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Research article

# Assessment of factors influencing adoption of postharvest loss reduction practices along the mango value chain in Embu, Machakos, and Nairobi counties, Kenya

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ABSTRACT

Use of loss reduction practices are critical to ensuring losses are reduced significantly along the value chain. This necessitates for the need to assess the factors that influence adoption of the loss reductio practices to have better targeting and development. Therefore, the current study assessed the factors that influence adoption, and multistage sampling technique was employed. The counties and the sub-counties were purposively selected, and the mapping began from Nairobi which is the main market for mangoes. Wholesalers, and retailers were interviewed making use of snowballing, while farmers were randomly selected. A total of 70 farmers were selected, 74 wholesalers, and 98 retailers were sampled.

From the study, at the farm level results revealed that about 38.7 % of the farmer respondents prefer use of stick and bag. On the other hand, about 37.1 % of farmers in Machakos had preference of hand picking as the main method of harvesting. Wholesaler preferred the use of cartons in Nairobi, while those in Embu and Machakos had higher preference of use of shades. Result from the empirical model showed that credit was a critical factor to use of the practices at the farm with a 40 % influence on use of multiple practices. Experiencing higher losses influenced adoption of the practices by 4.3 %, and would influence use of multiple practices by 19.2 %. Organized selling was the critical factor for wholesalers and influenced adoption by 43.4 %.

Retailers in Embu and Machakos on the other hand, were 19.9 % less likely to take up the practices. The results further showed that higher PHL influence retailer to take up loss reduction practices by 30.2 %, and those that were more experience were 20 % more likely to take up the practices.

From the result it was thus concluded that cost effectiveness, ability to reduce losses, and increase of incomes were some of the things actors were interested with before they could take up any loss reduction practice. Through the study it was evident that high PHL less to higher use of the practices, and also positively influence the intensity of use of the practices. It was thus recommended that there is need for upgrading the current low-cost technologies to make them more user friendly so that they are not time-wasting during harvest, and for the traders they are able to carry optimal quantities that lead to profit maximization.

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## 1. Introduction

There has been a lot of changes reported in the agricultural sector. This has been more so as the needs and preferences among the consumers have been changing. Research has also shown evidence of changes in the staples, fruits and vegetables due to changing demands which has influenced production [1]. In the developing countries agricultural products play critical role in development as they shape about 80 % of rural households lives [2]. It has a critical role towards food security, vision 2023 achievement, and SDG 1 and 2 on no poverty and zero hunger respectively. According to Ref. [3], there has been shifts in perceptions towards the importance of fruits and vegetables in the human diet which again has contributed to the shifts. With the shifts and transformations aligned to food security aimed at feeding the rising population, the importance of reducing waste along the food value chains has also been on the rise. This has led to heated debates on the need to use environmentally friendly and sustainable practices to help preserve quality and quantity of the perishable fruits and vegetables which are estimated to have a 30–40 % loss [1]. Researchers have also shown the need to have a more proactive systems to make the markets more competitive [1,4]. Although, this is true in theory, in practice there has been reports of rising PHLs as production increases. This calls for better strategies and interventions that would help conserve the already produced foods and thus improve on the efficiency of the food system by increasing food availability.

Recent research has shown evidence of the great interest there has been to increase production. This has led to a lot of interventions being directed towards increasing production. According to Refs. [5–7] proper post-harvest handling and practice results to reduced economic losses. This can explain the rise in mango fruit production with an estimated 2.8 % annual increase in production in the two counties of interest [5]. A study conducted by Ref. [8] shows that the two counties have witnessed a rise in production by 2 % each. This has been due to improvements in harvesting, handing, transportation, storage, and marketing [7]. The improvements have resulted to creation of opportunities for actors along the value chain although studies have shown that most technologies have remained widely under used. The researchers have recommended for further assessment to the adoption issue as the low adoption deters the efforts undertaken by different actors including the technology developers, chain actors, and researchers [4,9,10].

Research work with regards to effectiveness of loss reduction technologies has been on the rise. Recent studies to assess use and factors affecting use have been undertaken [1,2,4,7,8,11,12]. The research developments have had a lot of focus at the farm and less has been done along the whole value chain. This results to a need to assess what affects actors along the whole supply chain as a prerequisite to development of technologies that better suit the needs of the users. Most studies [1,3,4,6,9,10] have made the use of binary logic, binary probit, and Poisson models as separate models when looking at use and intensity despite the possibility of sample selection bias. This provided insights to the development of the current study which looked into the practices that are used along the chain making use of a two-stage model that correct for the bias. The study also considers the whole supply chains to provide information on other nodes whose empirical data has widely been missing in literature.

Objective: The objective of the study was to assess the factors influencing use and intensity of use of PHL reduction practices in three selected counties.

Hypothesis: Socio-economic and institutional factors have a significant influence on use and intensity of use of loss reduction practices along the mango value chain in three selected counties.

## 2. Materials and methods

### *2.1. Data collection*

The current study made use of primary data to achieve the study objective. The data used was collected in 2018 through use of survey method in Nairobi, Embu, and Machakos for different actors including farmers, wholesalers, and retailers. To be able to capture real time data as well as be able to get respondence from the traders who are always on the move, the study was undertaken immediately after a high mango season which in the eastern regions is from October to March.

Sampling was done at each stage of the data collection to get the respondents used for the study. To select Embu, and Machakos a purposive sampling technique was employed since this were Rockefeller Foundation preselected project areas. The donor had selected the areas with a need to reduce losses through adoption of loss reduction practices since mango play a critical role in the incomes of the households hence would help achieve the donor objective of poverty elevation through livelihood support. Nairobi on the other hand was selected for being the major market for mango fruits in the country and hence a critical end point of the mango supply chain. In Embu Runyenjes was selected while in Machakos Mwala/Masii sub-counties were selected. The two sub-counties were selected due to the critical role they play in the livelihood of people in the region as well as their high mango production levels [2].

