loss reduction practices. Contrary to the work of Ali (2012), the study reported a negative effect with regards to group membership. It was revealed that members belonging to a production group were 25% less likely to adopt the loss reduction practices compared to those that were not in production groups. These results were anchored to the fact that most people although associated with groups, they were not able to realize high sales. They also considered most of the practices slow, time wasting, and tedious. With regards to adoption based on geographical location, farmers in Machakos were found to be 12% more likely to adopt the loss reduction practices compared to those in Embu. This is in line with the work of Techno serve (2019) since this region has high production of Apples which are more delicate and require proper handling if losses were to be reduced significantly.

The number of productive trees although did not affect the rate of adoption, it had an impact on the intensity of the loss reduction practices that were adopted. The study reported that persons with more productive trees were 1% more likely to adopt more than one practice or have a combination of diverse practices. These results were contrary to those of Kader (2001), and Amentae (2016) who reported a negative adoption behaviour as the number of trees increased. In addition, people with access to credit were found to be 40% less likely to take more loss reduction practices compared to those who did not have credit. According to Murthy

& Naidu (2015) most framers divert their credit hence are left with no resources to commit for loss reduction.

As for model 2 and 3 as shown on Table 6.5, specific county results indicated that Embu and Machakos framers that used IPM (Integrated Pest Management) techniques were 38% and 39% more likely to adopt loss reduction practices compared to those who did not embrace IPM. In Embu, those making use of hired labour were 53% less likely to adopt loss reduction practice compared to those who used own family labour. In addition, farmers with more productive trees in Embu were more likely to adopt loss reduction practices by 1%. They were also likely to adopt a multiple number of practices by 1%. However, in Machakos, those with more productive trees were 1% less likely to adopt loss reduction practices. The difference was due to the fact that Machakos farmers had more delicate fruit types and the loss reduction practices were seen to be cumbersome. In both counties, those who had acquired formal education were more likely to adopt loss reduction practices though education did not affect the number of practices they would undertake. In Embu, the level of PHLs influenced the number of adopted practices by 26%, while in Machakos it had an effect on the choice to adopt and the number of practices adopted. Thus, farmers experiencing high PHL were more likely to adopt loss reduction practices by 4% and were 19% more likely to embrace a number of practices.

Table 6.5: Factors influencing adoption of loss reduction practices at wholesale level

Models	Model 1: Pooled				Model 2: Embu				Model 3: Machakos			
Explanatory variables	**Selection (Probit)**		**Outcome (Poisson)**		**Selection (Probit)**		**Outcome (Poisson)**		**Selection (Probit)**		**Outcome (Poisson)**	
Variables	*Coef.*	*Marginal effect*	*Coef*	*Marginal effect*	*Coef.*	*Marginal effect*	*Coef.*	*Marginal effect*	*Coef.*	*Marginal effect*	*Coef.*	*Marginal effect*
Intercept	-0.58 (2.69)	-	0.826 (1.28)	-	-5.04** (1.94)	-	-1.95 (1.89)	-	3.29*** (1.05)	-	1.54** (0.61)	-
mango types grown (x_1)	0.38* (0.21)	0.076	-	-	0.88** (0.42)	0.126	-	-	-0.24 (0.31)	-0.01	-	-
Log land in acres (x_2)	0.07 (0.23)	0.042	-	-	0.166 (0.35)	0.723	-	-	0.20 (0.34)	0.024	-	-
Use of IPM dummy (x3)	1.21** (0.48)	0.288	-	-	1.75* (0.95)	0.375	-	-	1.86** (0.86)	0.387	-	-
Group dummy (x_4)	-1.42** (0.55)	-0.253	-	-	-0.42 (0.99)	-0.049	-	-	-0.46 (0.94)	-0.050	-	-
extension dummy (x_5)	0.69 (0.54)	0.164	-	-	0.02 (0.80)	0.003	-	-	-0.03 (0.68)	-0.004	-	-
Count:1machakos (x_6)	0.76** (0.38)	0.122	-	-	-	-	-	-	-	-	-	-
hired labor dummy (x_7)	0.46 (0.51)	0.099	-0.24 (0.2)	-0.073	-1.91* (1.06)	-0.528	-0.57 (0.58)	-1.32	-1.26 (0.83)	-0.07	-0.51** (0.25)	-1.97
productive trees (x_8)	0.01 (0.01)	0.029	0.06* (0.03)	0.002	0.002** (0.001)	0.0003	0.02** (0.01)	0.005	-0.05*** (0.01)	-0.007	-0.01 (0.01)	-0.003
years of school (x_9)	0.07 (0.07)	0.015	0.04 (0.03)	0.113	0.30*** (0.09)	0.043	-0.10 (0.09)	-0.235	0.03*** (0.01)	0.003	0.05 (0.06)	0.110

