Reducing Food Losses in Sub-Saharan Africa

(improving Post-Harvest Management and Storage Technologies of Smallholder Farmers.)

An 'Action Research' evaluation trial from Uganda and Burkina Faso.

August 2013 – April 2014

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Executive Summary

The 1996 World Food Summit in Rome defined food security as existing "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." A declaration was made at the time to halve the proportion of chronically undernourished people by 2015. This bold aspiration, which formed the basis of the first Millennium Development Goal, may have seemed realistic at the time, but today, with an estimated 1 billion people going hungry every day, there is clearly a lot more work to be done.

*"...the new procedures and technologies enabled food losses to be reduced by **more than 98%**; regardless of the crop and regardless of the duration of storage."*

From August 2013 to April 2014, the World Food Programme took the initiative to conduct an Action Research Trial, involving Governments, NGO's and private sector partners to address one of the major contributing factors to food insecurity in sub-Saharan Africa, *post-harvest food losses*. Building upon the work already done by United Nations agencies FAO and IFAD to improve post-harvest practices, the research trial focused on two countries, Uganda and Burkina Faso, with an aim to actively meet the challenge issued by the UN Secretary-General for all partners "to scale up their efforts and turn the vision of an end to hunger into a reality."

The research trial proved to be highly successful. It illustrated clearly for the 400 farmers involved the benefits of improved post-harvest management procedures and the advantages of new storage technologies over traditional farming practices. For all participating farmers, without exception, the new procedures and technologies enabled food losses to be reduced by more than 98%; regardless of the crop and regardless of the duration of storage. The results were made even more impactful as crop losses in traditional storage units far exceeded previously reported country averages, due to farmers extending the storage period beyond their normal practices to accommodate the trial. To almost eradicate post-harvest food losses at the farm level is an extraordinary outcome, but when combined with the additional benefits of augmenting household finances, improving family well-being (through increased nutrition and reduced exposure to food contaminations) and increasing surplus, quality food for community consumption, it provides a resounding endorsement for implementing the same procedures on a much larger scale.

The results of this trial clearly indicate post-harvest crop losses in developing countries can be hugely reduced when appropriate capacity development and improved farming equipment are introduced.

The WFP Country Offices of Uganda and Burkina Faso acknowledge the support of the Logistics Division and Purchase for Progress (P4P) Coordination Unit of WFP, as well as the network of P4P supported farmers, for their contribution to the trial and commitment towards reducing food losses and increasing food security in sub-Saharan Africa. The Action Research Trials were undertaken, and primarily funded, under the umbrella of P4P in both Country Offices.

World Food Programme
Kampala, **Uganda** | Ouagadougou, **Burkina Faso**

1. Introduction

Background

"95% of research investments during the past 30 years have focused on increasing productivity and only 5% directed towards reducing losses!"

Every year across sub-Saharan Africa (SSA) unacceptable levels of food loss continue to occur. Although these losses are being recorded at every stage in the supply chain, from production through to retail and consumer levels, the area of highest concern (where the greatest % of crop losses are recorded) are pre-farm gate, where poor harvesting, drying, processing and storage of crops occurs. Post-harvest management at farm level is the critical starting point in the supply chain. Current inefficiencies in this segment represent one of the largest contributing factors to food insecurity in Africa, directly affecting the lives of millions of smallholder farming families every year and impacting enormously on available volumes of food for consumption and trade in low-income, food-deficit countries.

Despite increased warnings regarding the planet's inability to feed the expected population growth beyond 2050, alarmingly little is being done to preserve existing food production in regions most vulnerable. Over recent decades, significant focus and resources have been allocated to increase food production (95% of all research investments over the past 30 years have focused on increasing productivity and only 5% directed towards reducing losses (1)). The solution, however, requires more than an expansion of agricultural production. Improving farm management practices will not only increase the available food for consumption annually by millions of tonnes, but will achieve this without incurring the additional labour, land, materials, resources and biofuel expansion required with increased production. ***A sustainable solution to global food shortages will rely heavily on the preservation of existing food production; a reduced loss of food.***

In 2011, the Food and Agriculture Organization of the United Nations (FAO) reported annual food losses in SSA exceeding 30% of total crop production and representing more than USD$4 billion in value every year (2). It was disturbing to note these loss estimates escalated to much higher levels during the WFP Action Research Trial as farmers stored crops for periods longer than 4 weeks. Even at the lower estimation, these annual food losses far exceed the total amount of international food aid provided each year to SSA countries. Whilst there are numerous contributing factors to these post-harvest losses, the lack of adequate post-harvest management knowledge and equipment to implement sound grain preparation and storage practices amongst low-income farmers are seen to be the principal reasons.

*"A sustainable solution to global food shortages will rely heavily on the **preservation** of existing food production"*

Despite the large number of investigative papers written on the recurring post-harvest food losses in SSA, each providing recommendations as to how to resolve the problem, there is little evidence of the recommendations being acted upon (3). The intention of this trial was to move beyond theoretical discussions, desk studies and test pilots, to provide a medium-scale practical illustration (in multiple geographical regions) of the potential food loss reductions achievable when proven post-harvest management practices from developed countries are implemented in developing countries. With food representing as much as 80% of household spending in SSA and crop production remaining the principal source of family income (4) the impact of eradicating these losses is massive.

The WFP Action Research Trial was designed to complement a three-year inter-agency project with FAO and IFAD to mainstream food loss reduction initiatives. Sponsored by the Swiss Agency for Development and Cooperation, the joint project will provide a global information platform for streamlining best practices in post-harvest management, to which the learning's from the WFP field trials will directly contribute. The trials are also intended to contribute strongly towards the Zero Hunger Challenge, a United Nations global initiative to achieve 100% access to adequate food all year round, sustainable food systems, growth in smallholder productivity and income, and zero loss of food. The trial was also intended to provide the foundation for a Special Operation to implement similar improved post-harvest practices on a larger scale in 2014/15.

2. WFP Action Research Trial

Purpose

The Action Research Trial was intended to incorporate the existing base of knowledge regarding post-harvest handling and storing of grains at farm and local community levels, with a view to raise the profile of the current food losses in SSA and provide clear policy recommendations for a much larger implementation beyond the initial trial countries. The purpose of the trial was to apply proven practices from developed countries, recent learning's from successful trials in other developing regions, and a practical application of the theoretical recommendations from countless research papers on the subject. Information was referenced from a variety of sources including the Food and Agriculture Organization of the United Nations (FAO), the International Fund for Agricultural Development (IFAD), the Swiss Agency for International Development Cooperation (SDC), the World Bank (WB), the U.S. Department of Agriculture (USDA), the African Development Bank (AfDB), the European Union Delegation (EU), The Private Sector Foundation, OXFAM and the International Maize & Wheat Improvement Centre (CIMMYT).

"To apply proven practices from developed countries and a practical illustration of the theoretical recommendations in countless research papers..."