After mapping the counties and sub-counties of interest, the author needed to select respondent to be interviewed at the three nodes. The mapping began from Nairobi the main market where wholesalers sourcing mangoes from Embu and Machakos were interviewed making use of the trader's checklist, and the researcher was able to reach 48 of them. They also were requested to provide a list of brokers and farmers from the two regions. Also, they gave a list of retailers they sold their fruits to. The wholesalers provided a total of 60 retailers, and using the snowballing technique the researcher was able to get responses from a total of 48 retailers from different markets including Ngara, Marikiti, Muthurwa, and, Kangemi. In addition, the wholesalers provided a list of 7 brokers from Embu, and 6 brokers from Machakos, who gave a list of famers. A list of 50 farmers was given in Embu and a list of 47 farmers was given from Machakos. Making use of simple random sampling procedure, 35 farmers from each county were selected. During the interview with the selected farmers, the researcher requested the farmers to provide them with contact of local wholesalers they sold fruits to, and referral to 11 wholesalers in Embu (Marikiti market) and 15 wholesalers in Machakos (Uhuru market) were given and interviewed.

The researcher made use of snowballing to get retailers in Embu and Machakos where 25 retailers from each of the two counties were interviewed. At each stage of the data collection process, the researcher ensured that a signed consent form was filled. To respond to the study objective data relating to the level of PHLs, the technologies and practices for loss reduction used, social and institutional factors was gathered using semi-structured survey questionnaire. This led to reaching 98 retailers, 74 wholesalers, and 70 farmers.

## 3. Methods and data analysis

To be able to achieve the study objective and use of the two-stage model respondents were classified as adopter and non-adopters. This was to assess use where an adopter at any node including farmer, wholesaler, and retailer levels would be an actor using one or more loss reduction practices.

An empirical model was applied to estimate the factors. In the current study, the outcome variable was account. In addition, the study intended to look at use and intensity of use which necessitated for a two-stage empirical model. The socioeconomic factors were the independent variables. Therefore, to assume normal distribution as well as be able to use the count outcome variable a binary probit was selected at stage one, and a Poisson to take care of the count outcome variable was used in stage two. According to Ref. [1] binary probit, binary logit, and Poisson have been the majorly used models for estimating use and intensity.

The current study which looks at use and intensity made use of a model that would be able to ensure sample selection bias is eliminated. Accruing to Refs. [7,8] actors along the chain can use more than one practice to reduce the level of PHLs. Thus, use and intensity of use are highly liked. Past studies although recognize this, have been using independent two-stage models which have not been eliminating the sample selection bias, this led to the use of a HeckPoisoson model which runs a probit and a Poisson model concurrently as the selection, and outcome models respectively. The model in the first phase assumes normal distributions and in the second phase assumes a Poison distribution. It makes use of the maximum likelihood function and deals with selection bias. This makes the model a better estimation model compared to what has been used in past studies. Therefore, the model is estimated as

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

Where; $\lambda_i$ is the latent dependent variable, $\alpha$ the intercept, $\beta_i$ the coefficient, $X_i$ the independent variables (social, and institutional variables), and $\varepsilon_i$ the error term.

**Table 1**
Descriptive statistics for Embu farmers.

| Variable | Pooled<br>Average (std.dev) | Adopt (n = 27)<br>Average (std.dev) | Non-adopters (n = 8)<br>Average (std.dev) | t-value |
|---|---|---|---|---|
| Respondent characteristics | | | | |
| Respondent age (yrs) | 58.74 (14.31) | 58.11 (15.53) | 60.88 (9.63) | 0.4743 |
| Schooling (yrs) | 6.97 (3.07) | 7.55 (2.93) | 5 (2.88) | −2.18** |
| Household size | 4.34 (1.92) | 4.11 (1.83) | 5.13 (2.17) | 1.7234* |
| Experience (yrs) | 11.94 (6.96) | 12 (6.97) | 11.75 (7.40) | −0.0879 |
| **Assets/resources** | | | | |
| Monthly earnings (KES) | 25,478 (2144) | 27991.1 (2403.3) | 16996.3 (1128.1) | −1.2433 |
| Harvested (pcs) | 83534.4 (23264.2) | 92497.2 (13769.1) | 53350.4 (4549.3) | 1.7841* |
| Lost (psc) | 32,321 (4170) | 37,179 (2660) | 22,675 (1384) | 1.7478* |
| PHL techniques | 2.4 (1.73) | 2.96 (1.81) | 0.00 (0.00) | −2.38** |
| **Institutional factors** | | | | |
| Cultivated land (acres) | 3.80 (1.49) | 4.03 (2.06) | 2.99 (1.02) | −0.4684 |
| Market distance (km) | 4.07 (2.02) | 4.13 (1.95) | 3.88 (2.40) | −0.3080 |
| Mango plants | 232.83 (72.34) | 260.1 (99.92) | 140.75 (16.8) | −1.0919 |
| Mango types | 3.31 (0.87) | 3.41 (0.89) | 3 (0.6) | 1.1742 |
| | **Avg.(std.dev)** | **%** | **%** | **z- value** |
| Sex: men | 0.69 (0.27) | 48.61 | 20.1 | 1.7986* |
| Women | | 28.62 | 2.92 | 1.658* |
| PHL (%) | **49.39(22.91)** | 39.39 (24.24) | 59.37 (19.41) | 2.003** |
| Credit access (yes) | 0.57 (0.25) | 45.71 | 11.43 | 1.2592 |
| Land leasing (yes) | 0.14 (0.36) | 11.43 | 2.9 | 0.2575 |
| Group membership (yes) | 0.86 (0.36) | 65.7 | 30 | 2.1282** |
| Labor inadequacy (yes) | 0.71 (0.41) | 48.6 | 22.9 | 1.2217 |
| Favorable weather conditions (yes) | 0.31 (0.47) | 17.1 | 14.3 | 0.1267 |
| Inadequate storage (yes) | 0.63 (0.49) | 42.9 | 20 | 1.045 |
| hired labor (yes) | 0.83 (0.38) | 17.1 | 65.7 | −2.1340** |
| Transport inadequacy (yes) | 0.71 (0.46) | 51.4 | 20 | 1.6455* |
| IPM use (yes) | 0.34 (0.18) | 22.91 | 11.41 | 0.4781 |
| **Extension** | | | | |
| ICT (yes) | 0.74 (0.44) | 60 | 14.3 | 1.8373* |
| Attend demos (yes) | 0.54 (0.51) | 40 | 14.3 | 1.0472 |
| **Respondent behavior** | | | | |
| Diversification (yes) | 0.63 (0.49) | 54.3 | 8.6 | 1.6723* |
| Organized selling (yes) | 0.09 (0.023) | 8.57 | 0 | 0.9722 |