Models	**Model 1: Pooled**				**Model 2: Embu**				**Model 3: Machakos**			
Explanatory Variables	**Outcome (Poisson)**		**Selection (Probit)**		**Outcome (Poisson)**		**Selection (Probit)**		**Outcome (Poisson)**			
Variables	*Coef.*	*Marginal effect*	*Coef*	*Marginal effect*	*Coef.*	*Marginal effect*	*Coef.*	*Marginal effect*	*Coef.*	*Marginal effect*	*Coef.*	*Marginal effect*
Credit access dummy (x_{10})	-0.39 (0.41)	-0.079	-0.45* (0.24)	-1.40	-0.39 (0.67)	-0.056	-0.69** (0.31)	-1.60	-1.86** (0.94)	-0.32	-0.80** (0.32)	-2.001
Use of ICT dummy (x_{11})	0.44 (0.52)	0.094	0.29 (0.20)	0.873	0.7 (0.75)	0.130	0.79* (0.42)	1.85	0.32 (0.83)	0.02	0.53** (0.27)	0.978
Post-harvest losses (x_{12})	-1.62 (1.21)	-0.285	0.24 (0.45)	0.720	-0.36 (2.08)	-0.072	3.38* (1.90)	0.263	0.30*** (0.08)	0.043	1.52* (0.90)	0.192
Log household income (x_{13})	0.05 (0.23)	0.012	-0.01 (0.12)	-0.019	-0.53 (0.34)	-1.229	0.01 (0.15)	0.018	-0.03 (0.04)	-0.002	-0.01 (0.02)	-0.03
Age (x_{14})	-	-	0.002 (0.01)	0.005	-	-	0.02 (0.01)	0.048	-	-	-0.05 (0.01)	-0.014
Organized sell dummy (x_{15})	-	-	0.04 (0.20)	0.105	-	-	0.77** (0.40)	1.80	-	-	0.53* (0.31)	1.43
Diversification dummy (x_{16})	-	-	-0.29 (0.25)	-0.878	-	-	0.63 (0.54)	1.47	-	-	0.61** (0.31)	0.957
Leasing land dummy (x_{17})	-	-	0.18 (0.25)	0.532	-	-	-0.07 (0.43)	-0.173	-	-	-0.44* (0.26)	-1.232
On-farm demo dummy (x_{18})	-	-	0.34 (0.21)	1.02	-	-	0.71 (0.45)	1.65	-	-	0.36 (0.36)	0.852
Wald test for independence	Chi^2= 3.17, prob > chi2 = 0.0750				Chi^2= 9.06 prob > chi2 = 0.0026				Chi^2= 8.226 prob > chi2 = 0.005			
Log Pseudo likelihood	-131.1825				-59.90115				-67.95729			
Number of observations	70				35				35			
Waldchi2 (12)	34.84				126.67				119.86			
Probability > chi2	0.0005				0.0000				0.000			

6.7.2: At the Trader's Level

At the wholesale level as shown on Table 6.6, the study revealed that traders who had access to credit were 9% more likely to adopt loss reduction practices. Those that have diversified their enterprise to having more fruit types were 2% more likely to adopt loss reduction practices. Contrary to the work of Murthy & Naidu (2015), the current analysis found that PHL increase led to a 39.53% less likelihood of adopting one or multiple practices for loss reduction. PHL was found to have no effect on the choice to adopt a loss reduction practice. In addition, as income and age increased, the likelihood to adopting loss reduction practices reduced by 11% and 3% respectively. As for traders that were engaged in organized selling, they were 43% more likely to adopt one or more loss reduction practices. Besides, males were 9% more likely to adopt more practices which concurs to the work of Ali (2012).

Table 6.6: Factors influencing adoption of loss reduction practices at wholesale level

Variables	Selection model (probit)		Outcome model (Poisson)	
Explanatory variables	coefficient	Marginal effect	coefficient	Marginal effect
Intercept	1.697*** (2.411)	-	2.359*** (0.895)	-
County dummy: 1 Embu/Machakos (x_1)	-0.305 (0.437)	-0.0880	-	-
Access to credit dummy (x_2)	0.425* (0.239)	0.0941	-	-
Diversification of fruits dummy (x_3)	0.070* (0.042)	0.0163	-	-
Use of ICT dummy (x_4)	-0.153 (0.378)	-0.0357	-0.240 (0.151)	-0.7475
Post-harvest losses (x_5)	-0.556 (1.68)	0.139	-1.41** (0.718)	-0.3953
Log household income (x_6)	-0.425** (0.176)	-0.1049	-0.081 (0.074)	-0.2527
Age of the respondent (x_7)	-0.046** (0.0183)	0.0337	0.139 (0.102)	0.0043
Organized selling dummy (x_8)	-0.162 (0.400)	-0.0368	0.139* (0.0751)	-0.4335
Experience (x_9)	-	-	-0.042** (0.0186)	-0.0132
Sex (x_{10})	-	-	0.299* (0.1556)	0.0933
Wald test for independence		23.06 prob > chi2 = 0.000		
Log Pseudo likelihood		-152.3459		
Number of observations		74		
Wald chi2 (4)		20.06		
Probability > chi2		0.0385		

At the retailer's level, the results indicated as shown on Table 6.7 below that retailers in the local county were 20% less likely to adopt loss reduction practices. In addition, traders who diversified their fruits were 9% less likely to adopt loss reduction practices. Besides, PHL affected the rate of adoption. Hence with increase in PHLs, traders were 30% more likely to adopt the loss reduction practices. In addition, those that were experienced in mango trading were 5% more likely to adopt the practices. Also, traders experiencing high PHL were 4% more likely to adopt more than one loss reduction practice. As for increase in income, the traders were 1% more likely to adopt more than one loss reduction practice.

