Cost Benefit Analysis of Post-Harvest Management Innovations in Mozambique

Report

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List of Abbreviations

AfDB	African Development Bank
BCR	Benefit-Cost-Ratio
CAADP	Comprehensive Africa Agriculture Development Programme
CBA	Cost Benefit Analysis
CGIAR	Consortium of International Agricultural Research Centers
CRS	Catholic Relief Services
DFID	Department for International Development
EU	European Union
FANRPAN	Food Agriculture and Natural Resource Policy
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
ILO	International Labour Organisation
IRR	Internal Rate of Return
LGB	Larger Grain Borer
LSF	Large scale farmers
MDG	Millennium Development Goal
MS	Microsoft
MSF	Medium scale farmers
MZN/MT	Meticais
MT	Metric Tonnes
NGOs	Non-Governmental Organisations
NPV	Net present value
PHL	Post-harvest loss
PHLM	Post-harvest loss management
PHM	Post-harvest management
PSRSA	National Agriculture Policy
SADC	Southern Africa Development Committee
SDC	Swiss Development Cooperation
SSA	Sub-Saharan Africa
SSF	Small scale farmers
UN	United Nations
USAID	United States Agency for International Development
WFP	World Food Programme

Executive Summary

A. About the report

This report presents results of cost-benefit analysis of modern post-harvest technologies (metal silos and hermetic bags) with particular focus on maize, beans and cow peas in Mozambique. Sub-Saharan Africa has been incurring huge post-harvest losses estimated at $4 billion per year with cereal losses high at 14 million tonnes accounting for about 25% of the total crop harvested. This scenario presents justification to find ways of reducing or eliminating post-harvest food losses.

FANRPAN commissioned this study with the following objectives:

- To find out the extent to which post-harvest loss management (PHLM) issues are addressed through national agricultural and economic policies;
- To ascertain the state of knowledge of post-harvest economics in the country;
- To quantify crop production and post-harvest losses for selected staple crops;
- To find out PHLM innovations adoption rate;
- Carryout cost-benefit analysis (CBA) of PHLM innovations; and
- To make recommendations on possible financing arrangements for Mozambican government to support dissemination of improved PHLM technologies.

B. Methodology and limitations

B1 Desk review

The consultants identified and gathered relevant literature for Mozambique on post-harvest losses and how these are being addressed or otherwise in national policies, programmes and projects. Most of the literature was identified via e-resources while some was obtained from key stakeholders. The list of documents used is presented in Annex 2.

B2 Key Informant Interviews

The key stakeholders were drawn from government ministries, UN agencies funding agricultural programmes and NGOs implementing food security programmes. The Consultant received responses from a few stakeholders and then obtained through FANRPAN, some documents or reports which estimate crop (maize, common bean, cow pea) production disaggregated by province and agro-ecological region as well as the magnitude of post-harvest losses.

B3 Cost-benefit analysis of post-harvest technologies

Estimating the costs and benefits and constructing cash-flows

To undertake CBA, streams of incremental costs and benefits associated with the adoption of the metal silo and hermetic bag technologies were constructed in MS Excel, based on the knowledge available on PHLM practices of farmers in Mozambique. Net cash-flows were calculated. The cash-flows were prepared based on the expected lifespans of the metal silos and hermetic bags (20 years and 2 years, respectively). In keeping with standard practice in CBA, the study established both the counterfactual and treatment scenarios for smallholder, medium-scale and large scale farmers involved in production of maize, beans and cowpeas in Mozambique.

An assumption was made that farmers who chose to invest in a metal silo can derive benefits from reduction in post-harvest losses over the entire duration of the life of the metal silo (20 years). This was used as the project life. To standardise the period of comparison between the hermetic bag and metal silos, an assumption was made that farmers would invest in hermetic bags over the same period and derive benefits of the technology over a period of 20 years. However, with the hermetic bags, their lifespan is two (2) years, implying that for farmers to continue enjoying the benefits they have to replace the worn-out bags with new ones, hence the model for 20 years assumed that the hermetic bags would be replaced once every two years.

To establish the level of investment and the incremental benefit, the CBA modelling exercise constructed modules which were based on the carrying capacities of the metal silos. A standard module of 500 kg metal silo was used and it was based on the information available concerning the average yields and average hectarage per farmer planted to maize. For cost-benefit analysis, a 500 kg metal silo module was matched with a 10 x 50 kg bag module for hermetic bags.

Two counterfactual scenarios were constructed based on production, marketing and storage practices found in Mozambique and the fluctuations in commodity prices on the market in the various regions of the country. Scenario 1 assumed that some of the farmers who lack modern PHLM technologies decide to immediately sell their produce at harvest time to avoid losses in storage. Scenario 2 assumed that some of the farmers keep the commodities for home consumption later in the season, and do not sell immediately after harvest because they fear that the market might not have the commodities at an affordable price to purchase back later in the season. The scenario assumes that such farmers are not aware that when they store they lose part of the product to pest damage or decay in storage, and that it will be better to sell and salvage value from their production.

These two models were used for constructing the gains of PHLM technologies. Scenario 1 estimated the incremental benefits by calculating the quantity of food lost in storage without technology, and then multiplying this by the price differential between the immediate harvest period and the lean season price. An assumption was made that metal silos and hermetic bags were 100% effective in preserving the quantity of food harvested until the lean season (8 months later). These scenarios were used for all three crops, maize, beans and cowpeas.

Discounting of the cash flows

For each crop and model, the cash-flows comprising the cost of adoption of the technology and running costs of pesticides to treat the crop each year, and the benefits of improved storage technologies were computed for a period for 20 years for both metal silos and hermetic bags. These cash-flows were then discounted at a rate determined by the **Ramsey equation** or formula.

For purposes of this analysis a discount rate of 12% was used for the **base case**, 10% for the best case and 14% for the pessimistic scenario.

Viability indicators

To assess viability of the investments in PHLM technologies, five indicators were computed using the various scenarios of risk, farmer post-harvest management preferences and technology type, discussed above, but standardising the module (quantity stored) as 500kg. These indicators were:

- Net present value (NPV) (of the net cash flows);
- Internal rate of return;
- Benefit-to-cost ratio;
- Payback period; and

- Breakeven point.

Sensitivity analysis

In order to accommodate in the analysis the impact of variations in farmer types and capacity, year on year variations in staple food prices, variations in effectiveness of the technologies in reducing the post-harvest losses based on agro-climate conditions, differences in crop varieties, and variations in the workmanship of those manufacturing the metal silos and hermetic bags, on the estimated indicators of viability, the models were subjected to rigorous sensitivity analysis assuming the following four main scenarios:

- 20% less benefit from base case;
- 20% more benefit from the base case;
- 14% discount rate (assuming a more risky environment than base case of 12%); and
- 10% discount rate (assuming less risky environment).

B4. Limitations

Whereas questionnaires were sent to a wide range of stakeholders as had been planned, only a few responses were received. More information was obtained through FANRPAN and internet resources. However, the data was not disaggregated by province and agro-ecological region as needed.

Precise data on number and size of farmers growing each staple food crop (maize and pulses), the yields realised per size of farmer and per post-harvest loss management practice adopted could not be obtained, hence the limitation was mitigated by conducting the CBA analysis at the level of the technology (silo, or hermetic bag as the unit of analysis) and using assumptions on number of farmers using different types of technologies to assess potential impact on the value chains.

As the Consultants spoke English while the stakeholders interviewed in Mozambique mainly spoke Portuguese (with a few speaking English), and the report wanted in English, the language barrier was mitigated by engaging a Portuguese translator who translated the questionnaire into Portuguese, assisted in making telephone calls to the stakeholders, as well as translating the responses.

C. Key Findings and Recommendations

C1. The extent to which post-harvest loss management (PHLM) issues are addressed through national agricultural and economic policies

Post-harvest losses (PHL) are estimated at between 20 and 30% of harvest in Mozambique. Mozambique experiences about 400,000 MT food deficits every year and much of it is attributed to PHL. Food only lasts for three months after which it is lost due to poor storage conditions. This results in short seasonal commercialisation which exacerbates food insecurity.

The research carried out by Dr Lucas Tivana, et al, reveals that the Mozambique Strategic Plan for Agricultural Development Sector 2011-2020 contains a Post-harvest management strategy. However, there is no stand-alone policy on PHM which weakens institutional collaboration on the subject. Furthermore, he points out that there is no relevant research initiative on PHM in Mozambique and that there is a general lack of PHM service providers in Sub-Saharan Africa and SADC region. PHM aspects are therefore under-represented in most agricultural research and development strategies. PHM is affected by lack of investment in infrastructure such as roads, transportations and local oriented food industries, policy gaps, lack of training institutions for PHM, lack of capacity by farmers to access financing.

In the absence of a stand-alone policy PHM in Mozambique is guided by Comprehensive Africa Agriculture Development Programme (CAADP) and the SADC policy. Specifically, CAADP pillar II, III and IV are relevant for the promotion of PHM.

SADC Agricultural policy of 2013 is in line with CAADP objective of promoting sustainable and equitable African economic growth and social economic development to facilitate the attainment of millennium development goals in Africa. SADC policy proposes among other things promoting national and regional investments in storage and agro-processing infrastructures in an effort to deal with price volatility, seasonality and the unpredictability in food availability.

Mozambique agricultural policies are in line with CAADP and SADC agricultural policies. However, absence of a stand-alone policy on PHM weakens implementation.

C2. The state of knowledge of post-harvest economics in the country

The responses from the stakeholders show that there is a general lack of knowledge of modern PHM technologies among farmers, traders and food processors. Most farmers maintain the use of traditional methods which are not effective. Modern technologies have been introduced in some districts in the Northern provinces; some small holder farmers appreciate them but cannot afford the costs.

C3. Crop production and post-harvest losses for selected staple crops

In terms of food production, the country is divided into three regions; the south, central and north. The southern region is food deficient and relies on the central and north for staple food supply. The central and northern regions have better agro-ecological conditions and therefore produce surplus food. The central region produces 50% of the maize, while the north produces 40% and the south only 10%. However, because of poor road network and high transport costs the southern region imports maize from South Africa which is cheaper.

Crop production statistics for 2012-3, were used to estimate the losses, the returns to investment in storage, and the proportion of agricultural GDP preserved with the improved technologies. The production statistics were 1.63 million metric tonnes for maize, 190,000 metric tonnes of beans and 80,000 metric tonnes of cowpeas.

Post-harvest losses are estimated at between 20 and 40% depending on the crop and geographical location. Most farmers sell more than half of their crop within three months of harvest to avoid physical losses through infestations.

C4. PHLM innovations adoption rate

PHM innovations such as metal silos and hermetic bags have been introduced in the northern provinces which produce the bulk of food crops. The adoption rate was said to be low due to the cost of purchase of the technologies.

C5. Cost-benefit analysis (CBA) of PHLM innovations

C5.1 CBA Analysis Results for Maize

Viability of hermetic bags to farmers who produce and sell maize at harvest time (do not store)

For hermetic bags, CBA results for the **base case scenario** showed that the net present value of the cash-flows (incremental benefits minus incremental costs over a period of 20 years, discounted at a rate of 12% per annum) is positive (MZN 40,975.91), the benefit-to-cost ratio is 2.50, and the internal rate of return is greater than 100,000% (see Annex 6.1). The results showed that farmers would benefit if they adopt hermetic bags and stop the delay the sale of maize to the lean season when prices at three times higher (MZN 28.80 per kg up from MZN 8.50 per kg).

Programming implications of the results

For a maize farmer who has a practice of producing and selling his/her crop at harvest time, there is good rationale for the farmer to invest in hermetic bags, store the maize and sell in the lean season. The investment in the hermetic bags will give the farmer more benefits than the value the farmer gets when he/she sells at harvest time. The price differential between the harvest season and the lean season in Mozambique is so large that the investment dividend is worth the incremental cost of investing in improved storage technology. As this model is built on units of 50 kg bags, unless there is a significant discount offered to farmers for higher quantities of bags purchased, the results apply equally to lower and higher quantities produced and stored / sold. Adoption of hermetic bags would not necessarily be a better option for farmers who have a practice of selling their maize at harvest time, instead of the lean season.

Recommendation 1: The Government of Mozambique or development agencies willing to invest in Mozambique to support smallholder farmers to adopt the hermetic bag technology must encourage maize farmers who are already prudent to sell their surplus grain immediately after harvest to invest in hermetic bag technology or other similarly effective technologies as the investment is worthwhile.

Viability of hermetic bags to farmers who produce, store and sell (or consume) the maize during the lean season

The results for the **base case model** with 1,500 kg storage module, showed a positive NPV of MZN 69,546.53 (US$ 1,344), a BCR of 3.55, an IRR greater than 50,000%, and a payback period of three (3) years for a farmer or trader storing 1,500 kg of maize (Annex 6.1). These are all indicators of viability of the investment. Farmers who do not sell immediately after harvest, but choose to store for later use (sell or consume) will benefit from the technology as the returns will outweigh the investment costs by approximately 255% t. Such farmers can breakeven even with only 28% of the benefit. This means that farmers with a post-harvest loss of 8.4% (not 30%) when they do not use the technology would stand to benefit if they were to invest in hermetic bags to store for sale or consumption later in the season.

Programming implications of the results

The results of the CBA analysis clearly show that farmers who do not have a practice of selling their grain soon after harvest but store and lose up to 30% of their produce to post-harvest losses, stand to benefit immensely by investing in hermetic bags, whether or not they then consume or sell the preserved maize later in the consumption season.

Recommendation 2: The Government of Mozambique or development agencies seeking to support maize value chain actors to adopt hermetic bags as a grain storage technology can do so targeting farmers or traders whose current practice is to produce or purchase (respectively) and store maize for own use or sale later in the season. Among these they should target those who currently lose at least 12 %t of their harvest to pest and other forms of damage in storage. Those who are currently losing below 12% of their harvest in storage, do not gain by investing in hermetic bags because the value of the product preserved is not sufficient to off-set the investment cost of adopting hermetic bags. These should be encouraged to sell immediately after harvest where feasible.

Recommendation 3: Government of Mozambique and development agencies promoting adoption of the hermetic bags should ensure that they strengthen efficiency of the value chain for hermetic bags such that the cost to the farmer does not exceed MZN 490 with installation of the platform where the bags will be placed for safe storage. If it exceeds this figure it will not be viable to the maize farmers.

Recommendation 4: To increase the rate of adoption of hermetic bags by SSFs, MSFs, Traders, and Agro-industries, the Government of Mozambique and development agencies should strengthen the supply chain of hermetic bags, with the view to increasing efficiencies, exploiting economies of scale in their production, or importation and where possible encouraging government to co-invest by lowering import taxes on the bags, where applicable. The investment by government in lowering or removing import taxes on the bags such that they are available to farmers at a cost of MZN 140 (US$2.70) will bring MZN 2.50 per every MZN 1.00 invested (in the form of tax waivers) at the minimum.

Recommendation 5: Development agencies should aim to support the value chain of hermetic bags for storage of maize so that they reach farmers at a cost of MZN 140 (US$2.70) or less per 50 kg unit. The lower the price of the hermetic bag the more likely that it will be viable even for farmers or users who were incurring lower PHL. At a cost of MZN 140, farmers with a loss of 12 % per annum without the technology will be able to breakeven if they invest in the hermetic bags.

Recommendation 6: Given the challenge of inadequate supply, largely due to the high import duty on hermetic material (37%), donors and NGOs should work with the private sector and farmer organisations to lobby government to remove or lower the import duty on hermetic material, and in capacitating the private sector to manufacture the bags at scale and in a decentralised manners so that the bags can reach all of Mozambique’s major grain producing regions.

Recommendation 7: The interest, commitment and investments from the private sector in manufacturing, distributing and selling the hermetic bag technology should be promoted through demand creation among the farmers through training and product promotion to create incentives for the private sector to invest in developing the supply chain necessary for sustainability.

Recommendation 8: Scaling-up hermetic bag storage innovation in terms of extension activities should be considered by development practitioners (in government, the private sector and NGOs) as a prerequisite for building demand among farmers and traders that is large enough to attract more investment by the private sector into local supply of hermetic bags in Mozambique. Efforts should be dually on farmers and traders, as well as potential private sector manufacturers to help them understand the technology, quality requirements, potential market, and challenges in reaching smallholder farmers with the new product.

Recommendation 8: Given the short product life-span of two (2) years, and the payback period of Four (4) years (assuming 100 % effectiveness in reducing post-harvest losses), timely supply of the hermetic bags is critical in achieving this high level of effectiveness among smallholder farmers. Late supply of the bags will compromise loss reduction and reduce the viability of the investment. To be commercially viable, the bags will need to be effective right from the first year of use, hence they should be supplied before the farmers begin to harvest their crops.

Recommendation 9: To reach smallholder farmers, the capacity of local government and NGO extension services to understand the importance of storage pest management and deal with it through technology use and technology transfer should be strengthened in Mozambique, especially targeting Cabo Delgado, Nampula, Niassa, Zambezia and Nampula provinces which are among the major grain producing regions. These initiatives, should use both traditional and non-traditional extension approaches to implement hermetic bag promotion activities. These should include demonstrations of the technology in targeted villages as well as promotion via community radio and television programmes, and cell-phone videos. Community radio programmes can be developed and aired, which draw content and presenters from groups of farmers and traders that have successfully adopted the technology and found it working.

Recommendation 10: Given that sensitivity analysis shows that the payback period for an investment in hermetic bag technology for farmers willing to store maize and consume or sell in the lean season is short (three (3) years) for an investment over 20 years, development programmes to support hermetic bag technology should be designed to provide support to resource-poor and subsistence farmers for a minimum period of three (3) years, the longer the period the preferable. Promotion of this technology should not be a short-term undertaking given that farmers need to build a culture of buying new bags every second year to replace the worn-out ones. A period of three (3) years would be adequate to ensure that farmers can be left on their own to purchase the bags once every two years as they would have recouped in that period the projected future costs (for the remaining 17 years).