Design

- Two countries to be involved;
  - East SSA (Uganda) and West SSA(Burkina Faso)
- Multiple farming districts to be included in both countries
- Trial to commence in August 2013 and conclude at the end of April 2014
- All aspects of the trial to align with year-end harvest (December 2013)
- Partner with Governments at the central and district levels
- Partner with NGO's, other UN agencies and the private sector
- Link the trial to existing WFP programs wherever possible
- Build on established P4P networks and activities
- Involve 400 low-income farmers (200 families in both countries)
- Include 3 stages of the trial; Training, Equipping and Field Support.
- Monitor results for a 90 day period following storage
  - 3 stages of evaluation – after 30, 60 and 90 days of storage
- Circulate an evaluation paper at the conclusion of the research trial

Objectives

The Action Research Trial aimed to achieve the following objectives in the two selected countries; Uganda and Burkina Faso:

I. provide empirically based evidence to support/reject the theoretical proposition of improved post-harvest management practices resulting in reduced food losses (compared to traditional farming methods);

II. provide empirically based evidence to support/reject the theoretical proposition of utilising new technology for drying, processing and storage of crops will result in significant quantitative and qualitative gains for smallholder farmers (compared to traditional farming methods);

III. reduce the post-harvest food losses of grains, pulses and legumes of participating farmers by over 70%, leading to increased household food security, nutrition and income;

IV. increase the ability of participating low-income farmers to decide on the percentage of their harvest to retain and the timing of when surplus product can be sold;

V. increase the ability of smallholder farmers and small/medium-scale traders to link to quality-oriented markets, thereby increasing the overall marketable grain quantities, individual financial returns and improving the food security of participating communities.

3. Post-Harvest Challenges.

Understanding Post-Harvest Losses

"the rate of crop deterioration is highly influenced by a range of natural factors and individual farming practices"

All crops are naturally subject to biological deterioration, but the rate of deterioration can be highly influenced by a range of factors; starting from individual farming practices and continuing through the chain of interdependent activities between harvest and delivery of food to consumers. In 2011 the World Bank, in association with FAO and NRI, released an important industry study in which they described this continuum as a value chain, where a variety of functions are performed, including harvesting, assembling, drying, threshing, storage, transportation and marketing. Inefficient management practices which allow crops to be unnecessarily exposed to contamination by microorganisms, chemicals, excessive moisture, fluctuating temperature extremes, mechanical damage and ineffective storage practices contribute greatly to food losses (5). Adding to the losses caused by biological deterioration are the serious health risks which arise when damage caused to the external pods of legumes or husks/kernels of grains during pre and post-harvest stages, contribute to aflatoxin contamination and mould growth. For these reasons, a critical step in WFP's Action Research Trial was to educate farmers in understanding the influence of biological and environmental factors (as well as handling practices) on product deterioration and how new technologies and farming practices can improve the quality and safety of their crops.

Food Safety

"food poisoning has become an epidemic … 83% of cancer fatalities in East Asia and Sub-Saharan Africa are due to liver cancer"

Contamination of food is a major problem in SSA. Improving post-harvest management competencies amongst low-income farmers will not only lead to increased crop preservation and food volumes for consumption and trade, it has the potential to directly impact on the health and well-being of all people living in the region. The most serious of food related health risks is the constant threat of food poisoning caused by toxic aflatoxin contamination. Aflatoxins are highly carcinogenic toxins produced by the fungus Aspergillus flavus (6). They are naturally occurring toxic substances, particularly prominent in maize, and a major issue when produce comes into contact with soil during harvesting, threshing and drying. Contamination of crops can also occur after grain has been placed into storage, due to pest infestation and poor storage conditions that lead to accelerated growth rates of Aspergillus fungi. Aflatoxins are difficult to see; they have no smell, feel, or taste and laboratory testing is required to discover its presence (7). The World Health Organization explains aflatoxins are directly associated to liver cancer, impaired immune function, stunted growth in children and are the third leading cause of cancer deaths globally (8). The problem has become so widespread throughout Africa, particularly in the East African region, the poisoning has become an epidemic (9).

Controlling Aflatoxins through good Post-Harvest Management Practices

There is no procedure for eliminating an aflatoxin after it is produced, however limiting or avoiding concentrations can be achieved under proper management. Farmers involved in the trial were shown ways to limit the presence of poisonous aflatoxins on their crops and how contamination can be controlled with careful pre and post harvesting management. ***Pre-harvest*** instructions on land preparation and the correct timing of planting and harvesting to reduce a plants susceptibility to aflatoxins, as well as guidance on controlling moisture content and avoiding direct crop contact with exposed soil was provided. Farmers learned the importance of properly ***drying*** crops to reduce the chance of fungal growth and ways of creating low humidity ***storage*** conditions. The traditional practice of stockpiling dried crops either directly on the floor, in baskets, or in polypropylene sacks on the floor of their houses (due to fear of theft) was strongly advised against, regardless of the duration of storage.

"Smallholder farmers produce 80% of all the food consumed in Sub-Saharan

"Capacity development is critical to achieving lasting change."

4. Three Stage Trial (Overview)

In August 2013, WFP initiated the first of the three stage Action Research Trial by commencing post-harvest management education workshops in Burkina Faso and Uganda. 400 smallholder farmers participated in the training, of which 38% were female. Stages 1 and 2 of the trial were considered preparatory stages where farmers received capacity development support and were then equipped with new handling and storage technology to assist with the upcoming harvest. The third stage of the trial involved follow-up training on farms, field support for crop preparation and positioning of equipment, and close monitoring of the trial outcomes during the three months following harvest.

Stage 1: Capacity Development (Farmer Education)

Capacity development is critical to achieving lasting change. An indispensable component of reducing food losses involves farmer education on ways of improving post-harvest management. The Burkina Faso and Ugandan training workshops consisted of a one day (8 hours) training program and were held in different farming regions in both countries; Bobo-Dioulasso and Ouahigouya (in Burkina Faso); Gulu and Soroti (in Uganda) Participating farmers were selected from registered members of Purchase for Progress (P4P) Farmer Organisations in the respective districts. The training workshops were designed to address inappropriate post-harvest practices; poor crop drying systems (leading to grain rotting and fungal infestation); poor storage systems (resulting in qualitative and quantitative losses from insect and weather spoilage); and food safety issues. Of great benefit to the learning process was the decision to produce all of the training documentation in the local district languages. Although administratively challenging, it removed any potential language barriers and provided a document farmers could share with family members and villagers not attending.

See Illustration 1: training environment for the development workshops.

The capacity development training focused on increasing farmer awareness of key biological and environmental factors during 5 important procedural stages:

HARVESTING:

- Commencing at the right time to avoid losses (too early and crops are moist and grains unfilled / too late and attacks by insects, birds and rodents begin.)
- The susceptibility of crops to pest attacks after reaching physiological maturity (eg: for maize when the moisture content is between 18–25%).
- The impact of weather conditions at the time of harvest (especially in Uganda with bi-modal rainfall areas) causing dampening of crops and leading to mould growth and the risk of aflatoxin contamination.

DRYING:

- Minimising damage by reducing the moisture content below the level required for mould to grow during storage (eg: for maize ≤13%).
- Never allowing grain or cobs to have direct contact with the soil during drying.
- Limiting aflatoxin contamination (using tarpaulins to reduce the risk of contamination and to provide cover when exposed during damp weather.)
- Keeping animals away / Turning of rain / Measuring moisture content.

THRESHING

- Precautions to avoid damage to grain during threshing/shelling
- Options available for threshing grain
- Optimum ways to clean grain before storage

  Note: unthreshed crops are often stored in open cribs, but for the purpose of this trial, all crops were threshed prior to storage.

SOLARISATION

- An additional step to kill all life stages of insect pests prior to storage
- Creating a solar oven (dark plastic base with clear plastic cover) for 1–5 hours.

ON-FARM STORAGE

- Optimising the efficiency of post-harvest storage at the household level (improving on traditional cribs made in a rudimentary manner using timber and soil or polyethylene bag stacked inside the house.)
- Introducing hermetic storage units or new storage technologies to protect crops from insects, rodents, birds, rain, temperature fluctuations.
- Effective methods of controlling moisture and temperature fluctuations for problem-free storage.