The model used since makes use of the log likelihood function allows for estimation for the count variable which is non-negative and the results presented in relative rates based on probability of occurrence. However, although account for the non-linearity it assumes equal variance which is in most cases not true [12]. To be able to eliminate this bias a negative binomial model is assessed, and since the estimate is the same the standard Poisson model was used in the current study for the final estimation.

Dichotomous models have widely been used in research studies to assess use of technologies. To deal with the problem of linear probability models, logit and probit models have widely been adopted. Independent count models are applied where an actor is to choose a certain package like the use of IPM as applied by Ref. [7]. Although the models have been providing good estimations, they treat all technologies to have equal relevance which is not true in reality. However, although having that as a limitation, they are fit fo estimation of use and intensity of use and thus applied in the current study.

## 4. Results and discussions

### 4.1. Characterization of respondents

#### 4.1.1. Farm level

Tables 1 and 2 presents the descriptive characteristics of farmers in Embu and Machakos respectively [13]. The results show that farmers from Embu show significant difference in terms of education among the adopter and non-adopter at 5 % level of significance ($P < 0.05$) where adopters were more educated compared to the non-adopters. This could explain a high rate of adoption since education is a prerequisite to understanding the use of different practices, and their need for loss reduction. The results further showed that adopters had significantly smaller family sizes at 5 % level ($P < 0.05$). In addition, it was reported that adopter had higher level of production and results were significant at 5 % level. This concurs to the work of [1] which shows that as production increases, PHLs levels rise and thus necessitating more use of loss reduction practices. The current study showed evidence of more losses being experienced among the adaptors, which made them adopt an average of about 3 loss reduction practices. According to Ref. [2] PH handling results to reduction of losses. The current study concurs to these results since there is evidence of significantly higher level of losses among the non-adopters at 59.4 % at 5 % level of significance ($P < 0.05$) compared to 39.4 % among the adopters. The results also showed that adopters were more involved in groups (65.7 %), had higher embracement of ICT (60 %), and diversified their production (54.3 %). The results were significant at 5 % ($P < 0.05$) which could explain the higher adoption rate due to having more

**Table 2**
Descriptive statistics for Machakos farmers.

| | Pooled average (std.dev) | Adopters (n = 29) Average (std.dev) | Non-adopters (n = 6) Average (std.dev) | t-value |
|---|---|---|---|---|
| **Respondent characteristics** | | | | |
| Respondent age (yrs) | 57.3 (13.2) | 57.9 (13.9) | 54.8 (10.2) | −0.5041 |
| Schooling (yrs) | 8.1 (3.7) | 7.3 (3.6) | 9.1 (2.9) | 0.7928 |
| Household size | 4.7 (2.1) | 5.0 (2.0) | 3.2 (1.5) | −2.1330** |
| Experience (yrs) | 12.5 (7.9) | 18.8 (10.2) | 11.2 (6.8) | 2.2868** |
| **Assets/resources** | | | | |
| Monthly earnings (KES) | 27,236 (2801) | 27,838 (2310) | 24,324 (1947) | −0.3719 |
| Harvested (pcs) | 19940.1 (1937.2) | 18196.3 (1435.1) | 28366.2 (3541.2) | 1.1800 |
| Lost (psc) | 5442.1 (4215.1) | 4827.2 (3617.1) | 8413.2 (5899.1) | 1.9763** |
| PHL techniques | 2.77 (1.67) | 3.34 (1.55) | 0 (0) | −3.17*** |
| **Institutional factors** | | | | |
| Cultivated land (acres) | 6.4 (1.5) | 6.9 (2.6) | 4.1 (1.9) | −0.5228 |
| Market distance (km) | 5.4 (2.1) | 5.6 (1.9) | 4.6 (2.8) | −1.1197 |
| Mango plants | 135 (85.4) | 109.1 (17.4) | 260.3 (35.9) | 1.8861* |
| Mango types | 2.9.1 (1.11) | 2.92 (1.12) | 3.1 (0.91) | 0.1334 |
| | **Avg.(std.dev)** | **%** | **%** | **z- value** |
| Sex: men | 0.741 (0.441) | 62.91 | 44.41 | 0.6949 |
| Women | | 20.1 | 5.72 | 0.2888 |
| PHL (%) | **34.87(19.08)** | 32.94 (17.99) | 44.09 (23.24) | 1.7149* |
| Credit access (yes) | 0.34 (0.48) | 25.7 | 8.6 | 0.6252 |
| Land leasing (yes) | 0.4 (0.49) | 37.1 | 2.9 | 0.6925 |
| Group membership (yes) | 0.34 (0.18) | 20 | 14.3 | 0.2555 |
| Labor inadequacy (yes) | 0.71 (0.46) | 54.3 | 17.1 | 1.9956** |
| Favorable weather conditions (yes) | 0.6 (0.5) | 40 | 17.1 | 0.9971 |
| Inadequate storage (yes) | 0.5 (0.4) | 42.9 | 14.3 | 1.6556* |
| hired labor (yes) | 0.6 (0.5) | 11.4 | 48.6 | 1.6585* |
| Transport inadequacy (yes) | 0.66 (0.48) | 57.1 | 8.6 | 1.9669** |
| IPM use (yes) | 0.311 (0.47) | 20.2 | 11.41 | 0.3664 |
| **Extension** | | | | |
| ICT (yes) | 0.66 (0.48) | 51.4 | 14.3 | 1.6810* |
| Attend demos (yes) | 0.69 (0.47) | 51.4 | 17.1 | 1.6704* |
| **Respondent behavior** | | | | |
| Diversification (yes) | 0.6 (0.49) | 48.6 | 11.41 | 1.8585* |
| Organized selling (yes) | 0.57 (0.50) | 45.7 | 11.4 | 1.2589 |