Viability of metal silos to farmers who produce and sell maize at harvest time (do not store)

For metal silos, CBA results for the **base case scenario** showed that the net present value of the cash-flows (incremental benefits minus incremental costs over a period of 20 years, discounted at a rate of 12% per annum) is positive (MZN 56,958.87, or US$0.73 per kg of maize stored), the benefit-to-cost ratio is greater than one (1) (6.05), and the internal rate of return is positive which implies that the investment is viable (see Annex 6.2).

Programming implications of the results

If a farmer or trader desires to shift practice to production and storing of 1,500 kg of maize rather than selling immediately after harvest, there is an added benefit of introducing metal silos to encourage him/her to store and sell at a higher price later during the lean season. The magnitude of the added benefit is high (the value of the incremental benefit is 505% above the cost). The cost of the improved storage technology is lower than the value of the additional benefits of the technology (quantity preserved multiplied by the difference between lean season and harvest season prices). In other words, the farmer or trader will be better off in purchasing the metal silo and storing his/her maize and wait to sell during the lean season rather than harvest (or purchase) and sell soon after.

As this model is built on units of 1,500 kg metal silos, with increases (3%) in cost of production of smaller units of silos, the results indicate that the returns to investment for smaller units of silos (350 kg, 250 kg, 100 kg and 50 kg) would be slightly lower than for the 1,500 kg metal silo but farmers will remain viable, because the price of the metal silo has to increase nine-fold before the investment makes a loss. The loss of economies of scale is much lower than this hence farmers who buy smaller units even at three times higher cost will still earn more than what they invest.

Given the payback period of one (1) year (best case scenario), and two (2) years (worst case scenario), adoption of metal silos will always be a better option for farmers who have a practice of selling their maize at harvest time, instead of the lean season, if they intend to use the silo for at least two (2) years. Even those who use the metal silos only for three years and abandon the practice will recover their 20 years investment costs for the technology within the first two (2) years of use.

The same applies to traders who buy for immediate sale at harvest time and do not have a practice of storing but now wish to invest in the metal silos and store for a certain period for resale in the lean season.

Recommendation 11: Government of Mozambique or development agencies willing to promote adoption of the metal silo technology should only all willing farmers and traders willing to use the silo for at least three (3) years, otherwise the investment will not be worthwhile. Messaging to create demand among farmers and traders should emphasise the non-viability of shorter periods of use of the metal silo.

Viability of metal silos to farmers who produce, store and sell (or consume) the maize during the lean season

The results for the **base case model** showed a positive NPV of MZN 85,259.50, a BCR of 8.59, a very high IRR of 200,000 %, and a shorter payback period of one (1) year for a farmer or trader storing 1,500 kg of maize (Annex 6.2). The results show that it is a worthwhile investment. Farmers who do not sell immediately after harvest, but choose to store for later use (sell or consume) will benefit from the technology as the returns will outweigh the investment costs by approximately 759%. Such farmers can breakeven even with about 11.6% of the benefit (that is, even those who lose only 3.48% (not 30 %) without the technology would stand to benefit if they were to invest in metal silos to store for sale or consumption later in the season and if they were to do it continuously for 20 years).

Programming implications of the results

The results of the CBA analysis clearly show that farmers (or traders) who do not have a practice of selling their grain soon after harvest but store and lose up to 30% of their produce to post-harvest losses, stand to significantly gain more than those who have been selling at harvest. They will benefit by investing in metal silos, whether or not they then consume or sell the preserved maize later in the consumption season.

The metal silo remains viable even for farmers who will adopt and use it for shorter periods rather than the projected lifespan of the silos because the payback period is very short (one to two years depending on assumptions of about the level of incremental benefits).

Recommendations 12: Government of Mozambique or development agencies willing to promote adoption of the metal silo technology should especially target farmers and traders who have a culture of storing maize for later use if these are willing to use the silo for at least three (3) years, otherwise the investment will not be worthwhile. Messaging to create demand among such farmers and traders should emphasise the non-viability of shorter periods of use of the metal silo (i.e., less than three (3) years).

Recommendation 13: Given that sensitivity analysis shows that the payback period for an investment in metal silo technology for farmers (or traders) willing to store maize and consume or sell in the lean season is one (1) to two (2) years for an investment over 20 years, development programmes to support adoption of the metal silo technology for maize in Mozambique should be designed to provide support to resource-poor and subsistence farmers for a minimum period of three (3) years, the longer the period the more preferable. Promotion of this technology can be a medium-term undertaking given that farmers do not need to re-purchase the silo for 20 years. A period of three (3) years would be more than adequate to ensure that farmers have the skills to use the metal silo correctly and effectively, and they see the benefits, which will encourage them to continue using the silos. Within three (3) years, farmers and traders will have earned sufficient incremental benefits to cover the projected future costs (for the remaining 17 years before the silo becomes obsolete).

Recommendation 14: Given that the returns to investment for metal silos are higher than for hermetic bags (BCR of 8.59 for silos versus 3.55 for hermetic bags for farmers that have a culture of storing), and the payback period is shorter for metal silos than hermetic bags, post-harvest management programmes seeking to promote improved technologies over a shorter period of time should prioritise the metal silo ahead of the hermetic bag provided, holding all other things constant.

Recommendation 15: Given the high initial capital investment cost for the metal silo, post-harvest management programmes seeking to promote adoption of improved storage technologies for maize in Mozambique should consider the hermetic bag technology for wider reach with limited resources ahead of the metal silo, but actively promote the metal silo as a graduation pathway for hermetic bag adopters, because metal silos offer a more viable longer-term preferred choice if the resources allow. Hermetic bags might look cheaper on the surface but due to their short life-spans, they are more expensive for resource poor maize farmers in the longer-term because farmers have to replace them once every two (2) years.

C5.2 CBA Analysis Results for Beans

Hermetic bags

For hermetic bags and for farmers that sell their produce immediately after harvest, CBA results for the **base case scenario** showed that the net present value of the cash-flows (incremental benefits minus incremental costs over a period of 20 years, discounted at a rate of 12% t per annum) is positive (MZN 65,882.77), the benefit-to-cost ratio is 3.42, and the internal rate of return is greater than 50,000 which implies that the investment is viable (see Annex 6.3). The payback period for beans was three (3) years.

Programming implications of the results

A farmer able to produce and store beans but has a practice of selling his crop at harvest time, will stand to benefit if he/she changed to storing and selling later in the season. The value of the additional benefits of the technology (quantity preserved multiplied by the difference between lean season and harvest season prices) outweighs the incremental cost of the improved storage technology (hermetic bags). Adoption of hermetic bags would bring financial advantages that outweigh the associated incremental costs. Use of hermetic bags for storing beans would bring about higher returns (almost double) to farmers using the technology for preserving beans than those using it for maize.

Recommendation 16: Agricultural development programmes seeking to reduce post-harvest losses can promote adoption of the hermetic bag technology for bean producers and traders including targeting those who are selling immediately after harvest because they do not have proper storage facilities. Both scenario 1 and 2 farmers would benefit.

The results for farmers who have a practice of storing and using the beans later, or selling them in the lean season confirm that even those non-adopters of hermetic bags with low post-harvest losses, stand to benefit if they were to adopt hermetic bags and eliminate the losses. The benefits of improved technology outweigh the incremental costs by a wide margin. The BCR value of 9.4 shows that the investment can recover the costs as much as nine (9) times during the 20 years of investment.

Recommendation 17: Given that returns to investment in hermetic bags for storage of beans are superior to those of maize by 229% (for those who do not sell at harvest), Government of Mozambique and development agencies should consider promoting hermetic bags more for the storage of beans as opposed to maize, if prioritisation was to be made between the two crops. However, since the returns for maize are also high though not higher than for beans, it would be worthwhile also to promote the technology for maize as well without any reservations, depending on farmers' technology preferences.

Metal silos

For metal silos, and for farmers that would otherwise sell immediately after harvest, the **base case CBA model** showed a positive NPV of MZN81,865.73, a BCR of 8.26, an IRR greater than 200,000%, and a shorter payback period of one (1) year (e.g., for a farmer or trader storing 1,500 kg of beans) (Annex 6.4). The results show that the investment will pay-off even for smaller production units.

Farmers or traders who do not sell immediately after harvest, but choose to store for later use (sell or consume) will benefit even more from the technology as the returns will outweigh the investment costs by approximately 2,100% (21 times). Such farmers who previously had as little as 1.3% loss in storage (not 29.8%) before adopting the technology, would stand to benefit if they were to invest in metal silos to store for sale or consumption later in the season and if they were to use the technology for 20 years.

Recommendation 18: For farmers who can grow large quantities of beans (100 kg and above) and intend to store for later use or sale in the lean season, the metal silo should be promoted ahead of the hermetic bag technology. Programmes should focus on improving the capacity of local artisans to manufacture and distribute these silos, but being part of a larger range of products that artisans produce because the 20 years lifespan of a metal silo does not make it a viable mono-product long-term business opportunity for artisans.

Recommendation 19: Given the high payback period for the metal silo technology development programmes to support farmers in adopting this technology can be designed to support farmers for a period of at most three (3) years, as this is sufficient for them to have recouped investment costs for 20 years.

C5.3 CBA Analysis Results for Cowpeas

Hermetic bags

The **base case model** for the scenario where the farmer or trader has no tradition of storing, but sells immediately after harvest, showed that investment in hermetic bag technology would leave the farmer/trader better off, with an NPV of MZN19,312.66, BCR of 1.71 and IRR of more than 500,000% . The payback period is seven (7) years and breakeven loss is 58.5% of current loss of 30% (that is, if farmers preserve only 17.55% of their produce in storage rather than 30% they will recover the costs incurred in investing in hermetic bags over a 20 years lifespan). Sensitivity analysis also reveals that the project is viable with 20% less benefits and a discount rate that is more pessimistic, of 14% .

When the scenario of farmers that store for sale later in the season is considered these stands to earn higher incremental benefits from the technology (when compared to the period without technology), with a BCR of 4.7, IRR greater than 500,000% and a much shorter payback period of two (2) years. Breakeven point is reached with 49% of the estimated current benefits which means that even farmers with lower losses (14.7%), who have not been selling at harvest time but have been storing will stand to gain from the investment in hermetic bags. Sensitivity analysis of scenario 2 shows that the incremental benefits will always exceed the incremental costs by a factor of at least 270 percent (BCR ranges from 3.76 to 5.64) (Annex 6.5).

Programming implications of the results

The findings reveal that promotion of hermetic bag technology for cowpea producers is viable even for the scenario where farmers already practice some prudence by selling immediately after harvest. Returns to investment outweigh the investment cost by 71%. However, the payback period is longer given the need to purchase new bags once every one to two years (Raffia Bags last two (2) years while Super Bags last one year, wood poles that form the base have a lifespan of five (5) years). The returns are better than for maize; hence hermetic bag technology should therefore be promoted for storage of cowpeas and beans ahead of maize in areas where the local capacity to supply and install metal silos is not well developed.

Recommendations 20: Given the payback period of two (2) years for farmers and traders who store and sell later in the lean season, such farmers can be supported for at least a two (2) years period to adopt hermetic bags and this is sufficient to leave them when they will have earned enough benefits to stand on their own and continue investing in replacement bags once every two years. However, programmes keen to change the behaviour of farmers from selling immediately after the harvest to storing and selling later should invest for a longer period to support such farmers as the payback period is much longer (5 -10 years). If resources are limited, development programmes should not discourage those selling cowpeas onto the market immediately after harvest to stop doing so, but rather focus on those who are storing with substandard methods of storage to change to better storage methods (e.g. hermetic bag).

Metal silos

The **base case model** for cowpeas indicated that farmers who sell immediately after harvest, will benefit if they changed their practices to storing and selling later, and if they do so using the metal silo technology. The NPV for storing 1,500 kg of cowpea would be 35,295.62, IRR would be 4.13% and the payback period would be two (2) years. Breakeven point could be reached by a lower benefit

(24.3% of the projected PHL of 30%). Sensitivity analysis shows that the technology is so viable that even with 20% of benefit, farmers and traders could breakeven. This implies that even farmers with lower levels of losses (i.e., 6%) without metal silos, would benefit from adopting metal silos and drastically reducing their losses in storage.

When the scenario where farmers do not sell immediately after harvest but store using ineffective traditional methods is considered, the base case scenario shows that metal silos would have a significant impact on farmer incomes if they were to switch to metal silos. Returns to investment would outweigh the costs by 1,036% (BCR of 11.36). They could increase with a 20% increase in benefit to BCR of 13.63, and the cost of the investment over 20 years can be recouped in the first year of adoption of the metal silo technology (if installed and used in that same year).

Programming implications of the results

Cowpea producers who intend to store for sale later are better off with metal silos than hermetic bags, but both options are viable. Farmers or traders can recoup the costs of this investment in the first three (3) years which means support can be provided over a period of three (3) years and it will be enough to leave them with sufficient incremental benefits to reward them for the investment to be made in 20 years (including pesticide).

Recommendation 21: Post-harvest loss management programmes should prioritise the metal silo ahead of hermetic bags in situations where cowpea farmers can afford the metal silo, production is adequate to justify the use of the technology and farmers or traders would like to store the cowpeas for sale or use in the lean season. Even farmers who do not store but sell immediately after harvest can be dissuaded from this practice and encouraged to store and sell later in the season as the incremental benefits far outweigh the incremental costs by a large margin.

As for maize and beans, if the modelling assumes that farmers and traders adopt hermetic bags and metal silos such that all cowpeas produced is properly stored and is preserved, the study estimates that between 0.05 and 0.1% of agricultural GDP will be preserved through PHLM investments. The lower figure is for hermetic bags and the higher is for metal silos.

If the agricultural GDP preserved from storage of maize, beans and cowpeas is added together, the analysis shows that, annually, between 2.77 and 3.81% (US$0.99 million and US$ 1.82 million) of such GDP is preserved and can contribute to growth in the other sectors that are closely integrated with agriculture.

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1. Introduction

1.1 Background

Substantial post-harvest losses in cereals and other staple food crops contribute significantly to food, income and nutrition insecurity in Sub-Saharan Africa. Food producers, consumers, their national governments and other food value chain players are failing to prevent staple food losses after harvest. Losses vary by country, food commodity, capacity of farmers, post-harvest handling, processing and storage technologies and processes they use but range between 1-30% of harvest[1]. Currently, total food losses in Sub-Saharan Africa are estimated to be worth $4 billion per year, an amount which can feed 48 million people (FAO, 2013)[2]. Losses on cereals are estimated to be high and account for about 25% of the total crop harvested[3]. Those for perishables such as fruit and vegetable can reach 50%.

In sub-Saharan Africa, primary insect damage of stored cereal grain (e.g. maize and wheat) and pulses (e.g. common bean, cowpeas and bambarra nuts) is due to infestation mainly by species in the order Coleoptera (i.e. the beetles). Of the beetle species which are primary pests of stored cereal grains, the Larger Grain Borer (LGB), *Prostephanus truncatus* and Maize Weevil, *Sitophilus zeamais*, are the most damaging. In the case of the common bean, damage is due to the bruchid beetles *Acanthoscelides obtectus* and *Zabrotes subfasciatus*. However, of the two, the former is the most widely distributed and damaging species. Cowpeas and bambarra nuts are usually initially damaged by *Callosobruchus spp.* of which the most economically important species are *C. maculatus*, *C. chinensis* and *C. rhodesianus*.

1.2 Objectives of the Study

The objectives of the study were:

- To find out the extent to which Post-harvest management (PHM) issues are addressed through national agriculture and economic policies
- To ascertain the state of knowledge of Post-harvest economics in the country
- To quantify crop production and Post-harvest losses for selected staple crops
- To find out PHM innovations adoption rate
- Carry out cost benefit analysis (CBA) of PHM innovations
- To make recommendations on possible financing arrangements for Mozambican government to support dissemination of improved PHM technologies.

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[1] "*Post-harvest food losses estimation – development of consistent methodology, and introduction",* by Jaspreet Aulakh and Anita Regmi, 2013

[2] Food Balance Sheet Data. 2013. Available at: http://faostat3.fao.org . Accessed May 29, 2016.

[3] Post-harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania Adebayo B. Abass, Gabriel Ndunguru, Peter Mamiro, Bamidele Alenkhe, Nicholas Mlingi, Mateete Bekunda, 2013, Elsevier, *Journal of Stored Products Research* 57 (2014) 49e57

1.3 Methodology

Desk review

The consultant identified and gathered relevant literature for Mozambique on post-harvest losses and how these are being addressed or otherwise in national policies, programmes and projects. Most of the literature was identified via e-resources while some was obtained through key stakeholders. The list of documents used is on annex 6.3.

Key Informant Interviews

Lists of key stakeholders were obtained from the FANRPAN node in Mozambique. The stakeholders were drawn from government (ministries of agriculture, industry and commerce, or small and medium scale enterprises), development partners (e.g., AfDB, DFID, SDC, Helvetas, USAID, and EU) and UN agencies (FAO, WFP, ILO) funding agricultural programmes, agricultural research institutes such as CGIAR centres, private companies involved in production and supply of improved PHM technologies and NGOs implementing food security programmes. The Consultant sought to identify through the stakeholders any documents or research reports which estimate the magnitude of post-harvest losses and types of investments farmers and other value chain actors are making into PHL management systems, and the returns thereof. The consultant obtained from some of the key stakeholders' information on key literature that would assist with the analysis.

