Cost Benefit Analysis of Post-Harvest Management Innovations

Benin Case Study Report

15 March 2017

This report was prepared by Munhamo Chisvo (CBA Economist) and Ellen Jaka (Research Assistant) of JIMAT for FANRPAN with support from the Swiss Agency for Development and Cooperation.

This publication has not been peer reviewed.

SUGGESTED CITATION: FANRPAN. 2017. *Cost Benefit Analysis of Post-Harvest Management Innovations Benin Case Study.* Pretoria

ACKNOWLEDGEMENTS:

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

This publication is part of the regional project "Postharvest Management in Sub-Saharan Africa", which is funded by the Swiss Agency for Development and Cooperation and implemented in a consortium between HELVETAS Swiss Intercooperation and the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN), with the African Forum for Agricultural Advisory Services (AFAAS) and AGRIDEA as associated partners.

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Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN)
Physical address: 141 Cresswell Road, Weavind Park 0184, Pretoria, South Africa
Postal address: Private Bag X2087, Silverton 0127, Pretoria, South Africa
Tel: +27 (0) 12 804 2966 or +27 (0) 12 804 3186
Fax: +27 (0) 12 804 0600
Email: policy@fanrpan.org
Url: www.fanrpan.org

List of Abbreviations

AfDB	African Development Bank
CAADP	Comprehensive Africa Agriculture Development Programme
CARDER	Centre for Regional Action for Rural Development (Benin)
CBA	Cost Benefit Analysis
CRS	Catholic Relief Services
EU	European Union
FANRPAN	Food, Agriculture and Natural Resource Policy
FAO	Food and Agriculture Organisation
ILO	International Labour Organisation
LSF	Large scale farmers
MAEP	Ministry of Agriculture, Livestock and Fishery (Benin)
MDG	Millennium Development Goal
MSF	Medium scale farmers
PHLM	Post-harvest loss management
PHM	Post-harvest management
PNSA	Programme *National de Securite Alimentaire*
PSRSA	National Agriculture Policy
SADC	Southern Africa Development Committee
SSA	Sub-Saharan Africa
SSF	Small scale farmers
USAID	United States Agency for International Development
WB	World Bank

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Executive Summary

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 Benin. The need to reduce post-harvest losses for major food crops comes against the background of huge food losses being incurred in Sub-Saharan Africa as food producers, consumers, their national governments and other food value chain players fail to prevent them. 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. Currently, total food losses in Sub-Saharan Africa are estimated to be worth $4 billion per year and losses on cereals are estimated to be high at about 14 million tonnes and account for about 25% of the total crop harvested.

The objectives of the were to:

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

B. Methodology and limitations

B1 Desk review

The consultants identified and gathered relevant literature for Benin on post-harvest losses and how these are being addressed 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. United Nation (UN) agencies funding agricultural programmes and Non-Government Organisations(NGOs) implementing food security programmes. The Consultant obtained from these stakeholders documents or reports which estimate crop (maize, common bean, cowpea) production disaggregated by province and agro-ecological region as well as the magnitude of post-harvest losses and types of investments farmers and other value chain actors are making into PHLM systems, and the returns thereof.

B3 Cost-benefit analysis (CBA)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 Benin. 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 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 Benin.

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 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 hectorage 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 Benin 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 (eight (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 the discounting rate was rounded off to 12%, which assumes a more pessimistic scenario characterising agriculture (than r=11.3%), especially rain-fed smallholder agriculture.

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 500 kg. These indicators were:

- Net present value (NPV) (of the net cash flows);
- Internal Rate of Return (IRR);
- Benefit-to-Cost Ratio (BCR);
- Payback Period (PP); and

- Breakeven Point (BP).

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, responses were received mainly from government ministries and departments and NGOs. However, the information that was received from those able was satisfactory as it covered essential statistics on staple food production, post-harvest losses and PHLM technologies that have been adopted by farmers.

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).

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

C. Key Findings

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

Honfoga B. G, *et al*, (2014) reviewed the PHLM policies, programmes and strategies in Benin, particularly the seven (7) year Program National de Sécurité Alimentaire (PNSA) 2008-15, Strategic Plan for Boosting the Agricultural Sector (2008-2015) and the National Agriculture Policy (PSRSA) 2010-5. They found the PNSA as a comprehensive food security programme aimed at increasing food availability and accessibility through food production intensification, agricultural diversification and value chain development (storage, conservation, processing, quality development, commercialisation and trade facilitation). The value chain development includes PHLM. The Strategic Plan for Boosting the Agricultural Sector was launched in order to implement existing agricultural policies including actions to achieve MDG 1 with a focus on improving poor people's nutritional status.

Honfoga revealed that the challenges with PHLM are to do with inadequate knowledge among stakeholders, overall lack of efficient systems to reduce PHL, many gaps and constraints that impede adequate design and implementation of PHLM policies, and non-adoption of PHLM technology and innovations.

The PSRSA has PHLM relevant components clearly mentioned. However, there is need for them to be more focused in order to be effective. Novel equipment to store grains is non-existent and most public food processing industries are under-equipped. Local and international institutions recognise that PHLM systems in Benin are threatened by lack of innovation from harvesting, storage, processing and consumption systems. Various studies has been conducted on PHLM but focused mainly on storage and neglected other steps of the value chain.

The interviewed stakeholders indicated that PHLM issues are given medium to low priority by the government. This is reflected by the level of effort and public investment into PHLM strategies.

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

Results of the study indicated that there is generally moderate to poor knowledge of improved PHLM technologies among the various stakeholders. From the responses, the government has moderate to very good knowledge. A small percentage of farmers have very good knowledge while the majority have moderate to poor. More traders than farmers have poor knowledge. Food processors, UN agencies and NGOs generally have moderate knowledge of PHLM technologies.

C3. Crop production and post-harvest losses for maize, beans and cowpeas

In 2015 the production totals were 1,286,059 tonnes of maize, 99,106 tonnes of beans and 139,909 tonnes of cowpeas. Generally post-harvest losses for maize are estimated at between 15 and 30%. The major causes of such losses are poor drying, poor cleaning and sorting, lack of depots at village and district level, lack of silos, non-availability of conservation phytosanitary products, molds and insect pests. Post-harvest losses for beans and cowpeas are higher than maize. The estimated losses for the year 2015 were at 30% for all provinces while the ones for beans and cowpeas range between 29% and 30.6%, and an average loss of 29.8% was factored into the cost-benefit analysis.

C4. PHLM innovation adoption rates

Traditional methods of grain storage for maize and beans are still being used by small scale and medium scale farmers in nine (9) provinces and five (5) agro-ecological zones. Medium scale and traders resort to improved methods while large scale farmers and some traders use modern technologies in the same areas.

About 70% of medium scale, large scale farmers and agro industries have adopted use of metal silos in nine (9) provinces covering seven (7) agro-ecological zones. Small scale farmers, medium scale farmers, traders and agro-industries have adopted hermetic bags at a rate of 40-69%. The reason for this average adoption rate is limited availability of the bags. The table below provides the overview.

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 negative (CFAF 4,215.55), the benefit-to-cost ratio is less than 1 (0.66), and the internal rate of return is negative which implies that the investment is not worthwhile (see Annex 6.1).

Programming implications of the results

For a farmer able to produce and store 500 kg of maize but has a practice of selling his crop at harvest time, there is no added benefit of introducing hermetic bags to encourage him or her to store and sell at a higher price later during the lean season. The cost of the improved storage technology is higher than the value of the additional benefits of the technology. Although the magnitude of crop loss is quite high (30%) and therefore the quantity preserved by the technology is also very high, the price differential between the lean season and the harvest period is insufficient to compensate the farmer for the investment in the new technology. 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.

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** showed a positive NPV of CFAF 104,660, a BCR of 1.95, an IRR greater than 1,000%, and a PP of seven (7) years for a farmer or trader storing 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 95%. Such farmers can breakeven even with about half (51.5%) of the benefit (that is, even those who lose only 15.45% 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 gain by investing in hermetic bags, whether or not they then consume or sell the preserved maize later in the consumption season.

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 (CFAF 17,149.01), the benefit-to-cost ratio is greater than 1 (1.31), and the internal rate of return is positive which implies that the investment is viable (see Annex 6.2).

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 3% in cost of production per kg of storage space as units become smaller.

Programming implications of the results

For a farmer able to produce and store 500 kg of maize but has a practice of selling his crop at harvest time, there is an added benefit of introducing metal silos to encourage him or her to store and sell at a higher price later during the lean season, but the magnitude of the added benefit is low (only 31% more than 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 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. Although the magnitude of crop loss is quite high (30%) and therefore the quantity preserved by the technology is also very high, the price differential between the lean season and the harvest period is insufficient to compensate the farmer or trader for the investment in the new technology.

As this model is built on units of 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 even be lower than for the 500 kg metal silo.

Given the PP of nine (9) years (best case scenario), 11 years (base case scenario), and 12 years (worst case scenario), adoption of metal silos 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, unless they intend to use the silo for a minimum of nine (9) years, and ideally for a minimum of 12 years. The same applies to traders who buy for immediate sale at harvest time and do not have a practice of storing.

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 CFAF 159,252, a BCR of 3.87, an IRR greater of 89%, and a shorter PP of three (3) years for a farmer or trader storing 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 287%. Such farmers can breakeven even with about half 26% of the benefit (that is, even those who lose only 7.8% not 30%) when they do not use 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 used the technology continuously for 20 years.

Assuming that post-harvest management programmes are able to support adoption of hermetic bags and metal silos such that all maize produced in Benin is properly stored and is preserved, the study estimates that between 0.04 and 0.05% of agricultural Gross Domestic Product (GDP) 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 (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 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 than the projected lifespan of the silos because the PP is very short (1-2 years depending on assumptions of risk).

C5.2 CBA Analysis Results for Beans

Hermetic bags

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 (CFAF 107,150.69), the benefit-to-cost ratio is 2.39, and the internal rate of return is greater than 10,000 which implies that the investment is viable (see Annex 6.3).

For farmers who have a practice of storing and losing up to 29.8% 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 493,436 (per farmer storing 500 kg of beans), a BCR of 7.41, an IRR greater than 1 million, PP of two (2) years and breakeven benefit of only 13.5% 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 4% per year, would still benefit by switching to the hermetic bags.

Programming implications of the results

A farmer able to produce and store 500 kg of 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.

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 CFAF 128,515, a BCR of 3.31, an IRR of 66%, and a shorter PP of three (3) years for a farmer or trader storing 500 kg of maize (Annex 6.4). The results show that the investment will pay-off. 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 231%. Such farmers can breakeven even with 30.2% of the projected benefits (that is, even those who lose only 8.9% not 29.8%) of their produce when they do not use 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 used the technology continuously for 20 years.