exposure.

The result presented in Table 2 below shows the demographic characteristics of farmers in Machakos [13]. The results shows that adopters have bigger household sizes, they are more experience, have adopted about 3 loss reduction practices, and diversified their production significantly more (48.6 %) compared to the non-adopters with results being significant at 5 % level. The loss levels of the non-adopters were significantly higher (44.1 %) at 5 % level of significance ($P < 0.05$). These results are evidence of the importance of use of loss reduction practices. The loss levels of the adopters could be due to the challenges they faced with labour deficiencies (54.3 %), inadequacy in storage (42.9 %), and inadequate transport (57.1 %).

#### 4.1.2. Wholesale level

Table 3 below represent the results of the characteristics of the wholesalers [13]. The results showed that wholesalers using loss reduction technologies had significantly lower level of losses (14.5 %) at 5 % level of significance ($P < 0.05$). Gender was a significant factor and the result showed that males were more adopted. This could be due to the fact that mango is a male crop, and it being perennial the land tenure system favors males more. According to[7] loss reduction practices reduces the quantities handled at each stage, which could explain the lower income levels among the adopters since they are not able to completely eliminate losses in the highly perishable fruit as some of the problems, they face like diseases are pre-harvest problems. The results further showed that most traders made use of hired labour (77 %).

#### 4.1.3. Retail level

Table 4 below, shows the demographic characteristics of retailers [13]. The results reveal that the adopters use about 3 loss reduction practices, their losses are at 5 % level of significantly lower (18 %), they are members of groups (71 %), have higher use of ICT (48.5 %), and have organized selling (67.8 %). The results also showed that being in Embu or Machakos adoption of loss reduction practices is significantly low. However, there is evidence of low diversification among the adopters with only 42 % diversifying their fruits.

The descriptive results show evidence of effectiveness of use of the practices in attempt to reduce losses in mangoes. These results are evidence that at all nodes of the chain postharvest loss reduction practices would significantly result to reduced losses although there is need to do more to deal with the problems of labour inadequacy, transport challenges, storage challenges, and quantities handled challenges.

#### 4.1.4. Loss reduction techniques

*4.1.4.1. Farmer level.* Adoption of multiple practices for reduction of losses have been reported to show more effectiveeness [1]. A

**Table 3**
Descriptive statistics for wholesalers.

| Trader characteristics- whole sale | Pooled Average (std.dev) | Adopters (n = 61) average (std.dev) | Non-adopters (n = 13) average (std.dev) | t-value |
|---|---|---|---|---|
| **Respondent characteristics** | | | | |
| Respondent age (yrs) | 41.73 (10.39) | 41.52 (11.12) | 42.69 (11.12) | 0.3652 |
| Schooling (yrs) | 8.85 (4.22) | 8.97 (4.27) | 8.31 (4.09) | 0.509 |
| Experience (yrs) | 9.30 (4.96) | 9.62 (5.09) | 7.77 (4.13) | −1.23 |
| **Assets/resources** | | | | |
| Income (KES) | 358,869 (594,753) | 259,084 (197,441) | 827,088 (129,824) | 3.336*** |
| Purchases (pieces) | 29,358 (21,718) | 29,133 (20,835) | 30,506 (26,402) | 0.209 |
| Lost (pieces) | 2961 (1944) | 2872 (1982) | 3428 (1742) | 1.867* |
| PHL techniques | 3.311 (2.04) | 3.312 (2.03) | 0 (0) | 5.85*** |
| **Institutional factors** | | | | |
| Distance (Km) | 95.59 (109.85) | 100.39 (114.78) | 73.08 (82.96) | 0.812 |
| Varieties sold | 3.39 (1.35) | 3.41 (1.39) | 3.31 (1.18) | 0.246 |
| | ***%*** | ***Percent*** | ***Percent*** | |
| Sex: men | 0.4861 (0.5031) | 72.21 | 27.81 | 2.434** |
| Women | | 57.41 | 7.891 | 1.65* |
| County: 1 local (Embu/Machakos) | 0.649 (0.481) | 81.251 | 18.751 | 3.67*** |
| PHL (%) | 13.92 (10.59) | 11.80 (9.113) | 14.51 (7.91) | 1.683* |
| Credit access (yes) | 0.3649 (0.485) | 37.8 | 30.7 | 0.265 |
| Inadequate labor (yes) | 0.797 (0.405) | 80.33 | 76.92 | 0.246 |
| Favorable weather conditions (yes) | 0.689 (0.466) | 70.49 | 61.54 | 0.3727 |
| Inadequate storage (yes) | 0.297 (0.460) | 38.46 | 27.87 | 0.4531 |
| hired labor (yes) | 0.77 (0.424) | 85.96 | 14.04 | 4.41*** |
| Inadequate transport (yes) | 0.284 (0.454) | 27.87 | 30.77 | 0.1157 |
| IPM (yes) | 0.324 (0.471) | 32.79 | 30.77 | 0.0788 |
| **Extension** | | | | |
| ICT use (yes) | 0.541 (0.501) | 54.1 | 53.85 | 0.0121 |
| **Respondent behavior** | | | | |
| Diversification (yes) | 0.338 (0.476) | 32.79 | 38.46 | 0.1962 |
| Organized selling (yes) | 0.676 (0.471) | 67.21 | 69.23 | 0.1172 |

