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Returns to investment in postharvest loss reduction technologies among mango farmers in Embu County, Kenya

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Abstract

Horticultural production is a source of livelihood for many smallholder farmers in Kenya. However, the potential is hampered by high postharvest losses estimated at 40%–50% in fruit and vegetables. The losses are attributed to various factors including postharvest handling, lack of storage technologies, lack of processing facilities, and poor market access. Consequently, some farmer groups have resorted to aggregation of their mangoes and engagement in small scale processing of mangoes into shelf stable products that cannot be marketed widely. In order to bridge the lack of capacity of smallholder farmers, the University of Nairobi's postharvest project with support from the Rockefeller Foundation's YieldWise Initiative seeks to upgrade two fruit aggregation centers by creating awareness and providing existing, applicable, and proven postharvest loss reduction technologies such as tunnel solar driers, brick coolers, charcoal, and CoolbotTM cold storage technologies. However, the potential economic impact of the proposed investment is not known. Hence, this study aimed at assessing the potential economic returns to investment in postharvest loss reduction technologies among smallholder mango farmers in Embu County of Kenya. A critical overview on methods employed in analyzing returns to investment in agricultural technologies has been provided. The economic surplus model was used to estimate the potential benefits of the investment. Using the cost–benefit analysis (CBA) approach, a maximum adoption rate of 10% over 10 years, and a 10% discount rate, it was found that the investment was worthwhile. The NPV was US $ 1.3 billion. The IRR and BCR were 28% and 4.29, respectively. Sensitivity analyses showed that the investment is viable at higher adoption and lower discount rates indicating the need to promote the technologies even under more difficult macroeconomic conditions.

KEYWORDS

cost–benefit analysis, economic surplus, internal rate of return, net present value, postharvest loss

1 | INTRODUCTION

1.1 | Background

Postharvest loss reduction strategies offer unique income and food security opportunities for the over 200 million people that face food insecurity in the sub-Saharan Africa (FAO, 2019; Kikulwe et al., 2018). Historically, horticultural research has focused on increasing productivity (Kitinoja, Saran, Roy, Kader, & A., 2011). Consequently, mango yields have been on the rise over the last 5–10 years due to adoption of high yielding varieties, irrigation and improved crop husbandry (HCDA, 2008, 2010, 2012, 2014). However, given the inelasticity of scarce resources, focus should now shift to postharvest losses that are estimated at 40%–50% in the fruit subsector in Kenya (Gathambiri et al., 2006; KARI, 2004). The perishability of fruits is higher than that of other crops, making them more susceptible to higher losses. Globally, postharvest losses are estimated at 30% (FAO, 2011).

The high postharvest losses occur due to poor postharvest handling, lack of storage technologies, lack of processing facilities, and poor market access. The current desperate trend in the fruit produce supply chain management in developing countries is attributable to poor government policies and lack of consumer awareness of the need to reduce postharvest losses (Shukla & Jharkharia, 2013). In order to lower the postharvest losses, developing countries need to build the capacity of producers, improve infrastructure to ensure market access, develop value chains, improve postharvest technologies and collaboration between actors in supply chains (Hodges, Buzby, & Bennett, 2011). To reduce postharvest losses, harvesting should be done when it is colder during the day and produce should be protected from sunlight in the market (Kader, 2005).

In 2014, fruits in Kenya were valued at KES 51.4 billion, which domestically accounted for 26 percent of the horticultural produce value (HCDA, 2014). Fruit and vegetable sectors befit smallholder farmers allowing them to actively participate due to low land and labor requirements (Andrea, 2012). In Kenya, with respect to production and acreage, the mango (Mangifera indica, Linn) is the second largest crop next only to the banana (HCDA, 2014) and whose seed is a potential source of edible oils/fats (Muchiri, Mahungu, & Gituanja, 2012). Mangoes in Kenya are produced in 10 main Counties with Embu contributing 15% of the total production (HCDA, 2014). Kenya exports a paltry 2% of its national mango production. Between 2012 and 2013, mango exports grew by 141% earning Kshs. 1.4 billion ($14 million). It is estimated that between 2013 and 2022 local demand for mangoes will double while export demand will increase fivefold between 2011 and 2022 (USAID-KAVES, 2014).