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 CFAF 514,800.69, BCR of 10.62, IRR greater than 1,000%, and a PP of one (1) year. Even when benefits are reduced to 80% of the current level, the investment remains viable with a PP of two (2) years, and BCR of 8.1. Even with sensitivity analysis, the breakeven point is reached with benefits below 13% of current benefits which shows that the metal silos are highly viable for storing beans.

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 or trader better off, with an NPV of 46,866, BCR of 1.61 and IRR of 465%. The PP is eight (8) years and breakeven loss is 62.5 % of current loss of 29.8% (that is, if farmers preserve only 18.6% of their produce in storage rather than 29.8% they will recover the costs incurred in investing in hermetic bags over a 20 year 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 stand to earn high incremental benefits from the technology (when compared to the period without technology), with a BCR of 5.6, IRR greater than 200,000% and a PP of two (2) years. Breakeven point is reached with just 18% of the estimated current benefits which means that even farmers with very low losses, 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 two (2) shows that the incremental benefits will always exceed the incremental costs by a factor of at least 300% (BCR ranges from 4.48 to 6.73).

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 0.011 and 0.012% 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 between 0.06 and 0.07% of such GDP is preserved and can contribute to growth in the other sectors that are closely integrated with agriculture.

Programming implications of the results

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 61%. However the payback period is longer given the need to purchase new bags once every two 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.

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 a farmer storing 500 kg of cowpea would be CFAF 68,230.66, IRR would be 36.7% and the PP would be five (5) years. Breakeven point could be reached by a lower benefit (455 of the projected PHL of 29.8 %). Sensitivity analysis shows that the technology is so viable that even with 38% of benefit, farmers and traders could breakeven. This implies that even farmers with lower levels of losses 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 make a big difference to their welfare if they were to switch to metal silos. Returns to investment would outweigh the costs by 676% (BCR of 7.76). They could increase with a 20% increase in benefit to BCR of 9.31, and the cost of the investment over 20 years can be recouped in the first year or two of adoption of the technology. Breakeven point can be reached even by as little as 11% of the projected incremental benefits of adoption.

D. Recommendations

D1. Programming Recommendations

Recommendation 1: The Government of Benin or development agencies willing to invest in Benin to support smallholder farmers to adopt the hermetic bag technology must not dissuade maize farmers who are already prudent to sell their surplus grain immediately after harvest. The argument that they stand to benefit by storing their maize in hermetic bags for sale later in the season is not justified by the economics of storing maize in hermetic bags at market prices that prevailed in Benin in 2015.

Recommendation 2: The Government of Benin 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 15% of their harvest to pest and other forms of damage in storage.

Recommendation 3: Government of Benin 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 price to the farmer does not exceed CFAF 3,900 as it will be non-viable to farmers or traders storing maize.

Recommendation 4: To increase the rate of adoption of hermetic bags by SSFs, MSFs, Traders, and Agro-industries, the Government of Benin 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 CFAF 1,950 (US$3.21) will bring CFAF 1.94 per every CFAF invested (in tax waivers).

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 CFAF 1,755 (US$2.89) 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 CFAF 1,755 farmers with a loss of 15% per annum without the technology will be able to breakeven if they invest in the bags.

Recommendation 6: Given the challenge of inadequate supply and availability of hermetic storage technology on the market in Benin, yet it has been demonstrated to be viable to farmers who store for later sale or use, development programmes should aim to ensure sustainable availability of improved storage technology through increased participation of key stakeholders such as the private sector.

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 Benin. 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 long PP of seven (7) 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 Benin. 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 radio, television, 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 PP for an investment in hermetic bag technology for farmers willing to store maize and consume or sell in the lean season is 5-11 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 5-11 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 5-11 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 13 – 15 years).

Recommendation 11: Government of Benin or development agencies willing to promote adoption of the metal silo technology should only target farmers and traders who do not have a culture of storing maize for later use if these are willing to use the silo for at least 9-11 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.

Recommendations 12: Government of Benin 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 four (4) 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 four (4) 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 2-4 years for an investment over 20 years, development programmes to support adoption of the metal silo technology for maize in Benin should be designed to provide support to resource-poor and subsistence farmers for a minimum period of four (4) 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 four (4) 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 four (4) years, farmers and traders will have earned sufficient incremental benefits to cover the projected future costs (for the remaining 16-18 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 3.87 for silos versus 1.95 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 Benin 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.

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.

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 7.41 shows that the investment can recover the costs as much as seven (7) 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 as much as 83%, Government of Benin and development agencies should consider promoting hermetic bags more for the storage of beans as opposed to maize.

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 seasons, the metal silo should be promoted ahead of the hermetic bag technology.

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 four (4) years, as this is sufficient for them to have recouped investment costs for 20 years.

Recommendations 20: Given the PP of two (2) years for farmers and traders who store and sell later in the lean season, such farmers can be supported over a two (2) year 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 (6-7 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).

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, and 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.

D2. Recommendations on possible financing arrangements for Benin government to support dissemination of improved PHLM technologies.

Recommendation 22: FAO revealed that of the USD940 billion that needs to be invested to eradicate hunger in Sub-Saharan Africa, over a 44 year period to 2050, up to 47% 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 However it should be noted that the amount is huge therefore imperative that concerted efforts towards investment in post-harvest technologies be made by all potential sources of funding, including government, donors, NGOs, the private sector and the farmers themselves. Public-private-and-community partnerships should therefore be explored as recommended by FAO/World Bank. Private companies such as GrainPro who supply the modern technologies may partner with the government agriculture extension workers and NGOs to generate demand among smallholder farmers and training for artisans to ensure production of high quality products.

Recommendation 23: The Government of Benin is encouraged strongly to increase investment in post-harvest technologies through its budget on agriculture. It can source for supplementary funding from the World Bank and African Development Bank (AfDB)'s Africa Food Crisis Response. The programme contributes directly to the implementation of Pillar 2 (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 for generating demand for new technologies such as metal silos and hermetic bags for increased adoption by farmers.

Recommendation 24: 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 1-3 years. The farmers are encouraged to contribute towards the purchase of metal silos as a way of minimising dependency. However government and NGOs may pay the full cost for the poorest members of the community to provide a safety net for them.

Recommendation 25: The government may consider reducing customs duty charged on imported post-harvest storage materials such as hermetic bags and related raw materials. It may also consider subsidizing the materials up to the level where the returns to investment in hermetic bags outweighs cost of importing food and supplementing local production with food hand-outs.

1. Introduction

1.1 Post-harvest loss magnitude and causes

Food, income and nutrition insecurity in Sub-Saharan Africa is exacerbated by the inability of food producers, consumers, their national governments and other food value chain players 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 at about 14 million tonnes and account for about 25% of the total crop harvested[3]. Those for perishables such as fruit and vegetable can reach 50%. In addition there is loss in nutritional value, market opportunities, and possible adverse effects on health of population consuming poor quality products[4].

Although some marked increase in production volumes were recorded in Africa in recent years because of adoption of improved varieties and growing techniques, the pay-off after harvest is still insignificant[5]. This is because of costly losses, increased labour requirements, inappropriate facilities and poor product quality resulting in poor harvesting and handling systems.

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 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 Benin government to support dissemination of improved PHLM technologies.

[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

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

[5] Halos-Kim L., Toshiro M., 2005. *Improving Post-Harvest Systems: Promoting Agro-Industrial Development in Africa.* Sasakawa Africa Association funded by Nippon Foundation.

1.3 Methodology

Desk review

The consultants identified and gathered relevant literature for Benin 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.

Key Informant Interviews

Names of key stakeholders were obtained from the FANRPAN node in Benin. The stakeholders were drawn from government (ministries of agriculture, industry and commerce, or small and medium scale enterprises), development partners and UN agencies funding agricultural programmes and NGOs implementing food security programmes. The list of stakeholders who responded is presented in Annex 3. The Consultant obtained from these stakeholders 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 and types of investments farmers and other value chain actors are making into PHLM systems, and the returns thereof.

A key informant interview checklist was prepared. The checklist was further developed into a structured questionnaire which was translated to French and e-mailed to stakeholders for self-administration and completion, this being a preferred method than the option of telephone and Skype interviews which were affected by poor connectivity. A total of nine stakeholders returned completed questionnaires and these provided data that covered most of the requirements of the study.

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 Benin. 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 Benin.

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 hectorage per farmer planted to maize. A farmer who plants 0.5 ha to maize and harvests the average yield of 0.9 metric tonnes has enough maize at harvest to require a 500kg metal silo or nine(9) bags of hermetic bags with a storage capacity of 50 kg each. 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 Benin 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 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). 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 <u>risk of catastrophe wiping out the gains from a programme (L)</u> and the <u>rate of pure time preference</u> (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 1%).

For this study parameter **g was** derived from GDP growth rate for Benin and was assumed to be 5% per annum 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 eight(8) deaths per 1,000 people, that is 0.8%) to represent catastrophe risk, so ρ was assumed to be equal to 1.3%.

For parameter **μ,** Dasgupta (2006)[6] estimated that the value lies between two (2) and four (4) based on empirical evidence. For the PHLM study a value of two (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 Benin with a low GDP per capita, marginal utility of consumption decreases significantly with increase in disposable income.

Hence, if $r = \rho + \mu g$ and $\rho = 1.3\%$, $\mu = 2$, $g = 5\%$ then, $r = 1.3\% + (2*5\%) = 11.3\%$.

For purposes of this analysis *r* was rounded off to 12%, which assumes a more pessimistic scenario characterising agriculture (than r=11.3%), especially rain-fed smallholder agriculture. However, sensitive analysis was also performed assuming a discount rate of 10% (optimistic) and 14% (even more pessimistic) to check on strength of viability of potential investments into post-harvest technologies to support the staple-food value chain in Benin.

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 (IRR);
- Benefit-to-cost ratio (BCR);
- Payback period (PP); and
- Breakeven point (BP).

<u>Net Present Value</u>

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

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

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 or 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 1 meant the benefits outweighed the costs and the investment would be worthwhile, while a BCR of 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 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

Whereas questionnaires were sent to a wide range of stakeholders as had been planned, responses were received mainly from government ministries and departments and NGOs. No responses were received from UN agencies and research institutes. However, the information that was received from those able was satisfactory as it covered essential statistics on staple food production, post-harvest losses and PHLM technologies that have been adopted by farmers.

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).

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

2. Findings

2.1 National Policies on PHM

There are about 450,000 agricultural producers in Benin, dominated by small-scale farming[7]. The farming system is characterised by extensive production, low productivity and undeveloped markets. The average area cultivated per household is 0.5 hectares in the southern region and two (2) hectares in the north. PHL on maize is estimated at between 15 and 30% owing to precarious and archaic storage. Food deficits are high in most areas of the country averaging 28.3% of food production (maize, yams, cassava, beans and groundnuts).