A key informant interview checklist was prepared. However, because of communication limitations with Mozambican stakeholders who speak Portuguese the checklist was developed into a structured questionnaire. Moreover, many of the Mozambican stakeholders were not on skype and telephone calls to Mozambique faced challenges of network connectivity and high costs. The questionnaire was sent via email and two responses received via the same. Statistical data for Nampula province, disaggregated by district was received through the FANRPAN Research Assistant in South Africa.

Cost-benefit analysis of post-harvest technologies

Estimating the costs and benefits and constructing cash-flows

To undertake CBA, streams of incremental costs and benefits associated with the adoption of the metal silo and hermetic bag technologies were constructed in MS Excel, based on the knowledge available on PHLM practices of farmers in Mozambique. Net cash-flows were calculated. The cash-flows were prepared based on the expected lifespans of the metal silos and hermetic bags (20 years and two (2) years, respectively). In keeping with standard practice in CBA, the study established both the counterfactual and treatment scenarios for smallholder, medium-scale and large scale farmers involved in production of maize, beans and cowpeas in Mozambique.

An assumption was made that farmers who chose to invest in a metal silo can derive benefits from reduction in post-harvest losses over the entire duration of the life of the metal silo (20 years). This was used as the project life. To standardise the period of comparison between the hermetic bag and metal silos, an assumption was made that farmers would invest in hermetic bags over the same period and derive benefits of the technology over a period of 20 years. However, with the hermetic bags, their lifespan is two (2) years, implying that for farmers to continue enjoying the benefits they have to replace the worn-out bags with new ones, hence the model for 20 years assumed that the hermetic bags would be replaced once every two (2) years.

To establish the level of investment and the incremental benefit, the CBA modelling exercise constructed modules which were based on the carrying capacities of the metal silos. A standard module of 1,500 kg metal silo was used and it was based on the lowest common multiple of metal silo sizes to enable analysis at smaller unit level as well. For cost-benefit analysis, a 1,500 kg metal silo module was matched with a 30 x 50 kg bag module for hermetic bags.

Two (2) counterfactual scenarios were constructed based on production, marketing and storage practices found in Mozambique and the fluctuations in commodity prices on the market in the various regions of the country. Scenario 1 assumed that some of the farmers who lack modern PHLM technologies decide to immediately sell their produce at harvest time to avoid losses in storage. Scenario 2 assumed that some of the farmers keep the commodities for home consumption later in the season, and do not sell immediately after harvest because they fear that the market might not have the commodities at an affordable price to purchase back later in the season. In times of shortages some of the farmers who might have sold immediately after harvest (yet they are not net surplus producers of staple foods) often find themselves having to come back to the market to purchase food at a higher cost in the lean season and therefore find it difficult to secure product on the market to purchase back when they need it to supplement their food requirements. Scenario 2 assumes that such farmers who do not sell immediately at harvest are not aware that when they store they lose part of the product to pest damage or decay in storage, and that it will be better to sell and salvage value from their production.

These two (2) models were used for constructing the gains of PHLM technologies. Scenario 1 estimated the incremental benefits by calculating the quantity of food lost in storage without technology, and then multiplying this by the price differential between the immediate harvest period and the lean season price. An assumption was made that metal silos and hermetic bags were 100% effective in preserving the quantity of food harvested until the lean season (eight (8) months later). To cater for less effective performance, the model for incremental benefits was subjected to sensitivity analysis of 20% less benefit and 20% more benefit than the base case. The price differential was used because Scenario 1 farmers do salvage a value when they sell their food immediately after harvest, unlike the Scenario 2 farmers who lose the full value of their loss at lean season price. Hence for Scenario 2 farmers, the incremental benefit was calculated as the quantity lost in storage multiplied by the market price during the lean season.

These scenarios were used for all three crops, maize, beans and cowpeas.

Discounting of the cash flows

For each crop and model, the cash-flows comprising the cost of adoption of the technology and running costs of pesticides to treat the crop each year, and the benefits of improved storage technologies were computed for a period for 20 years for both metal silos and hermetic bags. These cash-flows were then discounted at a rate determined by the **Ramsey equation** or formula:

$$\mathbf{r = \rho + \mu g}$$

Whereby:

r is the discount rate;

ρ **is** the rate at which people discount future over present consumption assuming that income is fixed. (ρ) is the product of two elements namely the risk of catastrophe wiping out the gains from a programme (L) and the rate of pure time preference (δ);

δ is the pure rate of time preference arises from the fact that consumers are impatient and that because there is a chance they could die, would rather consume today rather at some point in future;

μ is the rate of per capita consumption growth; and

g is the elasticity of the marginal utility of consumption (the percentage fall in the marginal utility when consumption increases by one per cent).

For this study parameter **g was** derived from GDP growth rate for Mozambique and was assumed to be 6.3% per annum (a 10 years average) for the foreseeable future (e.g., next 10 years). Parameter **ρ** was estimated based on the DFID rate of time preference value for money used in the Green Book which is 0.5% and adding to it the estimated death rate (estimated at 11.9 deaths per 1,000 people, that is 1.19%) to represent catastrophe risk, so ρ was assumed to be equal to 1.69%.

For parameter **μ,** Dasgupta (2006)[4] estimated that the value lies between 2 and 4 based on empirical evidence. For the PHLM study a value of 2 was assumed which implies taking a cautious approach (and this is consistent with most development partners, e.g., DFID who could be approached to fund the scale-up of adoption of metal silos and hermetic bags). It is not unreasonable to expect that for a country like Mozambique with a low GDP per capita, marginal utility of consumption decreases significantly with increase in disposable income.

Hence, if $r = \rho + \mu g$ and $\rho = 1.69\%$, $\mu = 2$, $g = 6.3\%$ then, $r = 1.69\% + (2*6.3\%) = 14.3\%$.

For purposes of this analysis *r* was rounded off to 14%, which was taken as a more pessimistic scenario characterising rain-fed agriculture, compared to 10% used by DFID in Mozambique which was treated as the best case scenario, and r=12% was considered the base case which assumes a minimum growth rate of 5% per annum (the lowest growth rate over the past 10 years was 5.8%). Sensitivity analysis was performed to check on strength of viability of potential investments into post-harvest technologies to support the staple-food value chain in Mozambique.

Viability indicators

To assess viability of the investments in PHLM technologies, five indicators were computed using the various scenarios of risk, farmer post-harvest management preferences and technology type, discussed above, but standardising the module (quantity stored) as 500kg. These indicators were:

- Net present value (NPV) (of the net cash flows);
- Internal rate of return;
- Benefit-to-cost ratio;

[4] Dasgupta, Partha. 2006. "Comments on the Stern Review's Economics of Climate Change." University of Cambridge. November 11, 2006. (Revised: December 12).

- Payback period; and
- Breakeven point.

Net Present Value

For calculation of NPV the following formula was used:

$$\mathrm{NPV}(i,N) = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

Where:

t – is the time of the cash flow

i – is the discount rate, i.e. the return that could be earned per unit of time on an investment with similar risk.

R_t– is the net cash flow i.e. cash inflow – cash outflow, at time t.

The values of NPV were used to make a judgement whether the PHLM technologies that were analysed added value to farmers or not. A net present value greater than zero indicated that the investment would add value to the farmer (or actor in the value chain who adopted it), and the technology would be worth investing in. A net present value less than zero would mean that the investment would subtract value from the farmer, or the institution supporting the farmers to invest in such technologies and such technology should be rejected.

A technology exhibiting zero net present value would imply that the investment would neither gain nor lose value for the farmers (or value chain actors adopting the technology).

Internal rate of return

The internal rate of return was calculated for each investment model (scenario) for the PHLM technologies. It was defined as the "annualized effective compounded return rate" or rate of return that makes the net present value of all cash flows (both positive and negative) from a particular investment equal to zero. IRR also referred to the discount rate at which the present value of all future incremental cash inflows would equal the initial investment or, in other words, the rate at which an investment breaks even. For analysis, the IRR was considered to be high for an investment that added a lot of value to farmers / value chain actors in the short term.

Benefit-to-cost ratio

The BCR was computed by dividing the discounted incremental benefits for 20 years and the discounted incremental costs. For analysis of viability of the PHLM technologies, a BCR greater than one (1) meant the benefits outweighed the costs and the investment would be worthwhile, while a BCR of one (1) meant that the technology would not add or take away any value from the farmers, and should not be promoted, unless there would be wider social or economic benefits (other than financial), and a BCR of less than one (1) would mean the technology will come at a cost to farmers with no corresponding benefits and such a technology should be rejected.

Payback period

The pay-back period was calculated as the number of years for which benefits should continue accruing until the investment costs are covered. The longer the payback period the more uncertain an investment is in terms of being able to fully recover the costs, and the shorter the pay-back period for an investment, the better the prospects of recouping the costs of the investment made into the PHLM technologies.

Breakeven point

The break-even point was estimated as the minimum level of incremental benefits that would offset the costs of investing in the PHLM technology. The higher the breakeven point, the lower the viability of the investment.

Sensitivity analysis

In order to accommodate in the analysis the impact of variations in farmer types and capacity, year on year variations in staple food prices, variations in effectiveness of the technologies in reducing the post-harvest losses based on agro-climate conditions, differences in crop varieties, and variations in the workmanship of those manufacturing the metal silos and hermetic bags, on the estimated indicators of viability, the models were subjected to rigorous sensitivity analysis assuming the following four main scenarios:

- 20% less benefit from base case;
- 20% more benefit from the base case;
- 14% discount rate (assuming a more risky environment than base case of 12%); and
- 10% discount rate (assuming less risky environment).

Limitations

The first challenge was experienced in terms of communication. Stakeholders in Mozambique speak Portuguese while the consultant speaks English and would also write the report in English. The effect of difficulties in communication was however mitigated by engaging a Portuguese translator who translated the questionnaire into the respective languages and assisted in translating all the responses.

Whereas questionnaires were sent to all the different stakeholders as had been planned responses were received only from two stakeholders.

Precise data on number and size of farmers growing each staple food crop (maize and pulses), the yields realised per size of farmer and per post-harvest loss management practice adopted could not be obtained, hence the limitation was mitigated by conducting the CBA analysis at the level of the technology (silo, or hermetic bag as the unit of analysis) and using assumptions on number of farmers using different types of technologies to assess potential impact on the value chains. In addition, there was little information on actual quantities of various types of staple food stored by farmers (especially for beans and cowpeas).

2. Findings

2.1 National Policies on PHM

Post-harvest losses (PHL) are estimated at between 20 and 30% of harvest in Mozambique. Mozambique experiences about 400,000 MT food deficits every year and much of it is attributed to PHL. Food only lasts for three months after which it is lost due to poor storage conditions.[5] This results in short seasonal commercialisation which execrates food insecurity. There is a high surplus of food products available during harvesting which causes a drop-in producer prices resulting in low incomes.

The research carried out by Dr Lucas Tivana, et al, reveals that the Mozambique Strategic Plan for Agricultural Development Sector 2011-2020 contains a post-harvest management strategy. However, there is no stand-a-lone policy on PHM. He asserts that this weakens institutional collaboration on the subject. Furthermore, he points out that there is no relevant research initiative on PHM in Mozambique and that there is a general lack of PHM service providers in Sub-Saharan Africa and SADC region. PHM aspects are therefore under-represented in most agricultural research and development strategies. PHM is affected by lack of investment in infrastructure such as roads, transportation and local oriented food industries, policy gaps, lack of training institutions for PHM, lack of capacity by farmers to access financing.

In the absence of a stand-alone policy PHM in Mozambique is guided by Comprehensive Africa Agriculture Development Programme (CAADP) and the SADC policy. Specifically, CAADP pillar II, III and IV are relevant for the promotion of PHM

Pillar II aims at improving rural infrastructure and trade capacities for market access on a local, regional, and global level. This includes infrastructure for PHM. Pillar III aims at increasing food supply, reducing hunger, improving responses to food emergency crises. The pillar highlights the following PHM options for raising food security:

a) Development of PHM technologies at community and household level to increase shelf life of commodities;
b) Promotion of low cost and sustainable processing technology for quality; and
c) Promotion of low cost and sustainable marketing for quality and nutritious foods favoured by the poor and vulnerable.

Pillar IV aims at improving agricultural research and technology dissemination and adoption. The link of this pillar to PHM relates to transfer of technical knowhow from research results to the rural small holder farmer's social and economic environmental conditions.

SADC Agricultural policy of 2013 is in line with CAADP objective of promoting sustainable and equitable African economic growth and social economic development to facilitate the attainment of millennium development goals in Africa. SADC policy proposes among other things promoting national and

[5] Ngare L., Simtowe F., Massigue J., 2014. *Analysis of price volatility and implications for price stabilisation.* European journal of Business and Management. ISSN 2222-1905. Paper ISSN -2839 (online). Vol. 6, No. 22.

regional investments in storage and agro-processing infrastructures in an effort to deal with price volatility, seasonality and the unpredictability in food availability.

Mozambique agricultural policies are in line with CAADP and SADC agricultural policies. However, absence of a stand-alone policy on PHM weakens implementation.

2.2 Knowledge of improved PHM technologies by different actors

The responses from the stakeholders show that there is a general lack of knowledge of modern PHM technologies among farmers, traders and food processors. Most farmers maintain the use of traditional methods which are not effective. Modern technologies have been introduced in some districts in the Northern provinces. Some small holder farmers appreciate them but cannot afford the costs.

2.3 Production levels and prices for maize and pulses by sector and region

Mozambique is a vast country in Southern Africa covering 800,000km^2. It is divided into 10 provinces and has a population of 23.9 million[6]. The map below shows the provinces and summarises important statistics about the country.

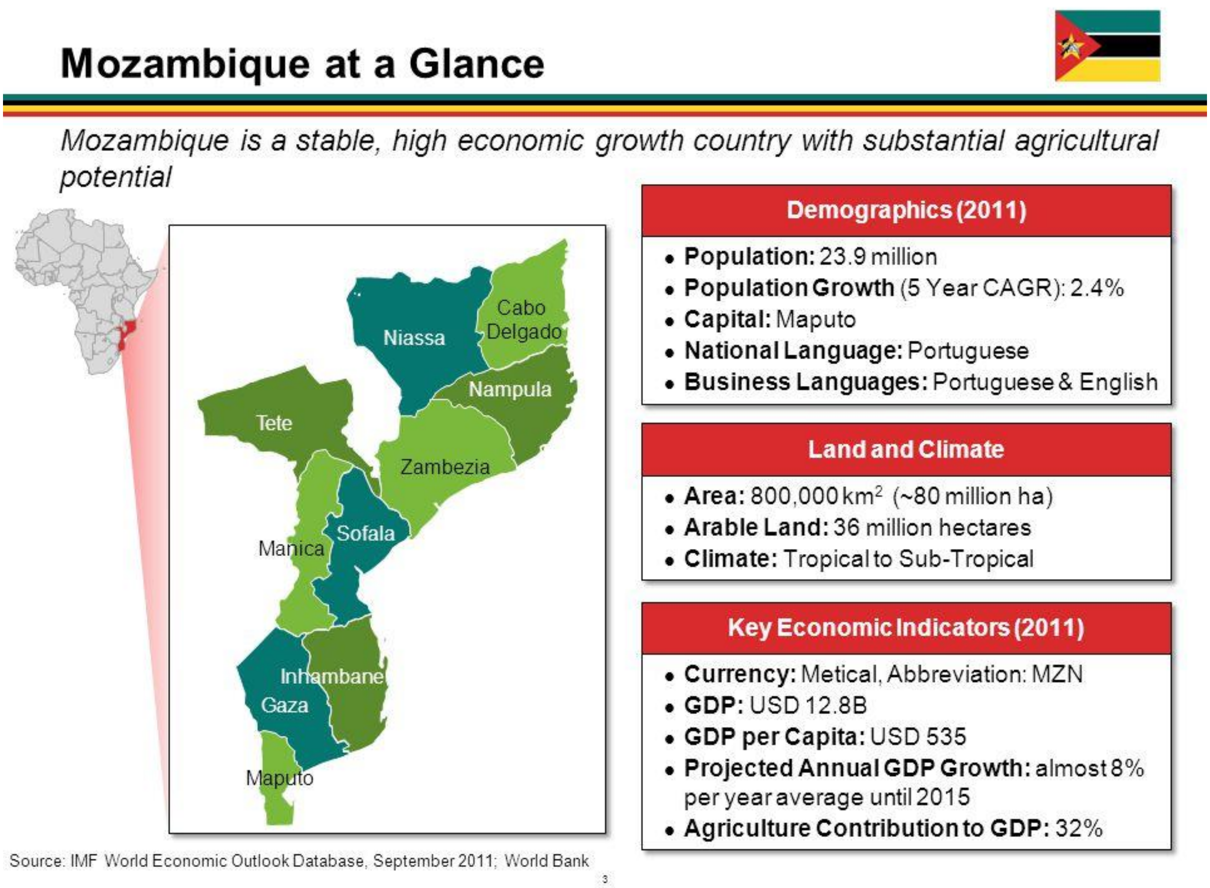


Figure 1: Provincial Map of Mozambique

[6] IMF World Economic Outlook Database, September 2011 World Bank

In Mozambique about 80% of population depends on agriculture.[7] Subsistence agriculture is predominant and small holder farmers account for 99% of rural households. There are about three (3) million small holder farmers. The landholdings are very small, averaging 0.9 to 1.2 hectares with low productivity which leaves most households as net buyers of food staples[8]. Forty five percent of the land is arable and only 11% or four (4) million hectares are cultivated. About 60,000 hectares are utilised by commercial farmers. Below are the total production statistics for maize, common beans and cow peas for 2012 and 2013[9].