Table 6.7: Factors influencing adoption at the retail level

Variables	Selection model (probit)		Outcome model (Poisson)	
Explanatory variables	coefficient	Marginal effect	coefficient	Marginal effect
Intercept	2.379 (1.472)	-	1.648** (0.755)	-
County dummy: 1 Embu/Machakos (x_1)	-0.696** (0.325)	-0.1993	-	-
Diversification of fruits dummy (x_3)	-0.2796** (0.1384)	-0.0942	-	-
Experience (x_9)	0.031* (0.0186)	0.04851	-	-
Sex (x_{10})	-0.0299 (0.1556)	-0.1238	-0.2088* (0.125)	-0.01423
Post-harvest losses (x_5)	0.5706*** (0.2075)	0.3016	1.2275** (0.5267)	0.0429
Log household income (x_6)	-0.0648 (0.0629)	-0.2133	0.0474*** (0.0144)	0.0129
Use of ICT dummy (x_4)	-	-	0.1045 (0.1597)	0.3443
Age of the respondent (x_7)	-	-	-0.007 0.008)	-0.023
Wald test for independence		15.34 prob > chi2 = 0.0214		
Log Pseudo likelihood		-206.6262		
Number of observations		101		
Wald chi2 (4)		11.51		
Probability > chi2		0.0484		

6.8: Challenges to Adoption

6.8.1: At the Farm Level

The results indicated as shown on Figure 6.4 that despite having social, economic, and institutional factors influencing adoption, the rate and intensity of adoption was still low. In Embu, most farmers claimed they were not involved (44%) in harvesting and thus adoption of loss reduction practices was not a priority for them. In Machakos, 39% claimed that the practices were labour intensive which hindered their adoption as well as ability to take up a lot of practices.

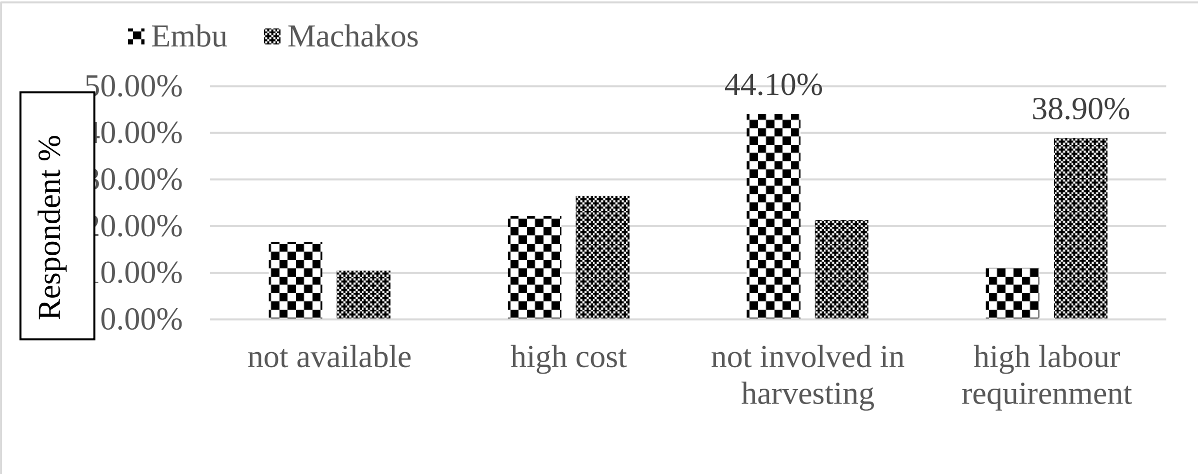

Figure 6.4: Major limiting factors to adoption as perceived by farmers

6.8.2: At the trader's level

Wholesalers argued that their major hindrance to adoption as shown on Figure 6.5 was with regards to reduced quantities (54%). In Embu, 53% of the traders argued that lack of store was a major limiting factor, while 26% in Machakos attributed the low adoption to time spent while handling the fruits.

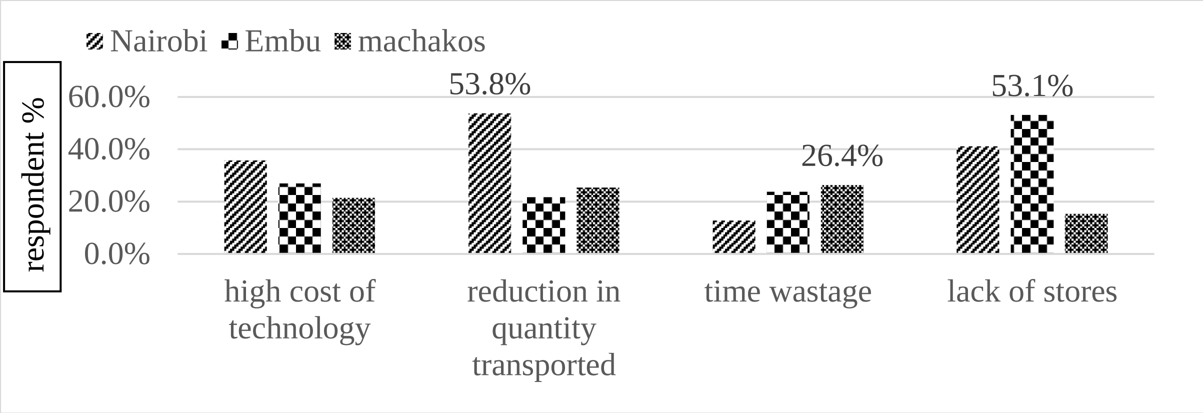

Figure 6.5: Major limiting factors to adoption as perceived by wholesalers

At the retail level, the results indicated as shown on Figure 6.6 that 36% of traders in Nairobi were limited by lack of stores, while 23% and 32% from Embu and Machakos were limited from taking in more fruits.