Postharvest losses increase costs of waste management, contribute to greenhouse gas emission and also waste limited resources employed in their production, all of which are negative externalities to society (Aulakh & Regmi, 2013). Greenhouse gas emission from mangoes is approximately 0.46 kg CO_2 equivalent per kilogram of mango, 32 percent of which is emitted during transportation and a further 28.5 percent from agrochemical use (Runyora, 2016). Elimination of postharvest losses in fruits alone could raise domestic horticultural revenue by 17%. This could pitch the fruit subsector ahead of the vegetable and floriculture subsectors that are currently the highest revenue earners in the horticultural sector. Reduction of these losses would increase food reserves while enhancing global food security (Kader, 2005) which is a concern with the high food prices occasioned by increased consumer demand.

The United Nation's Sustainable Development Goal (SDG 12.3) and the African Union Agenda 2063 are both committed to halve the postharvest losses from the current levels by the year 2030 and 2023, respectively. Thus, efficiency of food supply chains and enhancement of food security is anticipated. A review of international development projects focusing on horticultural postharvest technologies in five countries including Kenya from 1996 to 2012, revealed that 83% of the projects were successful with barriers to adoption including high cost of initial investment, complex postharvest infrastructure, lack of awareness, group dynamics and limited market access (Kitinoja, 2010). Results of cost–benefit analyses (CBA) of 30 commodity systems from 21 international horticultural postharvest technologies in 4 countries during 2009–2010, revealed that all the 21 postharvest technologies were profitable for smallholder farmers of which 81% increased returns by 30% or more (Kitinoja, 2013).

1.2 | Role of postharvest loss reduction technologies

In a given country, there exists a strong correlation between the extent of losses after harvest and both the technology that is available and how advanced the markets are (Parfitt, Bartheld, & Macnaughton, 2010). Postharvest value addition technologies have potential to reduce postharvest losses hence provide high returns for farmers. However, developing cold chains is critical to ensure quality and safety (Kader, 2009). Hardly 20% of Kenyans (GoK, 2008) access electricity at the rural level making it untenable and costly to invest in cold storage facilities (Shitanda, Oluoch, & Pascal, 2011). This exacerbates smallholder farmers' exploitation by middlemen due to their inability to maintain quality and/or prolong the shelf life. Applicable and proven storage technologies such as brick coolers, charcoal and Coolbot™ cold storage can thus minimize postharvest losses thereby increase income of smallholder farmer (Jha, 2008). However, there is still low adoption of modern technologies and high postharvest loses in Kenya (HCDA, 2014).

It is against this background that in Kenya, the University of Nairobi's postharvest project with support from the Rockefeller Foundation's YieldWise Initiative seeks to upgrade two fruit aggregation centers by creating awareness and providing existing, applicable and proven postharvest loss reduction technologies (PLRTs) such as brick coolers, charcoal and Coolbot™ cold storage technologies (Karithi, 2016; Shitanda et al., 2011) and solar driers. Past international and national horticultural postharvest project interventions are rarely, if ever, re-evaluated once they are completed to determine whether the interventions promoted during the project increase welfare and are sustainable (Kitinoja, 2010). Therefore, little is known on the extent of their potential economic impact. This study sought to address this knowledge gap by assessing welfare effects of investment in PLRTs among mango farmers in Kenya. Agricultural research is arguably one of the several competing investment alternatives available to national governments and international aid agencies. These funding agencies require concrete evidence of the potential net social benefits associated with each investment alternative in research (Maredia, Byerlee, & Anderson, 2000). This information assists in planning for research, priority setting, guides adoption, and investment decisions by farmers, donors, and policymakers.

2 | MATERIALS AND METHODS

2.1 | Study area

This study was conducted in Karurumo Location of Embu County. Embu County lies between latitude 0°8′ and 0°50′ South and longitude 37°3′ and 37°9′ East. Mango production is the mainstay for farmers in Embu and controls about 40% of the household income. Embu County has various agro ecological zones ranging from high altitude tea–dairy zone (LH1) to upper midland, maize–sunflower zone (UM4). Others include the LH0 which is the forest zone which is the same as UH0 and are basically catchment areas. The County's temperatures range from a minimum of 12°C in July to a maximum of 30°C in March with a mean average of 21°C. The County receives bimodal rainfall with short rains of between 1,200 and 1,850 mm received between October and December while long rains of between 850 and 1,850 mm are received between March and June. The study was conducted between June and July 2018. Major crops grown in the county are tea, coffee, millet, cassava, dairy, and horticultural crops. The main ethic group in the area is Aembu since this is their indigenous home, with other tribes like Akamba, Ambeere, and Akikuyu.