**Table 4**
Descriptive statistics for retailers.

| Trader characteristics- retailers | Pooled | Adopters | Non-adopters | t-value |
|---|---|---|---|---|
| **Respondent characteristics** | Average (std.dev) | average (std.dev) | average (std.dev) | |
| Age (yrs) | 37.16 (8.89) | 37.15 (8.65) | 37.25 (10.04) | 0.05 |
| Schooling (yrs) | 4.19 (2.09) | 3.98 (2.08) | 5.05 (1.93) | 2.097*** |
| Experience (yrs) | 9.24 (3.59) | 9.23 (3.48) | 9.25 (4.13) | 0.02 |
| **Assets/resources** | | | | |
| Monthly income (KES) | 17,868 (20,468) | 18,056 (19,945) | 17,111 (23,007) | 0.184 |
| Purchases (pieces) | 4222 (3426) | 4468 (3501) | 3225 (2982) | 1.761* |
| losses (pieces) | 821 (777) | 847 (797) | 714 (697) | 0.685 |
| PH practices | 2.36 (2.31) | 2.94 (2.22) | 0 (0) | 5.89*** |
| **Institutional factors** | | | | |
| Distance (km) | 1.10 (1.59) | 1.03 (1.47) | 1.41 (2.03) | 0.961 |
| Varieties sold | 2.83 (1.63) | 2.93 (1.70) | 2.45 (1.28) | 1.17 |
| | | ***percentage*** | ***percentage*** | ***Chi-value*** |
| Sex: men | 0.386 (0.489) | 35.81 | 25.64 | 0.7923 |
| Women | | 64.21 | 16.13 | 0.8469 |
| County: 1 local (Embu/Machakos) | 0.495 (0.502) | 45.68 | 65.1 | 1.986* |
| PHL (%) | 19.77 (11.61) | 18.97 (11.09) | 22.97 (13.37) | 1.834* |
| Credit access (yes) | 0.221 (0.271) | 20.43 | 12.50 | 0.7890 |
| Group membership (yes) | 0.710 (0.286) | 19.57 | 77.78 | 2.791*** |
| Inadequate labor (yes) | 0.267 (0.444) | 29.63 | 15.00 | 0.5321 |
| Favorable weather conditions (yes) | 0.663 (0.475) | 69.14 | 55.00 | 0.9106 |
| Inadequate storage (yes) | 0.218 (0.415) | 23.46 | 15.00 | 0.3271 |
| hired labor (yes) | 0.651 (0.357) | 62.59 | 69.77 | 0.5525 |
| Inadequate transport | 0.693 (0.464) | 69.14 | 70.00 | 0.0624 |
| IPM (yes) | 0.291 (0.313) | 28.89 | 18.18 | 0.9182 |
| **Extension** | | | | |
| ICT use (yes) | 0.485 (0.502) | 46.49 | 55.00 | 1.727* |
| **Respondent behavior** | | | | |
| Diversification (yes) | 0.522 (0.384) | 41.48 | 51.28 | 1.968** |
| Organized selling (yes) | 0.691 (0.313) | 67.78 | 22.22 | 3.6367*** |

study by Ref. [9] reported use of five techniques at a go help decrease the losses with a significant margin. Fig. 1 below shows the level of use of different practices presented as the percentage of respondence for each practice [13]. The results shown that in Embu stick with a bag is mor preferred practice, while hand picking is more preferred in Machakos.

*4.1.4.2. At the trader's level.* Fig. 2 shows the percentage respondence with respect to different practices ate the wholesale level where it is evident that in Nairobi most wholesalers (26.7 %) prefer use of cartons, while in Embu and Machakos they have more preference of shade with 38.2 % and 28.9 % response rate respectively. The rate of non-adoption was relatively high at this level with about 26 % in Nairobi, 13.7 % in Embu, and 12.9 % in Machakos.

For retailers as shown on Fig. 3, reported that use of peeling as the major loss reduction practice in Machakos, and Nairobi, while use of shared was the major practice for loss reduction in Embu 938.2 %). There was reported high level of non-adoption at this stage of about 26 % in Nairobi, 13.7 % in Embu, and 12.9 % in Machakos.

## 5. Critical factors affecting use and intensity of use of the techniques

### 5.1. Farmer level

Table 5 shows the results from the analysis of the HeckPoisson ate the farm level [13]. It is shown in model 1 that IPM significantly