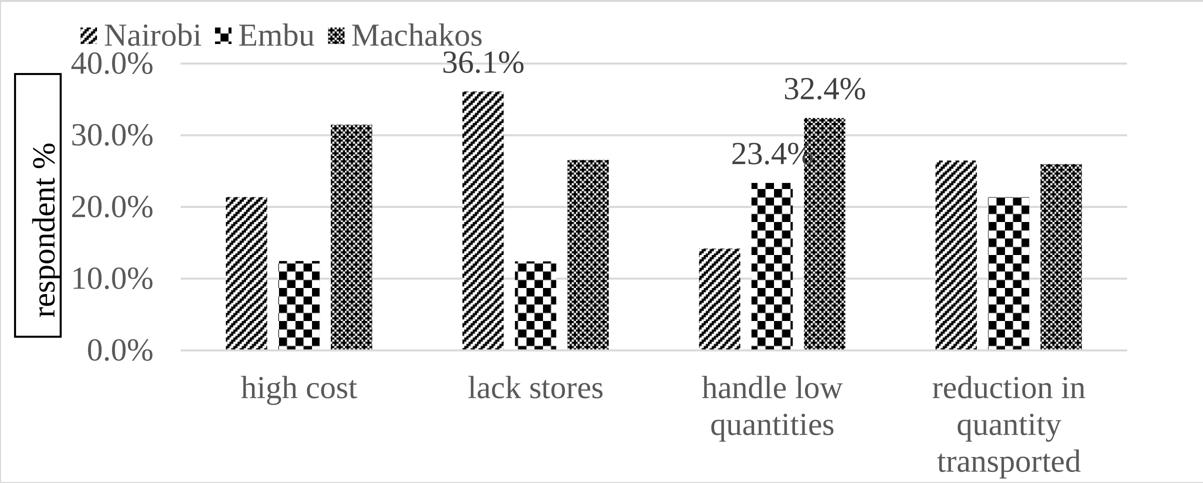

Figure 6.6: Major limiting factors to adoption as perceived by retailers

CHAPTER SEVEN

7.0: SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

7.1: Summary

The purpose of the study was to estimate the level of PHLs, causes of the losses, and the factors that influence adoption of loss reduction practices. The analysis was undertaken at three major stages including farm, wholesale, and retail levels. The mango value chain was analysed from production to marketing. Most farmers interviewed were small and medium scale. Mango production and marketing was faced with high PHLs, and attracted use of different technological innovations including crates, pallets, cartons, shades, and harvest poles to reduce the losses. However, there were major challenges that were reported along the chain including diseases, low prices, and physical injuries. The actors also complained of high cost involved with the loss reduction practices, time wastage, and the reduced level of fruits handled.

Mango production is mainly practiced as an individual enterprise with little engagement in organised selling. There is a lot of broker's engagement who constrain the little income farmers get. In addition, they have been interfering with market prices, and have caused farmers to lose a lot more fruits. The results of the survey indicated that the actors along the mango chain face high levels of PHLs. The losses were attributed to low prices, diseases, and physical injuries during transportation and storage. Besides, the actors have been influenced by socio-economic, and institutional factors through their adoption process. They attributed high cost of the loss reduction practices, lack of involvement, less quantities handled, lack of stores and time wastage as the major limiting factors to adoption. The actors have been influenced by different factors including the level of PHLs, sex, household income, age, diversification, organised selling, and credit. In addition, major losses were influenced by age, experience, income, storage, transport, and prevailing weather conditions.

The study estimated PHL levels at different nodes of mango value chain in two major mango producing areas in Kenya. The estimation was made at the farm, wholesale and retail levels. PHLs at the farm level were highest especially in Embu.

Through the percentage respondent analysis, respondents in Embu were found to belief that the high losses were attributed to low prices. At the market level, wholesalers and retailers attributed the losses to physical injuries. The regression analysis results at the farm level indicated that schooling, inadequate storage, ICT, and county type affected PHLs positively. At the wholesale level, purchased quantity, inadequate labour, inadequate transport, and ICT had a positive effect while at the retail level income, inadequate storage and purchased quantities had a positive effect.

Technological preference among respondents from the two counties were different. In Embu about they preferred stick and bag while respondents from Machakos preferred hand picking. At the wholesale level, respondent from Nairobi preferred use of cartons. In Embu and Machakos, they preferred use of shades. Retailers had preference for shades and peeling.

The Heckpoisson model at the farm level showed that IPM increased the probability of adopting the practices. Machakos County, farmers using IPM practices were more likely to adopt, and mango types increased the likelihood of adoption. However, membership to a group reduced the likelihood of adoption. The outcome model indicated that more productive trees one had, they were more likely to adopt multiple practices. However, those with access to credit were less likely to adopt more practices. In Embu, the level of PHL influenced the number of adopted practices, while in Machakos it had an effect on the choice to adopt and the number of practices adopted. Thus, farmers experiencing high PHLs were more likely to adopt loss reduction practices and were more likely to embrace a number of practices.