2.2 | Sampling and data collection

Multistage sampling technique was employed to select 160 farmers based on Cochran (1963). Accordingly, $n = (Z^2pq)/e^2$, where n is the sample size and Z is the standard normal deviate at the selected confidence level. The value of Z is 1.96 for the commonly used 95% confidence interval, p is the proportion in the target population estimated to have characteristics being measured (proportion of farmers producing mangoes in Karurumo Location), $q = 1 - p$ and e is the desired level of precision (5%–10%). Thus, $n = 1.96^2 \times 0.88 \times 0.12/(0.05)^2 = 160$. Embu County was purposively selected since an earlier project (yield wise) had been implemented in the study area to ensure proper agronomic practices to reduce preharvest losses. A household survey was conducted to obtain primary data on mango yield, price, cost of current postharvest loss management practices/interventions and willingness to pay for the proposed PLRT. The quantity of mangoes that farmers were willing to handle in the tunnel solar driers, charcoal, and brick coolers over a period of 10 years indicated the adoption lag, the adoption rate, and the number of years to maximum adoption. Expert opinion was also sought from researchers, scientists, and extensionists on variables such as expected yield increases, success rate, and the depreciation rate. According to expert opinion, the PLRTs would increase yield by 40% on average. A conservative maximum adoption rate of 10% was assumed. Price elasticities of supply and demand and discount rate were obtained from secondary data. The research activities would culminate in extension activities that would enhance knowledge of the technology among the farmers. Gaaya (1994) estimated the cost of extension per farmer per annum, and these estimates were used to project the cost of extension. The cost of implementation of the technology by farmers was estimated from the cost of experiments that were set up in the study.

2.3 | Methods of data analysis

Returns to investment in agricultural technologies can be evaluated using several approaches. These include the scoring models, mathematical programming, simulation models, and cost–benefit analysis (Braunschweig, 2000). Scoring models or weighted criteria methods involve ranking and do not provide decisions on resource allocation a priori. Criteria that reflect objectives of research are defined and weighted. Research alternatives are then scored based on each criterion. Finally, these scores are multiplied by each criterion weight and then added up to determine the order of priorities. This ordinal ranking of alternatives serves as a basis for allocation decisions, and the alternatives can be funded according to their ranking until the research budget is exhausted. These models are relatively easy to employ and allow the incorporation of multiple objectives. However, they are costly and time-consuming. The models also lack sound theoretical frame work.

Mathematical programming is an optimization technique for guiding the allocation of limited resources (Marconi, Raggi, Viaggi, Lefebvre, & Paloma, 2015). Unlike scoring which only produces a ranking of alternatives, mathematical programming aims at selecting an optimal research portfolio. Mathematical programming methods have the ability to deal with varying levels of funding for each activity. However, the functional relationship between the level of funding and the benefits must be known. Programming methods are also time-consuming. Simulation models are based on principles of production economics (Antle, Murshed-E-Jahan, Crissman, & Valdivia, 2015). They estimate the functional relationship between input (research investments) and agricultural output. By modeling the agricultural production sector or parts of it, simulation models usually operate on a higher aggregated level. A production function may be used to represent the econometric relationship between agricultural productivity on the one hand, research (and extension) expenditures, and additional determining factors on the other. Then, the effects on productivity of various research expenditures, such as introducing different technological innovations, are simulated. The resulting changes in productivity are translated into a supply curve shift, illustrating its economic consequences. The mathematical relationships necessary to build the model need to be determined. Estimation of econometric relationships is based on time-series data, which are not readily available in the case of postharvest technologies.