Table 1: Mozambique crop production statistics 2012-3

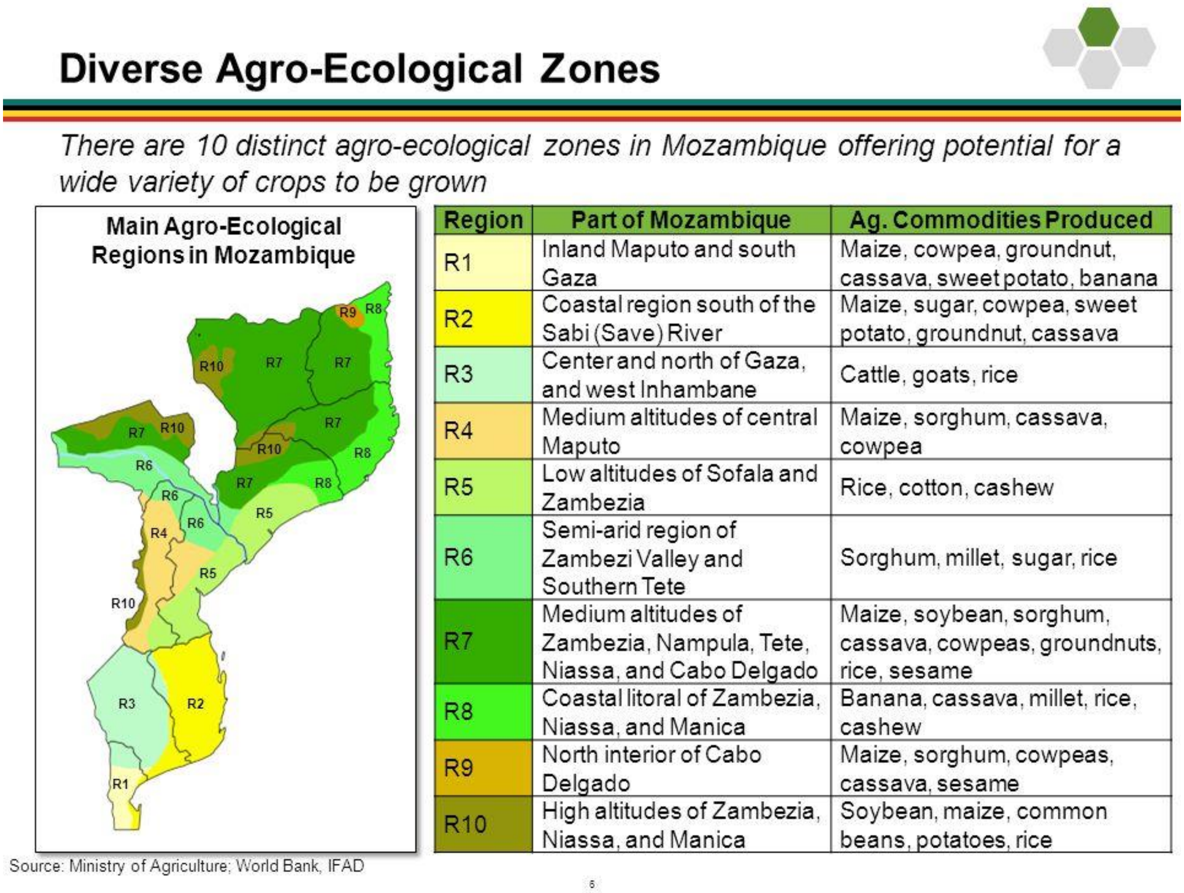
Year	**Total Production (tonnes)**		
	Maize	**Common Beans**	**Cow Peas**
2012	1,177,000	196,437	85,484
2013	1,631,000	190,000	80,000

.

In terms of food production, the country is divided into three regions; the south, central and north. The southern region is food deficient and relies on the central and north for staple food supply. The central and northern regions have better agro-ecological conditions and therefore produce surplus food. The central region produces 50% of the maize, while the north produces 40% and the south only 10%[10]. However, because of poor road network and high transport costs the southern region imports maize from South Africa which is cheaper. The map below shows the agro-ecological zones and the major crops grown.

[7] Ngare L., Simtowe F., Massigue J., 2014. *Analysis of price volatility and implications for price stabilisation.* European journal of Business and Management. ISSN 2222-1905. Paper ISSN -2839 (online). Vol. 6, No. 22.

[8] Ibid
[9] Knoema Production Statistics- Crops, Crops Processed – February 2015. https://knoema.com/FAOPRDSC2015Feb/production-statistics-crops-crops-processed-february-2015?country=1001320-mozambique&item=1000900-maize
[10] Ngare L., Simtowe F., Massigue J., 2014. *Analysis of price volatility and implications for price stabilisation.* European journal of Business and Management. ISSN 2222-1905. Paper ISSN -2839 (online). Vol. 6, No. 22.



Region	Part of Mozambique	Ag. Commodities Produced
R1	Inland Maputo and south Gaza	Maize, cowpea, groundnut, cassava, sweet potato, banana
R2	Coastal region south of the Sabi (Save) River	Maize, sugar, cowpea, sweet potato, groundnut, cassava
R3	Center and north of Gaza, and west Inhambane	Cattle, goats, rice
R4	Medium altitudes of central Maputo	Maize, sorghum, cassava, cowpea
R5	Low altitudes of Sofala and Zambezia	Rice, cotton, cashew
R6	Semi-arid region of Zambezi Valley and Southern Tete	Sorghum, millet, sugar, rice
R7	Medium altitudes of Zambezia, Nampula, Tete, Niassa, and Cabo Delgado	Maize, soybean, sorghum, cassava, cowpeas, groundnuts, rice, sesame
R8	Coastal litoral of Zambezia, Niassa, and Manica	Banana, cassava, millet, rice, cashew
R9	North interior of Cabo Delgado	Maize, sorghum, cowpeas, cassava, sesame
R10	High altitudes of Zambezia, Niassa, and Manica	Soybean, maize, common beans, potatoes, rice

Figure 2: Agro-ecological zones of Mozambique

2.4 Post-harvest losses by crop, sector and region

The Mozambican government has put in place strategies to improve yields through research and extension services and improving agricultural infrastructure. Nevertheless, Mozambique continues to experience food deficits estimated at 400,000 tonnes per year which is attributed by government to poor storage and marketing.[11] Farmers store 500-1000kg of maize and 200-300kg beans. Storage losses range from 20 to 40% depending on crop and geographical location[12]. Storage losses force farmers to sell their produce early to avoid physical losses and hence reducing opportunities to sell at favourable prices. Farmers sell half or more of their crops within three (3) months of harvest.25% is sold during the rest of the year while 25% is kept for seed. Harvest kept for seed is specially stored separately but also gets affected by insects and pests. Average returns to storage of maize are as shown in the table below.

Table 2: Average returns to storage of maize by region

Region	Average returns
Southern	35.13%
Central	66.91%
Northern	92.12%

[11] Ngare L., Simtowe F., Massigue J., 2014. *Analysis of price volatility and implications for price stabilisation.* European journal of Business and Management. ISSN 2222-1905. Paper ISSN -2839 (online). Vol. 6, No. 22.

[12] Ibid

Region	Average returns
Maputo	22%
Cuamba	113%

Results imply that the producer will make highest returns if they stored and sold to markets in the northern region during periods of high prices and lower returns if they sold in the south where seasonal price variability is lower.

2.5 Costs and benefits of post-harvest storage innovations (metal silos and hermetic bags)

Metal Silo

Capacity (250 kg)

Dimensions: 0.6m diameter x 1.20m height,

(Quantity of grain: 250 kg)

This round cylindrical structure is made from galvanized steel sheet, 0.5 mm thick and soldered with tin to be hermetic. It is placed on a wooden platform 15 cm above ground level. The silo should be in a protected area from rain and sun. It may be in the gallery as well as in a storage room or in a room inside the house. The silo has an opening on top to fill the grain and an outlet on the side to take the grain. These two openings are closed with a lid. The grain is selected, shelled, cleaned and dried at least 3 days in the sun before it transferred to the silo. Before putting the grain in the silo, it should be cooled to the temperature of the air. Grain should be treated before putting it in the silo. When using super Actalm, you mix the powder before putting the grain into the silo. If you use Phostoxin® you put the grain inside, then use the fumigant. The silo must be sealed with a rubber band.

When treating grain, if one uses Actellic should be mixed with the grain before putting it into the silo. If using Phostoxin the grain must first be put in the metal silo and then the tablets. The silo must be closed with rubber on the two openings. Apply 1 tablet Phostoxin out rata with Actellic super dust 2% (powder). Dose: 1 tablet Phostoxin for every 250 kg Actellic 200gr for each silo 250 kg. Periodically check the condition of the ears. The grain will stay protected for at least 12 months.

There are different metal silo capacities: 250kg, 300kg, 500 kg, 700kg, 1000kg, 1200kg, and 1,500 kg.

Life / Duration: 20 years cost annual approximately: 135 Mts

Cost:

1. Investment:

Purchase price 300 kg silo:	Mts 2,300
Wood Base or stick:	Mts 100
Total	Mts 2,400
Investment annual cost	Mts 105
2. Treatment: - Phostoxin: 1 tablet:	Mts 15
Cost of treatment per year	Mts 15

The study done by Schneider K. (2014) in northern Mozambique revealed prices of metal silos including duties, taxes, transportation, retail margin and manufacturing labour to be as shown in the table below.

Table 3: Silo capacity and price

Silo capacity (kg)	Price (US$)
300	78
500	92
700	102

Benefits of metal silos

Grain can be stored for a period of more than one (1) year ensuring food availability throughout the year. It also relieves farmers of pressure to sell their produce soon after harvest when prices are very low and gives them an opportunity to sell when prices are high during the lean season thereby maximizing their income.

Use of the silo results in a loss reduction of 15% and a stored market gain of 50%.

The silo has a long lifespan of up to 20 years.

Super-bag

Dimensions: 0.5m wide x 0.9m high, (50kg each)

(Quantity of grain: 250 kg = 5 unit)

The Super-bag is made of plastic and can be found in the market. The capacity is about 50 to 100kg. It is recommended to combine it with raffia bags for better resistance. The plastic should be airtight and care should be taken not to break it. To protect it from mice attack it is recommended to suspend the bags under the ceiling. It can be stored outside or inside the home. The grain that is kept inside the bag must be threshed, dried, and well selected. It should be dried in the sun for a period of at least three (3) days. Before filling the bag clean the grain very well, close it and suspend it. Periodically check the condition of the grain. The grain will stay protected for at least eight (8) months.

Life one (1) year Super-bag / two (2) years' bags raffias.

Annual cost approximately: MT350

Cost:

1. Investment:

Local Material:	5 bags of raffia (15MT / bag)		MT75 (5 bags)
		5 Super-bags	MT 500
		Poles to suspend	MT 75
Labour:	Local labour/day (1 day)		MT 50
Total			**MT 700**
	Cost annual investment		MT 350

Benefits of super-bags

Same as benefits of PICS bags above.

2.6 Opportunities and risks for smallholder farmers in investing in postharvest technologies

Opportunities

There are a number of development partners and NGOs that are promoting adoption of improved PHM technologies in order to minimise losses on staple foods. For example, GrainPro, an American based company works with NGOs in training farmers on PHM and to promote adoption of hermetic bags in Northern Mozambique. FAO has been working with EU under the MDG 1c to support farmers to develop Post-harvest technologies. Since inception of the project in 2013 over 260 artisans were trained in 15 districts in building and promoting improved silos locally called Gorongosa silo. The FAO trained artisans are working in Manica, Sofala, Tete, Zambezia, and Nampula in the central and northern regions. The project aims to build 10,000 Gorongosa silos and train 20,000 farmers. Gorongosa silos are more affordable than metal silos and grain can stay for more than eight months thereby reducing the need for chemical treatments

Adopting improved PHM technologies provides an opportunity to store grain for longer periods thus enhancing household food security and nutrition. Families are able to engage in some socio-economic activities utilising the time they would have spent looking for food during the lean season. If technologies that do not require chemical treatment are employed the health of people is enhanced as side effects from chemicals are avoided. Using improved technologies also helps to maximise income by storing grain and selling it when prices become favourable.

Risks

Traditional silos do not offer adequate protection against pests and the elements causing significant post-harvest losses. Continued reliance on traditional techniques exposes farmers to risk of post-harvest losses continually.

Farmers in Mozambique prefer metal silos and super bags which are expensive and beyond the reach of many. If their production does not increase they may not realise return on their investment. In Mozambique, hermetic bags are expensive mainly because of the 37% import duty charged on hermetic material. If farmers purchase the silos on credit they risk failing to pay because of uncertainty of production in the light of frequent droughts in the wake of climate change.

Artisans interested in manufacturing the metal silos, may not find live off the business of producing metal silos due to slow volumes and the long shelf-life of the metal silos. Local production of silos needs to be combined with other products to diversify the demand for the wares produced and sold by artisans if the local supply will be sustained.

Some artisans who are not adequately skilled manufacture low quality metal silos which are not able fail to bring the expected benefits. Farmers risk incurring costs by purchasing low quality metal silos without realising benefits of reducing post-harvest losses.

3. Economics of the postharvest value chain for smallholder farmers

Maize Value Chain

CBA Modelling Scenarios and Assumptions for Maize

As explained in the section on the methodology, two scenarios were constructed for maize under which models were constructed to assess the returns to investment associated with improved PHLM technologies (hermetic bags and metal silos). Scenario 1 assumed that some of the farmers who lack modern PHLM technologies decide to immediately sell their produce at harvest time to avoid losses in storage or to take care of immediate financial needs. Scenario 2 assumed that some of the farmers keep the produce for home consumption later in the season, and do not sell immediately after harvest because their perception of risk is higher. They fear that the market might not have the staple food commodities at an affordable price to purchase back in the lean season. Others who decide to keep rather than sell their produce at harvest time do so partly for reason of low prices or lack of demand prevailing on the local market due to a seasonal glut. As alluded to earlier, the immediate post-harvest price for maize in Mozambique was found to be MZN 8.5 per kg while the lean season price stood at MZN 28.8[13] per kg (Table 4), a difference of 239%

Table 4: **CBA modelling assumptions for Maize and Hermetic Bags (Base Case)**

Indicator	Scenario 1: Farmer sells		Scenario 2: Farmer stores	
	MZN	USD	MZN	USD
Project lifespan, years	20 years		20 years	
Project duration, years	20 years		20 years	
Benefits start accruing in Year:	Year 1		Year 1	
Loss without technology	30%		30%	
Production, in kg	1500		1500	
Product stored, kg	1500		1500	
Loss reduced by PHLM tech, in kg	450		450	
Post-harvest price, MZN/kg	8.5	0.16	8.5	0.16
Value preserved at PH price, MZN	3825	73.93	3825	73.93
Lean season price, MZN/kg	28.8	0.56	28.8	0.56
Value preserved at LS price, MZN	12960	250.48	12960	250.48
Incremental cost (Hermetic Bags, 30x50kg)	4200	81.17	4200	81.17
Lifespan of Technology: Hermetic Bag	2 years		2 years	
Discount rate, base case	12%		12%	
Incremental benefit	9135	176.56	12960	250.48

Notes: LS=Lean Season; KG=Kilogram; PHLM=Post-harvest loss Management; MZN=Mozambican Metical.

Exchange rate: 1USD=MZN 51.74 (March 2016)

Source: Own source.

The base case scenarios for maize assumed that farmers have sufficient production to have a need to store 1,500 kg of maize (Table 4). The discount rate was set at 12%, as estimated in Chapter 1. Project lifespan was taken to be 20 years which is linked to the expected lifespan of the metal silo. The metal

[13] FEWSNET, Mozambique Price Bulletin, March 2016.

silo information collected from Mozambique showed that the technology can be purchased, installed and used in the same year that the decision to adopt is made, resources permitting. Hence farmers will immediately start accruing the benefits of adopting the silos in the year they purchase the technology.

The loss of maize without adoption of technology was taken as the highest level of 30% in Mozambique, and sensitivity and breakeven point analyses were used to estimate viability of technology adoption by farmers with post-harvest losses lower than 30%. The base case scenarios assumed that both the hermetic bag and metal silo technologies were 100% effective in reducing post-harvest losses, if used appropriately. The viability of the technologies at lower levels of effectiveness was computed using sub-models that assumed a 20% lower benefit, and breakeven analysis which computed the minimum level of effectiveness of the technology which would make the investments worthwhile. At 80% benefit (i.e., 20% less benefit), the post-harvest level would be equivalent to 24% of the harvest preserved (80 percent of 30%). On the other hand, 20% more benefit assumed a higher loss of 36 percent which would be eliminated with improved storage.

The values of product preserved due to adoption of the two technologies (hermetic bag and metal silo) were estimated by multiplying the quantity preserved by the technology (prevented from pest and other types of damage in storage) with the post-harvest and lean season prices. At 30% loss, 450kg from every 1,500kg of maize stored could have been lost without technology. However, with the adoption of technology the 450% of maize would be preserved using either hermetic bags or metal silos (assuming 100% effectiveness). For maize, the monetary values of the quantities of maize preserved from loss due to adoption of PHLM technologies were MZN 3,825.00 and MZN 12,960.00 at post-harvest and lean season price, respectively. For farmers that sell immediately after harvest, they reduce the financial loss that could happen by storing and losing 30% of their maize in storage. They recover MZN 3,825.00 in value immediately after harvest (450 kg of potential loss multiplied by the post-harvest price of MZN8.50 per kg). However, those that do not sell lose the opportunity to earn MZN 3,825.00, and because they do not use improved technologies cannot take advantage of the lean season price of MZN28.80 which could have enabled them to earn MZN 12,960 by selling the 450 kg in the lean season. Hence the total loss to those who do not sell at post-harvest is MZN 12,960.00 while to those who sell immediately after harvest they only lose the opportunity to earn MZN 12,960.00 in the lean season but will salvage MZN 3,825.00 by selling the produce (450 kg) at harvest. Hence those who sell at harvest therefore only lose the difference between these two values (MZN 3,825.00 and CFAF 12,960.00), which is equivalent to MZN 9,135.00.