At the wholesale level the results indicated that traders who had access to credit were more likely to adopt loss reduction practices, and those that diversified their fruits were also more likely to adopt loss reduction practices. In addition, traders that were engaged in organized selling were more likely to adopt one or more loss reduction practices, while males were more likely to adopt more practices. On the other hand, PHL increase led to a less likelihood of adopting one or multiple practices for loss reduction, while as income and age increased, the likelihood to adopting loss reduction practiced reduced. At the retailer's level, the results indicated that retailers in the local county were less likely to adopt loss reduction practices, as well as those that diversified their fruits. On the other hand, those experienced in mango trading were more likely to adopt the practices, as well as increase in PHLs. Also, as income increased, the traders were more likely to adopt more than one loss reduction practice.

7.2: Conclusion

Generally, the study concluded that major losses occurred at the farm level, followed by retail level and lowest losses were at wholesale level. The mix of different varieties led to increased losses, since some varieties are not favoured. For instance, in Embu, the study revealed that highest losses were with variety tommy, Vandyke, and apple. This is because of low preference, poor climatic condition, and production during periods when markets are flooded with fruits from other regions. With Kent, losses are minimal, it is less infected by diseases, and is favoured by Embu climate which delays its maturity leading to maturity at time of low market flooding. Machakos has high losses with the tommy variety which is highly infected and has wrong market timing. Apple is favoured by the climatic conditions which makes it sweet and most preferred by customers. It also gets to the market at the bests time ripping high prices. Moreover, from the results it was possible to conclude that according to the respondent's, diseases and lack of market at the farm as well as physical injuries at the market were the most sever causes of the PHLs along the mango value chain. The study also concludes that Embu has higher losses, which the respondents attribute to low prices. At the wholesale level, high losses are due to the high volumes purchased which are being attributed to physical injuries due to poor transportation and storage. A similar case is being witnessed at the retail level.

The findings also revealed that technologies preferred were those that are cost effective, could reduce PHLs, and could increase the respondent's income. It is also evident that as PHLs increase, the likelihood of adopting loss reduction practices increases. In addition, with high PHLs respondents are willing to adopt multiple loss reduction practices at the different levels of the value chain. Experience is also a great determinant in determining the rate of adoption. However, credit is not an effective way of dealing with adopt as respondents were found to divert the funds thus negatively impacting on adoption. The study also asserted that most farmers were not involved in harvesting thus did not have control over harvesting and handling practices. Wholesalers were majorly involved, and feared of reduced quantities and lack of store. Similar fears were witnessed at the retail level. Therefore, it can be concluded that chain actors are for reduction of PHL, but the technologies that have been put forth are not favouring their operations which has a negative effect on their incomes, profits, and business sustainability.

The current study contributes to the body of literature on postharvest management. The results specifically contribute to impacting understanding and knowledge on the crucial factors that causes losses, as well as the factors to consider for effective technological adoption. Besides, it enhances understanding of the magnitude of the losses along the chain which is a first step to management. The study builds on past literature on PH management especially its critical aspect to providing a value chain aspect which has found little consideration.

7.3: Policy Recommendations

Based on the findings of the current research and losses estimated, the study suggests a possible solution to the problem of PHLs at the farm level could be production based on production of varieties doing well in the regions which the government should ensure are readily available at affordable prices. This would not only help reduce PHL considerably but will reduce the problem of market flooding, help deal with diseases, low prices, and increase income. In addition, it would have a ripple effect to the market thus reducing overall loss. In addition, the government should intervene by making the suited improved varieties available to farmers in large scale. Also, the government and development partners should intervene by providing disease and pest control chemicals to farmers at low cost. Besides, At the market level, interventions driven towards adoption of loss reduction technologies to reduce physical injuries, ensure proper storage, handling and transportation including; use of crates, cartons, pallets, fruit treatment for increased shelf life and cold storage would be recommended.

It is essential that policy attention is directed mainly on the factors that increase the level of PHLs and thus the major drivers of PHLs at the farm include inadequate storage and inappropriate use of ICT. Hence massive training to farmers so that they can be able to store fruits properly, use appropriate technologies as well as be able to use ICT to reduce losses is needed. At the wholesale level, major drivers included inadequate transport, inadequate labour, and quantities purchased. Hence, recommended for adoption of loss reduction techniques to ensure fruits are transported properly and in ample quantities. While at the retail level, major drivers were income, inadequate storage and quantities purchased. From the results the researcher recommended for intervention driven towards adoption of loss reduction technologies that would help manage quantities as well as ensure proper storage. In addition, traders would require financial management training to be able to prioritise issues that affect their business like PHLs. Besides, detailed research directed towards upgrading of the available loss reduction practices to ensure they allow chain actors to meet their objective of profit maximization as well as meet the need for PHL reduction is needed.

7.4: Limitations and Suggestions for Further Research

The current study was limited by a number of factors. First, the scope was limited to only three nodes of the value chain with exclusion of processor and exporters. Hence the researcher suggests for a multi-dimensional approach to undertaking the PH research. This will reveal the magnitude of losses even with other channels along the mango value chain. Also, the study was limited in its sample which was small and thus recommend for use of large samples and follow a similar methodology to assessing the magnitude, causes, and factors influencing adoption for results validation. In addition, despite acknowledging that losses, and their causes are specific to crops, seasons and area, only one season was considered in the current study and one crop. Thus, recommend for detailed research covering different season and crops to be able to get a clear picture to the PH issues.