Cost–benefit methods usually employ the concept of economic surpluses. The economic surplus method developed by Alston, Norton, and Pardey (1995) is based on the need for efficient allocation of scarce resources for agricultural research. The method is anchored on welfare economics which is based on Pareto efficiency and compensation principles. Accordingly, a policy change is socially desirable if, by the change, both consumers and producers can be made better off. The model measures benefit to consumers and producers as net changes in consumer and producer surpluses. These benefits are then compared to the cost of research to estimate the aggregate social net benefit of research. The main limitation of the model is that in its static representation of the commodity market, it overlooks other dynamics which may affect the potential impact of a given intervention. The economic surplus method combined with discounted benefit–cost measures has been employed widely to assess the impact of novel agricultural innovations (Kassie, Marenya, et al., 2018; Kassie, Stage, et al., 2018; Mujuka et al., 2017; Muriithi et al., 2016) and was used in this study. Potential benefits of investing in PLRTs were estimated using the change of economic surplus, and the Net Present Value (NPV) was calculated using a discount rate of 10% in 2019 dollars. For this study, a static partial-equilibrium, comparative model was used (Kristjanson & Zerbini, 1999).

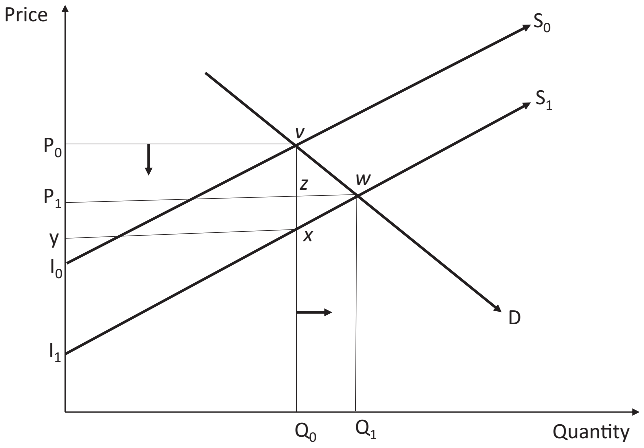

FIGURE 1 Estimating change in total surplus. *Source*: Adopted from Alston et al. (1995).

2.3.1 | Conceptualizing economic surplus modeling in a closed economy

Economic surplus approach is based on the interaction between supply and demand resulting in equilibrium quantity and price. Producers' production costs are represented by the supply curve while consumer consumption values are represented by the demand curve. Economic welfare gains due to research arise from producers earning more than the marginal costs they incur and consumer willingness to pay more than the market price (Figure 1). Since few mangoes from Kenya are traded internationally, a closed economy model was assumed. The adoption of a yield-increasing PLRT may reduce prices. Thus, consumers gain through cheaper access to mangoes while producers increase supplies and benefit from economies of scale. Simple linear supply and demand curves were assumed with parallel shifts (Kristjanson & Zerbini, 1999). On the basic economic surplus model of returns to research, D denotes the demand function for mangoes, while S_0 and S_1 are the supply functions for mangoes before and after investment in PLRTs, respectively. P_0 represents the price before the research induced shift while P_1 is the price after the shift. Q_0 and Q_1 are the equilibrium quantities before and after the changes induced by research.

Change in consumer surplus is represented by the area P_0vwP_1 while change in producer surplus is represented by the area P_1wxy. The change in total surplus ($P_0vwP_1 + P_1wxy$) is represented by the area I_0vwI_1. Without PLRT, this surplus would not be realized. Before adoption of PLRT, Q_0 of mangoes is demanded and supplied at price, P_0. Hence, the equilibrium is at (v) with P_0 denoting the equilibrium price and Q_0 denoting the equilibrium quantity. After the adoption, the supply curve shifts from S_0 to S_1; hence, P_1 is the new equilibrium price and Q_1 is the new equilibrium quantity. Gross returns to research are estimated by the area beneath the demand curve and between the two supply curves, or the area I_0vwI_1 in Figure 1. This is the change in total surplus and is a result of both the gains to producers and consumers as a result of research induced shift. Producer surplus which is a measure of producer welfare is the difference between the price that producers are willing and able to sell their produce and the market price, while consumer surplus (CS) is the gain to consumers when they pay for a good at a lower price than the market price (Ashok et al., 2017). The change in PS and CS depend on the elasticity of supply and demand (Kassie, Marenya, et al., 2018; Kassie, Stage, et al., 2018).