From the above calculations, by adopting PHLM technology, farmers who have a practice of selling immediately after harvest have an incremental benefit of MZN 9,135.00 which is the additional value they realise. The technology enables them to preserve 450 kg for sale later in the consumption season at a higher price, otherwise they would still realise some value by selling immediately after harvest. The difference between the counterfactual income (earned immediately after harvest) and that earned with the technology (at lean season price) is the additional benefit associated with the adoption of the technology.

However, for farmers that store and lose 450kg in storage, the incremental benefit is derived from the value they get after selling the 450 kg of maize during the lean season (MZN 9,135.00). The counterfactual is therefore a loss of MZN 12,960.00 in value of product stored that perishes due to pest and other forms of damage due to sub-optimal crop storage conditions.

Cost of the hermetic bags was reported to be MZN 140.00 or (US$2.70) per 50 kg bag. The cost of a 10 bags module (that can store 1,500 kg of maize) was therefore found to be equivalent to the MZN 4200.00 altogether. As no chemical is needed in hermetic bags, the incremental cost of hermetic bags was found to be MZN 4200.00 which would be incurred once every two years which is the lifespan of a hermetic bag. The bags are hung on poles and these poles were assumed to have a lifespan of five (5) years.

Table 5: **CBA modelling assumptions for Maize and Metal Silo**

Indicator	Scenario 1: Farmer sells		Scenario 2: Farmer stores	
	MZN	USD	MZN	USD
Project lifespan, years	20 years		20 years	
Project duration, years	20 years		20 years	
Benefits start accruing in Year:	Year 1		Year 1	
Loss without technology	30%		30%	
Production, in kg	1500		1500	
Product stored, kg	1500		1500	
Loss reduced by PHLM tech, in kg	450		450	
Post-harvest price, MZN/kg	8.5	0.16	8.5	0.16
Value preserved at PH price, MZN	3825	73.93	3825	73.93
Lean season price, MZN/kg	28.8	0.56	28.8	0.56
Value preserved at LS price, MZN	12960	250.48	12960	250.48
Incremental cost (Metal Silo, 1500kg)	12000	389.99	12000	389.99
Cost of treatment/year MZN	75	1.45	75	1.45
Lifespan of Technology: Metal silo, years	20 years		20 years	
Discount rate, base case	12%		12%	
Incremental benefit	9135	176.55	12960	250.48

Notes: LS=Lean Season; KG=Kilogram; PHLM=Post-harvest loss Management; MZN=Mozambican Metical.

Exchange rate: 1USD=MZN 51.74 (March 2016)

Source: Own source.

The modelling scenarios for metal silos were also two, the first being where the farmer sells immediately after harvest and the second where the farmer sells during the lean season. As for hermetic bags, the incremental benefits are equivalent to MZN 3,825.00 and MZN 12,960.00 respectively while the incremental cost for a metal silo with a storage capacity of 500 kg was found to be the cost of the silo and installation (MZN 12,000.00) in year 1 and MZN 75.00 per year for pesticides for the 20 years project life.

CBA Analysis Results for Maize

Viability of hermetic bags to farmers who produce and sell maize at harvest time (do not store)

For hermetic bags, CBA results for the **base case scenario** showed that the net present value of the cash-flows (incremental benefits minus incremental costs over a period of 20 years, discounted at a rate of 12% per annum) is positive (MZN 40,975.91), the benefit-to-cost ratio is 2.50, and the internal rate of return is greater than 100,000 percent (see Annex 6.1). The results showed that farmers would benefit if they adopt hermetic bags and stop the delay the sale of maize to the lean season when prices at three times higher (MZN 28.80 per kg up from MZN 8.50 per kg).

Furthermore, results of sensitivity analysis showed that the breakeven point for the investment would be reached with 40% the current level of incremental benefits. This means breakeven point would be reached if the product lost in storage (by non-adopters of hermetic bags) was of the order of 12% of what was harvested and stored. Available literature shows that post-harvest losses in maize are very high in Mozambique in most maize producing regions, due to ineffective storage technology.

When the discount rate is lowered to 10% (which is for a more optimistic scenario depicting lower risk, and used by donor projects to discount cash-flows for their investments in Mozambique), the breakeven point would be reached if losses without improved storage technology were of the order of 12%. Even under a more pessimistic discount rate of 14% the breakeven point would be reached at 40% of current benefits.

These results are generalizable for smaller units of production (350 kg, 250 kg, 100 kg, and 50 kg) because of the size of a bag of 50 kg. The model of 1,500 kg is worked on assuming the use of 30 product units of 50 kg each and the price of the hermetic bag is fixed from one to 30 bags. If farmers enjoy a discount when they purchase more than one bag, and buying below 31 bags, then viability may improve and reduce the breakeven point further.

Programming implications of the results

For a maize farmer who has a practice of producing and selling his/her crop at harvest time, there is good rationale for the farmer to invest in hermetic bags, store the maize and sell in the lean season. The investment in the hermetic bags will give the farmer more benefits than the value the farmer gets when he/she sells at harvest time. The price differential between the harvest season and the lean season in Mozambique is so large that the investment dividend is worth the incremental cost of investing in improved storage technology. As this model is built on units of 50 kg bags, unless there is a significant discount offered to farmers for higher quantities of bags purchased, the results apply equally to lower and higher quantities produced and stored / sold. Adoption of hermetic bags would not necessarily be a better option for farmers who have a practice of selling their maize at harvest time, instead of the lean season.

Recommendation 1: The Government of Mozambique or development agencies willing to invest in Mozambique to support smallholder farmers to adopt the hermetic bag technology must encourage maize farmers who are already prudent to sell their surplus grain immediately after harvest to invest in hermetic bag technology or other similarly effective technologies as the investment is worthwhile.

Viability of hermetic bags to farmers who produce, store and sell (or consume) the maize during the lean season

The results for the **base case model** with 1,500 kg storage module, showed a positive NPV of MZN 69,546.53 (US$ 1,344), a BCR of 3.55, an IRR greater than 50,000%, and a payback period of three (3) years for a farmer or trader storing 1,500 kg of maize (Annex 6.1). These are all indicators of viability of the investment. Farmers who do not sell immediately after harvest, but choose to store for later use (sell or consume) will benefit from the technology as the returns will outweigh the investment costs by approximately 255%. Such farmers can breakeven even with only 28% of the benefit. This means that farmers with a post-harvest loss of 8.4% (not 30%) when they do not use the technology would stand to benefit if they were to invest in hermetic bags to store for sale or consumption later in the season.

Sensitivity analysis also showed that with 20% more benefit, the project's net worth would increase by 28% , the BCR would be 4.26, internal rate of return would increase to much more than 50,000% , and the payback period would shorten to two years. In addition, even if benefits were to be reduced by 20%,the NPV would remain positive (MZN 50,185) and BCR would stand at 2.84.

Under an optimistic scenario that has 10% as the discount rate, the return would be treble the investment costs, leading to a BCR of 3.56 and a payback period of three (3) years. The benefits of the technology are so robust that even under a more pessimistic scenario with a discount rate of 14% incremental benefits associated with the value of stock preserved from perishing post-harvest, would exceed the incremental costs (of investing in the hermetic bags by 255%).

When the cost of the hermetic bags is increased to double the current cost, the CBA results show that the investment remains worthwhile with a BCR of 1.75 for adopters.

Furthermore, sensitivity analysis shows that the hermetic bag remains worthwhile to farmers up to a price of MZN 490 (bag and fittings). If the cost increases beyond this figure the investment will not be worthwhile.

Assuming that post-harvest management programmes are able to support adoption of hermetic bags and metal silos such that all maize is properly stored and is preserved, the study estimates that between 2.29 and 3.18% per annum of agricultural GDP, at the minimum, will be preserved through PHLM investments. The lower figure is for hermetic bags and the higher is for metal silos.

Programming implications of the results

The results of the CBA analysis clearly show that farmers who do not have a practice of selling their grain soon after harvest but store and lose up to 30% of their produce to post-harvest losses, stand to benefit immensely by investing in hermetic bags, whether or not they then consume or sell the preserved maize later in the consumption season.

Recommendation 2: The Government of Mozambique or development agencies seeking to support maize value chain actors to adopt hermetic bags as a grain storage technology can do so targeting farmers or traders whose current practice is to produce or purchase (respectively) and store maize for own use or sale later in the season. Among these they should target those who currently lose at least 12% of their harvest to pest and other forms of damage in storage. Those who are currently losing below 12% of their harvest in storage, do not gain by investing in hermetic bags because the value of the product preserved is not sufficient to off-set the investment cost of adopting hermetic bags. These should be encouraged to sell immediately after harvest where feasible.

Recommendation 3: Government of Mozambique and development agencies promoting adoption of the hermetic bags should ensure that they strengthen efficiency of the value chain for hermetic bags such that the cost to the farmer does not exceed MZN 490 with installation of the platform where the bags will be placed for safe storage. If it exceeds this figure it will not be viable to the maize farmers.

Recommendation 4: To increase the rate of adoption of hermetic bags by SSFs, MSFs, Traders, and Agro-industries, the Government of Mozambique and development agencies should strengthen the supply chain of hermetic bags, with the view to increasing efficiencies, exploiting economies of scale in their production, or importation and where possible encouraging government to co-invest by lowering import taxes on the bags, where applicable. The investment by government in lowering or removing import taxes on the bags such that they are available to farmers at a cost of MZN 140 (US$2.70) will bring MZN 2.50 per every MZN 1.00 invested (in the form of tax waivers) at the minimum.

Recommendation 5: Development agencies should aim to support the value chain of hermetic bags for storage of maize so that they reach farmers at a cost of MZN 140 (US$2.70) or less per 50 kg unit. The lower the price of the hermetic bag the more likely that it will be viable even for farmers or users who were incurring lower PHL. At a cost of MZN 140, farmers with a loss of 12% per annum without the technology will be able to breakeven if they invest in the hermetic bags.

Recommendation 6: Given the challenge of inadequate supply, largely due to the high import duty on hermetic material (37%), donors and NGOs should work with the private sector and farmer organisations to lobby government to remove or lower the import duty on hermetic material, and in capacitating the private sector to manufacture the bags at scale and in a decentralised manners so that the bags can reach all of Mozambique's major grain producing regions.

Recommendation 7: The interest, commitment and investments from the private sector in manufacturing, distributing and selling the hermetic bag technology should be promoted through demand creation among the farmers through training and product promotion to create incentives for the private sector to invest in developing the supply chain necessary for sustainability.

Recommendation 8: Scaling-up hermetic bag storage innovation in terms of extension activities should be considered by development practitioners (in government, the private sector and NGOs) as a prerequisite for building demand among farmers and traders that is large enough to attract more investment by the private sector into local supply of hermetic bags in Mozambique. Efforts should be dually on farmers and traders, as well as potential private sector manufacturers to help them understand the technology, quality requirements, potential market, and challenges in reaching smallholder farmers with the new product.

Recommendation 8: Given the short product life-span of two (2) years, and the payback period of four (4) years (assuming 100% effectiveness in reducing post-harvest losses), timely supply of the hermetic bags is critical in achieving this high level of effectiveness among smallholder farmers. Late supply of the bags will compromise loss reduction and reduce the viability of the investment. To be commercially viable, the bags will need to be effective right from the first year of use, hence they should be supplied before the farmers begin to harvest their crops.

Recommendation 9: To reach smallholder farmers, the capacity of local government and NGO extension services to understand the importance of storage pest management and deal with it through technology use and technology transfer should be strengthened in Mozambique, especially targeting Cabo Delgado, Nampula, Niassa, Zambezia and Nampula provinces which are among the major grain producing regions. These initiatives, should use both traditional and non-traditional extension approaches to implement hermetic bag promotion activities. These should include demonstrations of the technology in targeted villages as well as promotion via community radio and television programmes, and cell-phone videos. Community radio programmes can be developed and aired, which draw content and presenters from groups of farmers and traders that have successfully adopted the technology and found it working.

Recommendation 10: Given that sensitivity analysis shows that the payback period for an investment in hermetic bag technology for farmers willing to store maize and consume or sell in the lean season is short (three (3) years) for an investment over 20 years, development programmes to support hermetic bag technology should be designed to provide support to resource-poor and subsistence farmers for a minimum period of three (3) years, the longer the period the more preferable. Promotion of this technology should not be a short-term undertaking given that farmers need to build a culture of buying new bags every second year to replace the worn-out ones. A period of three (3) years would be adequate to ensure that farmers can be left on their own to purchase the bags once every two years as they would have recouped in that period the projected future costs (for the remaining 17 years).

Viability of metal silos to farmers who produce and sell maize at harvest time (do not store)

For metal silos, CBA results for the **base case scenario** showed that the net present value of the cash-flows (incremental benefits minus incremental costs over a period of 20 years, discounted at a rate of 12% per annum) is positive (MZN 56,958.87, or US$0.73 per kg of maize stored), the benefit-to-cost ratio is greater than 1 (6.05), and the internal rate of return is positive which implies that the investment is viable (see Annex 6.2).

Furthermore, results of sensitivity analysis showed that the breakeven point for the investment would be reached at a lower incremental benefit of 16.6% of current benefit. This means breakeven point would be reached if the product lost in storage (by non-adopters of hermetic bags) was of the order of 4.98% of what was harvested and stored. Available literature shows that post-harvest losses in maize are higher than 30% in some parts of Mozambique which means any farmer or trader with a loss ranging from 4.98 to 30% would stand to benefit from investing in the metal silo technology.

Data on cost of producing metal silos shows that economies of scale in production of metal silos exist as metal silos of lower size are 20 – 40% more expensive, which implies that less farmers would stand to benefit from adopting metal silos of lower sizes. This is due to the fact that the breakeven point would increase to more than 4.98% of product stored being preserved with improved technology (metal silo).

When the discount rate is lowered to 10% (which is for a more optimistic scenario depicting lower risk), the breakeven point would be reached if losses without improved storage technology were of the order of 4.4% and the same amount would be preserved with improved technology (metal silo). When using a discount rate of 14% (a more pessimistic scenario) the breakeven point would be reached at 18% of current benefits (that is, 5.4% of stored product preserved by using the metal silo technology).

The payback period of the investment, assuming a lifespan of 20 years for metal silos, is estimated at two (2) years for farmers who were already prudent to sell at harvest and now are being encouraged to store and sell in the lean season (Base Case) and only one year for farmers were storing and losing a significant portion of their grain to losses in storage. If sensitivity analysis is considered the payback period ranges from 1-2 years with a 20% more benefit and 20% less benefit, respectively.

These results cannot be generalized for smaller units of production (350 kg, 250 kg, 100 kg, and 50 kg) because of economies of scale in metal silo production which show an increase of 20 to 41 in the cost of production of silos (expressed as cost per kg of storage space) as units become smaller.

Programming implications of the results

If a farmer or trader desires to shift practice to production and storing of 1,500 kg of maize rather than selling immediately after harvest, there is an added benefit of introducing metal silos to encourage him/her to store and sell at a higher price later during the lean season. The magnitude of the added benefit is high (the value of the incremental benefit is 505% above the cost). The cost of the improved storage technology is lower than the value of the additional benefits of the technology (quantity preserved multiplied by the difference between lean season and harvest season prices). In other words, the farmer or trader will be better off in purchasing the metal silo and storing his/her maize and wait to sell during the lean season rather than harvest (or purchase) and sell soon after.

As this model is built on units of 1,500 kg metal silos, with increases (3%) in cost of production of smaller units of silos, the results indicate that the returns to investment for smaller units of silos (350 kg, 250 kg, 100 kg and 50 kg) would be slightly lower than for the 1,500 kg metal silo but farmers will remain viable, because the price of the metal silo has to increase 9-fold before the investment makes a loss. The loss of economies of scale is much lower than this hence farmers who buy smaller units even at three times higher cost will still earn more than what they invest.

Given the payback period of one (1) year (best case scenario), and two (2) years (worst case scenario), adoption of metal silos will always be a better option for farmers who have a practice of selling their maize at harvest time, instead of the lean season, if they intend to use the silo for at least two (2) years. Even those who use the metal silos only for three (3) years and abandon the practice will recover their 20 years investment costs for the technology within the first two (2) years of use.

The same applies to traders who buy for immediate sale at harvest time and do not have a practice of storing but now wish to invest in the metal silos and store for a certain period for resale in the lean season.

Recommendation 11: Government of Mozambique or development agencies willing to promote adoption of the metal silo technology should only all willing farmers and traders willing to use the silo for at least three (3) years, otherwise the investment will not be worthwhile. Messaging to create demand among farmers and traders should emphasise the non-viability of shorter periods of use of the metal silo.

Viability of metal silos to farmers who produce, store and sell (or consume) the maize during the lean season

The results for the **base case model** showed a positive NPV of MZN 85,259.50, a BCR of 8.59, a very high IRR of 200,000%, and a shorter payback period of one (1) year for a farmer or trader storing 1,500 kg of maize (Annex 6.2). The results show that it is a worthwhile investment. Farmers who do not sell immediately after harvest, but choose to store for later use (sell or consume) will benefit from the technology as the returns will outweigh the investment costs by approximately 759%. Such farmers can breakeven even with about 11.6% of the benefit (that is, even those who lose only 3.48% (not 30%) without the technology would stand to benefit if they were to invest in metal silos to store for sale or consumption later in the season and if they were to do it continuously for 20 years).

Sensitivity analysis also showed that with 20% more benefit, the project's net worth would increase by 23%, the BCR would be 10.30, internal rate of return would exceed 200,000% , and the payback period would be one year. In addition, even if benefits were to be reduced by 20% , the NPV would remain positive (MZN 77,168.70) and BCR would stand at 6.87.