Honfoga B. G, *et al*, (2014) reviewed the PHLM policies, programmes and strategies in Benin, particularly the 7 year Program National de Sécurité Alimentaire (PNSA) 2008-15, Strategic Plan for Boosting the Agricultural Sector (2008-2015) and the National Agriculture Policy (PSRSA) 2010-5. They found the PNSA as a comprehensive food security programme aimed at increasing food availability and accessibility through food production intensification, agricultural diversification and value chain development (storage, conservation, processing, quality development, commercialisation and trade facilitation). The value chain development includes PHLM. The Strategic Plan for Boosting the Agricultural Sector was launched in order to implement existing agricultural policies including actions to achieve MDG 1 with a focus on improving poor people's nutritional status.

Malnutrition is high for children under the age of five, with delayed growth at 31% from 1996 to 2001 and 45% from 2007 to 2011. Severe malnutrition rose from 8% to 16% during the same period. Honfoga B. G, et *al* revealed that the challenges with PHLM are to do with inadequate knowledge among stakeholders, overall lack of efficient systems to reduce PHL, many gaps and constraints that impede adequate design and implementation of PHLM policies, and non-adoption of PHLM technology and innovations.

The PSRSA has PHLM relevant components clearly mentioned. However, there is need for them to be more focused in order to be effective. Novel equipment to store grains is non-existent and most public food processing industries are under-equipped. There is need to focus on availing grain storage facilities and adequate modern equipment for public food processing industries. Innovation is required from harvesting, storage, processing and consumption systems.

Local and international institutions recognise that PHLM systems in Benin are threatened by lack of innovation from harvesting, storage, processing and consumption systems. A lot of research on PHLM has been done but focused mainly on storage and neglected other steps of the value chain.

The interviewed stakeholders indicated that PHLM issues are given medium to low priority by the government. This is reflected by the level of effort and public investment into PHLM strategies.

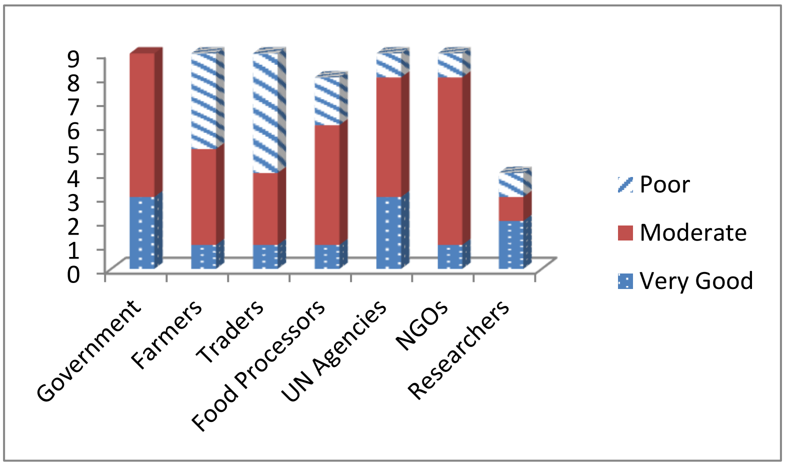
2.2 Knowledge of improved PHM technologies by different actors

Stakeholders indicated that there is generally moderate to poor knowledge of improved PHLM technologies among the various stakeholders. From the responses, the government has moderate to very good knowledge as it is the one that formulates policies and also commissions some researches. A small percentage of farmers have very good knowledge while the majority have moderate to poor. More traders than farmers have poor

[7] Honfoga B. G., Akissoe N. H., Guedenon A., & Vihotogbe C. N. S., 2014. *Post, harvest management policies, programmes and strategies in Benin and Sub-Saharan Africa Benin Report.* FANRPAN.

knowledge. Food processors, UN agencies and NGOs generally have moderate knowledge of PHLM technologies. The responses are depicted in the figure below.

Figure 1: Knowledge of improved PHM Technologies



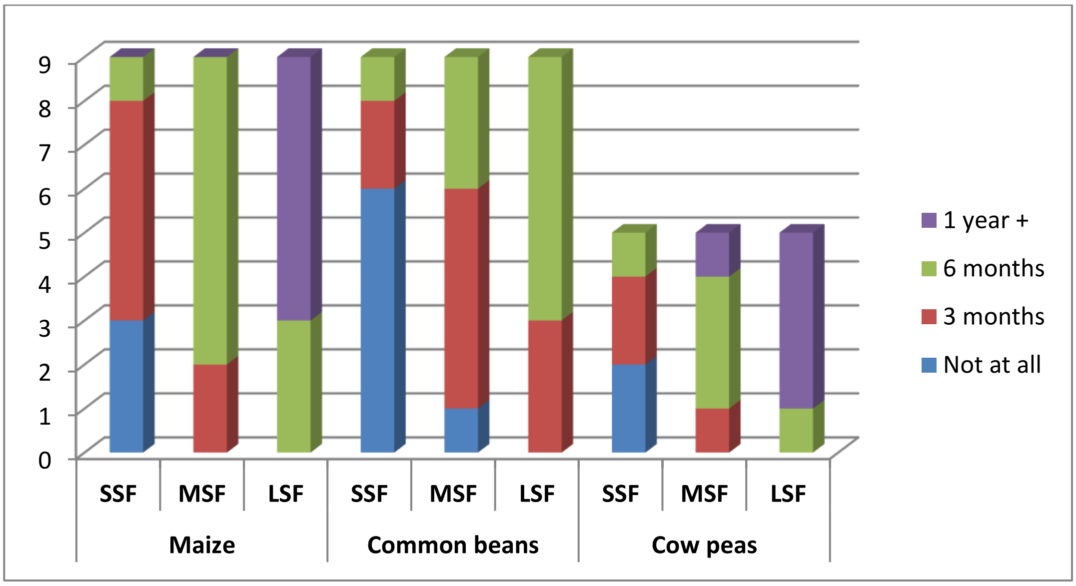
2.3 Production levels for maize and pulses by sector and region (including prices)

Benin is divided into three distinct agro-climatic zones. The northern part falls in the semi-arid zone where the major farming activity is agro-pastoral. The central part falls in the sub-humid zone and farming is focused on root and tuber crops while the southern part is humid and suitable for cereal and root crops. In 2015 the production totals were 1,286,059 tonnes of maize, 99,106 tonnes of beans and 139,909 tonnes of cow peas. Annex 4 shows production statistics for each of the 10 provinces on Annex 1 and for each of the 8 agro-ecological zones on Annex 2.

Grain storage practices by different farmers

Responses from the key informants suggest that a significant percentage of SSF do not store maize at all, while a much bigger percentage also does not store common beans at all. Since the majority of the 450,000 agricultural producers in Benin are SSF it means that they sell their produce soon after harvest when prices will be at the lowest. They will then need to buy it *back* from the market when prices would have gone up, a situation that worsens food insecurity. Both SSF and MSF generally store food for a maximum period of six months. This may indicate that they have not yet adopted technologies that help store food for longer periods.

Figure 2: Grain storage practices by different types of farmers (%)



2.4 Post harvest losses by crop, sector and region

Post-harvest losses for maize are estimated at between 15 and 30%. The major causes of such losses are as follows:

- Non-existence of drying areas including poor field drying;
- Winnowing not done;
- Poor sorting of grain;
- Non-existence of depot at village and even at district level;
- Non-existence of silos in some districts;
- Unavailability of conservation phytosanitary products; and
- Mold and especially pest insects (maize weevil, *tribolium castaneum* and larva *sitotroga cerealella*).

Post-harvest losses for beans and cow peas are higher than maize and the major causes are:

- Late harvest causing the first pest infestations;
- Storage structure not prepared prior to harvest time;
- Pods are not removed on time because they create an extra work;
- Poor drying method (high humidity rate);
- Poor storage system;
- Unavailability of appropriate bags (triple layer sachets) for small scale farmers' conservation; and
- The weevil *callosobruchus maculatus*.

The table below compares the production figures for each of the three crops and the estimated losses for each province for 2015. The losses for maize are pegged at 30% for all provinces while the ones for beans and cow peas range between 29% and 30.6%

Table 1: Post-harvest losses by Province 2015

Province	Production and Post-Harvest Losses (tonnes) 2015					
	Maize		Beans		Cow peas	
	Production	Loss	Production	Loss	Production	Loss
Alibori	236,436	70,930.8	11,022	3,306.6	12,327	3,699
Atacora	196,674	59,002.2	15,645	4,694.1	21,009	6,302. 7
Borgou	202,712	60,813.6	10,145	3,043.5	56,802	17,040.6
Donga	45,508	13,652.4	4,926	1, 477.8	8,961	2,688.30
Collines	94,566	28,369.8	17,470	5,241	27,854	8,356.2
Zou	63,032	18,909.6	15,579	4,673.7	11,497	3,449.1
Plateau	173,690	52,107	4, 567	1,370.1	919	275.7
Couffo	81,776	24,532.8	11,930	3,579	507	150.9
Mono	50,351	15,105.3	873	261.9	16	4.9
Atlantic	88,263	26,478.9	3,579	1,856	503	150.9
Littoral	-	-	-	-	-	-
Oueme	53,051	15,915.3	5,091	1,527.3	-	-
Total	1,286,059	**385,817.7**	99,106	**32,754**	139,909	**42,123.2**

PHM Technologies used by different farmers in the regions

Traditional methods of grain storage for maize and bean are still being used by small scale and medium scale farmers in nine provinces and five agro-ecological zones. Medium scale and traders resort to improved methods while large scale farmers and some traders use modern technologies in the same areas. The table below provides an overview.

Table 2: PHM technology by crop farmer and region

PHM Technology	Crop	Type of structure	Type of farmer	Agro-ecological region	Province
Traditional	Maize, beans	Jar, gourd, Clay granaries	Small Scale Farmers Medium Scale Farmers	Z1, Z2, Z3, Z4 Z5	Alibori Borgou Donga Atacora Collines Zou Couffo Mono Plateau
Improved	Maize, Beans	Plastic container drums tanks	MSF, Traders	Z1, Z2, Z3, Z4 et Z5	Alibori Borgou Donga Atacora Collines Zou Couffo Mono Plateau
Modern	Maize, beans soya beans	Sacs Pics (triple layer sachets) sacs polyéthylènes	Large Scale farmers Traders	Z1, Z2, Z3, Z4 et Z5	Alibori Borgou Donga Atacora Collines Zou Couffo Mono Plateau

Adoption of modern technologies by different actors in the value chain

About 70% of medium scale, large scale farmers and agro industries have adopted use of metal silos in nine (9) provinces covering seven (7) agro-ecological zones. Small scale farmers, medium scale farmers, traders and agro-industries have adopted hermetic bags at a rate of 40-69%. The reason for this average adoption rate is limited availability of the bags. The table below provides the overview.