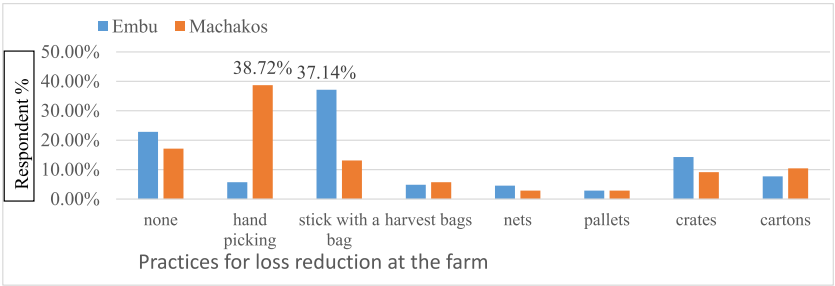


**Fig. 1.** Practices for loss reduction at the farm.

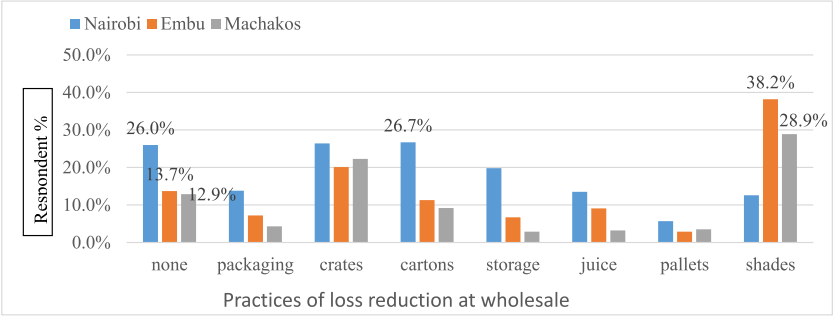


**Fig. 2.** Practices of loss reduction at wholesale.

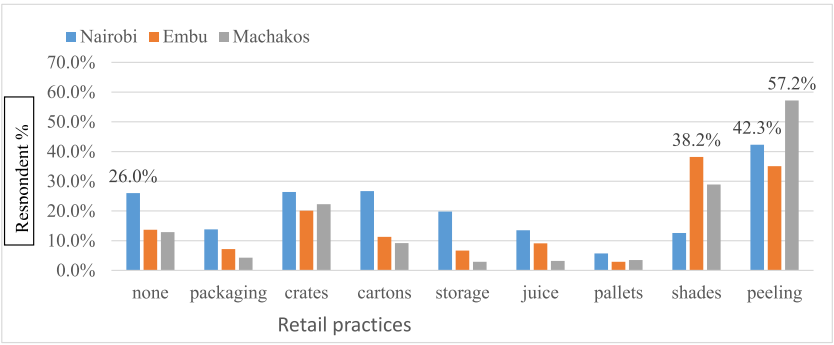


**Fig. 3.** Retail practices.

($P < 0.05$) increases the likelihood of use of loss reduction practices by 28.8 %, and varieties significantly increase the likelihood of use by 7.6 % at 5 % level of significance. This is in line with the work of [9,12] who reported that some mango varieties like apple require more care compared to others like Kent. Results also showed contrary to Ref. [1] that being in a group reduced the chances of use by 25.3 % and the results were significant at 5 % level. This could be due to the reported cases of the technologies and training through groups being expensive and time consuming thus most people did not use them. The results further showed that farmers in Machakos would more likely take up the techniques by 12.2 % compared to those in Embu and the result were significant at 5 % level. The results concurred to the work of [12] who reported that areas with high apple variety production have more adherence to loss reduction practices since the variety is very perishable.

The number of trees a farmer had, had an effect on the intensity of use of the practices of 0.2 %, and the results were significant at 5 %. These results were contrary to the work of [2,6] who reported a negative relationship since more trees means more production, and since the technologies are time consuming, there would be reduced adoption rate. The current study results could be due to the use of only large farmers who are targeted by brokers to supply the Nairobi market, and thus likely to look for farmers considering good practices to reduce losses, and have high reliance on Mango as the source of income. The results also showed that credit was a critical factor where people with access were 40 % less likely to take more practices which could be attributed to the high level of diversion of agricultural loans as reported by Ref. [9].

Model 2 and 3 show the two counties' results. The use of IPM was critical in both counties with 37.5 % and 38.7 % effect respectively and the results were significant at 5 % level. Hired labour did not have significant effect in Machakos, but has a significant effect in Embu at 55 of 52.8 %. This could be because people who work as casual would find the technologies time consuming, they are paid by the number of pieces picked, and slow. The results further showed that farmers with more productive trees in Embu were 0.03 % more likely to take up the practices, and were 0.5 % more likely to use many practices. Both counties, showed evidence of the positive effect of education on use of technologies. PHL in Embu had a significant effect on the level of adoption at 5 % level of 26.3 %.

### 5.2. *At the trader's level*

Table 6 shows the estimated model results at the wholesale level [13]. The results show that credit access has a significant effect on the likelihood of use of the practices of about 9.41 % and the results are significant at 5 %. Diversification was also a significant factor which had a 1.63 % effect on the likelihood of adoption and the results were significant at 5 %. The current result showed that higher PHL would reduce the likelihood of adoption multiple practices by 39.5 % and the results were significant at 5 % which is contrary to the work of [9]. The results further showed that income had a significant positive effect of 10.5 % on use of the practices, while.

Retail level results as shown on Table 7 below indicated that being in Emu or Machakos, a retailer is 19.9 % less likely to use the loss