Under an optimistic scenario that has 10% as the discount rate, the return would be nine (9) times the investment costs, leading to a BCR of 9.55 and a payback period of one (1) year. The benefits of the technology are so robust that even under a more pessimistic scenario with a discount rate of 14%, incremental benefits associated with the value of stock preserved from perishing post-harvest, would exceed the incremental costs of investing in the metal silo by 679% (BCR=7.79).

When the cost of the metal silo is flexed to double the current price of MZN12,000 (US$231.93) for a 1,500 kg silo, the CBA results show that the investment remains viable for adopters, even when the product preserved in storage is low (16.5% of stored product instead of 30%). Hence there is scope for promoting local artisans to produce metal silos since the price of silos can be increased without offsetting altering much project viability.

Programming implications of the results

The results of the CBA analysis clearly show that farmers (or traders) who do not have a practice of selling their grain soon after harvest but store and lose up to 30% of their produce to post-harvest losses, stand to significantly gain more than those who have been selling at harvest. They will benefit by investing in metal silos, whether or not they then consume or sell the preserved maize later in the consumption season.

The metal silo remains viable even for farmers who will adopt and use it for shorter periods rather than the projected lifespan of the silos because the payback period is very short (1-2 years depending on assumptions of about the level of incremental benefits).

Recommendations 12: Government of Mozambique or development agencies willing to promote adoption of the metal silo technology should especially target farmers and traders who have a culture of storing maize for later use if these are willing to use the silo for at least three (3) years, otherwise the investment will not be worthwhile. Messaging to create demand among such farmers and traders should emphasise the non-viability of shorter periods of use of the metal silo (i.e., less than three (3) years).

Recommendation 13: Given that sensitivity analysis shows that the payback period for an investment in metal silo technology for farmers (or traders) willing to store maize and consume or sell in the lean season is 1-2 years for an investment over 20 years, development programmes to support adoption of the metal silo technology for maize in Mozambique should be designed to provide support to resource-poor and subsistence farmers for a minimum period of three (3) years, the longer the period the more preferable. Promotion of this technology can be a medium-term undertaking given that farmers do not need to re-purchase the silo for 20 years. A period of three (3) years would be more than adequate to ensure that farmers have the skills to use the metal silo correctly and effectively, and they see the benefits, which will encourage them to continue using the silos. Within three (3) years, farmers and traders will have earned sufficient incremental benefits to cover the projected future costs (for the remaining 17 years before the silo becomes obsolete).

Recommendation 14: Given that the returns to investment for metal silos are higher than for hermetic bags (BCR of 8.59 for silos versus 3.55 for hermetic bags for farmers that have a culture of storing), and the payback period is shorter for metal silos than hermetic bags, post-harvest management programmes seeking to promote improved technologies over a shorter period of time should prioritise the metal silo ahead of the hermetic bag provided, holding all other things constant.

Recommendation 15: Given the high initial capital investment cost for the metal silo, post-harvest management programmes seeking to promote adoption of improved storage technologies for maize in Mozambique should consider the hermetic bag technology for wider reach with limited resources ahead of the metal silo, but actively promote the metal silo as a graduation pathway for hermetic bag adopters, because metal silos offer a more viable longer-term preferred choice if the resources allow. Hermetic bags might look cheaper on the surface but due to their short life-spans, they are more expensive for resource poor maize farmers in the longer-term because farmers have to replace them once every two (2) years.

Beans Value Chain

CBA Modelling Scenarios and Assumptions for Beans

Two scenarios were also constructed for beans under which models were constructed to assess the returns to investment associated with improved PHLM technologies (hermetic bags and metal silos in particular). Scenario 1 assumed that some of the farmers who produce beans or traders who buy beans but lack modern PHLM technologies decide to immediately sell their bean produce at harvest time to avoid losses in storage or to take care of immediate financial needs. Scenario 2 assumed that some of the farmers or traders keep the produce for home consumption or sale later in the season, they do not sell immediately after harvest because their perception of risk is higher. The immediate post-harvest price for beans in Mozambique was reported to be MZN 48.50 per kg tonne while the lean season price stood at MZN 76.21[14] per kg (Table 6) a difference of 57%.

The base case scenarios for beans assumed a module of 1,500 kg of beans stored by traders (or farmers) (Table 6). The discount rate was set at 12%, as estimated in Chapter 1. Project life was taken to be 20 years (which is linked to the expected lifespan of the metal silo for standardisation). Benefits to adopters of the technology start accruing in the year they purchase the technology (both for hermetic bags and metal silos).

Table 6: CBA Modelling Assumptions for Beans and Hermetic Bags (Base Case)

Indicator	Scenario 1: Farmer sells		Scenario 2: Farmer stores	
	MZN	USD	MZN	USD
Project lifespan, years	20 years		20 years	
Project duration, years	20 years		20 years	
Benefits start accruing in Year:	Year 1		Year 1	
Loss without technology	30%		30%	

[14] FEWSNET, Mozambique Price Bulletin, March 2016.,

Production, in kg	1500		1500	
Product stored, kg	1500		1500	
Loss reduced by PHLM tech, in kg	450		450	
Post-harvest price, MZN/kg	48.50	0.94	48.50	0.94
Value preserved at PH price, MZN	21825	421.82	21825	421.82
Lean season price, MZN/kg	76.21	1.47	76.21	1.47
Value preserved at LS price, MZN	34294.50	662.82	34294.50	662.82
Incremental cost (Hermetic Bag,30x 50kg)	4200	81.17	4200	81.17
Lifespan of Technology: Hermetic Bag,	2 years		2 years	
Discount rate, base case	12%		12%	
Incremental benefit	12469.50	241.00	34294.50	662.82

Notes: LS=Lean Season; KG=Kilogram; PHLM=Post-harvest loss Management; MZN=Mozambican Metical.

Exchange rate: 1USD=MZN 51.74 (March 2016)

Source: Own source.

The loss of beans without adoption of technology was taken as 30% in Mozambique, and sensitivity and breakeven-point analyses were used to estimate investment viability for losses lower than this level. As for maize, the base case scenarios assumed that both the hermetic bag and metal silo technologies were 100% effective in reducing post-harvest losses, if used appropriately. The viability of the technologies at lower levels of effectiveness was computed using sub-models that assumed a 20% lower benefit, and breakeven analysis which computed the minimum level of effectiveness of the technology which would make the investments worthwhile. At 80% benefit (i.e., 20% less benefit), the post-harvest level would be equivalent to 24% of the harvest preserved (80% of 30). On the other hand 20% more benefit assumed a higher loss of 36% which would be eliminated with improved storage.

As for maize, the values of product preserved due to adoption of the two technologies (hermetic bag and metal silo) were estimated by multiplying the quantity preserved by the technology (prevented from pest and other types of damage in storage) with the post-harvest and lean season prices. At 30% loss, 450 kg from every 1.500 kg of beans stored could have been lost without technology. However, with the adoption of technology the 450 kg of beans would be preserved using either hermetic bags or metal silos (assuming 100% effectiveness). For beans the monetary values of the quantities of beans preserved from loss due to adoption of PHLM technologies were MZN 21,825.00 and MZN 34,294.50 at post-harvest and lean season price, respectively.

For farmers that sell beans immediately after harvest, they reduce the financial loss that could happen by storing and losing 30% of their beans in storage. They recover MZN 21,825.00 in value immediately after harvest (450 kg of potential loss multiplied by the post-harvest price of MZN 48.50 per kg). However, those that do not sell lose the opportunity to earn MZN 34,294.50 and because they do not use improved technologies, they cannot take advantage of the lean season price of MZN 76.21, which could have enabled them to earn MZN 34,294.50 by selling the 450 kg in the lean season. Hence the total loss to those who do not sell at post-harvest is MZN 34,294.50 while to those who sell immediately after harvest they only lose the opportunity to earn an extra MZN 12,469.50 in the lean season but will salvage MZN 21,825.00 by selling the produce (450 kg) at harvest. Hence those who sell at harvest only lose the difference between these two values (MZN 21,825 and MZN 34,294.50), which is equivalent to MZN 12,469.50.

Table 7: CBA Modelling Assumptions for Beans and Metal Silos (Base Case)

Beans- Metal Silo

Indicator	Scenario 1: Farmer sells		Scenario 2: Farmer stores	
	MZN	USD	MZN	USD
Project lifespan, years	20 years		20 years	
Project duration, years	20 years		20 years	
Benefits start accruing in Year:	Year 1		Year 1	
Loss without technology	30%		30%	
Production, in kg	1500		1500	
Product stored, kg	1500		1500	
Loss reduced by PHLM tech, in kg	450		450	
Post-harvest price, MZN/kg	48.5	0.94	48.5	0.94
Value preserved at PH price, MZN	21825	421.82	21825	421.82
Lean season price, MZN/kg	76.21	1.47	76.21	1.47
Value preserved at LS price, MZN	34294.5	662.82	34294.50	662.82
Incremental cost (Metal Silo, 1500kg)	12000	389.99	12000	389.99
Lifespan of Technology: Metal silo, years	20 years		2 years	
Discount rate, base case	12%		12%	
Incremental benefit	12469.50	241.00	34294.50	662.82

Notes: LS=Lean Season; KG=Kilogram; PHLM=Post-harvest loss Management; MZN=Mozambican Metical.

Exchange rate: 1USD=MZN 51.74 (March 2016)

Source: Own source.

From the above computations, by adopting PHLM technology, farmers who have a practice of selling immediately after harvest have an incremental benefit of MZN 12,469.50 which is the additional value they realise. The technology enables them to preserve 450 kg for sale later in the consumption season at a higher price, otherwise they would still realise some value by selling immediately after harvest. The difference between the counterfactual income (earned immediately after harvest) and that earned with the technology (at lean season price) is the additional benefit associated with the adoption of the technology.

However, for farmers that store and lose 450 kg in storage, the incremental benefit is derived from the value they get after selling the 450 kg of beans during the lean season (MZN 34,294.50). The counterfactual is therefore a loss of MZN 34,294.50 in value of product stored that perishes due to pest and other forms of damage due to sub-optimal crop storage conditions (Table 7).

As for maize, the incremental cost of hermetic bags was found to be MZN 4,200.00 which would be incurred once every two years (the lifespan of a hermetic bag).

The modelling scenarios for metal silos were also two, the first being where the farmer sells immediately after harvest and the second where the farmer sells during the lean season. As for hermetic bags, the incremental benefits are equivalent to MZN 12,469.50 and MZN 34,294.50

respectively while the incremental cost for a metal silo with a storage capacity of 500 kg was found to be the cost of the silo and installation (MZN 12,000) in year 1 and MZN 75.00 per year for pesticides for the 20 years project life.

CBA Analysis Results for Beans

Hermetic bags

For hermetic bags and for farmers that sell their produce immediately after harvest, CBA results for the **base case scenario** showed that the net present value of the cash-flows (incremental benefits minus incremental costs over a period of 20 years, discounted at a rate of 12% per annum) is positive (MZN 65,882.77), the benefit-to-cost ratio is 3.42, and the internal rate of return is greater than 50,000 which implies that the investment is viable (see Annex 6.3). The payback period for beans was three (3) years.

Results of sensitivity analysis also showed that the breakeven point for the investment would be reached with only 29.3% of the benefit (post-harvest loss of 8.79% instead of 30%). The same applies to a more optimistic scenario that assumes a 10% discount rate. When using a discount rate of 14%(a more pessimistic scenario) the breakeven point would be reached at 30% of current benefits (i.e., a post-harvest loss of 9% instead of 30%). Additional analyses show that these results are generalizable for smaller units of production (below 1,500 kg of beans).

For farmers who have a practice of storing and losing up to 30% of their product due to PHL, adoption of improved hermetic bag storage technology would generate even more benefits than those with a practice of selling at harvest time. The base case scenario showed an NPV of MZN 228,903.38 (e.g.,unit of stored product of 1,500 kg of beans), a BCR of 9.4, an IRR greater than 500,000% , shorter payback period of one (1) year and lower breakeven benefit of only 11% of current benefits (Annex 6.3). This means that even farmers who were using other methods of storage and reduced their post-harvest losses to four (4)% per year, would still benefit by switching to the hermetic bags.

<u>Programming implications of the results</u>

A farmer able to produce and store beans but has a practice of selling his crop at harvest time, will stand to benefit if he/she changed to storing and selling later in the season. The value of the additional benefits of the technology (quantity preserved multiplied by the difference between lean season and harvest season prices) outweighs the incremental cost of the improved storage technology (hermetic bags). Adoption of hermetic bags would bring financial advantages that outweigh the associated incremental costs. Use of hermetic bags for storing beans would bring about higher returns (almost double) to farmers using the technology for preserving beans than those using it for maize.

Recommendation 16: Agricultural development programmes seeking to reduce post-harvest losses can promote adoption of the hermetic bag technology for bean producers and traders including targeting those who are selling immediately after harvest because they do not have proper storage facilities. Both scenario 1 and 2 farmers would benefit.

The results for farmers who have a practice of storing and using the beans later, or selling them in the lean season confirm that even those non-adopters of hermetic bags with low post-harvest losses, stand to benefit if they were to adopt hermetic bags and eliminate the losses. The benefits of improved technology outweigh the incremental costs by a wide margin. The BCR value of 9.4 shows that the investment can recover the costs as much as nine (9) times during the 20 years of investment.

Recommendation 17: Given that returns to investment in hermetic bags for storage of beans are superior to those of maize by 229% (for those who do not sell at harvest), Government of Mozambique and development agencies should consider promoting hermetic bags more for the storage of beans as opposed to maize, if prioritisation was to be made between the two crops. However, since the returns for maize are also high though not higher than for beans, it would be worthwhile also to promote the technology for maize as well without any reservations, depending on farmers' technology preferences.

Metal silos

For metal silos, and for farmers that would otherwise sell immediately after harvest, the **base case CBA model** showed a positive NPV of MZN81,865.73, a BCR of 8.26, an IRR greater than 200,000%, and a shorter payback period of one (1) year (e.g., for a farmer or trader storing 1,500 kg of beans) (Annex 6.4). The results show that the investment will pay-off even for smaller production units.

Sensitivity analysis confirms that the investment remains viable for those who have been selling immediately after harvest even if the returns to investment are reduced by 20% (the BCR is 6.61), or if a pessimistic discount rate of 14% is considered (BCR is 7.49). The payback period remains short at 1-2 years for all scenarios considered.

When the cost of the metal silo is flexed to double the current price of MZN 12,000 per 1,500 kg silo (US$231.92), the CBA results show that the investment remains viable for adopters (who have been selling soon after harvest), even when the product preserved in storage is low (7.5% of stored product instead of 30%).

When the scenario of farmers who store for later use is considered the CBA results confirm that the investment is even more viable, with an NPV of MZN 244,886.34, BCR of 22.72, IRR greater than 200,000%, and a payback period of one year. Even when benefits are reduced to 80% of the current level, or the discount rate is increased to 14%, the investment remains viable with a payback periods of one (1) year, and BCR of 18.18 and 20.60, respectively. Even with sensitivity analysis, the breakeven point is reached with benefits below 4.5% of current benefits which shows that the metal silos are highly viable for storing beans.

Farmers or traders who do not sell immediately after harvest, but choose to store for later use (sell or consume) will benefit even more from the technology as the returns will outweigh the investment costs by approximately 2,100% (21 times). Such farmers who previously had as little as 1.3% loss in storage (not 29.8%) before adopting the technology, would stand to benefit if they were to invest in metal silos to store for sale or consumption later in the season and if they were to use the technology for 20 years.

Sensitivity analysis also showed that with 20% more benefit, the project's net worth would increase by 25%, the BCR would be 27.26, internal rate of return would increase above 200,000%, and the payback period would remain at one (1) year.

Under an optimistic scenario used by some donors (such as DFID) that has 10 percent as the discount rate, the discounted incremental benefits would be about 25 times the investment costs, leading to a BCR of 25.28 and a payback period again of one (1) year.

The benefits of the technology are so robust that even under smaller production units, storage of beans in smaller silos is viable. For example, smaller silos cost between 26 to 41% more per kg storage space. To test for the implications of smaller silos on viability, the cost of the silo was doubled.

When the cost of the metal silo was flexed to double the current price, the CBA results showed that the investment remains viable for adopters (who have not been selling soon after harvest), even when the product preserved in storage is low (3% of stored product instead of 30%).

Assuming that post-harvest management programmes are able to support adoption of hermetic bags and metal silos such that all bean harvest is properly stored and is preserved, the study estimates that between 0.43 and 0.53% of agricultural GDP per annum will be preserved through hermetic bag and metal silo investments in Mozambique (i.e., US$8 million, and US$10.85 million, respectively). This is in the form of the NPV for the investments over the 20 years project lifespan.

Recommendation 18: For farmers who can grow large quantities of beans (100 kg and above) and intend to store for later use or sale in the lean season, the metal silo should be promoted ahead of the hermetic bag technology. Programmes should focus on improving the capacity of local artisans to manufacture and distribute these silos, but being part of a larger range of products that artisans produce because the 20 years lifespan of a metal silo does not make it a viable mono-product long-term business opportunity for artisans.

Recommendation 19: Given the high payback period for the metal silo technology development programmes to support farmers in adopting this technology can be designed to support farmers for a period of at most three (3) years, as this is sufficient for them to have recouped investment costs for 20 years.

CBA Modelling Scenarios and Assumptions for Cowpeas

As done for maize and beans, two scenarios were also constructed for cowpeas under which models were constructed to assess the returns to investment associated with improved PHLM technologies (hermetic bags and metal silos in particular). Scenario 1 assumed that some of the farmers or traders do not store but immediately sell their cowpeas at harvest time. Scenario 2 assumed that some of the farmers or traders keep the produce for sale or other uses later in the season. The immediate post-harvest price for cowpeas in Mozambique was found to be half the price of beans[15] MZN 24.25 per kg while the lean season price stood at MZN 38.11 per kg (Table 8) a difference of 57.15 percent.