Table 3: Adoption of PHM Technologies

PHM Technology	Type of farmer	Agro-ecological region	Province Department	Adoption rate *High=70%+* *Average=40-69%* *Low =>40%*
Metal granaries or Tanks	Medium Scale Farmers Large Scale Farmers agro-industries	Z1, Z2, Z3, Z4, Z5, Z6, Z7	Alibori, Borgou, Donga, Atacora, Collines, Zou, Couffo, Mono, Plateau.	High=70%+ (High cost)
Plastic sacs (Hermetic bags)	SSFs MSFs Traders Agro-industries	Z1, Z2, Z3, Z4, Z5, Z6, Z7	Alibori, Borgou, Donga, Atacora, Collines, Zou, Couffo, Mono, Plateau, Ouémé et Littoral	Average=40-69% (Not available)
Others (Clay or hay Granaries)	Small Scale Farmers	Z1, Z2, Z3, Z4, Z5, Z6, Z7	Alibori, Borgou, Donga, Atacora, Collines, Zou, Couffo, Mono, Plateau Atlantic	Low =>40% (Limited means)

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

Metal silos

Figure 3: Metal Silo

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 located in a protected area from rain and sun. It may be placed 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 three(3) days in the sun before it is 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, and then use the fumigant. The silo must be sealed with a rubber band.

Apply Bextoxin 57% (Phostoxin®) 1 tablet or deal with super Actalm. Dose: Bextoxin tablet to 250 kg, super Actalm 250gr for a silo of 500 kg. Check periodically the health of the grain. The grain will be protected for least 12 months.

Metal silos are found in different capacities of 250 kg, 500 kg, 1000 kg, 1200 kg, and 1500 kg. Their useful life or duration is approximately 20 years. The cost per year is 3,200 FCFA.

Cost:

1. Investment:	
Purchase price, silo 500 kg:	60,000.00
Wooden Platform:	1,000.00
Total	**FCFA 61, 000.00**
Investment per year	FCFA 3,050.00
2. Treatment - Bextoxin 2 tablet:	FCFA 150.00
Treatment cost per year:	FCFA150.00

Annexes 5.1 and 5.2 provide a cost calculation schedule for the different sizes of metal silos in Benin.

Benefits of metal silos

1. 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.
2. Use of the silo results in a loss reduction of 15% and a stored market gain of 50%
3. The silo has a long lifespan of up to 20 years

Figure 4: PICS bag

Dimensions: width 0.5 m x 0.9mx height (50 kg each)
(Quantity of grain: 500 kg = 10 units)

PICS bag is made with two materials. Inside is plastic and the exterior is made from polypropylene. They can be found on the market. Their capacity is about 50 kg. The use is combined with polypropylene bags for durability. The plastic must be sealed and cannot be damaged. The grain is stored in the bag already shelled, dried and selected. The grain should be exposed for at least three days in the sun to dry before putting it in the clean grain bags. The bags are to be properly closed and placed on a board raised from the ground or pallet. Periodic checks to ascertain health of grain are needed. The grain will be protected for at least eight months.

Duration: 2 year plastic pocket / 2 years approximately bag Polypropylene
Cost per year: 9,750.00
Cost:
1. Investment:

Material: 10 PICS bags (FCFA 1,500.00 / bag)	15,000.00 (10 bags)
Wooden Platform	2,000.00
Labour: Platform structures one day	2,000.00
Total	**FCFA 19,500.00 or US$32.34** (1US$=FCFA603)
Investment cost per year	FCFA 9,750.00 or US$16.17

Benefits of PICS Bags

1. Grain can be stored for up to eight (8) months thus relieving farmers of pressure to sell produce soon after harvest at depressed producer prices. They can then sell their produce during the lean season thereby maximizing their income. For example in Plateau Province whereas they can sell maize at FCFA 115,000 per tonne soon after harvest they can store it and sell it later at FCFA190,000 during lean season. Even if they do not sell later they will be food secure for a longer period.
2. When storing grain in PIC bags there is no need to treat it for weevils and other insects that damage crops.
3. The high temperature conditions and control of external air prevents development of aflatoxins which cause cancer. Use of the bags promotes health and nutrition.

FAO/World Bank (2010) highlighted the following disadvantages of hermetic technology:

1. The technology does not work well in cold climates as insects tend to hibernate

2. The bag is not biodegradable as would be desired by some environmentalists but that would defeat the whole purpose of storage.

3. It is not an in-and-out-system, so can only be applicable as a plan for longer-term storage

4. As aflatoxin production occurs due to pre-harvest drought stress and postharvest activities before storage, hermetic storage cannot by itself prevent contamination with aflatoxins.

5. Hermetic storage is more resistant to damage from rodents but still susceptible to other issues arising from its exposure, including mishandling by unqualified personnel. Of primary concern was the issue of security of stocks in cocoons. In this regard, cocoons need to be fenced in and guarded.

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

Opportunities

Adopting improved PHM technologies provides an opportunity to store grain for longer periods thus enhancing household food security and nutrition. Families and particularly women 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 food quality is maintained and the health of people is enhanced as side effects from chemicals are avoided. Using improved technologies also helps to maintain food balance at household level and maximise income by storing grain and selling it when prices become favourable.

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. It reduces food availability in the home during the lean season and may result in malnutrition among children and pregnant and lactating women. Women leaders indicated that post-harvest losses cause food imbalance at household level which result in several nutritional diseases. The burden of looking for food, which is mainly borne by women is increased. The negative effects of malnutrition especially stunting may be long term, affecting the individuals, their families and the nation as a whole. Stunting can affect the cognitive ability of children, which affects their learning performance and ultimately their livelihoods and contribution to gross national product.

Survey results from women show that some families do not even use the traditional PHM techniques resulting in large quantities of food being wasted. Others wrongly apply chemical for food preservation resulting in alteration of the food quality and in some instances making it poisonous. Failure to reduce post-harvest losses reduces household incomes and increases poverty. Families buy food at high prices during the lean season reducing availability of money for other important uses such as school fees, medication, shelter and clothing. Poverty increases. Women indicated that loss of income as a result of PHL ranges from 15% up to 100% depending on the crop and region.

The results of the survey show that agricultural production is dominated by women, who contribute significantly to the national food security. However the women complained that they are not involved in policy dialogue and policy formulation in the agricultural sector. If this continues their issues will never be addressed and their enthusiasm towards production will be dampened.

Risks

Farmers in Benin 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. If farmers purchase the silos on credit they risk failing to pay because of uncertainty of production in the light of frequent droughts.

Some artisans who are not adequately skilled manufacture low quality metal silos which are not able to bring the expected benefits.

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, 2 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 in particular). 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 Benin was reported to be CFAF 126,833.33 per metric tonne while the lean season price stood at CFAF 191,750 per metric tonne (Table 4), a difference of 51%.

The base case scenarios for maize assumed that farmers have sufficient production to have a need to store 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 silo information collected from Benin 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.

Table 4: CBA Modelling Assumptions for Maize and Hermetic Bags (Base Case)

Indicator	Scenario 1: Farmer sells		Scenario 2: Farmer stores	
	FCFA	USD	FCFA	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	500		500	
Product stored, kg	500		500	
Loss reduced by PHLM tech, in kg	150		150	
Post-harvest price, CFAF/Metric Tonne	126,833.33	208.95	126,833.33	208.95
Value preserved at PH price, CFA Francs	19,025.00	31.34	19,025.00	31.34
Lean season price, CFAF/MT	191,750.00	315.90	191,750.00	315.90
Value preserved at LS price, CFAF	28,762.50	47.38	28,762.50	47.38
Incremental cost (Hermetic Bags, 10x50kg)	19,500.00	32.13	19,500.00	32.13
Lifespan of Technology: Hermetic Bag, years	2 years		2 years	
Discount rate, base case	12%		12%	
Incremental benefit	9,737.50	16.04	28,762.50	47.38

Notes: LS=Lean Season; MT=Metric tonne; PHLM=Post-harvest loss Management; CFAF=Communauté Financière Africaine Franc.

Source: Own source.

The loss of maize without adoption of technology was taken as the highest level of 30% in Benin, 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% of 30%). On the other hand 20% more benefit assumed a higher loss of 36% 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, 150 kg from every 500 kg of maize stored could have been lost without technology. However with the adoption of technology the 150 kg 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 CFAF 19,025 and CFAF 28,762.50 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 CFAF 19,025 in value immediately after harvest (150 kg of potential loss multiplied by the post-harvest price of CFAF 126,833.33 per tonne or CFAF 126.83 per kg). However those that do not sell lose the opportunity to earn CFAF 19,025, and because they do not use improved technologies cannot take advantage of the post-harvest price of CFAF 191,750, which could have enabled them to earn CFAF 28,762.50 by selling the 150 kg in the lean season. Hence the total loss to those who do not sell at post-harvest is CFAF 28,762.50 while to those who sell immediately after harvest they only lose the opportunity to earn CFAF 28,762.50 in the lean season but will salvage CFAF 19,025 by selling the produce (150 kg) at harvest. Hence those who sell at harvest therefore only lose the difference between these two values (CFAF 19,025 and CFAF 28,762.50), which is equivalent to CFAF 9,737.50.

From the foregoing computations, by adopting PHLM technology, farmers who have a practice of selling immediately after harvest have an incremental benefit of CFAF 9,737.50, which is the additional value they realise. The technology enables them to preserve 150 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 150 kg in storage, the incremental benefit is derived from the value they get after selling the 150 kg of maize during the lean season (CFAF 28,762.50). The counterfactual is therefore a loss of CFAF 28,762.50 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 CFAF 1,950 or (USD3.21) per 50 kg bag. The cost of a 10 bag module (that can store 500 kg of maize) was therefore found to be equivalent to the CFAF 19,500, altogether. As no chemical is needed in hermetic bags, the incremental cost of hermetic bags was found to be CFAF 19,500 which would be incurred once every two years which is the lifespan of a hermetic bag.

Table 5: CBA Modelling Assumptions for Maize and Metal Silos (Base Case)

	Scenario 1: Farmer sells		Scenario 2: Farmer stores	
	FCFA	USD	FCFA	USD
Project lifespan	20 years		20 years	
Project duration	20 years		20 years	
Benefits start accruing	Year 1		Year 1	
Loss without technology	30%		30%	
Production in kg	500		500	
Product stored	500		500	
Loss prevented in kg	150		150	
Post-harvest price FCFA/MT	126,833.33	208.95	126,833.33	208.95
Cost of treatment/year	150.00	0.25	150.00	0.25
Value preserved at PH price FCFA	19,025.00	31.34	19,025.00	31.34
Lean season price FCFA/MT	191,750.00	315.90	191,750.00	315.90
Value preserved at LS price FCFA	28,762.50	47.38	28,762.50	47.38
Price of metal silo	61,000.00	100.49	61,000.00	100.49
Lifespan of metal silo	20 years		20 years	
Discount rate	12%		12%	
Incremental benefit	9,737.50	16.04	28,762.50	47.38

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 CFAF 9,737.50 and CFAF 28,762.50, 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 (CFAF 61,000.00) in year 1 and CFAF 150 per year for pesticides for the 20 year 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 negative (CFAF 4,215.55), the benefit-to-cost ratio is less than 1 (0.66), and the internal rate of return is negative which implies that the investment is not worthwhile (see Annex 6.1).