Stage 2: Distribution of New Technology Farming Equipment

In addition to improved farming practices, the introduction of new farming equipment was vital to the success of the trial. Given the variances which exist between the two countries (differing climatic conditions, bimodal vs unimodal rainfall areas and crops) it was deemed necessary to trial a range of new-technologies. The training workshops in all districts included demonstrations of various new post-harvest farming equipment and five new storage technologies. Four of the five new storage options employed in the trials provided hermetic, pesticide-free, storage environments (preventing air from entering or leaving the storage unit) and the sixth new storage option involved improvements to traditional storage methods.

Detailed demonstrations regarding the correct handling procedures for the new storage units were provided and all participating farmers received one or more of the new storage units, as well as equipment to assist with drying and solarisation of crops, to use on their farms for the upcoming harvest.

SMALL (<100kg) **Option 1: Super Grain Bags.**
Multi-layer polyethylene storage bags created a highly effective, hermetic storage environment for all crops. Water resistant and completely airtight. Placed inside ordinary storage bags for additional layer of protection.
Life: 2-3 harvests **Price: USD $2.50 – 3.00**

SMALL (<100kg) **Option 2: Zero Fly Bags.**
Insecticide infused polypropylene bags provided a powerful killing action against insects, limiting infestation of the grain within the bag. Not hermetic. Short period where insects were able to survive before contact with inner lining of bag.
Life: 2-3 harvests **Price: USD $1.00 – 1.20**

Medium (100 - 150kg) **Option 3: Plastic Silos.**
Plastic PVC storage units – simple conversion of locally produced liquid storage containers. Created a highly durable storage facility and with some minor adjustments provided an effective hermetic storage environment.
Life: 5-7 Years **Price: USD $20.00 – 36.00**

Med/Lge (540 – 1200+kg) **Option 4: Metal Silos**
Robust units constructed from galvanized iron. Outstanding storage environment for all crops. Water resistant and hermetic. Positioned correctly created an effective non-living storage environment. Long-term solution.
Medium Price: USD $200.00 – 250.00
Life: 20-25 Years **Large Price: USD $260.00 – 320.00**

Large (1000+kg) **Option 5: GrainSafes**
Made of food-grade, UV-resistant flexible PVC. Designed for both indoor and outdoor installations. Able to store all crops for prolonged periods without risk of moisture ingress, pest infestation and fungal growth. Hermetic.
Life: T.B.A **Price: USD $180.00 – 200.00**

Large (1000+kg) **Option 6: Traditional Granaries.**
Improvement to traditional storage. Made of local material and inexpensive to construct. Elevated and rodent protection added, but unable to resolve major post-harvest problems of pest infestation, moisture control and resistance to the elements. Not hermetic.
Price: USD $TB

Illustration 2: New storage options employed in the trial.

What is Hermetic Storage?

"it is impossible for insects and moulds to survive"

When a sealed container does not allow oxygen and water to move between the outside atmosphere and the internally stored grain, the internal build-up of carbon dioxide will eventually reach a level of toxicity where it is impossible for insects and moulds to survive. Such a storage structure is referred to as being hermetic. Oxygen leakage back into the closed system substantially reduces the effectiveness of the high carbon dioxide atmosphere, and careful management during the trial was required to prevent or repair punctures and tears that occurred to containers during storage.

In the case of the metal silos, the process of removing oxygen was achieved more quickly by placing lit candles on a plate inside the silo before closing. The candles would burn until all of the remaining oxygen had been consumed, swiftly creating an uninhabitable environment for pests. There was no de-oxygenation process applied to the plastic silos, PVC safes or super-grain bags. Oxygen depletion occurred naturally, but over a longer period of time which allowed for minor damage to occur during the first week of storage.

A Precedent Worth Following.

WFP benefitted greatly in preparing for the Action Research Trial from the well documented research conducted in Central America by the Swiss Agency for Development and Cooperation. The 'PostCosecha' program was developed in Honduras in the 1980's and scaled up throughout Central Amercia (10). It was a highly successful initiative which greatly advanced post-harvest management practices of local smallholder farmers and lead to extremely high adoption rates of new storage technologies and significant reductions in annual food losses over a period of more than 20 years. Although the Central American program favoured the metal storage units (today there are over 800,000 metal silos ranging in capacity from 0.1 to 3 tonnes being utilised by smallholder farmers) WFP decided to not limit the research trial to only one new storage technology.

Zero Fumigants

WFP decided to not allow the use of phosphine fumigation against pest infestation during the trial. It was felt that if the hermetic storage units were correctly sealed, the oxygen deprived environment would promptly kill any pest, insect or living organism present at the time of storage. Given the official prohibition on farmers using fumigants in certain African countries, the outcome of this decision was viewed as another strong benefit to participating farmers.

"independent monitoring on the physical and biological deterioration of stored grain after 30, 60 and 90 days of storage.

Stage 3: Field Support / Monitoring & Evaluation

Responsibility for managing the third stage of the Action Research Trial, field monitoring and trial evaluations, was given to three independent Farmer Organizations. In Uganda, the Soroti Rural Development Agency (SORUDA) were awarded the contract and in and Burkina Faso the work was managed by Union Provinciale des Professionnels Agricoles du Houet (UPPA-Houet) and l'Association Française de Droit Rural (AFDR). Each organisation assisted in a selection process to decide on which of the 400 farmers who had received the post-harvest management training and new technology storage equipment would comprise the evaluation component of the trial. Our objective was to ensure a balanced representation of small and medium size farming families and the inclusion of all new storage technologies, all major crop varieties and at least 3 sub-counties from each of the farming districts. Our aim was to involve at least 30% of the farmers who had participated in the training; the actual number achieved was 32%.

The first step in the monitoring and trial evaluations was for a representative of the three Farmer Organisations to be present at the time when the storage units (both the new technology units and the traditional storage units) were being filled. This was not only to ensure the training instructions had been correctly followed, but to enable an important moisture content % reading to be taken, as well as accurately record the setting dates, product details and the weight of stored grain. Although this was not achieved on the actual setting date for every farm, it was achieved within the first week for the few farms who were unable to wait for the representative to be present. Following the initial visit, a detailed log of records was created for all districts and used as the base for the following 30, 60 and 90 days inspections.

Stage 3: Monitoring & Evaluation (cont.)

All farmers were requested to not open the storage units between scheduled inspections. After 30 days of storage the first loss measurements were recorded. A representative crop sample (of between 500g and 1000g) was taken from both the traditional and new storage units on each farm. Each sample was inspected for any physical or biological degradation and any damaged product identified was removed. At the conclusion of this process, the weight of the undamaged grain was calculated and the information recorded. The same process was followed on 3 occasions, at 30 day intervals, regardless of the farm size, storage methods or crop variety.

Research Districts

Within the four farming districts selected for the research trial, target study sites were located within small villages in the following sub-counties: Anaka and Goma (Gulu); Aperikira, Alwa, Kuju, Asuret, Orungo and Pingire (Soroti); Farakôba, Baré/Péfrou and Kouakoualé (Bobo-Dioulasso); and Tangaye, Ouahigouya, Thiou, Barga districts (Ouahigouya).

See Illustration 3: farming districts of the Action Research Trial.