**Table 5**
Heck-Poisson model at Farm level.

| *Independent variable* | Combined model (M) = 1 | | | | Embu, M = 2 | | | | Machakos, M = 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Selection (Probit) | | Outcome (Poisson) | | Selection (Probit) | | Outcome (Poisson) | | Selection (Probit) | | Outcome (Poisson) | |
| | $\beta$ | | $\beta$ | $\frac{\partial y}{\partial x}$ | $B$ | $\frac{\partial y}{\partial x}$. | $B$ | $\frac{\partial y}{\partial x}$. | $\beta$ | $\frac{\partial y}{\partial x}$ | $\beta$ | $\frac{\partial y}{\partial x}$ |
| $\beta_0$ | −0.58 (2.69) | – | 0.826 (1.28) | – | −5.04** (1.94 | – | −1.95 (1.89) | – | 3.29*** (1.05) | – | 1.54** (0.61) | – |
| varieties ($x_1$) | 0.38* (0.21) | 0.076 | – | – | 0.88** (0.42) | 0.126 | – | – | −0.24 (0.31) | −0.01 | – | – |
| Ln land size ($x_2$) | 0.07 (0.23) | 0.042 | – | – | 0.166 (0.35) | 0.723 | – | – | 0.20 (0.34) | 0.024 | – | – |
| IPM (x3) | 1.21** (0.48) | 0.288 | – | – | 1.75* (0.95) | 0.375 | – | – | 1.86** (0.86) | 0.387 | – | – |
| Group membership ($x_4$) | −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 | – | – |
| County:1 = Macha ($x_6$) | 0.76** (0.38) | 0.122 | – | – | – | – | – | – | – | – | – | – |
| hired labor ($x_7$) | 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 |
| trees planted ($x_8$) | 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 |
| schooling ($x_9$) | 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 |
| Credit access ($x_{10}$) | −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 |
| ICT ($x_{11}$) | 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 |
| PHLs ($x_{12}$) | −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 |
| Ln earnings ($x_{13}$) | 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 ($x_{15}$) | – | – | 0.04 (0.20) | 0.105 | – | – | 0.77** (0.40) | 1.80 | – | – | 0.53* (0.31) | 1.43 |
| Diversification ($x_{16}$) | – | – | −0.29 (0.25) | −0.878 | – | – | 0.63 (0.54) | 1.47 | – | – | 0.61** (0.31) | 0.957 |
| Land leasing ($x_{17}$) | – | – | 0.18 (0.25) | 0.532 | – | – | −0.07 (0.43) | −0.173 | – | – | −0.44* (0.26) | −1.232 |
| Demo ($x_{18}$) | – | – | 0.34 (0.21) | 1.02 | – | – | 0.71 (0.45) | 1.65 | – | – | 0.36 (0.36) | 0.852 |
| | **Pooled** | | | | **Embu** | | | | **Machakos** | | | |
| Wald $\chi^2$ | 3.17 pro.> $\chi^2 = 0.0750$ | | | | 9.06 pro.> $\chi^2 = 0.0026$ | | | | 8.226 pro.> $\chi^2 = 0.005$ | | | |
| Log Pseudo | −131.1825 | | | | −59.90115 | | | | −67.95729 | | | |
| Count | 70 | | | | 35 | | | | 35 | | | |
| Wald (12) | 34.84 | | | | 126.67 | | | | 119.86 | | | |
| Prob. > χ2 | 0.0005 | | | | 0.0000 | | | | 0.000 | | | |

The intensity of use of the practices is evident in Machakos. The results thus showed that having higher PHL significantly ($P < 0.05$) reduces the chance of use by 4.3 % and possibility of using multiple practices by 19.2 %.

**Table 6**
Heck-Poisson model at wholesale level.

| Critical factors | Wholesale level | | | |
|---|---|---|---|---|
| | Selection (Probit) | | Outcome (Poisson) | |
| *Independent variables* | *B* | $\frac{\partial y}{\partial x}$ | *B* | $\frac{\partial y}{\partial x}$ |
| β0 | 1.6971*** (2.4112) | – | 2.359*** (0.895) | – |
| County: 1 Embu/Machakos ($x_1$) | −0.3051 (0.4371) | −0.0880 | – | – |
| Credit ($x_2$) | 0.4251* (0.2391) | 0.0941 | – | – |
| Diversification ($x_3$) | 0.0701* (0.0421) | 0.0163 | – | – |
| ICT ($x_4$) | −0.1530 (0.3781) | −0.0357 | −0.2401 (0.151) | −0.74751 |
| PHLs ($x_5$) | −0.5561 (1.680) | 0.1391 | −1.410** (0.718) | −0.39532 |
| Ln earnings ($x_6$) | −0.425** (0.176) | −0.1049 | −0.081 (0.074) | −0.25270 |
| Age ($x_7$) | −0.0461** (0.0183) | 0.0337 | 0.1391 (0.102) | 0.00431 |
| Organized selling ($x_8$) | −0.1620 (0.400) | −0.0368 | 0.1390* (0.0751) | −0.43350 |
| Experience ($x_9$) | – | – | −0.0421** (0.0186) | −0.01321 |
| gender ($x_{10}$) | – | – | 0.2992* (0.1556) | 0.09332 |
| | Wholesale | | | |
| Wald $\chi^2$ overall | 23.06 pro > $\chi^2$ = 0.000 | | | |
| Log Pseudo | −152.3459 | | | |
| Count | 74 | | | |
| Wald $\chi^2$ (7) | 20.06 | | | |
| Prob. > $\chi^2$ | 0.0385 | | | |

reduction practices [13]. On the other hand, diversification of practices would result to a 9.4 % increase in the likelihood of use the practices. Also, the results showed that with higher PHLs the traders were 30.2 % more likely to take up the practices, more experience would increase adoption by 4.85 %, and higher incomes would cause 1.3 % more chances of adopting the practices, and the result were significant at 5 % level.

The results from the empirical models are a clear indication that the varieties being produced or trades, use of IPM, diversification, and the county of participation are critical factors to adoptions of loss reduction practices.

## 6. Challenges to adoption

### 6.1. At the farm level

Fig. 4 below shows that the use levels for different practices is low [13]. This is attributed to different reasons with farmers in Embu associating it to them not being involved with harvesting (44.1 %). On the other hand, in Machakos they associate the low use to them being labor intensive (38.9 %).

### 6.2. Trading level

Fig. 5 below shows the loss causing factors at the wholesale level which shows that reduced quantities are the main hindrances (53.8 %) in Nairobi, lack of stores in Embu (53.1 %), and time wastages in Machakos (26.4 %).

Fig. 6 below shows the challenges faced by traders at the retail level, and it is evident that lack of stores (36.1 %) was the major challenge, while low quantities purchased being the main problem in Embu (23 %) and Machakos (32 %).

## 7. Conclusions and recommendations

Use of loss reduction practices along the value chain is critical if losses along the chain were to be reduced. This led to assessment of critical factors that would influence adoption of the practices which gave basis to the current study. The study was undertaken in three counties including Nairobi, Machakos, and Embu at the farm, wholesale and retail levels. The main aim was to assess use and intensity of use of loss reduction practices in three selected counties. For the counties considered there was evidence of differences in technologies used which could be due to difference in varieties mainly grown.