Furthermore, results of sensitivity analysis showed that the breakeven point for the investment would be reached only if benefits were to increase by 89% from the current level. This means breakeven point would be reached if the product lost in storage (by non-adopters of hermetic bags) was of the order of 60.48% of what was harvested and stored. Available literature shows that post-harvest losses in maize are not that high in Benin. 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 43.5%. When using a discount rate of 14% (a more pessimistic scenario) the breakeven point would be reached at 58.5% more benefits (47.55% of stored product preserved by using the technology).

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 500 kg is worked on assuming the use of 10 product units of 50 kg each and the price of the hermetic bag is fixed from one to 10 bags. If farmers enjoy a discount when they purchase more than one bag, and buying below 11 bags, then viability may improve and lower the breakeven point somewhat.

Programming implications of the results

For a farmer able to produce and store 500 kg of maize but has a practice of selling his crop at harvest time, there is no added benefit of introducing hermetic bags to encourage him or her to store and sell at a higher price later during the lean season. The cost of the improved storage technology is higher 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 will be worse off in purchasing the hermetic bags and storing him or her maize and wait to sell during the lean season. Although the magnitude of crop loss is quite high (30%) and therefore the quantity preserved by the technology is also very high, the price differential between the lean season and the harvest period is insufficient to compensate the farmer for the investment in the new 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 or 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 Benin or development agencies willing to invest in Benin to support smallholder farmers to adopt the hermetic bag technology must not dissuade maize farmers who are already prudent to sell their surplus grain immediately after harvest. The argument that they stand to benefit by storing their maize in hermetic bags for sale later in the season is not justified by the economics of storing maize in hermetic bags at market prices that prevailed in Benin in 2015.

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** showed a positive NPV of CFAF 104,660, a BCR of 1.95, an IRR greater than 1,000%, and a PP of seven (7) years for a farmer or trader storing 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 95%. Such farmers can breakeven even with about half 51.5% of the benefit (that is, even those who lose only 15.45% 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 41%, the BCR would be 2.34, internal rate of return would increase to more than 10,000%, and the PP would shorten to five (5) years. In addition, even if benefits were to be reduced by 20%, the NPV would remain positive (CFAF 66,692) and BCR would stand at 1.55.

Under an optimistic scenario that has 10% as the discount rate, the return would be twice the investment costs, leading to a BCR of 2.04 and a PP of six (6) 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 87% (BCR=1.87).

When the cost of the hermetic bags is flexed to double the current price of CFAF 1950 per bag (US$3.21), the CBA results show that the investment becomes a loss making one for adopters, even when the reduction in post-harvest losses is large.

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 0.04

and 0.05% of agricultural GDP 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 gain 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 Benin 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 15% of their harvest to pest and other forms of damage in storage.

Recommendation 3: Government of Benin 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 price to the farmer does not exceed CFAF 3,900 as it will be non-viable to farmers or traders storing maize.

Recommendation 4: To increase the rate of adoption of hermetic bags by Small-Scale Farmers (SSFs), Medium Scale Farmers (MSF), Traders, and Agro-industries, the Government of Benin 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 CFAF 1,950 (US$3.21) will bring CFAF 1.94 per every CFAF invested (in tax waivers).

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 CFAF 1,755 (US$2.89) 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 CFAF 1,755 farmers with a loss of 15% per annum without the technology will be able to breakeven if they invest in the bags.

Recommendation 6: Given the challenge of inadequate supply and availability of hermetic storage technology on the market in Benin, yet it has been demonstrated to be viable to farmers who store for later sale or use, development programmes should aim to ensure sustainable availability of improved storage technology through increased participation of key stakeholders such as the private sector.

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 Benin. 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 long PP of seven (7) 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 NGOs extension services to understand the importance of storage pest management and deal with it through technology use and technology transfer should be strengthened in Benin. 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 radio, television, 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 5-7 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 5-7 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 5-7 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 13 – 15 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 (CFAF 17,149.01), the BCR is greater than 1 (1.31), 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 76.5% 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 22.95% of what was harvested and stored. Available literature shows that post-harvest losses in maize are at most 30% in Benin which means any farmer or trader with a loss ranging from 22.5 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 3% more expensive, which implies that less farmers would stand to benefit from adopting metal silos of lower sizes. This due to the fact that the breakeven point would increase to 23.6% of product stored is preserved with improved technology (metal silo) instead of 22.95% for a 500 kg 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 20.7% 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 15% less benefits (25.5% of stored product preserved by using the metal silo technology).

The PP of the investment, assuming a lifespan of 20 years for metal silos, is estimated at 11 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). If sensitivity analysis is considered the PP ranges from 9-12 years with a 20% more benefit and 14% discount rate, 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 3% in cost of production per kg of storage space as units become smaller.

Programming implications of the results

For a farmer able to produce and store 500 kg of maize but has a practice of selling his crop at harvest time, there is an added benefit of introducing metal silos to encourage him or her to store and sell at a higher price later during the lean season, but the magnitude of the added benefit is low (only 31% more than 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 off in purchasing the metal silo and storing his or her maize and wait to sell during the lean season rather than harvest (or purchase) and sell soon after. Although the magnitude of crop loss is quite high (30%) and therefore the quantity preserved by the technology is also very high, the price differential between the lean season and the harvest period is insufficient to compensate the farmer or trader for the investment in the new technology.

As this model is built on units of 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 even be lower than for the 500 kg metal silo.

Given the PP of nine (9) years (best case scenario), 11 years (base case scenario), and 12 years (worst case scenario), adoption of metal silos 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, unless they intend to use the silo for a minimum of nine (9) years, and ideally for a minimum of 12 years. The same applies to traders who buy for immediate sale at harvest time and do not have a practice of storing.

Recommendation 11: Government of Benin or development agencies willing to promote adoption of the metal silo technology should only target farmers and traders who do not have a culture of storing maize for later use if these are willing to use the silo for at least 9-12 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 CFAF 159,252, a BCR of 3.87, an IRR greater of 89%, and a shorter PP of three (3) years for a farmer or trader storing 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 287%. Such farmers can breakeven even with about half (26%) of the benefit (that is, even those who lose only 7.8% not 30%) when they do not use 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 used the technology continuously for 20 years.

Sensitivity analysis also showed that with 20% more benefit, the project's net worth would increase by 27%, the BCR would be 4.64, internal rate of return would increase to 130%, and the PP would shorten to two (2) years. In addition, even if benefits were to be reduced by 20%, the NPV would remain positive (CFAF 116,287) and BCR would stand at 3.09.

Under an optimistic scenario that has 10% as the discount rate, the return would be four times the investment costs, leading to a BCR of 4.32 and a PP 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 metal silo by 250% (BCR=3.50).

When the cost of the metal silo is flexed to double the current price of CFAF 61,000 per 500 kg silo (US$100.49), 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%).

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 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 than the projected lifespan of the silos because the PP is very short 2-4 years depending on assumptions of risk).

Recommendations 12: Government of Benin 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 four (4) 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 four (4) 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 2-4 years for an investment over 20 years, development programmes to support adoption of the metal silo technology for maize in Benin should be designed to provide support to resource-poor and subsistence farmers for a minimum period of four (4) 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 four (4) 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 4 years, farmers and traders will have earned sufficient incremental benefits to cover the projected future costs (for the remaining 16-18 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 3.87 for silos versus 1.95 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 Benin 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

As done for maize, 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 Benin was reported to be CFAF 347,083.30 per metric tonne while the lean season price stood at CFAF 512,500.00 per metric tonne (Table 6), a difference of 48%.

The base case scenarios for beans assumed that farmers have sufficient production to have a need to store 500 kg of beans (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	
	FCFA	USD	FCFA	USD
Project Lifespan	20 years		20 years	
Project duration	20 years		20 years	
Benefits start accruing	Year 1		Year 1	
Average loss without technology	29.80%		29.80%	
Effectiveness	100.00%		100.00%	
Production in kg	500		500	
Product stored in kg	500		500	
Loss prevented in kg	149		149	
Post-harvest price CFAF/MT	347,083.30	571.80	347,083.30	571.80
Cost of treatment/year in CFAF	-	-	-	-
Value preserved at PH in CFAF	51,715.41	85.20	51,715.41	85.20
Lean season price CFAF/MT	512,500.00	844.32	512,500.00	844.32
Value preserved at LS price in CFAF	76,362.50	125.80	76,362.50	125.80
Price of HB	19,500.00	32.13	19,500.00	32.13
Lifespan of HB	2 years		2 years	
Discount rate	12%		12%	
CFAF value saved	24,647.09	40.60	76,362.50	125.80
Incremental benefit	24,647.09	40.60	76,362.50	125.80

Notes: LS=Lean Season; MT=Metric tonne; PHLM=Post-harvest loss Management; CFAF=Communauté Financière Africaine Franc.

Source: Own source.

The loss of beans without adoption of technology was taken as the highest level of 29.8% in Benin, 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 23.8% of the harvest preserved (80 of 29.8%). On the other hand 20% more benefit assumed a higher loss of 35.8% which would be eliminated with improved storage.

As for maize, the values of product preserved due to adoption of the two (2) 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 29.8% loss, 149 kg from every 500 kg of beans stored could have been lost without technology. However with the adoption of technology the 149 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 CFAF 51,715.41 and CFAF 76,362.50 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 29.8% of their beans in storage. They recover CFAF 51,715.41 in value immediately after harvest (149 kg of potential loss multiplied by the post-harvest price of CFAF 347,083.30 per tonne or CFAF 347.08 per kg). However those that do not sell lose the opportunity to earn CFAF 51,715.41 and because they do not use improved technologies, they cannot take advantage of the lean season price of CFAF 512,500.00, which could have enabled them to earn CFAF 76,362.50 by selling the 149 kg in the lean season. Hence the total loss to those who do not sell at post-harvest is CFAF 76,362.50 while to those who sell immediately after harvest they only lose the opportunity to earn an extra CFAF 24,647.09 in the lean season but will salvage CFAF 51,715.41 by selling the produce (149 kg) at harvest. Hence those who sell at harvest only lose the difference between these two values (CFAF 51,715.41 and CFAF 76,362.50), which is equivalent to CFAF 24,647.09.

From the foregoing computations, by adopting PHLM technology, farmers who have a practice of selling immediately after harvest have an incremental benefit of CFAF 24,647.09, which is the additional value they realise. The technology enables them to preserve 149 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 149 kg in storage, the incremental benefit is derived from the value they get after selling the 149 kg of beans during the lean season (CFAF 76,362.50). The counterfactual is therefore a loss of CFAF 28,762.50 in value of product stored that perishes due to pest and other forms of damage due to sub-optimal crop storage conditions.