"The Action Research Trials benefitted greatly from the active support of the P4P division of WFP in both countries"

Purchase for Progress (P4P)

The Action Research Trials benefitted greatly from the active support of the P4P division of WFP in both countries and the strong relationships already existing within the substantial network of P4P Farmer Organisations. Utilising this established knowledge and resource infrastructure enabled the trial to move more quickly than would have otherwise been possible and build upon the good work already done in the chosen districts by P4P, FAO and IFAD to improve post-harvest systems at the community level. P4P also played a critical role beyond the research trial by providing the participating smallholder farmers with increased opportunities to connect with agricultural markets and receive fair market prices for their surplus product. Without an effective marketing strategy, much of the gains identified in this research trial will be negated.

4. Impact Evaluation / Results

To accurately assess the impact of the Action Research Trial on the farming families involved required WFP to gather detailed measurement of the performance of the new technology farming equipment employed against an alternate; in this case the counterfactual being traditional handling and storage practices. Ultimately, the decision by smallholder farmers in Uganda and Burkina Faso to adopt new post-harvest management practices and purchase new storage technology will depend on the measurable benefits each farmer perceives they will receive from investing in the change. The trial results illustrate such benefits aren't limited to just increasing food for consumption, they also encompass improving household finance, health/well-being, security and status for farming families.

"increased food for consumption ... improved finance, health, security and status for farming families"

Sampling and data collection

The resources and time allocated to this trial restricted all farms being monitored during the 100 day period following the storage of grain. Whilst support was provided to 100% of households for equipment positioning, cleaning and drying of grains, only a third of the total farming families trained participated in the monthly sampling and data collection process.

Calculation of the impact of the new post-harvest management practices and storage technologies was executed using the Count and Weigh method (15) in the following way. In the first stage (pre-storage), all participating farmers were asked to follow the same post-harvest management procedures of transporting, threshing, drying, cleaning and processing their crop. In the second stage of the trial (storage), all participating farmers were asked to take a representative sample (≤ 100kg) of their crop and store it in their traditional storage unit, placing the balance of their crop into one of the new-technology storage units. Storage units were allocated according to the expected volume of grain harvested. The independent variables were the different storage environments on each farm and the dependent variable was the recorded volume of loss after >90 days of storage. The study did not make allowances for individual factors such as gender, literacy, education, land size or crop variety. The data collected was specifically targeted on determining whether new storage technology was more effective than traditional storage units in reducing crop losses (and if so, by what margin?)

Loss percentages relating to discoloration, contamination, reduced nutrition (qualitative losses) were not recorded at farm level, however subsequent laboratory tests for aflatoxins were sought following the trial. The results of these tests were pending at the time of drafting this report.

"The results of the trial were unequivocal!"

Results

The results of the trial were unequivocal! From the very first inspections the difference in crop preservation between the new technology and traditional storage units was immense. On all participating farms, without exception, the new technology enabled farmers to retain over 98% of their harvest, regardless of the crop and regardless of the duration of storage.

The results were the same in both Uganda and Burkina Faso (see Figures 1, 2, 3 & 4). The performance gap only widened as the number of storage days increased. The theoretical benefits expected to be derived from employing new technology for drying, processing and storage of crops were clearly and emphatically proven in the practical results achieved for all participating smallholder farmers.