Similar to what was done for maize and beans, the base case scenarios for cowpeas assumed that farmers have sufficient production to have a need to store 1500 kg of cowpeas (Table 8). The discount rate was set at 12%, as estimated in Chapter 1. Project life was taken to be 20 years (which is linked

[15] FAO. Improved post-harvest handling raises incomes for Mozambique farmers. http://www.fao.org/in-action/improved-post-harvest-handling-raises-incomes-for-mozambique-farmers/en/

to the expected lifespan of the metal silo for standardisation). Benefits to adopters of the technology start accruing in the year they purchase the technology (both for hermetic bags and metal silos).

Table 8: **CBA modelling assumptions for cow peas and hermetic Bags (Base Case)**

Indicator	Scenario 1: Farmer sells		Scenario 2: Farmer stores	
	MZN	USD	MZN	USD
Project lifespan, years	20 years		20 years	
Project duration, years	20 years		20 years	
Benefits start accruing in Year:	Year 1		Year 1	
Loss without technology	30%		30%	
Production, in kg	1500		1500	
Product stored, kg	1500		1500	
Loss reduced by PHLM tech, in kg	450		450	
Post-harvest price, MZN/kg	24.25	0.48	24.25	0.48
Value preserved at PH price, MZN	10912.50	210.90	10812.50	210.90
Lean season price, MZN/kg	38.105	0.74	38.105	0.74
Value preserved at LS price, MZN	17147.30	331.41	17147.30	331.41
Incremental cost (Hermetic Bags, 30x50kg)	4200	81.17	4200	81.17
Lifespan of Technology: Hermetic Bag	2 years		2 years	
Discount rate, base case	12%		12%	
Incremental benefit	6234.75	120.50	17147.3	331.41

Notes: LS=Lean Season; KG=Kilogram; PHLM=Post-harvest loss Management; MZN=Mozambican Metical.

Exchange rate: 1USD=MZN 51.74 (March 2016)

Source: Own source.

Similar to beans, the post-harvest loss of cowpeas without adoption of technology was taken as the highest level of 30% in Mozambique, and sensitivity and breakeven-point analyses were used to estimate investment viability for losses lower than this level. As was the case for maize and beans, the base case scenarios assumed that both the hermetic bag and metal silo technologies were 100% effective in reducing post-harvest losses. The viability of the technologies at lower levels of effectiveness was computed using sub-models that assumed a 20% lower benefit, and breakeven analysis. At 80% benefit (i.e., 20% less benefit), the post-harvest level would be equivalent to 24% of the harvest preserved (80% of 30%). On the other hand, 20% more benefit assumed a higher loss of 36% which would be eliminated with improved storage.

As for maize, the values of product preserved due to adoption of the two technologies (hermetic bag and metal silo) were estimated by multiplying the quantity preserved by the technology (prevented from pest and other types of damage in storage) with the post-harvest and lean season prices. At 30% loss, 450 kg from every 1500 kg of cowpeas stored could have been lost without technology. However, with the adoption of technology the 450 kg of cowpeas would be preserved using either hermetic bags or metal silos (assuming 100% effectiveness). For cowpeas, the monetary values of the quantities of cowpeas preserved from loss due to adoption of PHLM technologies were MZN 10,912.50 and MZN 17,147.30 at post-harvest and lean season prices, respectively.

For farmers that sell cowpeas immediately after harvest, they reduce the financial loss that could happen by storing and losing 30% of their cowpeas in storage. They recover MZN 10,912.50 in value immediately after harvest (450 kg of potential loss multiplied by the post-harvest price of MZN38.11 per kg). However, those that do not sell lose the opportunity to earn MZN 17,147.30 and because they do not use improved technologies, they cannot take advantage of the lean season price of MZN 38.11, which could have enabled them to earn MZN 17,147.30 by selling the 450 kg in the lean season. Hence the total loss to those who do not sell at post-harvest is MZN 17,147.30 while to those who sell immediately after harvest they only lose the opportunity to earn an extra MZN 6,234.75 in the lean season but will salvage MZN 10,912.50 by selling the produce (450 kg) at harvest. Hence those who sell at harvest only lose the difference between these two (2) values (MZN 17,147.30 and MZN 10,912.50), which is equivalent to MZN 6,234.75.

From the foregoing computations, by adopting PHLM technology, farmers who have a practice of selling immediately after harvest have an incremental benefit of MZN 6.234.75 which is the additional value they realise. The technology enables them to preserve 450 kg for sale later in the consumption season at a higher price, otherwise they would still realise some value by selling immediately after harvest. The difference between the counterfactual income (earned immediately after harvest) and that earned with the technology (at lean season price) is the additional benefit associated with the adoption of the technology.

However, for farmers that store and lose 450 kg in storage, the incremental benefit is derived from the value they get after selling the 450 kg of cowpeas during the lean season (MZN 17,147.30). The counterfactual is therefore a loss of MZN 17,147.30 in value of product stored that perishes due to pest and other forms of damage due to sub-optimal crop storage conditions (Table 9).

As for maize and beans, the incremental cost of hermetic bags was the same at MZN 4,200.00 which would be incurred once every two years (the lifespan of a hermetic bag).

Table 9: CBA Modelling Assumptions for Cowpeas and Metal Silos (Base Case)

Indicator	Scenario 1: Farmer sells		Scenario 2: Farmer stores	
	MZN	USD	MZN	USD
Project lifespan, years	20 years		20 years	
Project duration, years	20 years		20 years	
Benefits start accruing in Year:	Year 1		Year 1	
Loss without technology	30%		30%	
Production, in kg	1500		1500	
Product stored, kg	1500		1500	
Loss reduced by PHLM tech, in kg	450		450	
Post-harvest price, MZN/kg	24.25	0.48	24.25	0.48
Value preserved at PH price, MZN	10912.50	210.90	10812.50	210.90
Lean season price, MZN/kg	38.105	0.74	38.105	0.74
Value preserved at LS price, MZN	17147.30	331.41	17147.30	331.41
Incremental cost (Metal Silo, 1500kg)	12000	389.99	12000	389.99
Lifespan of Technology:	20 years		20 years	
Discount rate, base case	12%		12%	
Incremental benefit	6234.75	120.50	17147.30	331.41

Notes: LS=Lean Season; KG=Kilogram; PHLM=Post-harvest loss Management; MZN=Mozambican Metical.

Exchange rate: 1USD=MZN 51.74 (March 2016)

Source: Own source.

The modelling scenarios for metal silos were also two (2), the first being where the farmer sells immediately after harvest and the second where the farmer sells during the lean season. As for hermetic bags, the incremental benefits were MZN 6,234.75 and MZN 17,147.30 respectively, while the incremental cost for a metal silo with a storage capacity of 1,500 kg was MZN 12,000.00 and MZN 75.00 per year for pesticides for the 20 years project life.

CBA Analysis Results for Cowpeas

Hermetic bags

The **base case model** for the scenario where the farmer or trader has no tradition of storing, but sells immediately after harvest, showed that investment in hermetic bag technology would leave the farmer/trader better off, with an NPV of MZN19,312.66, BCR of 1.71 and IRR of more than 500,000%. The payback period is seven (7) years and breakeven loss is 58.5% of current loss of 30% (that is, if farmers preserve only 17.55% of their produce in storage rather than 30% they will recover the costs incurred in investing in hermetic bags over a 20 years lifespan). Sensitivity analysis also reveals that the project is viable with 20% less benefits and a discount rate that is more pessimistic, of 14%.

When the scenario of farmers that store for sale later in the season is considered these stands to earn higher incremental benefits from the technology (when compared to the period without technology), with a BCR of 4.7, IRR greater than 500,000% and a much shorter payback period of two (2) years. Breakeven point is reached with 49% of the estimated current benefits which means that even farmers with lower losses (14.7%), who have not been selling at harvest time but have been storing will stand to gain from the investment in hermetic bags. Sensitivity analysis of scenario 2 shows that the incremental benefits will always exceed the incremental costs by a factor of at least 270% (BCR ranges from 3.76 to 5.64) (Annex 6.5).

Programming implications of the results

The findings reveal that promotion of hermetic bag technology for cowpea producers is viable even for the scenario where farmers already practice some prudence by selling immediately after harvest. Returns to investment outweigh the investment cost by 71%. However the payback period is longer given the need to purchase new bags once every one to two years (Raffia Bags last two (2) years while Super Bags last one year, wood poles that form the base have a lifespan of five (5) years). The returns are better than for maize; hence hermetic bag technology should therefore be promoted for storage of cowpeas and beans ahead of maize in areas where the local capacity to supply and install metal silos is not well developed.

Recommendations 20: Given the payback period of two (2) years for farmers and traders who store and sell later in the lean season, such farmers can be supported for at least a two (2) years period to adopt hermetic bags and this is sufficient to leave them when they will have earned enough benefits to stand on their own and continue investing in replacement bags once every two years. However, programmes keen to change the behaviour of farmers from selling immediately after the harvest to storing and selling later should invest for a longer period to support such farmers as the payback period is much longer (5-10 years). If resources are limited, development programmes should not discourage those selling cowpeas onto the market immediately after harvest to stop doing so, but rather focus on those who are storing with substandard methods of storage to change to better storage methods (e.g. hermetic bag).

Metal silos

The base case model for cowpeas indicated that farmers who sell immediately after harvest, will benefit if they changed their practices to storing and selling later, and if they do so using the metal silo technology. The NPV for storing 1,500 kg of cowpea would be 35,295.62, IRR would be 4.13% and the payback period would be two (2) years. Breakeven point could be reached by a lower benefit (24.3% of the projected PHL of 30%). Sensitivity analysis shows that the technology is so viable that even with 20% of benefit, farmers and traders could breakeven. This implies that even farmers with lower levels of losses (i.e., 6%) without metal silos, would benefit from adopting metal silos and drastically reducing their losses in storage.

When the scenario where farmers do not sell immediately after harvest but store using ineffective traditional methods is considered, the base case scenario shows that metal silos would have a significant impact on farmer incomes if they were to switch to metal silos. Returns to investment would outweigh the costs by 1,036% (BCR of 11.36). They could increase with a 20% increase in benefit to BCR of 13.63, and the cost of the investment over 20 years can be recouped in the first year of adoption of the metal silo technology (if installed and used in that same year).

Breakeven point can be reached even by as little as 8.8% of the projected incremental benefits of adoption (2.64% instead of 30% post-harvest loss).

Programming implications of the results

Cowpea producers who intend to store for sale later are better off with metal silos than hermetic bags, but both options are viable. Farmers or traders can recoup the costs of this investment in the first three (3) years which means support can be provided over a period of three (3) years and it will be enough to leave them with sufficient incremental benefits to reward them for the investment to be made in 20 years (including pesticide).

Recommendation 21: Post-harvest loss management programmes should prioritise the metal silo ahead of hermetic bags in situations where cowpea farmers can afford the metal silo, production is adequate to justify the use of the technology and farmers or traders would like to store the cowpeas for sale or use in the lean season. Even farmers who do not store but sell immediately after harvest can be dissuaded from this practice and encouraged to store and sell later in the season as the incremental benefits far outweigh the incremental costs by a large margin.

As for maize and beans, if the modelling assumes that farmers and traders adopt hermetic bags and metal silos such that all cowpeas produced is properly stored and is preserved, the study estimates that between 0.05 and 0.1% of agricultural GDP will be preserved through PHLM investments. The lower figure is for hermetic bags and the higher is for metal silos.

If the agricultural GDP preserved from storage of maize, beans and cowpeas is added together, the analysis shows that, annually, between 2.77 and 3.81% (US$0.99 million and US$ 1.82 million) of such GDP is preserved and can contribute to growth in the other sectors that are closely integrated with agriculture.

4. Proposed financing mechanisms for improved Post-harvest loss management technologies

FAO estimates that about USD940 billion should be invested to eradicate hunger in Sub-Saharan Africa over a 44 years period to 2050 and that up to 47% of the amount will be required in the post-harvest sector to cover investments in cold and dry storage, rural roads , rural and wholesale market facilities and first stage processing[16]. FAO is optimistic the needs will be met considering the commitment in Africa to invest in agriculture. Most countries, including Mozambique are implementing strategic frameworks that are in line with CAADP pillar 2. However, it should be noted that the amount is huge and African governments on their own may not be able to meet it because of current economic challenges. It is therefore imperative that concerted efforts towards investment in post-harvest technologies be made by all sectors including government, donors, NGOs, the private sector and the farmers. Public private and community partnerships should therefore be explored as recommended by FAO/World Bank. Already in Mozambique, Grainpro a private, United States based company is partnering with NGOs in promoting hermetic bags. The company imports hermetic materials, manufactures hermetic bags and sells them while a partner NGO together with a Grainpro representative does awareness raising and training for farmers. Such partnerships should be promoted in order to improve the reach and increase coverage.

The Mozambican government has increased investment in agricultural production in the past two (2) or three (3) decades but there has been minimal improvement in the food security. This is attributed to post-harvest losses. It is therefore critical to address PHL. The Government of Mozambique is encouraged strongly to increase investment in post-harvest technologies through its budget on agriculture. It can source for funding from the World Bank and African Development Bank (AfDB)'s Africa Food Crisis Response. The AfDB's Agriculture and Agro-Industry Department (OSAN) has since 2009 been developing a Post-harvest Losses Programme (PHLP) whose overall goal is to enable Regional Member Countries to achieve supply chain efficiencies through targeted, investment in rural infrastructure, post-harvest and agro-processing technologies, thus contributing to a reduction of physical losses, improved food availability and enhanced product quality in a sustainable manner.[17] The programme contributes directly to the implementation of Pillar II (Improving Rural infrastructure and Trade related Capacities) within the Comprehensive African Agriculture Development Programme (CAADP). Promotion of new technologies through agricultural extension and further research is required. Extension workers may be trained so that they may cascade the training to small-holder farmers in their areas. NGOs may provide funding and partner with the extension workers in providing training. The training is important in bringing awareness of the benefits of new technologies such as metal silos and hermetic bags for increased adoption by farmers.

Private companies such as GrainPro who supply the modern technologies may partner with the extension workers and NGOs to provide awareness to smallholder farmers and training for artisans who will manufacture the metal silos within the communities. This will help to guard against manufacture of poor quality of metal silos, a scenario which may compromise the effectiveness of the technology and thereby also compromise the accrual of benefits.

[16] FAO/World Bank. 2010. *Workshop on reducing Post-Harvest Losses in Grain Supply Chain in Africa*. Rome.

[17] Ibid

The private sector, specifically finance or micro-finance companies are encouraged to provide affordable loans to small holder farmers so that they can buy silos and repay their loans over two (2) or three (3) years. In order to guard against dependency farmers are encouraged to contribute towards purchase of their silos. They may be asked to pay a certain percentage of the cost from own resources and then get top up from finance companies. However, NGOs may pay the full cost for the poorest members of the community to provide a safety net for them.

The government may solicit for funds from its donors to fund the promotion of technologies as well as reduce custom duty on imported post-harvest material such as hermetic material. The import duty for hermetic material is currently 37%. This cost is obviously pushed to the consumer, making the hermetic very expensive for the small-holder farmers who represent about 99% of farmers in Mozambique. It may also consider subsidizing the material to improve access of the technology by poor households who require it most.

5. Conclusions

1. Mozambique Strategic Plan for Agriculture Development Sector 2011-20 contains a PHM strategy. There is however, no stand-a-lone policy on PHM which weakens institutional collaboration on the subject. There is no relevant research initiative on PHM and there is general lack of PHM service providers in Sub-Saharan Africa and SADC region. PHM in Mozambique is affected by lack of infrastructure, transportation and local oriented food industries, policy gaps, lack of training institutions for PHM and lack of capacity by farmers to access funding.

2. There is general lack of adequate knowledge of PHM among stakeholders.

3. Storage losses range from 20 to 40% depending on crop and geographical location. Storage losses force farmers to sell their produce early to avoid physical losses thereby reducing opportunities to sell at favourable prices.

4. Average returns to storage of maize are very low in Maputo and Southern region (22%) where there is low production and low seasonal price variation and very high in the Northern region which is characterised by high production and high seasonal price variability.

5. Small scale farmers who constitute 99% of the farmers prefer super bags and metal silos but only a few afford them because of high costs.

Annexes

Annex 1: Terms of reference

Terms of Reference for Study to Develop proposal for inclusion of PHM in existing frameworks.

Background

The **Postharvest Management in Sub-Saharan Africa (PHM-SSA)** is a project under the Global Programme Food Security (GPFS) of SDC coordinated by HELVETAS Swiss Inter-cooperation (HSI) and implemented in a consortium with FANRPAN (Food, Agriculture and Natural Resources Policy Analysis Network), AFAAS (African Forum for Agricultural Advisory Services) and Agridea. The goal of the project is to increase food security of smallholder farmers in Sub-Saharan Africa through reduced postharvest losses at farm and community level. The project duration is six (6) years.

The project aims to improve food security (increased food self-sufficiency and incomes) of smallholder men and women farmers in SSA through reduction of postharvest losses of food crops (grains and pulses) by addressing major constraining factors of technology dissemination and adoption, knowledge and information sharing, rural advisory services (RAS) and policies related to PHM. The project has a regional focus and intervention logic, including pilot activities in Benin and Mozambique. The expected outcomes of the project are:

1. Improved handling and storage options within the grains and pulses value chains are benefitting smallholder farmers in pilot countries.
2. Good practice options for reducing post-harvest losses are compiled, disseminated and scaled up.
3. Appropriate regulatory frameworks on reducing post-harvest losses in food supply chains are introduced and implemented at national and regional levels.