As for maize, the incremental cost of hermetic bags was found to be CFAF 19,500 which would be incurred once every two years (the lifespan of a hermetic bag).

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

	Scenario 1: Farmer sells		Scenario 2: Farmer stores	
	FCFA	USD	FCFA	USD
Project Lifespan	20 years		20 years	
Project duration	20 years		20 years	

	Scenario 1: Farmer sells		Scenario 2: Farmer stores	
	FCFA	USD	FCFA	USD
Benefits start accruing	Year 1		Year 1	
Average loss without technology	29.80%		29.80%	
Effectiveness	100.00%		100.00%	
Production in kg	500		500	
Product stored in kg	500		500	
Loss prevented in kg	149		149	
Post-harvest price CFAF/MT	347,083.30	571.80	347,083.30	571.80
Cost of treatment/year in CFAF	150.00	0.25	150.00	0.25
Value preserved at PH in CFAF	51,715.41	85.20	51,715.41	85.20
Lean season price CFAF/MT	512,500.00	844.32	512,500.00	844.32
Value preserved at LS price in CFAF	76,362.50	125.80	76,362.50	125.80
Price of Metal silo in CFAF	61,000.00	100.49	61,000.00	100.49
Lifespan of Metal silo	20 years		20 years	
Discount rate	14%		14%	
CFAF value saved	24,647.09	40.60	76,362.50	125.80
Incremental benefit	24,647.09	40.60	76,362.50	125.80

Notes: LS=Lean Season; MT=Metric tonne; PHLM=Post-harvest loss Management; CFAF=Communauté Financière Africaine Franc.

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 CFAF 24,647.09 and CFAF 76,362.50, 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 (CFAF 61,000.00) in year 1 and CFAF 150 per year for pesticides for the 20 year project life.

CBA Analysis Results for Beans

Hermetic bags

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 (CFAF 107,150.69), the BCR is 2.39, and the IRR is greater than 10,000 which implies that the investment is viable (see Annex 6.3).

Results of sensitivity analysis also showed that the breakeven point for the investment would be reached with only 42% of the benefit (post-harvest loss of 12.5% instead of 29.8%). 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 43% of current benefits (i.e., a post-harvest loss of 12.8% instead of 29.8%). These results are generalizable for smaller units of production (below 500 kg of beans).

For farmers who have a practice of storing and losing up to 29.8% 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 493,436 (per farmer storing 500 kg of beans), a BCR of 7.41, an IRR greater than 1 million, PP of two (2) years and breakeven benefit of only 13.5% 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 4% per year, would still benefit by switching to the hermetic bags.

Programming implications of the results

A farmer able to produce and store 500 kg of beans but has a practice of selling his crop at harvest time, will stand to benefit if he or 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.

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.

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 7.41 shows that the investment can recover the costs as much as seven (7) 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 as much as 83%, Government of Benin and development agencies should consider promoting hermetic bags more for the storage of beans as opposed to maize.

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 CFAF 128,515, a BCR of 3.31, an IRR of 66%, and a shorter payback PP of three (3) years for a farmer or trader storing 500 kg of maize (Annex 6.4). The results show that the investment will pay-off. 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 231%. Such farmers can breakeven even with 30.2% of the projected benefits (that is, even those who lose only 8.9% not 29.8%) of their produce when they do not use 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 used the technology continuously for 20 years.

Sensitivity analysis also showed that with 20%more benefit, the project's net worth would increase by 29%,the BCR would be 3.97, IRR would increase to 93%, and the PP would remain approximately three (3) years. In addition, even if benefits were to be reduced by 20%, the NPV would remain positive (CFAF 91,695) and BCR would stand at 2.65.

Under an optimistic scenario that has 10% as the discount rate, the discounted incremental benefits would be about three-and-a-half times the investment costs, leading to a BCR of 3.7 and a PP 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 metal silo) by 199% (BCR=2.995).

When the cost of the metal silo is flexed to double the current price of CFAF 61,000 per 500 kg silo (US$100.49), the CBA results show that the investment remains viable for adopters, even when the product preserved in storage is low (20.9% of stored product instead of 29.8%).

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 CFAF 514,800.69, BCR of 10.62, IRR greater than 1,000%, and a PP of one (1) year. Even when benefits are reduced to 80% of the current level, the investment remains viable with a PP of two (2) years, and BCR of 8.1. Even with sensitivity analysis, the breakeven point is reached with benefits below 13% of current benefits which shows that the metal silos highly viable for storing beans.

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 0.012 and 0.013% of agricultural GDP will be preserved through PHLM investments. The lower figure is for hermetic bags and the higher is for metal silos.

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 seasons, the metal silo should be promoted ahead of the hermetic bag technology.

Recommendation 19: Given the high PP 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 four (4) years, as this is sufficient for them to have recouped investment costs for 20 years.

Cowpeas Value Chain

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 Benin was reported to be CFAF 276,250.00 per metric tonne while the lean season price stood at CFAF 387,500.00 per metric tonne (Table 8), a difference of 40.2%.

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 500 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 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 Cowpeas and Hermetic Bags (Base Case)

Indicator	Scenario 1: Farmer sells		Scenario 2: Farmer stores	
	FCFA	USD	FCFA	USD
Project Lifespan	20 years		20 years	
Project duration	20 years		20 years	
Benefits start accruing	Year 1		Year 1	
Average loss without technology	29.80%		29.80%	
Effectiveness	100.00%		100.00%	
Production in kg	500		500	
Product stored in kg	500		500	

Loss prevented in kg	149		149	
Post-harvest price FCFA/MT	276,250.00	455.11	276,250.00	455.11
Cost of treatment/year in FCFA	-	-	-	-
Value preserved at PH in FCFA	41,161.25	67.81	41,161.25	67.81
Lean season price FCFA/MT	387,500.00	638.39	387,500.00	638.39
Value preserved at LS price in FCFA	57,737.50	95.12	57,737.50	95.12
Price of HB	19,500.00	32.13	19,500.00	32.13
Lifespan of HB	2 years		2 years	
Discount rate	12%		12%	
FCFA value saved	16,576.25	27.31	57,737.50	95.12
Incremental benefit	16,576.25	27.31	57,737.50	95.12

Notes: LS=Lean Season; MT=Metric tonne; PHLM=Post-harvest loss Management; CFAF=Communauté Financière Africaine Franc.

Source: Own source.

Similar to beans, the post-harvest loss of cowpeas without adoption of technology was taken as the highest level of 29.8% in Benin, 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 23.8% of the harvest preserved (80% of 29.8%). On the other hand 20% more benefit assumed a higher loss of 35.8% 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 29.8% loss, 149 kg from every 500 kg of cowpeas stored could have been lost without technology. However with the adoption of technology the 149 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 CFAF 41,161.25 and CFAF 57,737.50 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 29.8% of their cowpeas in storage. They recover CFAF 41,161.25 in value immediately after harvest (149 kg of potential loss multiplied by the post-harvest price of CFAF 276,250.00 per tonne or CFAF 276.25 per kg). However those that do not sell lose the opportunity to earn CFAF 41,161.25 and because they do not use improved technologies, they cannot take advantage of the lean season price of CFAF 387,500.00, which could have enabled them to earn CFAF 57,737.50 by selling the 149 kg in the lean season. Hence the total loss to those who do not sell at post-harvest is CFAF 57,737.50 while to those who sell immediately after harvest they only lose the opportunity to earn an extra CFAF 16,576.25 in the lean season but will salvage CFAF 41,161.25 by selling the produce (149 kg) at harvest. Hence those who sell at harvest only lose the difference between these two values (CFAF 41,161.25 and CFAF 57,737.50), which is equivalent to CFAF 16,576.25.

From the foregoing computations, by adopting PHLM technology, farmers who have a practice of selling immediately after harvest have an incremental benefit of CFAF 16,576.25, which is the additional value they realise. The technology enables them to preserve 149 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 149 kg in storage, the incremental benefit is derived from the value they get after selling the 149 kg of cowpeas during the lean season (CFAF 57,737.50). The counterfactual is therefore a loss of CFAF 57,737.50 in value of product stored that perishes due to pest and other forms of damage due to sub-optimal crop storage conditions.

As for maize and beans, the incremental cost of hermetic bags was the same at CFAF 19,500 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)

	Scenario 1: Farmer sells		Scenario 2: Farmer stores	
	FCFA	USD	FCFA	USD
Project Lifespan	20 years		20 years	
Project duration	20 years		20 years	
Benefits start accruing	Year 1		Year 1	
Average loss without technology	29.80%		29.80%	
Effectiveness	100.00%		100.00%	
Production in kg	500		500	
Product stored in kg	500		500	
Loss prevented in kg	149		149	
Post-harvest price CFAF/MT	276,250.00	455.11	276,250.00	455.11
Cost of treatment/year in CFAF	150.00	0.25	150.00	0.25
Value preserved at PH in CFAF	41,161.25	67.81	41,161.25	67.81
Lean season price CFAF/MT	387,500.00	638.39	387,500.00	638.39
Value preserved at LS price in CFAF	57,737.50	95.12	57,737.50	95.12
Price of Metal silo	61,000.00	100.49	61,000.00	100.49
Lifespan of Metal silo	20 years		20 years	
Discount rate	14%		12%	
CFAF value saved	16,576.25	27.31	57,737.50	95.12
Incremental benefit	16,576.25	27.31	57,737.50	95.12

Notes: LS=Lean Season; MT=Metric tonne; PHLM=Post-harvest loss Management; CFAF=Communauté Financière Africaine Franc.

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 were CFAF 16,576.25 and CFAF 57,737.50, respectively, while the incremental cost for a metal silo with a storage capacity of 500 kg was CFAF 61,000.00 in year 1 and CFAF 150 per year for pesticides for the 20 year 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 or trader better off, with an NPV of 46,866, BCR of 1.61 and IRR of 465%.The PP is eight (8) years and breakeven loss is 62.5% of current loss of 29.8% (that is, if farmers preserve only 18.6% of their produce in storage rather than 29.8% they will recover the costs incurred in investing in hermetic bags over a 20 year 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 stand to earn high incremental benefits from the technology (when compared to the period without technology), with a BCR of 5.6, IRR greater than 200,000 % and a PP of two (2) years. Breakeven point is reached with just 18 % of the estimated current benefits which means that even farmers with very low losses, 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 300% (BCR ranges from 4.48 to 6.73).

Programming implications of the results

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 61%. However the PP is longer given the need to purchase new bags once every two 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 PP of two (2) years for farmers and traders who store and sell later in the lean season, such farmers can be supported over 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 PP is much longer (6-11 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 a farmer storing 500 kg of cowpea would be CFAF 68,230.66, IRR would be 36.7% and the payback period would be five (5) years. Breakeven point could be reached by a lower benefit (45% of the projected PHL of 29.8%). Sensitivity analysis shows that the technology is so viable that even with 38% of benefit, farmers and traders could breakeven. This implies that even farmers with lower levels of losses 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 make a big difference to their welfare if they were to switch to metal silos. Returns to investment would outweigh the costs by 676% (BCR of 7.76). They could increase with a 20% increase in benefit to BCR of 9.31, and the cost of the investment over 20 years can be recouped in the first year or two of adoption of the technology. Breakeven point can be reached even by as little as 11% of the projected incremental benefits of adoption.