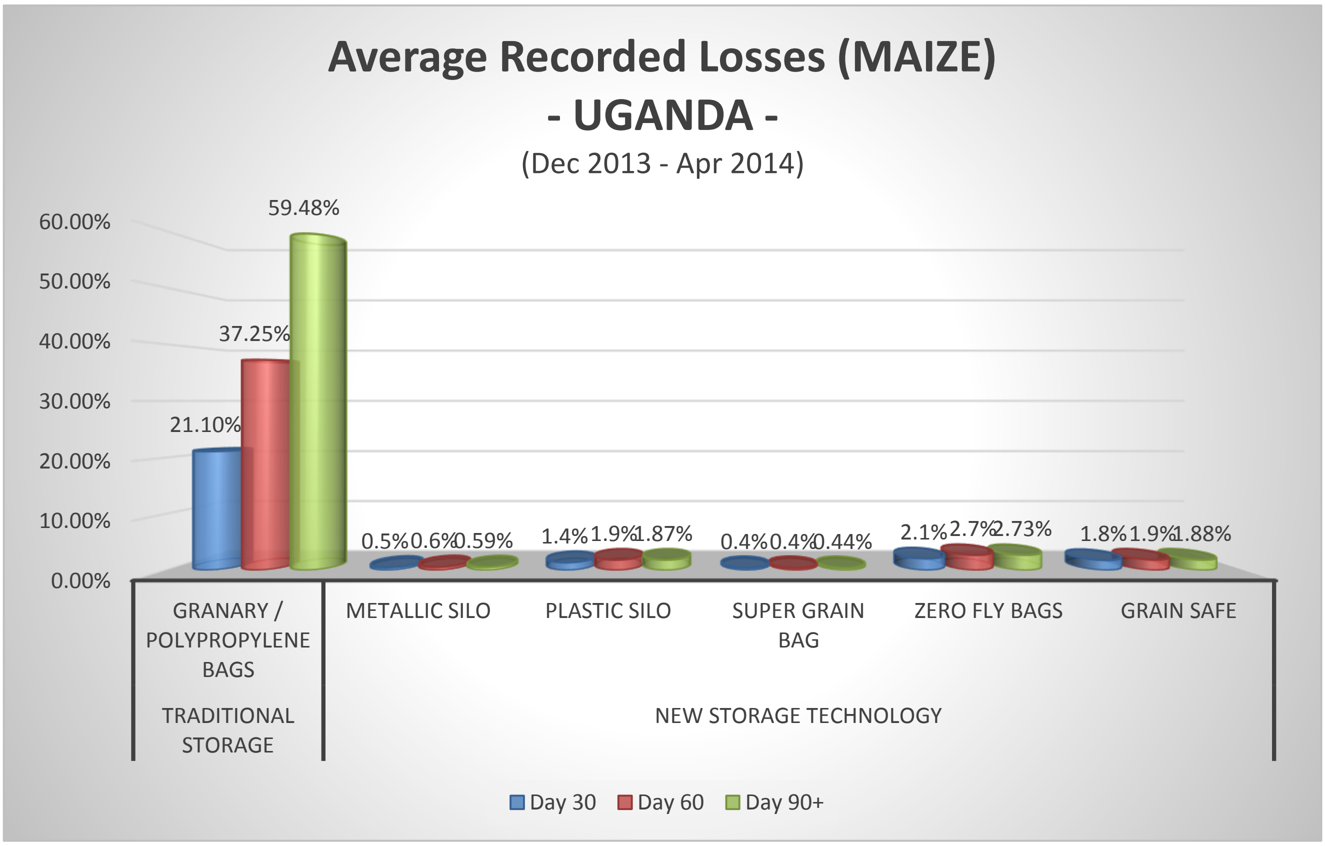

Figure 01: Average Recorded Losses (MAIZE) - UGANDA

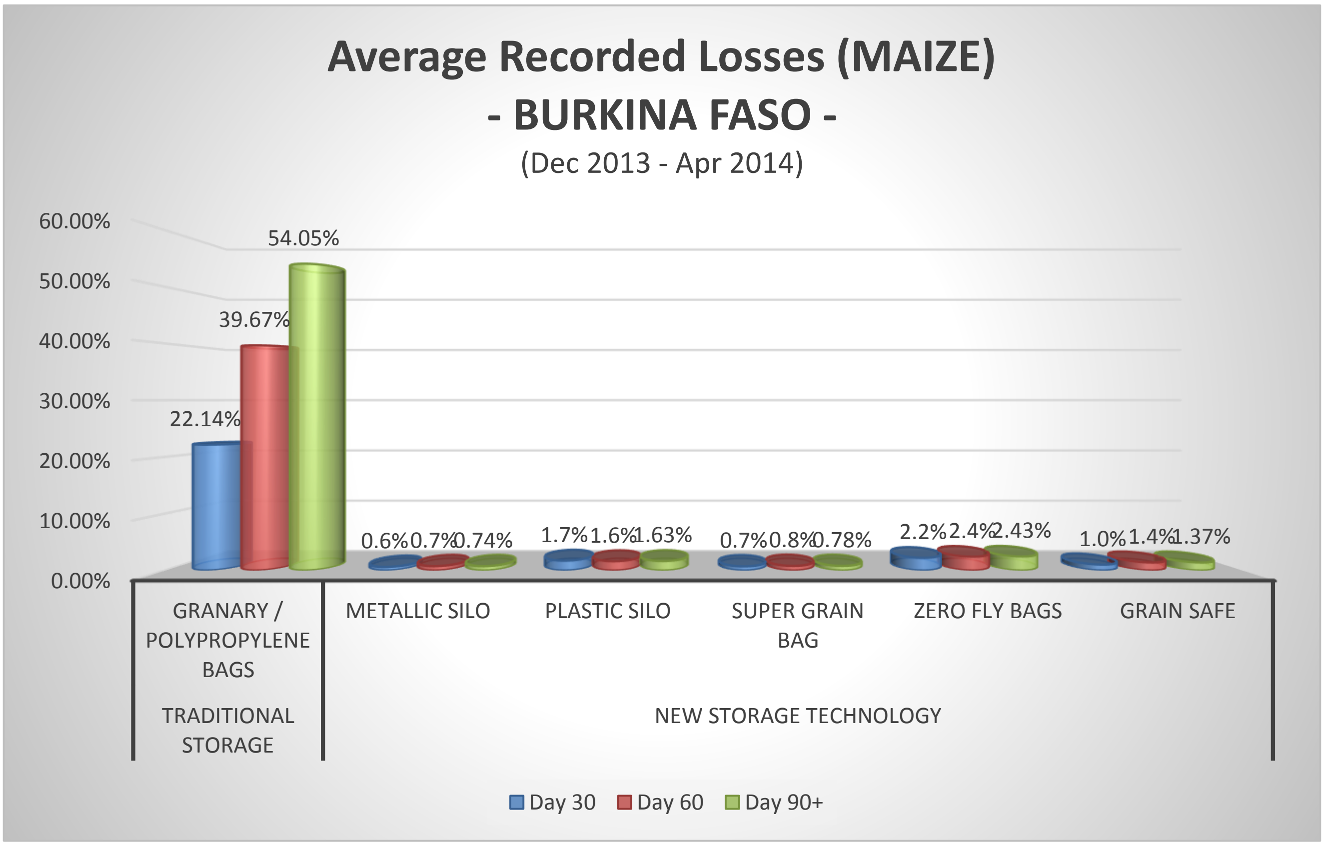

Figure 02: Average Recorded Losses (MAIZE) – BURKINA FASO

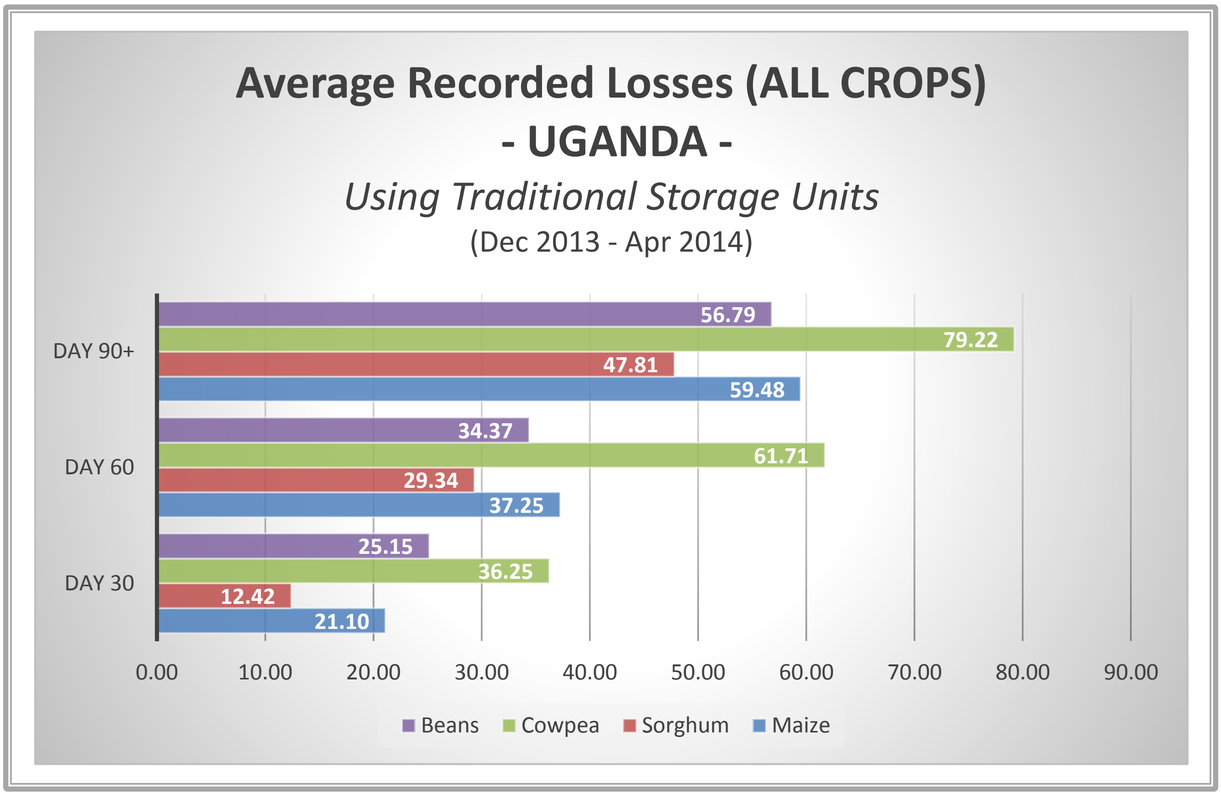

Figure 03: Average Recorded Losses (ALL CROPS) - UGANDA

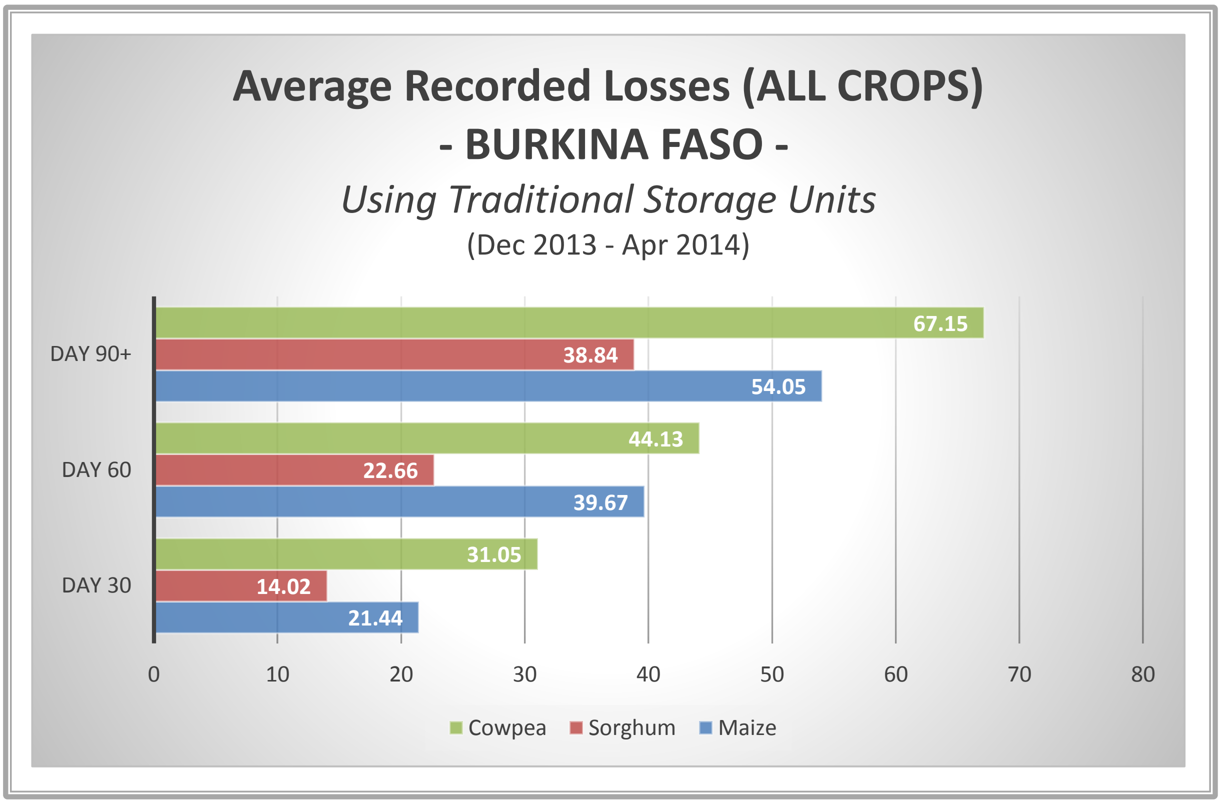

Figure 04: Average Recorded Losses (ALL CROPS) – BURKINA FASO

Performance of the 6 New Storage Options

"All of the new technology storage units proved to be highly effective."

All of the new technology storage units proved to be highly effective. The hermetic units performed marginally better than the treated, non-hermetic storage units, however compared to the biological impact recorded within the traditional non-treated, non-airtight environment, all 5 of the new options were successful. The sixth option, the modified traditional granary, failed to provide measurable improvements against the non-modified units.

SMALL

Option 1: Super Grain Bags.

- Performance (compared to traditional storage) : **Excellent**
- Average Recorded Losses (>90 Days) in Uganda : **0.44%**
- Average Recorded Losses (>90 Days) in B.Faso : **0.78%**
- Positives: Excellent results; Low cost product; Easy to open/close; Hermetic; Easily Transportable.
- Negatives: Limited repeat usages; Environmental issues for disposal (plastic); Unable to provide rodent protection; Currently unable to be produced locally.

Option 2: Zero Fly Bags.

- Performance (compared to traditional storage) : **Very Good**
- Average Recorded Losses (>90 Days) in Uganda : **2.73%**
- Average Recorded Losses (>90 Days) in B.Faso : **2.40%**
- Positives: Very strong performance; Low cost product; Creates an insect free environment for the entire storage area.
- Negatives: Limited repeat usages; Environmental issues for disposal (plastic); Unable to provide rodent protection; Currently unable to be produced locally.

Medium - Large

Option 3: Plastic Silos.

- Performance (compared to traditional storage) : **Very Good**
- Average Recorded Losses (>90 Days) in Uganda : **1.87%**
- Average Recorded Losses (>90 Days) in B.Faso : **1.63%**
- Positives: Very strong performance; Low cost product; Hermetic; Very strong; Rodent and pest proof.
- Negatives: Difficult to deoxgenate when filling; issues with maintaining hermeticity around seals' Environmental issues for disposal (plastic).

Option 4: Metal Silos (medium & large).

- Performance (compared to traditional storage) : **Excellent**
- Average Recorded Losses (>90 Days) in Uganda : **0.59%**
- Average Recorded Losses (>90 Days) in B.Faso : **0.74%**