Activities towards meeting the set objectives involve the engagement of the services of a Consultant identified through national institutions to:

- Conduct an analysis of existing policy and regulatory frameworks for food standards/norms related to post –harvest management with a focus on staple grains in each study country;
- Identify and analyze gaps in the frameworks related to post-harvest management; and
- Develop proposal for inclusion of PHM in existing frameworks.

The detailed terms of reference and expected outputs are provided below.

Scope of the Assignment

FANRPAN seeks to engage the services of two national consultants (Benin and Mozambique) to conduct an analysis of existing national post-harvest management economics (with a focus on staple grains). This will be based on a compilation and presentation of existing data on the economics of the postharvest value chain at national level; including capacity and quality of and access to postharvest innovations like metal silos, general storage, transport, and communications.

<u>The specific policy evaluation assignment will include the following activities:</u>

1. Conducting a desk study to include the review of national, regional and global literature on post-harvest economic policies.
2. State of knowledge on post-harvest economics in the country
    - Reviews of economic frameworks of postharvest management in national government policies and strategies
3. Conducting interviews with a minimum of 10 relevant in-country stakeholders- to include women leaders and women organizations that will be identified jointly with FANRPAN;
4. Compiling and presenting data on the value of postharvest loss in the country with a focus on staple foods
5. Identifying national research and development programme initiatives on postharvest technologies/innovations for smallholder farmers;
6. Compiling and presenting data on costs and benefits of improved postharvest storage innovations including metal silos.
7. Assessing the opportunities and risks for smallholder farmers in investing in postharvest technologies based on existing data.
8. Assessing the economics of the postharvest value chain based on existing data in the country with bias toward smallholder farmers
9. What is required to improve the economics of the postharvest value chain in order for it to benefit smallholder farmers?
10. Sharing the draft analysis report on the economics of the post-harvest value chain with FANRPAN, AFAAS and HSI, as well as with relevant in-country stakeholders for input;
11. Incorporating inputs from stakeholders and FANRPAN, AFAAS and HSI;
12. Identifying key themes for discussion during the national dialogue where the report will be validated;
13. Participating in planning meetings for the national dialogue;
14. Sharing list of stakeholders to invite to the national policy dialogue on frameworks for food standards and norms (one national dialogue per country);
15. Presentation of report at the national study validation workshop (report guidelines will be provided); and
16. Production of the final study report.

Expected Outputs

1. Comprehensive analysis of postharvest economics report; and
2. Presentation of national draft study report at the national workshop at which the report will be validated.

Qualifications and Experience

Resident consultants (in the country where study will be conducted) with post graduate qualification in Agriculture/Agriculture economics and or Food Science, and six (6) years-experience in the agricultural sector as well as a good command of the English language. Please note that consultants from Mozambique should be fluent in English and Portuguese and consultants from Benin should be fluent in both English and French. A PhD qualification would be an added advantage.

Annex 2: Documents reviewed

1. Aulakh J., & Regmi A., *Post-harvest food losses- Development of consistent methodology*.
2. *Country Strategy for Development Cooperation with Mozambique 2014-2017*. Ministry of Foreign Affairs of Finland.
3. FANRPAN Policy Brief. 2014. *PHLM in Mozambique- Towards a Specific Post-harvest Loss Management Policy and Strategy for Mozambique.*
4. FEWSNET. March 2016. Mozambique Price Bulletin.
5. FAO. Improved post-harvest handling raises incomes for Mozambique farmers. http://www.fao.org/in-action/improved-post-harvest-handling-raises-incomes-for-mozambique-farmers/en/
6. FAO/WFP. 2010. *FAO/WFP Crop and Food Supply Assessment Mission to Mozambique.* Special Report.
7. Ngare L., Simtowe F., Massigue J., 2014. *Analysis of price volatility and implications for price stabilisation.* European journal of Business and Management. ISSN 2222-1905. Paper ISSN -2839 (online). Vol. 6, No. 22.
8. Knoema Production Statistics- Crops, Crops Processed – February 2015. https://knoema.com/FAOPRDSC2015Feb/production-statistics-crops-crops-processed-february-2015?country=1001320-mozambique&item=1000900-maize.
9. Schneider K., 2014. *Post-harvest management in Sub-Saharan Africa- Feasibility study on promotion of Post-harvest technologies in the north of Mozambique- Mission Report*.
10. Tivana L., Casimiro A., Madzara M., & Monjane I. 2014. *Post-harvest management policy and strategies in Mozambique and Sub-Saharan Africa- Mozambique Report*. FANRPAN.

Annex 3: People Interviewed

Name	Organisation	Function	Province	Telephone	E-mail
Daniel Haleselassie	Grainpro Inc.	Continent Manager	Maputo		Daniel@grainpro.com
Lucas Daniel Tivana	Faculty of Agronomy and Forest Engineering	Lecturer	Maputo		

Annex 4: Crop Production Statistics Tables

Annex 4.1: Crop Production figures for Nampula Province 2014-15

DISTRICTS	Maize		Beans		Soybean	
	Real Production (ton)	Marketing	Real Production (ton)	Marketing	Real Production (ton)	Marketing
Malema	30,287	12,212	17,330	4,735	1,383	1,953
Ribaue	42,326	11,665	14,381	4,033	994	1,952
Lalaua	24,898	8,814	9,012	1,708	0	0
Mecuburi	18,155	7,510	6,345	2,000	0	0
Murrupula	16,789	5,243	7,820	2,135	345	995
Rapale	17,731	5,544	6,992	2,836	345	0
Muecate	12,698	3,635	6,383	1,345	0	0
Meconta	8,907	5,892	5,064	3,436	1,687	0
Nacaroa	5,738	3,295	3,878	1,848	0	0
Erati	25,377	6,660	6,025	3,462	0	0
Memba	13,423	5,541	3,395	3,194	0	0
Nacala Velha	3,134	1,898	3,916	1,089	0	0
Nacala Porto	2,762	1,545	2,187	1,588	0	0
Mossuril	4,123	429	3,525	1,765	0	0
I. de Moçambique	1,015	407	1,534	458	0	0
Monapo	21,342	7,086	8,964	3,204	0	0
Liupo	7,694	2,174	1,528	1,845	0	0
Mogincual	16,584	2,630	2,941	1,874	0	0
Mogovolas	14,379	3,675	4,611	1,990	0	0
Angoche	11,982	3,131	5,490	2,275	0	0
Moma	8,945	3,229	4,537	1,120	0	0
Larde	5,349	2,096	2,232	1,347	0	0
Nampula Cidade	2,345	609	1,033	458	0	0
	315,983	**104,920**	**129,123**	**49,745**	**4,754**	**0**

Annex 4.2: Nampula Province Food Production and loss by district

DISTRICT	Total production of food crops	Food consumption	Seeds	Loss (10%)	Final surplus
Malema	387,134.60	61,163.47	31,003.21	38,713.46	256,254.47
Ribaue	463,674.65	79,925.72	25,084.18	46,367.47	312,297.29
Lalaua	243,312.73	27,444.97	35,184.05	24,331.27	156,352.43
Mecuburi	354,210.89	57,924.65	23,200.98	35,421.09	237,664.17
Murrupula	502,459.36	54,435.63	15,782.97	50,245.94	381,994.82
Npl-Distr.	419,493.04	88,404.02	16,507.24	41,949.30	272,632.48
Muecate	269,298.49	35,754.28	13,701.02	26,929.85	192,913.34
Meconta	334,358.47	59,772.93	25,667.14	33,435.85	215,482.55
Nacaroa	298,256.13	39,316.98	12,550.92	29,825.61	216,562.62
Erati	455,732.38	97,304.02	15,782.97	45,573.24	297,072.16
Memba	302,361.22	82,522.41	23,059.65	30,236.12	166,543.03
N.Velha	199,983.81	37,282.76	14,226.57	19,998.38	128,476.10
N.Porto	142,570.79	75,582.63	16,308.51	14,257.08	36,422.57
Mossuril	238,006.64	43,286.64	11,113.77	23,800.66	159,805.57
Ilha Moç.	85,142.32	17,306.19	8,427.14	8,514.23	50,894.76
Monapo	330,621.10	117,513.23	29,285.26	33,062.11	150,760.51
Mogincual	502,891.07	51,178.63	19,967.08	50,289.11	381,456.25
Mogovolas	303,973.11	131,557.09	21,503.25	30,397.31	120,515.46
Angoche	390,961.65	102,621.26	16,308.51	39,096.16	232,935.71
Moma	493,924.72	114,983.63	20,650.90	49,392.47	308,897.71
Cid. Nampula	93,738.86	195,151.40	9,122.71	9,373.89	(119,909.13)

Annex 4.3: Mozambique Maize Prices by Province- April 2015- March 2016[18]

Province/ Market Hub	2015/16 price MZN/kg		5-year average price MZN/kg	
	Lowest	Highest	Lowest	Highest
Beira	7	29	7	13
Chimoio	7	27	7	11
Chokwe	10	32	8	10
Gorongosa	6	23	6	10
Maputo	13	37	12	13
Maxixe	9	28	8	11
Mocuba	7	27	6	13
Nampula	8	28	7	12
Pemba	10	30	7	13
Tete	8	27	7	11

[18] FEWSNET. March 2016 Mozambique Price Bulletin

Annex 5: Cost-Benefit Analysis Models

Annex 5.1: Price calculation for metal silos

Heading	Unit price		150 kg		300 kg		500 kg		700 kg		1000 kg	
	Unit	Price Mts	Unit	Price Mts	Unit	Price Mts	Unit	Price Mts	Unit	Price Mts	Unit	Price Mts
Metal sheet 0.9 x 1.6m (0.5mm)	cal 0.5mm (G26)	480	1		3	1,440	3.5	1,680	4	1,920	4.5	2,160
Tin 50 : 50 (lead : tin)	100 gr	100	1		4	400	5	500	5.5	550	6.4	640
Charcoal	kg	4	1.5		2	8	7	28	8	32	10	40
Pine resin / Amonium chlorid	kg	30	50		0.07	2	0.9	27	0.1	3	0.15	5
Hydrochlorid Acide	dl	60	0.1		0.15	9	0.18	11	0.2	12	0.25	15
Aluminium Paint	lt	175	0.025		0.05	9	0.05	9	0.06	11	0.08	14
materiel cost				**-**		**1,868**		**2,255**		**2,528**		**2,874**
Transportation						150		150		150		150
labor cost						300		325		350		375
Dépreciation tools and workbench						15		15		15		15
cost of the silo				**-**		**2,333**		**2,745**		**3,043**		**3,414**
US$						78		91		101		114
Price per 100 kg en US$						25.9		18.3		14		16

Annex 5.2: Cost benefit Analysis: Metal silo

Description	Description of calculation	Calculation	Silo 250 kg	Silo 500 kg	Silo 700kg	Silo 1000kg
Loss estimation	15% of loss at MT 10.- / kg	37.5kg x 10.-	375.-			
	15% of loss at Mt 10.- / kg	75 kg x 10.-		750.-		
	15% of loss at Mt 10.- / kg	105 kg x 10.-			1050.-	
	15% of loss at Mt 10.- / kg	150kg x 10.-				1500.-
Market win	Price differential: Mt. 6.- harvest Mt 4.- Shortage Mt. 10.- applied to 50% of storage capacity	250kg x 50% x Mt 6.-	750.-			
	Price difference: Mt. 6.- harvest Mt 4.- Shortage Mt. 10.- applied to 50% of storage capacity	500kg x 50% x Mt 6.-		1500.-		
	Price difference: Mt. 6.- harvest Mt 4.- Shortage Mt. 10.- applied to 50% of storage capacity	700kg x 50% x Mt 6.-			2100.-	
	Price difference: Mt. 6.- harvest Mt 4.- Shortage Mt. 10.- applied to 50% of storage capacity	1000kg x 50% x Mt 6.-				3000.-
Total additional income			**1,125.-**	**2250.-**	**3150.-**	**4500.-**
Price of silo			2335.-	2745.-	2528.-	2874.-

Annex 6: Results of Cost Benefit Analysis

Annex 6.1: Maize- Hermetic Bags

	Base Case r=12%	Benefits + 20%	Benefits less 20%	r=10%	R=14%
SCENARIO A- - Farmer stores all the harvested crop					
NPV	69,546.53	88,907.33	50,185.73	79,315.5	61,630.22
BCR	3.55	4.26	2.84	3.56	3.55
IRR	>50,000%	>50,000%	>50,000%	>50,000%	>50,000%
PAYBACK	3	2	3	3	2
BREAKEVEN	28.1%	23.4%	35.2%	28%	28.1%
SCENARIO B- Farmer sells part of the harvest soon after harvest					
NPV	40,975.91	54,622.58	27,329.24	46,751.12	36,296.74
BCR	2.50	3	2	2.51	2.50
IRR	>100,000%	>100,000%	>100,000%	>100,000%	>100,000%
PAYBACK	3	3	4	4	3
BREAKEVEN	40%	33.4%	50%	40%	40%

Annex 6.2: Maize- Metal Silo

	Base Case r=12%	Benefits + 20%	Benefits less 20%	r=10%	R=14%
SCENARIO A- Farmer stores all the harvested crop					
NPV (MZN)	85,259.5	104,890.29	66,168.70	98,788.18	74,812.72
BCR	8.59	10.30	6.87	9.55	7.79
IRR	200,000%	>200,000%	>100,000%	200,000	>100,000%
PAYBACK	1	1	2	1	1
BREAKEVEN	11.6%	9.7%	14.5%	10.5%	13%
SCENARIO B- Farmer sells part of the harvest soon after harvest					
NPV	56,958.87	70,605.55	43,312.20	66,223.80	49,479.25
BCR	6.05	7.26	4.84	6.73	5.49
IRR	>50,000%	>100,000%	>20,000%	>100,000%	>20,000%
PAYBACK	2	2	2	2	2
BREAKEVEN	16.6%	13.8%	20.6%	14.8%	18%

Annex 6.3: Beans- Hermetic Bags

	Base Case r=12%	Benefits + 20%	Benefits less 20%	r=10%	R=14%
SCENARIO A- Farmer stores all the harvested crop					
NPV	228,903.38	280,135.54	177,671.31	260,948.00	202,931.40
BCR	9.40	11.28	7.52	9.41	9.38
IRR	>500,000%	>500,000%	>500,000%	>500,000%	>500,000%
PAYBACK	1	1	1	1	1
BREAKEVEN	11%	9%	13.5%	11%	11%
SCENARIO B- Farmer sells part of the harvest soon after harvest					

NPV	65,882.77	84,510.82	47,254.72	75,139.59	58,381.57
BCR	3.42	4.10	2.73	3.42	3.41
IRR	>50,000	>50,000%	>50,000%	>50,000	>50,000%
PAYBACK	3	2	3	3	2
BREAKEVEN	29.3%	24.5%	37%	29.3^	30%

Annex 6.4: Beans- Metal Silo

	Base Case r=12%	Benefits + 20%	Benefits less 20%	r=10%	R=14%
SCENARIO A- - Farmer stores all the harvested crop					
NPV	244,886.34	307,393.00	193,654.17	280,420.80	216,113.90
BCR	22.72	27.26	18.18	25.28	20.60
IRR	>200,000%	>200,000%	>2000,000%	>200,000	>200,000%
PAYBACK	1	1	1	1	1
BREAKEVEN	4.5%	3.7%	5.5%	4%	4.9%
SCENARIO B- Farmer sells part of the harvest soon after harvest					
NPV	81,865.73	100,493.78	63,237.69	94,612.27	71,564.08
BCR	8.26	9.91	6.61	9.19	7.49
IRR	>100,000%	>100,000%	500%	200,000%	>100,000%
PAYBACK	1	1	2	1	1
BREAKEVEN	12%	10%	15%	11%	13%

Annex 6.5: Cowpeas- Hermetic Bags

	Base Case r=12%	Benefits + 20%	Benefits less 20%	r=10%	R=14%
SCENARIO A- Farmer stores all the harvested crop					
NPV	100,822.96	126,439.04	75,206.88	114,963.92	89,362.92
BCR	4.7	5.64	3.76	4.71	4.69
IRR	>500,000%	>500,000%	>500,000%	>500,000&	>500,000%
PAYBACK	2	2	2	3	2
BREAKEVEN	21.2%	17.8%	26.5%	21.2%	21.3
SCENARIO B- Farmer sells part of the harvest soon after harvest					
NPV	19,312.66	28,626.68	9,998.63	22,059.65	17,088.01
BCR	1.71	2.05	1.37	1.71	1.71
IRR	>500,000	>500,000	>500,000	>500,000	>500,000%
PAYBACK	7	5	10	8	6
BREAKEVEN	58.5%	49%	74%	58.5%	58.5

Annex 6.6: Cowpeas- Metal Silo

	Base Case r=12%	Benefits + 20%	Benefits less 20%	r=10%	R=14%
SCENARIO A- Farmer stores all the harvested crop					
NPV	116,805.92	142,422.01	91,189.84	134,436.60	102,545.42
BCR	11.36	13.63	9.09	12.64	10.30
IRR	>50,000%	>10,000%	>10,000%	>10,000%	>10,000%

	Base Case r=12%	Benefits + 20%	Benefits less 20%	r=10%	R=14%
PAYBACK	1	1	1	1	1
BREAKEVEN	8.8	7.3%	11%	7.9%	9.7%
SCENARIO B- Farmer sells part of the harvest soon after harvest					
NPV	35,295.62	44,609.69	25,981.60	41,532.33	30,270.51
BCR	4.13	4.96	3.30	4.60	3.75
IRR	100%	160%	70%	105%	110%
PAYBACK	2	2	3	2	2
BREAKEVEN	24.3%	20.2%	30.4%	21.8%	26.8%