Programming implications of the results

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, and 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.

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 0.011 and 0.012% 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 between 0.06 and 0.07% 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 revealed that of the USD940 billion that needs to be invested to eradicate hunger in Sub-Saharan Africa, over a 44 year period to 2050, up to 47% 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[8]. FAO is optimistic the needs will be met considering the commitment in Africa to invest in agriculture. Most countries, Benin included, are implementing strategic frameworks that are in line with CAADP Pillar 2. However, it should be noted that the amount is significantly large and African governments on their own may not be able to meet this target because of current economic challenges. It is therefore imperative that concerted efforts towards investment in post-harvest technologies be made by all potential sources of funding, including government, donors, NGOs, the private sector and the farmers themselves. Public-private-and-community partnerships should therefore be explored as recommended by FAO/World Bank whereby the public sector invests in research and extension services to create demand by advising farmers on the technologies with the highest returns, and farmers incrementally invest in these technologies to reap the benefits. Post-harvest losses imply the loss of value that the farmer already has (what the farmer has produced, is then destroyed by pests and other causes). So what is essential is to stop that loss of this asset through additional investments and enable farmers to realise the benefit thereof (financially or otherwise) such that they are enabled to invest further into the use of the technology in future. If beans or cowpeas are stored and then sold at a higher price in the lean season farmers or traders stand to benefit from additional income and they can use that additional income to invest in improved storage (purchasing new hermetic bags or a metal silo).

Many governments in Africa have increased investment in agricultural production in the past two (2) or three (3) decades but there has been minimal improvement in food security. This is attributed to post-harvest losses. It is therefore critical to address PHL. The Government of Benin is encouraged strongly to increase investment in post-harvest technologies through its budget on agriculture. It can source for supplementary 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.[9] The programme contributes directly to the implementation of Pillar 2 (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 create and increase awareness of technologies among smallholder farmers and training for artisans who will manufacture the metal silos within the communities. This will help to guard against the 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.

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

[9] Ibid

If the risk of financing agriculture is mitigated, the private sector, specifically finance or micro-finance companies could also provide affordable loans to small holder farmers so that they can buy silos and repay their loans over two (2) or three (3) years. The European Commission through the European Development Fund, has been testing blending options for promoting financial inclusion targeting smallholder agriculture. What is important to emphasise is that promoting innovative value-chain financing to support market integration of smallholder farmers is premised on advancing market linkage development models for smallholder farmers to supply produce to larger actors in the value chain who access funds through the commercial banking sector (at subsidised interest rates) and channel the resources to the smallholder sector. The development partner's role will be to capacitate the smallholder farmers on how to work with a large scale private sector actor, as well as equipping commercial banks and the nuclear value-chain actor (lead) with working tools on how to do business securely with the smallholder farmer, and providing the needed finance to hedge the commercial bank and the value chain lead against the risk of default from the smallholder sector. The commercial bank will provide the capital to the lead value chain actor, for own use and lending to smallholder producers. The public sector will create a conducive policy environment to lower the risk for the bank and the value-chain actors, including smallholder farmers, and complement with research and extension services delivery. Government may also provide a reliable market for the farmers' produce.

What is needed for smallholder farmers is knowledge, then start-up capital and blending options for financing storage technologies. The farmers are encouraged to contribute towards the purchase of metal silos as a way of minimising dependency. They may be asked to pay a certain percentage of the cost from own resources and pay the balance using loans from finance companies. However NGOs may pay the full cost for the poorest members of the community to provide a safety net for them. They can do so by converting the food handout money into productive assets (that prevent food produced by the resource poor families from being lost to pest damage and other causes).

The government may solicit for funds from development partners to fund the promotion of technologies as well as reduce customs duty charged on imported post-harvest storage materials such as hermetic bags and related raw materials. It may also consider subsidizing the materials up to the level where the returns to investment in hermetic bags outweighs cost of importing food and supplementing local production with food hand-outs.

6. Conclusion

For maize farmers it is evident that those who are selling their maize immediately after harvest are more prudent than those storing using sub-optimal technologies and thus losing their crop to pests and other causes. Such farmers are better off than those investing in hermetic bags to store and sell their maize later in the lean season. Post-harvest loss management programmes should not discourage farmers or traders from selling their maize at harvest time preferring that they adopt hermetic bags, the latter leaves them worse-off.

For maize farmers who are already disposing of their maize immediately after harvest, storing their maize using the metal silo technology and selling later in the lean season is a more viable option than either selling immediately at harvest or adopting the hermetic bag technology and then selling in the lean season. The price differential in maize between the harvest time and lean season does not generate a sufficiently high financial benefit for such farmers to offset the price of the hermetic bag especially the biennial replacement requirement for the bags give their shorter lifespan.

For the farmer who is growing beans and cowpeas, the incremental benefits of improved technology permit the farmer to invest either in hermetic bags or metal silo since they outweigh the costs of hermetic bags or silos, irrespective of the counterfactual status of the farmer.

The payback periods for farmers who have to shift from selling at harvest to storing and selling in the lean season are longer that for those who have been storing till the lean season without the technology. For such farmers the payback periods for both hermetic bags and metal silos are long, although they are shorter for metal silos even though the initial investment cost (in the short term) is higher for metal silos.

Hence, at the minimum, government or donor programmes to promote these technologies should aim to achieve sustained use over a long period of time (preferably beyond 10 years) if the technologies are to add value to the farmers. Sustaining their use will require investments in building the supply chain of the technologies and sufficient demand creation as a pre-requisite of private sector investment in the manufacture, distribution and sale of PHLM technologies.

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 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 or 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 or 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.

Annex 2: Documents reviewed

1. Adebayo B. Abass, Gabriel Ndunguru, Peter Mamiro, Bamidele Alenkhe, Nicholas Mlingi, Mateete Bekunda, 2013. *Post-harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania Elsevier*, Journal of Stored Products Research 57 (2014) 49e57
2. African Development Bank. 2008. *Africa Food Crisis Programme.*
3. Aulakh J., & Regmi A., *Post-harvest food losses- Development of consistent methodology*.
4. *FAO/World Bank Workshop on reducing Post-Harvest Losses in Grain Supply Chain in Africa: Lessons learnt and practical guidelines.* 2010. Rome. Report compiled by Mhlanga N., Njie S. E. & Gallat S. Rome.
5. Halos Kim L., Toshiro M., 2005. *Improving Post-Harvest Systems: Promoting Agro-Industrial Development in Africa.* Sasakawa Africa Association funded by Nippon Foundation.
6. Honfoga B. G., Akissoe N. H., Guedenon A., & Vihotogbe C. N. S., 2014. *Post, harvest management policies, programmes and strategies in Benin and Sub-Saharan Africa Benin Report.* FANRPAN.
7. McNamara P.E. & Tata J.S. *Principles of Designing and Implementing Agricultural Extension Programs for Reducing Post-Harvest Loss.* Agriculture 2015, 5, 1035-1046; doi: 10.3390/ agriculture 5041035. www.mdpi.com/journal/agriculture
8. 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.

Annex 3: People interviewed

Name	Organisation	Function	Province
1.Bohoun Bernadette	CARDER/ QUEME/PLAT	C/SCNQPV	Porto-novo
2. Dr. Dossa Aguemon	MAEP	DAPP	Cotonou
3. Gbessemehlan Victor	GRAPAD	Executive Director	Cotonou
4. Goulole Appolinaire Echee	CARDER Atlantic/ Littoral	Chief Service	Abomey-Calavi
5.Agassounon Celestin	GABF	Nutritionist	Pobe
6.Vodouhe D. Simplice	AFAAS-Benin	Focal Point	Cotonou
7.Bodea Simon	Synergie Paysanne	Secretary General	Bohicon
8.Dr. Rachidatou	Institut National des Recherches Agricole du Bénin (INRAB)	Researcher	

Annex 4: Production Statistics Tables

Annex 4.1: Benin Crop Production figures by Province

Province(Département)	Production in tonnes (2015)		
	Maize	Beans	Cow peas
Alibori	236 436	11 022	12 327
Borgou	202 712	10 145	56 802
Atacora	196 674	15 647	21 009
Donga	45 508	4 926	8 961
Collines	94 566	17 470	27 854
Zou	63 032	15 579	11 497
Plateau	173 690	4 567	919
Ouémé	53 051	5 091	-
Mono	50 351	873	16
Couffo	81 776	11 930	503
Littoral	-	-	-
Atlantic	88 263	1 856	21
Total	1 286 059	99 106	139 909

Annex 4.2: Benin Crop Production Figures by Agro-Ecological Region

Agro-ecological region	Production in tonnes (2015)		
	Maize	Beans	Cow peas
1	439 148	21 167	69 129
2	242 182	20 573	29 970
3	157 598	33 049	39 351
4	132 127	12 803	519
5	226 741	9 658	919
6	88 263	1 856	21
7	-	-	-
8	-	-	-
Total	**1 286 059**	**99 106**	**139 909**

Annex 4.3: Benin Crop prices by season and province

Crop	Price soon after harvest per tonne in FCFA	Price during lean season per tonne, in FCFA	Province (s) (Départements)
Maize	115 000	190 000	Plateau
	172 000	230 000	Ouémé
	105 000	160 000	Collines
	125 000	180 000	Zou
	107 000	167 000	Alibori
	125 000	184 000	Borgou
	120 000	205 000	Couffo
	146 000	215 000	Mono
	112 000	175 000	Donga
	125 000	190 000	Atacora
	145 000	205 000	Littoral
	125 000	200 000	Atlantic
Beans	350 000	500 000	Plateau
	400 000	600 000	Ouémé
	350 000	500 000	Zou
	300 000	400 000	Collines
	300 000	400 000	Alibori
	400 000	600 000	Borgou
	265 000	450 000	Couffo
	300 000	500 000	Mono
	350 000	500 000	Donga
	400 000	600 000	Atacora
	400 000	600 000	Littoral
	350 000	500 000	Atlantic

Crop	Price soon after harvest per tonne in FCFA	Price during lean season per tonne, in FCFA	Province (s) (Départements)
Cow peas	300 000	400 000	Plateau
	300 000	400 000	Ouémé
	250 000	400 000	Zou
	225 000	350 000	Collines
	200 000	350 000	Alibori
	240 000	350 000	Borgou
	300 000	400 000	Couffo
	350 000	400 000	Mono
	250 000	400 000	Donga
	300 000	400 000	Atacora
	300 000	400 000	Littoral
	300 000	400 000	Atlantic