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APPENDICES

Appendix 1: Variance Inflation Factor (Multiple regression) –farm

Variable (Xi)	**VIF**	**Tolerance=1/VIF**
Sex	1.27	0.79
age_in_years	1.19	0.84
Log_Inc	1.30	0.77
HHD_size	1.12	0.89
Distance	1.33	0.75
No_years_school	1.40	0.72
Logland	1.60	0.63
Logoutput	1.82	0.55
Weather_unfavourable	1.35	0.74
Labour_ Inadequate	1.12	0.89
Storage_ Inadequate	1.49	0.67
ICT	1.17	0.85
CountyD	2.09	0.48
Mean VIF	1.40	

Appendix 2: Variance inflation factor (heck-Poisson model) -farm

Variable (Xi)	**VIF**	**Tolerance=1/VIF**
Mango_type	1.23	0.81
Logland	1.10	0.91
Log_Inc	1.23	0.81
IPM	1.04	0.96
ICT	1.42	0.70
No_years_school	1.29	0.76
PRO-trees	1.51	0.66
Group	1.73	0.58
Extension	1.45	0.69
County	1.02	0.89
Credit	1.94	0.52
Phl	1.71	0.58
Mean VIF	1.39	

Appendix 3: Household Survey Questionnaire

BASELINE SURVEY: CURRENT STATUS OF POSTHARVEST LOSSES, ON-GOING INTERVENTIONS TO REDUCE LOSSES AND STAKEHOLDERS' PERCEPTIONS - FARMERS' CHECKLIST

Questionnaire S/No…… Enumerator…………………. Date………………… GPS…………………………. County………………….

Sub-county…………………. Ward………………

SECTION 1: METADATA

Name of farmer…………………………. Phone number………………Sex *0= female, 1= male…....* Year of birth……………… Number of household members………………… Number of years in school…….. Number of years in mango trading…………

A1: ASSETS, RESOURCES, AND EXTENSION

Amount of land owned……….. Amount of land cultivated……….. Amount of land under mango production…… number of varieties planted…………. number of mango tree planted per variety 1………..2……… 3…… 4…….5…… total…… ….. Have you leased land for mango production 0= no ( ) 1= yes ( ). Do you have access to credit for agricultural production 0= no ( ) 1= yes ( ). Are you a member of a production group 0= no ( ) 1= yes ( ).

Amount of income generated from farm activities…………. income from off-farm and remittances………. Income from non-farm …………. Total………………….

Distance to the nearest market in km………. Do you have access to extension 0= no ( ) 1= yes ( ). Do you attend trainings and demonstration 0= no ( ) 1= yes ( ). Do you have organised selling arrangements 0= no ( ) 1= yes ( ). If yes which arrangements....................................

A2. MARKET PERFORMANCE

Who mainly buys your fruits? *Code D:* ***1= Retailer; 2=Broker; 3=Processor; 4=Wholesaler; 5=Exporter; 6=Cooperative society; 7=Consumers; 8=Institutions (Hotels/restaurants); 9=Others:___________***

How do you handle your fruits after harvest?

Code B: 1= on ground in the sun, 2= on ground in the shade, 3= in baskets, 4= crates, 5= plastic bags, 6= use pallets, 7= pile all fruits, 8= place each a lot to remove latex, 7= cover with leaves, 8= place in a cold room, 9=others (specify) ……………………..

What value addition do you do to your mangoes?

Code: A= washing, 2= labelling, 3= packing, 4=grading, 5=sorting, 6=storage, 7= cooling, 8= transportation, 9= processing (sun drying, juice, nectar, pulp), 10=none 11= others (specify...)

Transaction costs incurred during value addition? ....

During the mango marketing, was there any time wasted in the trading? 0= no ( ) 1= yes ( ) 1.4: if yes, under what instances was the time wasted? ....how many hours did you waste..................

Do you take your fruits to the market or buyers come for them? ....

SECTION 2: MANGO MARKETING AND POSTHARVEST LOSSES

Have you diversified your fruits enterprise 0= no ( ) 1= yes ( )

Do you have a physical storage structure? 0= no ( ) 1= yes ( ) is the storage adequate to ensure mangoes are well handled 0= no ( ) 1= yes ( )

Is the weather during the harvest period favourable 0= no ( ) 1= yes ( ) Do you transport your fruits from the field 0= no ( ) 1= yes ( )

If yes is the transport mode adequate 0= no ( ) 1= yes ( ) do you hire labour for harvesting and handling of mangoes 0= no ( ) 1= yes ( ). If yes is the labour available adequate 0= no ( ) 1= yes ( )

Do you use ICT tools to get information on mango production and marketing 0= no ( ) 1= yes ( ).