- Positives: Excellent results; Hermetic; Highly durable; Expected 20+ year life; Rodent & pest proof; Strong protection of stored crops from thieves; Good environmentally.
- Negatives: Expensive; Difficult to fabricate locally; Structural adjustments required to the home prior to storage; Problem with integrity of seals.

Option 5: GrainSafes

- Performance (compared to traditional storage) : **Very Good**
- Average Recorded Losses (>90 Days) in Uganda : **1.88%**
- Average Recorded Losses (>90 Days) in B.Faso : **1.37%**
- Positives: Very strong performance; Watertight; Hermetic; Compact storage for large grain volumes.
- Negatives: Expensive; Unable to provide rodent protection; Currently unable to be produced locally.

Option 6: Improved Traditional Granaries.

- Performance (compared to new technology storage: **Poor**
- Average Recorded Losses (>90 Days) in Uganda : **>30%**
- Average Recorded Losses (>90 Days) in B.Faso : **>30%**
- Positives: Low cost, Durable, Made by locals from local materials.
- Negatives: Non-hermetic; Ineffective against major household pest issues; Performed poorly compared to new storage technologies.

Controlling Moisture Content

As important as it is to ensure crops are correctly dried before storing, the challenge of controlling moisture content does not end there. A small percentage difference in moisture content can make a huge difference in the potential infestation of stored crops by damaging insects. Although the moisture content of crops dried and stored in both the new and traditional storage units were well below the set maximum (≤13%) at the time of filling, the moisture content in the traditional storage units escalated quickly as a result of temperature fluctuations and increasing weevil metabolic activity. The greater the infestation levels, the higher the moisture levels became in the traditional storage units. Adding to this, the bodies of the dead insects provide an excellent substrate for the poisonous fungus Aspergillus flavus to grow, creating the ideal environment for insect feeding and reproduction as well as fungal contamination of the stored crops. Although tests were not conducted in the field for aspergillus flavus contamination, a report written by Beti et al (19) indicates that aflatoxin levels in infested maize increases significantly with increased numbers of contaminated weevils (which carry aflatoxin spores both internally and externally.)

"A small percentage difference in moisture content can make a huge difference in the potential infestation of stored crops by damaging insects."