Annex 4.4: Food supply chain actors by province

Province	Actor				
	Small holder farmers	Medium scale farmers	Large scale farmers	Traders	Food processing companies
Alibori	8 500	5 500	4 500	4 000	400
Atacora	9 000	6 000	4 200	3 800	400
Borgou	9 000	7 000	5 500	4 000	600
Donga	6 500	4 500	4 000	3 500	480
Collines	8 800	7 500	5 000	4 300	800
Zou	8 000	6 800	6 000	4 000	750
Plateau	8 000	5 200	4 500	4 000	700
Couffo	9 000	7 600	4 600	3 500	680
Mono	7 500	5 500	3 800	3 400	700
Atlantic	8 000	6 500	4 500	3 500	800
Littoral	5 000	3 200	3 500	3 200	1 000
Oueme	7 000	6 500	4 600	4 000	1 000
Total	**94 300**	**71 800**	**54 700**	**45 200**	**8 310**

Annex 5: Cost-Benefit Analysis Modelling Assumptions for Benin

Annex 5.1: Price calculation for metal silo

Concept	Unit Price		30 kg		250 kg		350 kg		500 kg		1000 kg	
	Unit	Price FCFA	Unit	Price FCFA	Unit	Price FCFA	Unit	Price FCFA	Unit	Price FCFA	Unit	Price FCFA
Metal sheet 4 x 8 (1.22m x 2.44m)	cal 0.5mm (G26)	14,000	0.3	4,200	1.1	15,400	1.4	19,600	2.1	29,400	2.8	39,200
Tin 50 : 50 (Tin:lead)	1 gr	23.00	125	2,875	250	5,750	350	8,050	400	9,200	500	11,500
Charcoal	kg	2	1	2	2	4	4	8	4	8	5	10
Amonium chloride	kg	600	0.05	30	0.07	42	0.1	60	0.1	60	0.15	90
Hydrochloric Acid	dl	1,500	0.1	150	0.2	300	0.20	300	0.25	375	0.35	525
Aluminium paint	lt	5,000	0.03	150	0.05	250	0.06	300	0.06	300	0.07	350
Total Cost of Materials				**7,407**		**21,746**		**28,318**		**39,343**		**51,675**
Transport				1,800		3,600		4,500		5,400		7,200
Labour				3,650		5,110		7,300		9,125		10,950
Wear and tear costs of equipment				183		256		292		329		365
Cost of Silo				**13,040**		**30,712**		**40,410**		**54,197**		**70,190**
In US$				22		51		67		90		116
Materials in US$				12.28		36.06		46.96		65.25		85.70
Percentage of Total Cost				57%		71%		70%		73%		74%
Sheet (1.22 x 2.44m)	US$	23.22										
Tin (100gr)	US$	3.81										

Notes: (a) **Additional Information:** Cost of Sheet (1.22 x 2.44m) **USD** 23.22

Tin (100g) **USD** 3.81

(b) *Exchange Rate: **USD** 1.00=**FCFA** 607

Annex 5.2: Cost benefit analysis assumptions for metal silo

Description	**Description of Calculation**	***Calculation***	**Silo 250 kg**	**Silo 350 kg**	**Silo 500 kg**	**Silo 1000kg**
Loss estimation	15% loss to FCFA 175.-/kg	37.5kg*175.-	6562.5			
	15% loss to FCFA 175.- / kg	52.5 kg*175.-		9187.5		
	15% loss to FCFA 175.- / kg	75 kg*175.-			13125	
	15% loss to FCFA 175.- / kg	150 kg*175.-				26250
Profit from sales	*Difference of prices: Harvest period*: FCFA 175.- *(Lean Season)*: FCFA 250.- Difference: FCFA 75.- *This difference is applicable to 50% of the stocked capacity*	250kg*50%*FCFA 75.-	9375			
	Difference of prices : Harvest period FCFA 175.- Lean season FCFA 250.- Difference: FCFA 75.- This difference is applicable to 50% of the stocked capacity	350kg*50%*FCFA 75.-		13125		
	Difference of prices : Harvest period FCFA 175.- Lean season FCFA 250.- Difference: FCFA 75.- This difference is applicable to 50% of the stocked capacity	500kg*50%*FCFA 75.-			18750	
	Difference of prices : Harvest period FCFA 175.- Lean season FCFA 250.- Difference: FCFA 75.- This difference is applicable to 50% of the stocked capacity	1000kg*50%*FCFA 75.-				37500
Total additional revenue			**15,938**	**22,313**	**31,875**	**63,750**
Price in FCFA			35,000	45,000	60,000	80,000

Annex 6: Results of Cost Benefit Analysis Modelling for PHLM Technologies

Annex 6.1: Maize- Hermetic Bags

Viability Indicator	Base Case r=12%	Benefits + 20%	Benefits less 20%	Optimistic r=10%	Pessimistic r=14%
SCENARIO A- Farmer sells part of the harvest soon after harvest					
NPV (CFAF)	-4,215.65	-22,898.00	-18,762.39	-45,059.14	-4,307.35
BCR	0.66	0.79	0.59	0.69	0.63
IRR (%)	Negative	Negative	Negative	Negative	Negative
PAYBACK (Years)	N/A	N/A	N/A	N/A	N/A
BREAKEVEN (%)	N/A	N/A	89.00%	45.00%	58.50%
SCENARIO B- Farmer stores all the harvested crop					
NPV (CFAF)	104,660.52	147,628.50	66,692.55	125,052.32	88,783.54
BCR	1.949	2.34	1.55	2.04	1.87
IRR (%)	>1000%	>1000%	>1000%	>1000%	>1000%
PAYBACK (Years)	7	5	6	6	6
BREAKEVEN (%)	51.50%	0.43%	0.64%	0.49%	0.54%

Annex 6.2: Maize- Metal Silo

Viability Indicator	Base Case r=12%	Benefits + 20%	Benefits less 20%	Optimistic r=10%	Pessimistic r=14%
SCENARIO A- Farmer sells part of the harvest soon after harvest					
NPV (CFAF)	17,149.01	31,695.75	2,602.27	26,169.25	9,990.50
BCR	1.31	1.57	1.05	1.46	1.18
IRR (%)	18%	23%	13%	ii	18%
PAYBACK (Years)	11	9	17	10	12
BREAKEVEN (%)	76.50%	64.00%	96%	69%	85.00%
SCENARIO B- Farmer stores all the harvested crop					
NPV (CFAF)	159,225.17	202,223.14	116,287.20	188,139.80	-135,995.55
BCR	3.87	4.64	3.09	4.32	3.5
IRR (%)	89	130	60	89	89
PAYBACK (Years)	3	2	4	3	3
BREAKEVEN (%)	26.00%	22.00%	33.00%	23.00%	23.00%

Annex 6.3: Beans- Hermetic Bags

Viability Indicator	Base Case r=12%	Benefits + 20%	Benefits less 20%	Optimistic r=10%	Pessimistic r=14%
SCENARIO A- Farmer sells part of the harvest soon after harvest					
NPV (CFAF)	107,150.69	143,970.65	70,330.67	122,874.58	94,440.79
BCR	2.39	2.87	1.9	2.41	2.37
IRR (%)	>10000	>10000	>10000	>10000	>10000
PAYBACK (Years)	5	4	6	5	4
BREAKEVEN (%)	42.00%	35.00%	53%	42%	43.00%
SCENARIO B- Farmer stores all the harvested crop					
NPV (CFAF)	493,436.00	607,513.10	379,358.95	563,157.04	436,958.72
BCR	7.41	8.89	5.93	7.48	7.35

IRR (%)	>1 mln	>1 mln	>1 mln	>1 mln	>1 mln
PAYBACK (Years)	1	1	2	2	2
BREAKEVEN (%)	13.50%	11.30%	16.90%	13.50%	13.60%

Annex 6.4: Beans- Metal Silo

Viability Indicator	Base Case r=12%	Benefits + 20%	Benefits less 20%	Optimistic r=10%	Pessimistic r=14%
SCENARIO A- Farmer sells part of the harvest soon after harvest					
NPV (CFAF)	128,515.00	165,335.34	91,696.33	21,396.37	108,738.64
BCR	3.31	3.97	2.65	3.7	2.995
IRR (%)	66%	93%	47%	66%	66%
PAYBACK (Years)	3	3	4	4	3
BREAKEVEN (%)	30.20%	0.25%	38%	27%	33.50%
SCENARIO B- Farmer stores all the harvested crop					
NPV (CFAF)	514,800.69	628,877.76	400,723.61	593,385.43	451,256.57
BCR	10.26	12.31	8.21	11.46	9.28
IRR (%)	>1000	>1000	>1000	>1000	>1000
PAYBACK (Years)	1	1	2	1	1
BREAKEVEN (%)	9.89%	8.20%	12.50%	8.80%	10.80%

Annex 6.5: Cowpeas- Hermetic Bags

Viability Indicator	Base Case r=12%	Benefits + 20%	Benefits less 20%	Optimistic r=10%	Pessimistic r=14%
SCENARIO A- Farmer sells part of the harvest soon after harvest					
NPV (CFAF)	46,866.00	71,029.08	22,102.93	54,162.99	40,986.58
BCR	1.61	1.93	1.29	1.62	1.6
IRR (%)	465%	>1000%	110%	465%	465%
PAYBACK (Years)	8	6	11	8	7
BREAKEVEN (%)	62.50%	52.00%	78%	62%	63.00%
SCENARIO B- Farmer stores all the harvested crop					
NPV (CFAF)	354,317.64	440,591.04	268,064.24	404,591.91	213,602.95
BCR	5.6	6.75	4.48	5.65	5.56
IRR (%)	>200000%	>500000%	>500000%	>500000%	>500000%
PAYBACK (Years)	2	2	2	2	2
BREAKEVEN (%)	18.00%	15.00%	23.00%	17.80%	18.00%

Annex 6.6: Cowpeas- Metal Silo

Viability Indicator	Base Case r=12%	Benefits + 20%	Benefits less 20%	Optimistic r=10%	Pessimistic r=14%
SCENARIO A- Farmer sells part of the harvest soon after harvest					
NPV (CFAF)	68,230.68	142,422.01	91,189.84	134,436.60	102,545.42
BCR	2.28	13.63	9.09	12.64	10.30
IRR (%)	37%	>10,000%	>10,000%	>10,000%	>10,000%
PAYBACK (Years)	5	1	1	1	1
BREAKEVEN (%)	45.00%	7.3%	11%	7.9%	9.7%
SCENARIO B- Farmer stores all the harvested crop					
NPV (CFAF)	375,683.30	461,935.70	289,428.90	434,820.31	327,900.76

BCR	7,76	9.31	6.2	8.66	7.08
IRR (%)	1685%	10000%	300%	1685%	1685%
PAYBACK (Years)	2	1	2	2	2
BREAKEVEN (%)	13.00%	11.00%	16.00%	12.00%	14.00%