Rank the factors listed below based on their importance in limiting farmers ability to engage in mango production (1) being the Most constraining, (15) the least constraining) **label first 4**

1=poor road infrastructure……., 2=Inadequate storage capacity……., 3=lack of appropriate storage facility…….., 4=inadequate start-up capital………, 5=poor access to credit………., 6=price instability………, 7=low trade margin…….., 8=lack of standard measures……, 9= Perishability………, 10 =poor access to transport………, 11= Bulkiness………, 12 = lack of market information…………, 13= long distance movement between supply and resale markets……., 14= High transaction costs…………, 15= high level of losses………., 16= rains, 17= lack of market, 18= perishability, 19= pests, 20= diseases, 21=Others (Specify)………………………………………

Provide the following details. Instructions: the unit of measure should be in the number of pieces if given in other units' e.g bags or kilograms necessary conversions should be made. The quantities should be for the season under consideration (Nov 2017- April 2018)

Variety	No. of Trees planted	No. of productive trees	QTY harvested (pieces)	QTY consumed (pieces)	QTY sold (pieces)	QTY lost (harvested but not sold or consumed) (pieces)	Price per piece (ksh)	Major cause of the loss (code A) rank on bases of the most sever cause (give 5, 1 being the most severe and 5 being the least.	
Apple								***Cause***	***Rank***
Tommy									
Kent									
Keitt									
Ngowe									
Van Dyke									
Others (specify)									
total									
Code A: 1= time of harvest 2= lack of credit 3= inadequate extension 4= poor access to markets/lack market 5= low prices 6= pests 7= diseases 8= inadequate 9= distance to the market 10= inadequate storage 11= do not use appropriate technologies for loss reduction, 12= rains, 13=others (specify)..................									

List then rank (where one is the most important) five things you would recommend to be done for you to be able to fight the problems you have names above to have led to your losses.

1)............................... [ ] 2).............................. [ ] 3)..................................... [ ] 4.. [ ] 5.. [ ]

Code C: 1=access to credit 2= training 3= sales in kgs to improve prices 4= provision of chemicals at low prices 5=assistance in accessing markets 6=processing plant 7=removal of brokers 8=assistance with harvest and storage technologies 9= others (specify)..............................

SECTION 3: TECHNOLOGIES ATTRIBUTES, KNOWLEDGE AND PERCEPTIONS

Instructions: only ask the questions in this section to farmers who have used the technologies/practices

3.0: how do you harvest your fruits)? ....

Are you aware of any harvesting, handling, and storage loss reduction technique 0= no ( ) 1= yes ( ).

If yes which ones (code

D...

Code D: 1= hand picking 2= nets 3= stick with bag 4= crates, 5= cartons, 6= use pallets, 7= harvest bags, 8= place each alone to remove latex, 9= cover with leaves, 10= place in a cold room, 11=others (specify) ……………………..

Have you used any of the above mentioned technologies 0= no ( ) 1= yes ( ).

If yes which one (code D)……………………………………………………………………………………………………….

3.1: state any other practice you have undertaken to reduce the level of losses? 1...

2... 3..

3.2: Instructions: the two questions below are for respondents who have heard but have not used and those who have not heard (circle whether the respondent has heard or not)

Would you like to use any of the practices in the future? Yes= 1 no= 0.......................

If **yes** give three recommendations that you would like done to facilitate your adoption 1……………………………… 2……………………… 3………………………

Code C: 1=access to credit 2= training 3= sales in kgs to improve prices 4= provision of chemicals at low prices 5=assistance in accessing markets 6=processing plant 7=removal of brokers 8=assistance with harvest and storage technologies 9= others (specify)..............................

3.4: list some of the challenges that have constrained you in taking up the technologies? 1.............................. 2... 3...............

Code F: *1=lack of information……., 2=Inadequate storage capacity……., 3=lack of capital……., 4=low product prices………, 5=poor access to credit………, 9= Perishability………, 15= high level of losses………., 16= rains, 17= lack of market, , 18= pests, 19= diseases, 20=*Others *(Specify)………………………………………*

Appendix 4: Traders Check List

Questionnaire S/No**……** Enumerator…………………. Date………………… Market…………………………. County…………………. Sub-county…………………. Ward………………

SECTION 1: METADATA

Name of trader…………………………. Phone number………………………… Sex *0= female, 1= male*…..... Year of birth……………… Marital status………………… Number of years in schooling……………………….. Number of years in mango trading………..

A1. Market Performance:

Type of trader *(Code A*)………………...... No. of months engaged in trading last season…………………………………………………

*Code A: 1= Retailer; 2=Broker; 3=Processor; 4=Wholesaler; 5=Exporter; 6=Other (Specify):*____________

Number of mango varieties traded………………………. Do you have access to credit for agricultural production 0= no ( ) 1= yes ( ). Are you a member of a marketing group 0= no ( ) 1= yes ( ).

Amount of income generated from trading activities……………………………….Distance to the nearest market in km………. Do you have organised selling arrangements 0= no ( ) 1= yes ( ). If yes which arrangements....................................

Who mainly buys your fruits? *Code D: 1= Retailer; 2=Broker; 3=Processor; 4=Wholesaler; 5=Exporter; 6=Cooperative society; 7=Consumers; 8=Institutions (Hotels/restaurants); 9=Others:*____________

How do you handle your fruits after purchase?

Code B: 1= on ground in the sun, 2= on ground in the shade, 3= in baskets, 4= crates, 5= plastic bags, 6= use pallets, 7= pile all fruits, 8= place each a lot to remove latex, 7= cover with leaves, 8= place in a cold room, 9=others (specify) ……………………..

1.1: For the fresh mangoes, what have you been doing to increase on your sales?