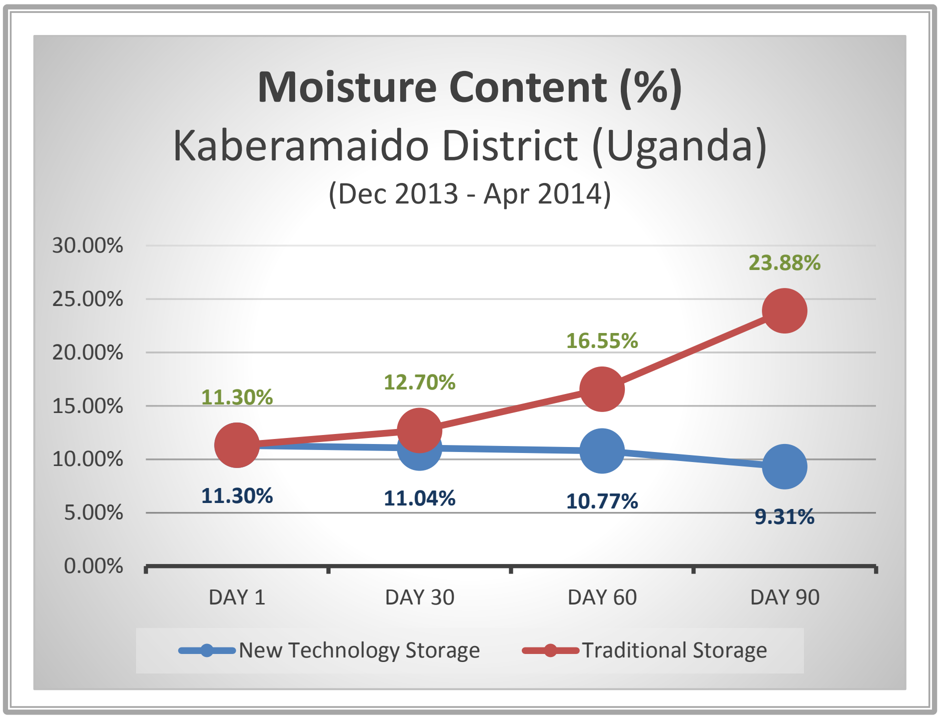

Figure 05: Increasing Moisture Content %

Outcomes vs. Objectives

Remaining cognisant of the trial objectives was critical throughout the trial. Carefully measuring the outcomes of all aspects of the three trial stages was not only important to assist donors in understanding the contribution and effect of their investments, but to also support interested parties in other developing regions considering similar post-harvest interventions. The trial objectives (refer page 4) were very clear in their intent and remained the primary focus of attention throughout the trial.

- Empirical evidence was produced to support improving post-harvest management practices and employing new technology for drying, processing and storage of crops;
- Post-harvest losses of crops were reduced by well over the targeted 70%;
- Farmers had the previously unknown luxury of choosing when surplus product could be sold; and
- P4P assisted in linking the smallholder farmers to quality-oriented markets.

Economic Incentives in PHL Reductions

*"this represents a potential **64% gain** in household income."*

For low-income farmers to adopt new post-harvest management practices and purchase new storage technology, they must be confident of measurable returns on their investment. Through the Action Research Trial, WFP, P4P and, most importantly, the farmers involved, were able to quickly assess the financial benefits of having increased control over the timing of when product is sold and the advantages of retaining a higher % of the total harvest. A smallholder farmer harvesting maize in Uganda in December 2013, would normally attempt to sell the majority of his crop within a few weeks of harvest to minimise the expected losses. This farmer selling maize in the early weeks of January 2014 would have received somewhere in the range of UGX 480 and UGX 520 per kg. By utilising the new storage technology and taking his crop to market three months later (April 2014) he received somewhere in the range of UGX 760 and UGX 820. This represents a potential 64% gain in household income for this family. It is worth noting, there is another level of farmer who traditionally has minimal excess grain beyond the family's consumption requirements, who utilising the new storage technologies will have the option of trading (at a time of their choosing) surplus grain created through reduced post-harvest losses. To these families, this would represent a 100% gain in household income.

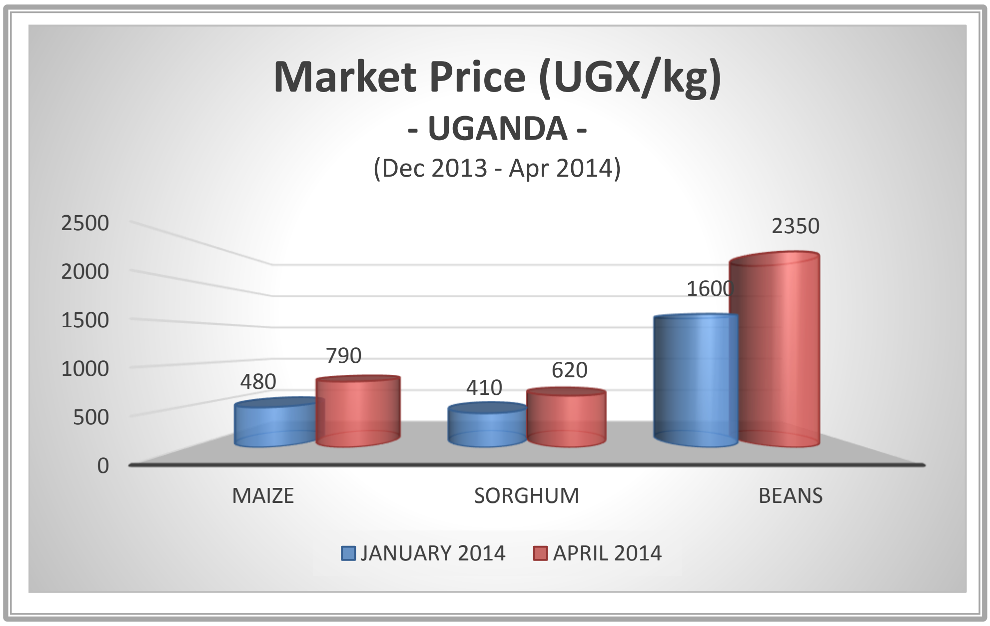

Figure 06: Market Prices (Uganda)

Financial Independence (***family***, ***gender*** and ***community*** benefits)

The trial provided WFP with enough empirical information to convincingly determine smallholder farmers in Uganda and Burkina Faso will experience significantly higher improvements in their well-being should they choose to adopt the new post-harvest management procedures. Increased preservation of crops, improved marketing of harvests and a reduced need to buy food, all lead to greater financial independence for low-income farmers. Greater financial freedom can also lead to better health and education for the children of these farmers and potentially help to address gender inequalities issues (women's workload was reportedly reduced due to new storage units eliminating the timely daily process of cleaning and shelling cereals). Farmers having increased control regarding the timing of crop sales also has an indirect effect on other households. Because the supply of food from local producers will no longer be limited to harvest periods, price peaks on local markets can be expected to decline. Thus, by adopting new-technology storage techniques, farmers would contribute to less variable prices (13), more affordable food for poor households and greater consistency of food availability. In summary, an overall increase in food security.

Grain storage, be it on a large scale or using effective decentralised household storage, serves an important role in stabilizing market prices, by taking the produce off market during peak season and releasing it back when the grain is in short supply (14). Increasing the number of effective household storage units in each farming district therefore becomes an important aspect of regional food security and rural livelihoods since it ensures continuous stable supply of food, better farm incomes and significantly increases the 'bank' of safely stored grain in each region (even more critical in countries such as Burkina Faso with unimodal rainfall distribution and frequent periods of extended drought.)

5. Conclusion

"Food loss is a solvable problem in sub-Saharan Africa... determined leadership is required"

From numerous different perspectives, the WFP Action Research Trial has been an important and highly worthwhile initiative. It has clearly illustrated the benefits of improved post-harvest management procedures and the significant advantages new storage technology provides low-income farmers over traditional farming practices in Uganda and Burkina Faso. The reaction of farmers and clarity of results have been powerful. For every farmer involved, the new technology outperformed traditional practices. Despite crop loss %'s of traditional storage far exceeding reported national averages, the alternative new storage environments recorded nearly 0% losses over a 90+ day period. The positive, measurable impacts for these farming families are undeniable. To reduce food losses by >98% is a wonderful outcome. Add to this increased household incomes, improved family well-being (through increased nutrition and reduced exposure to food contaminations) and increased surplus of quality food for consumption and there is a very strong argument for implementing the same procedures on a much larger scale.

"To reduce food losses by >98% is an extraordinary outcome, but when combined with the additional benefits ...