2.4 | Data needs, sources, and analysis

Parameters needed for estimation of the surpluses are shown in Table 1, where K is the shift of the supply curve, η is the absolute value of the elasticity of demand, ε is the elasticity of supply, $Z = K\varepsilon/(\varepsilon + \eta)$ is the reduction in price, p is the success rate and assumed to be 1 and δ is the reduction of expected yield and was assumed to be 0. Different sources of these parameters have been specified. Descriptive statistics were generated using STATA Version 14. The cost–benefit analysis was performed using the EXCEL spreadsheet. The spreadsheet was used to show the sensitivity of the results to changes in discount rates and adoption levels.

3 | RESULTS AND DISCUSSION

3.1 | Descriptive statistics

Results of this study revealed that most (84%) of the household heads were male with an average age of 49 years and 11 years of experience in mango production (Table 2). According to Abdulai and Huffman (2005), aging male farmers have more experience and are more resource endowed (Kaliba, Verkuijl, & Mwangi, 2000) due to their high chances of accessing capital. Results reveal that 8% of the respondents had access to credit. The average number of years of completed formal education among the respondents was 8 years. This is an indication of relatively high level of literacy. Literate farmers have higher cognitive ability, access to information and are more likely to adopt technologies that have potential for higher economic gains. This is shown by the high level of awareness on PLRTs (67%) and further supported by the high access to agricultural extension services (44%). This explains the respondents' willingness to pay for PLRTs. Agricultural groups are social network platforms through which farmers learn about new technologies such as PLRTs. Out of the sample, 23% of the farmers belonged to agricultural groups.

3.2 | Deterministic cost–benefit analysis

Results reveal that 81%, 56%, and 51% of the farmers were willing to pay for charcoal coolers, brick coolers, and tunnel solar driers, respectively. These results indicate acceptability of PLRTs and are further supported by findings of Ogumo, Kunyanga, Okoth, and Kimenju (2017) that estimated the adoption rate of charcoal coolers in Kenya at 80% in Kajiado and Narok Counties in Kenya. This is attributable to the low payback period estimated for horticulture evaporative coolers (Tilahun, 2010).

Evaporative cooling technologies are not new worldwide but their use in Kenya is limited. Therefore, research costs were not factored in the cost–benefit analysis, following Karl, Holst, and Otte (2012). The cost of extension activities throughout the adoption period was estimated at US$ 5 per farmer per year (Perraton, Jamison, Jenkins, Orivel, & Wolft, 1983). This cost was added annually to the cost of installing a charcoal cooler (4M × 4M × 2.5M), a zero energy cooler (3M × 2M × 1M) and a tunnel solar drier (17.5M × 1.5M × 1M).

Farmers provided data on the number of mangoes that they were willing to handle in the PLRTs for a period of 10 years, (the number of years they were expected to use the technology based on expert opinion) from 2019. This proportion out of their total output was assumed to be the adoption rate and was calculated annually. The average adoption rate was estimated at 45%. However, a conservative cumulative adoption rate of 10% was assumed starting with 1% adoption in year one. The cost of the structures was estimated based on the corresponding expected adoption rate. There was no adoption lag as no farmer was not willing to store mangoes in 2019. Farmers were expected to start benefiting from PLRT from 2019. The change in total surplus over a period of 10 years formed the benefit stream. These potential benefits were then discounted at 10% (the lending rate for agricultural loans) per annum and compared against discounted cost of the technologies and extension. Investment methods such as the NPV, IRR, and BCR were used to assess the potential impact of investment in postharvest loss reduction technologies.