Code: 1= washing, 2= peeling, 3= packing, 4=grading, 5=sorting, 6=storage, 5= others (specify..)

SECTION 2: MANGO MARKETING AND POSTHARVEST LOSSES

2.1: Have you diversified your fruits enterprise 0= no ( ) 1= yes ( )

Do you have a physical storage structure? 0= no ( ) 1= yes ( ) is the storage adequate to ensure mangoes are well handled 0= no ( ) 1= yes ( )

Is the weather during the harvest period favourable 0= no ( ) 1= yes ( ) Do you transport your fruits from the point of purchase to sale 0= no ( ) 1= yes ( )

If yes is the transport mode adequate 0= no ( ) 1= yes ( ) do you hire labor for harvesting, trading and handling of mangoes 0= no ( ) 1= yes ( ). If yes is the labour available adequate 0= no ( ) 1= yes ( )

Do you use ICT tools to get information on mango production and marketing 0= no ( ) 1= yes ( ).

2.2: **Rank** the factors listed below based on their importance in limiting traders' ability to engage in mango product(s) trade (1) being the Most constraining, (15) the least constraining)

1=poor road infrastructure……., 2=Inadequate storage capacity……., 3=lack of appropriate storage facility…….., 4=inadequate start-up capital………, 5=poor access to credit………., 6=price instability………, 7=low trade margin…….., 8=lack of standard measures……, 9= Perishability………, 10 =poor *access to transport………, 11= Bulkiness………, 12 = lack of market information…………, 13= long distance movement between supply and resale markets……., 14= High transaction costs…………, 15= high level of losses………., 16= Others (Specify)………………………………………*

2.5: provide the following details. Instructions: the unit of measure should be in the number of pieces if given in other units' e.g bags or kilograms necessary conversions should be made. The quantities should be for the season under consideration (Nov 2017- April 2018)

Variety	QTY purchased (pieces)	Price per unit	QTY that reached the market (pieces)	QTY lost (purchased but dint reach market) pieces	Major cause of the loss (code E)	QTY stored if any (pieces)	Days taken to sell	QTY sold (from the store per day (pieces)	Price per unit **(list all the prices)**	QTY lost (stored but not sold) (pieces)	Major cause of the loss (code E)
Apple											
Tommy											
Kent											
Keitt											
Ngowe											
Van Dyke											
Others (specify)											
Code E: 1= time of harvest 2= credit availability 3= extension 4= poor access to markets 5= prices 6= pests 7= diseases 8= mode of transport 9= distance to the market 10= lack of market 11= storing with other crops 12= time of harvest 13= lack of contact with buyers before harvest 14= lack of multiple potential buyers 15= physical injury 16= bruises 17=we don't clean the store 18= store not well constructed 19= long storage before getting a buyer 20= do not use necessary technologies for loss reduction 21= lack of contracts, 22=others (specify)..................											

List three things you would recommend to be done for you to be able to fight the problems you have names above to have led to your losses.

1)... 2)...

3)..

SECTION 3: TECHNOLOGIES ATTRIBUTES, KNOWLEDGE AND PERCEPTIONS

Where do you source your fruits..

Distance from point of purchase to sale..

Instructions: only ask the questions in this section to farmers who have used the technologies/practices

3.0: how do you handle your fruits after purchase your fruits)? ....

How do you transport your fruits..?

*Code C: 1. basket on foot, 2.bicycle, 3.hand cart/push truck, 4.motor bike, 5.pick-up, 6. Lorry, 7. Others (specify:*____________

To whom do you sell your fruits..?

*Code D: 1= Retailer; 2=Broker; 3=Processor; 4=Wholesaler; 5=Exporter; 6=Cooperative society; 7=Consumers; 8=Institutions (Hotels/restaurants); 9=Others:*____________

Are you aware of any transport, handling, and storage loss reduction technique 0= no ( ) 1= yes ( ).

If yes which ones (code D..

Code D: 1= evaporative coolers 2= nets 3= shades 4= crates, 5= cartons, 6= use pallets, 7= place in a cold room, 8= brick storage, 9= waxing, 10= peeling, 11= value addition and processing, 12=others (specify) ……………………..Have you used any of the above mentioned technologies 0= no ( ) 1= yes ( ).

If yes which one (code D)…….

3.1: state any other practice you have undertaken to reduce the level of losses? 1...

2.. 3..

3.2: Instructions: the two questions below are for respondents who have heard but have not used and those who have not heard (circle whether the respondent has heard or not)

Would you like to use any of the practices in the future? Yes= 1 no= 0........................

If **yes** give three recommendations that you would like done to facilitate your adoption 1……………………………… 2………………………

3………………………

Code C: 1=access to credit 2= training 3= sales in kgs to improve prices 4= provision of chemicals at low prices 5=assistance in accessing markets 6=processing plant 7=removal of brokers 8=assistance with harvest and storage technologies 9= others (specify)..............................

3.4: list some of the challenges that have constrained you in taking up the technologies? 1.. 2...

3..

Code F: 1=lack of information……., 2=Inadequate storage capacity……., 3=lack of capital……., 4=low product prices………, 5=poor access to credit………., 9= Perishability………, 15= high level of losses………., 16= rains, 17= lack of market, , 18= pests, 19= diseases, 20=Others (Specify)…………………………………