The Two-stage model results shows that at the farm critical factors were IPM, membership to a group, number of trees planted, credit, and the level of losses. Wholesale level critical factors included; credit access, PHL levels, diversification, and organized selling while at retail, experience, income levels were reported as the critical factors.

The current findings let to the conclusion that technologies that are cost effective, would reduce losses, and improve incomes would be the most preferred. It is also evident that higher losses push actors to have a need to adopt loss reduction practices, and they are more willing to use multiple practices. Experience, organized selling, and diversification are also critical factors that need to be considered in attempt to influence adoption of practices and reduction of losses. However, credit is not an effective strategy for use to influence adoption. Since the study showed that most farmers are not engaged in harvesting, and traders fail to use the practices due to reduced quantities and time consumption the study concluded that the available practices are not in favor of the actors which compromised adoption.

**Table 7**
Heck-Poisson model at retail level.

| Critical factors | Retail level | | | |
|---|---|---|---|---|
| | Selection (Probit) | | Outcome (Poisson) | |
| *independent variable* | *B* | $\frac{\partial y}{\partial x}$ | $\beta$ | $\frac{\partial y}{\partial x}$ |
| $\beta_0$ | 2.3791 (1.472) | – | 1.648** (0.755) | – |
| County 1 = Machakos/Embu ($x_1$) | −0.696** (0.325) | −0.19932 | – | – |
| Diversification ($x_3$) | −0.2796** (0.1384) | −0.09421 | – | – |
| Experience ($x_9$) | 0.0312* (0.0186) | 0.048513 | – | – |
| Gender ($x_{10}$) | −0.0299 (0.1556) | −0.12381 | −0.20881* (0.125) | −0.01423 |
| PHLs ($x_5$) | 0.57061*** (0.2075) | 0.30162 | 1.2275** (0.52670) | 0.04292 |
| Ln earnings ($x_6$) | −0.06480 (0.0629) | −0.21330 | 0.0474*** (0.01441) | 0.01294 |
| ICT ($x_4$) | – | – | 0.10451 (0.1597) | 0.34432 |
| Age ($x_7$) | – | – | −0.0072 | −0.0233 |
| | | | 0.0083) | |
| | Retailers | | | |
| Wald $\chi^2$ | 15.34 pro. > $\chi^2$ = 0.0214 | | | |
| Log Pseudo | −206.6262 | | | |
| Count | 101 | | | |
| Wald $\chi^2$ (4) | 11.51 | | | |
| Prob. > $\chi^2$ | 0.0484 | | | |

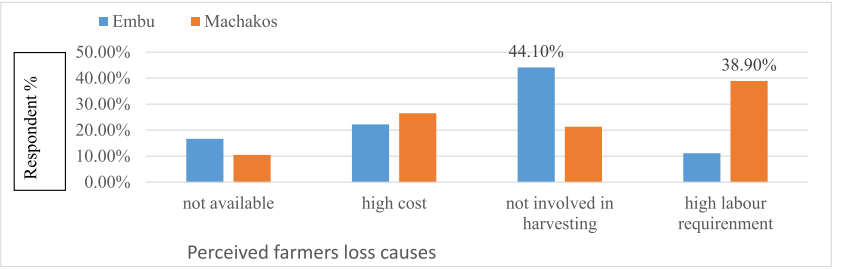


**Fig. 4.** Perceived farmers loss causes.

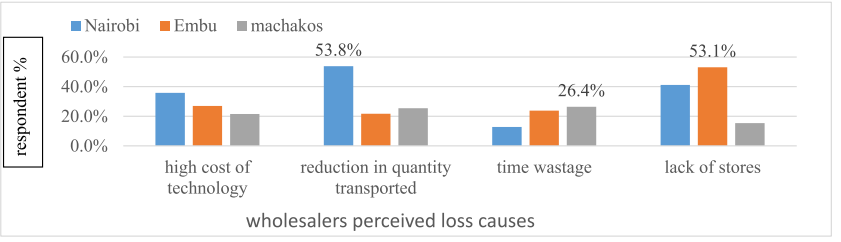


**Fig. 5.** Wholesalers perceived loss causes.

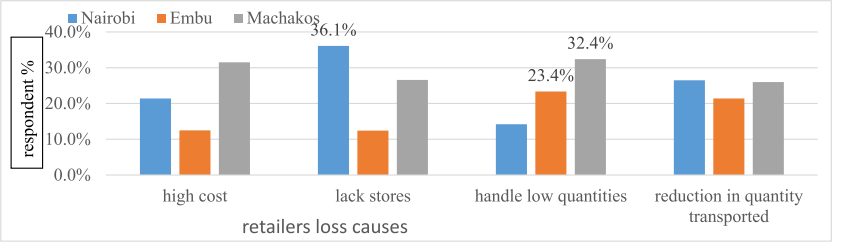


**Fig. 6.** Retailers loss causes.

Therefore, the study recommended for upgrading of the existing low-cost technologies and practices to allow chain actor maximize on their incomes as well as achieve the objective of loss reduction. Further studies are also recommended to assess each of the technologies effectiveness to be able to advice on the best practices and the best combinations of practices for loss reduction.

## Data availability statement

Data available: Yes.
Name of repository: Mendeley data.
https://doi.org/10.17632/s8v25w53wx.1.
Link to the data: https://data.mendeley.com/datasets/s8v25w53wx/1. The data is also referenced in the reference list.

## CRediT authorship contribution statement

**R.O.S.E. Githumbi:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **J.O.H. N. Mburu:** Supervision, Funding acquisition. **A.C.K.E.L.L.O. Ogutu:** Supervision. **J.A.N.E. Ambuko:** Supervision, Funding acquisition.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e25146.

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