According to TBCS (1998) and Affognon (2010), a social discount rate ranging between 8% and 12% per annum with a most likely value of 10% per year is credible. The cost of capital for agricultural loans as provided by the Agricultural Finance Corporation (AFC) in 2019 was 10%. This was consistent with subsidized lending rates for purchase of farm

TABLE 1 Variables used in measuring potential benefits of postharvest loss reduction technologies

Parameters	Formula/Symbol		Source
Elasticity of supply	ε	$0.74^{1\&3}$	Giblin and Mathews (2005)[1] Alston et al. (1995)[3]
Elasticity of demand	η	0.58	Bundi, Nzuma, and Mbatia (2013) Ecker and Qaim (2008)
Proportionate increase in yield (%)	$E(Y) = (Y_1 - Y_0)/Y_0$	10	Expert opinion (Conservative estimate)
Cost reduction (%)	$E\,(C)$	121	Own calculation
Net reduction in cost (%)	$\mathbf{K} = \left[\frac{\mathbf{E(Y)}}{\varepsilon} - \frac{\mathbf{E(C)}}{1+\mathbf{E(Y)}}\right] p \mathbf{A_t (1 - \delta_t)}$	−8.79	Own calculation
Adoption rate	A_t	0.45	Mean of annual proportion of mangoes farmers were willing to manage through the postharvest technologies
Relative reduction in price (%)	$Z = K\varepsilon/(\varepsilon + \eta)$	−4.93	Own calculation
Initial equilibrium price (USD)	P_0	150	Survey data
Yield (before research induced change) (Tons)	Y_0	23.24	Survey data
Yield (after research induced change) (Tons)	Y_1	25.56	Expert opinion
Change in consumer surplus (M) USD/Ha	$Z\,P_0\,Y_0\,[1 + (0.5Z\eta)]$	639	Own calculation
Change in producer surplus (M) USD/Ha	$(K - Z)\,P_0\,Y_0\,[1 + (0.5Z\eta)]$	500	Own calculation
Change in total surplus (M) USD/Ha)	$K\,P_0\,Y_0\,[1 + (0.5Z\eta)]$	1,139	Own calculation

Source: Adopted from Kristjanson and Zerbini (1999) and Alston et al. (1995).

inputs at Equity Bank in Kenya at the time of the study. The NPV of the research was US $ 1.29 billion, with an IRR of 28% and a BCR of 4:1 (Table 3). The positive NPV imply that the proposed investment in PLRTs has fairly attractive returns given the cautious assumption made on the annual 1% adoption rate and a maximum adoption rate of 10% in 10 years. The estimated IRR exceeded the market rate of 10% implying that investing in the PLRTs has potential of yielding a higher return than investing the same capital on alternative investments. An IRR of 28% suggests that investing in the PLRTs would yield 28 times more return than alternative investments. A BCR of 4:1 means that the investor can expect $ 4 in benefits for every $ 1 in cost. This implies the technology is profitable and worth investing in.

These findings concur with Moussa, DeBoer, Fulton, and Boys (2011) who evaluated the economic impact of improved cowpea storage technologies in West and Central Africa and found that recipient countries found the project viable since the regional IRR estimated at 29% surpassed the cost of capital. According to the principal donor (the US government), the project was worth investing in since then, the opportunity cost of capital was lower. The NPV was greater than 295 million US dollars valued at about 17 million annually. Further, in assessing the return on investing in improved postharvest technologies, Mwebaze and Mugisha (2011) estimated the BCR at between 4.3 and 5.5 indicating that the benefits of PLRTs use are higher than the costs involved.

Similarly, Kimenju and De Groote (2010) provided evidence that investing in improved maize storage technologies in Kenya is viable. The authors found that the NPV

TABLE 2 Summary descriptive statistics of respondents

Explanatory variable ($n = 160$)	Mean	*SD*
Household characteristics		
Age (years)	48.51	16.15
Gender of Household Head (% Males)	0.84	0.37
Experience (Years)	11.49	6.60
External support services		
Group membership (% Yes)	0.23	0.42
Access to extension services (% Yes)	0.44	0.50
Access to credit (% Yes)	0.08	0.27
Farm characteristics		
Total land size (acres)	3.16	3.90
Area under mangoes (acres)	0.66	1.47
Education of household head (Years)	8.13	4.12
Willingness to pay for postharvest technologies		
Aware of postharvest technologies (% Yes)	0.67	0.47
Willingness to pay for a charcoal cooler (% Yes)	0.30	0.46
Willingness to pay for a brick cooler (% Yes)	0.15	0.36
Willingness to pay for a tunnel solar drier (% Yes)	0.48	0.50

TABLE 3 Cost–benefit analysis results of investing in postharvest technologies in Kenya

Period	Costs (US$)	Benefits (US$)	Net benefits (US$)	Discounted costs (US$)	Discounted benefits (US$)	Cumulative discounted benefits (US$)
2019	10,872,012	−133,199,198	144,071,210	9,893,531	−121,211,270	−131,104,801
2020	22,613,784	−225,146,559	247,760,343	18,769,441	−186,871,644	−205,641,085
2021	35,277,504	−263,384,217	298,661,721	26,458,128	−197,538,163	−223,996,291
2022	48,918,139	−233,324,654	282,242,792	33,264,334	−158,660,764	−191,925,099
2023	63,593,580	−117,957,646	181,551,226	39,428,020	−73,133,741	−112,561,760
2024	79,364,788	102,478,595	−23,113,807	44,444,281	57,388,013	12,943,732
2025	96,295,943	450,866,177	−354,570,234	49,110,931	229,941,750	180,830,819
2026	114,454,606	953,620,651	−839,166,045	53,793,665	448,201,706	394,408,041
2027	133,911,889	1,641,153,500	−1,507,241,611	56,242,994	689,284,470	633,041,477
2028	154,742,628	2,548,389,491	−2,393,646,863	60,349,625	993,871,902	933,522,277
Net present value = US$ 1,289,517,310			Internal rate of return = 28%		Benefit cost ratio = 4.29	

Source: Own calculation.

for the four new maize postharvest technologies was USD 2,060, 2,111, 1,828, and 2,216 with benefit–cost ratios (BCR) of 7.1, 3.2, 0.5, and 3.0, respectively. In addition, Regassa (2014) evaluated the ex-ante benefits of reduction of postharvest maize losses in Darimu Woreda, Ethiopia. The NPV of the project was found to be USD 36.4M. The IRR was 250%, and the BCR was estimated at 253. These results demonstrate that investments in postharvest technologies pay off.

3.3 | Sensitivity analysis

Our analysis attempted to assess the potential economic impact of investment in PLRTs assuming certainty and timing of costs and benefits as well as the adoption profile of potential adopters. This is not always the case in the real world. In order to take care of uncertainty in the timing of costs and benefits and adoption rates, a sensitivity analysis was undertaken on the results to test validity and robustness of the assumptions made in the economic surplus model. This involved changing both the adoption and discount rates. Increasing the adoption rate to 12% the NPV increased to $ 4.58 billion and the IRR and BCR doubled to 58% and 9.4, respectively. Reducing the interest rate to 8% increased the NPV to $ 1.61 billion. Further, increasing the interest rate to 12% reduced the NPV to $ 993 million and the BCR to 3.9. The results displayed sensitivity to changes in the adoption and interest rates. Attractive results were displayed at higher adoption rates and lower discount rates. This implies that returns to PLRTs highly depend on adoption decisions by the farmers. Therefore, there is need to actively promote the technology to ensure high adoption levels by the farmers. These results show that, as expected, investment in PLRTs is worthwhile at lower discount rates. Lower discount rates imply cheaper cost of capital and hence higher returns reflected by investment appraisal indicators.

4 | CONCLUSION AND RECOMMENDATION

This study aimed at assessing the potential economic impact of investing in postharvest loss reduction technologies among mango farmers in Embu county in Kenya. Results from the study revealed that existing, applicable, proven, and low cost PLRTs are acceptable among smallholder farmers. This is in a bid to try and reduce the postharvest losses that are estimated at 40% - 50% in the fruit subsector, increase shelf life, and thereby farm income. The results indicate that farmers were willing to invest in charcoal coolers, brick coolers and tunnel solar driers, respectively. Further, the estimated potential benefits to consumers and producers were substantial. Using the cost–benefit analysis (CBA) approach, a maximum adoption rate of 10% over 10 years and a 10% discount rate it was found that the investment was worthwhile. The NPV was positive and the IRR was greater than the cost of capital. Sensitivity analyses indicated that the investment is viable at higher adoption and lower discount rates indicating the need to promote the technologies even under difficult macroeconomic conditions. The cost of capital should also be maintained at affordable rates. Further research to estimate the value of the mean willingness to pay, which will demonstrate the acceptability of the postharvest loss reduction technologies, guide pricing decisions and product development is worth considering.

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CONFLICT OF INTEREST

None declared.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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