The World Food Programme makes no claim to originality in any part of this Action Research Trial. No aspect of the three stages of capacity development, equipping of farmers and field support, were discovered or created by WFP. No equipment or procedures employed in the trial are new. Rather than inventing, WFP put into effect proven farming practices from developed countries and well-researched ideas from other notable organisations and learning institutions. In countries where food represents as much as 80% of household spending and crop production remains the principal source of income for most households, food preservation must share the highest level of priority in Government policy making in these countries.

Food loss is a solvable problem in sub-Saharan Africa. The degree to which the current concerns can be eliminated will depend largely on the supporting policies of the incumbent Governments and the willingness of corroborative agencies and the global community to assist with implementing the proven solutions over the coming years. We may not achieve the declaration of the 1996 World Food Summit to halve the proportion of chronically undernourished people in the world by 2015, however there are some very clear obligations we must embrace to ensure the food losses contributing to the reported 1 billion people going hungry every day are eradicated. On the strength of the results of this Action Research Trial, WFP intends to lead an ambitious Special Operation, commencing in 2014, to increase the number of farmers able to benefit from these improved technologies and farming practices in and beyond the two trial countries.

"WFP intends to lead an ambitious Special Operation ..."

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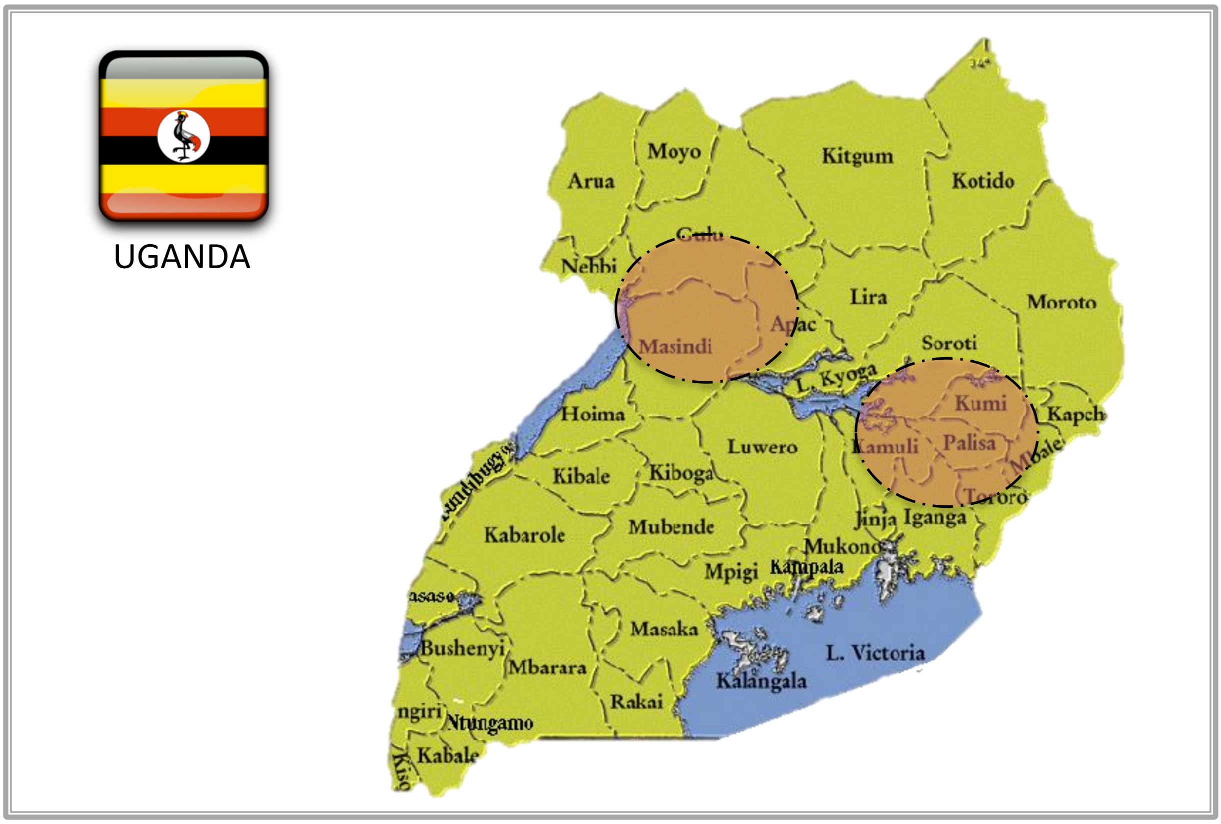


Illustration 3: Selected farming districts for the WFP Action Research Trial.

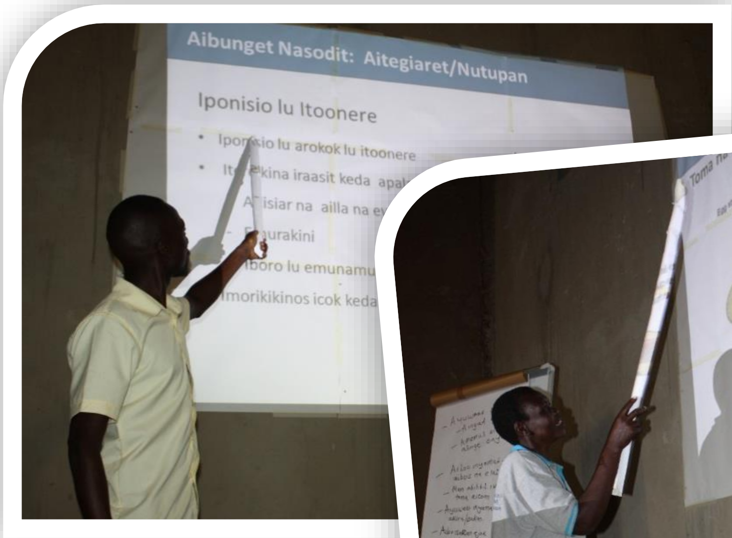
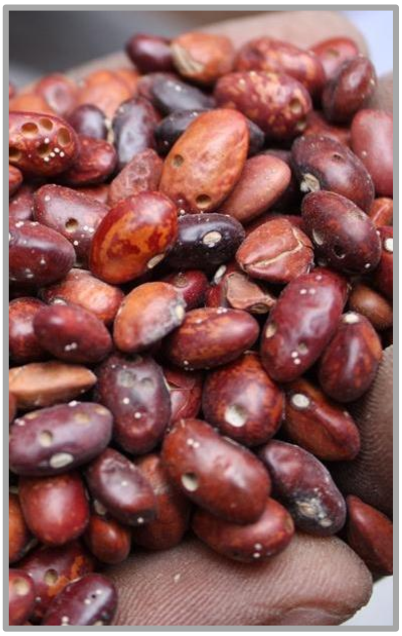
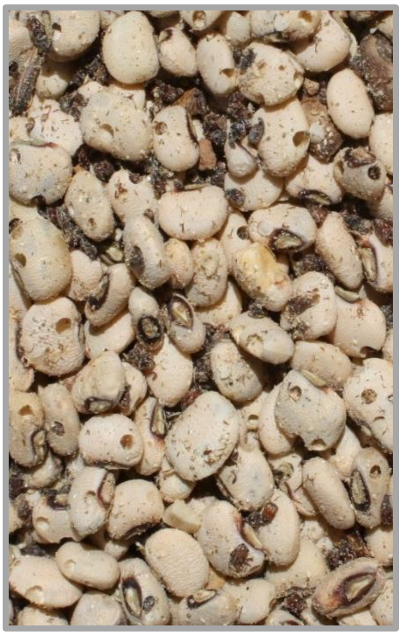


Illustration 4: Capacity Development / Farmer Training Workshops

Illustration 5: Improved household storage units.





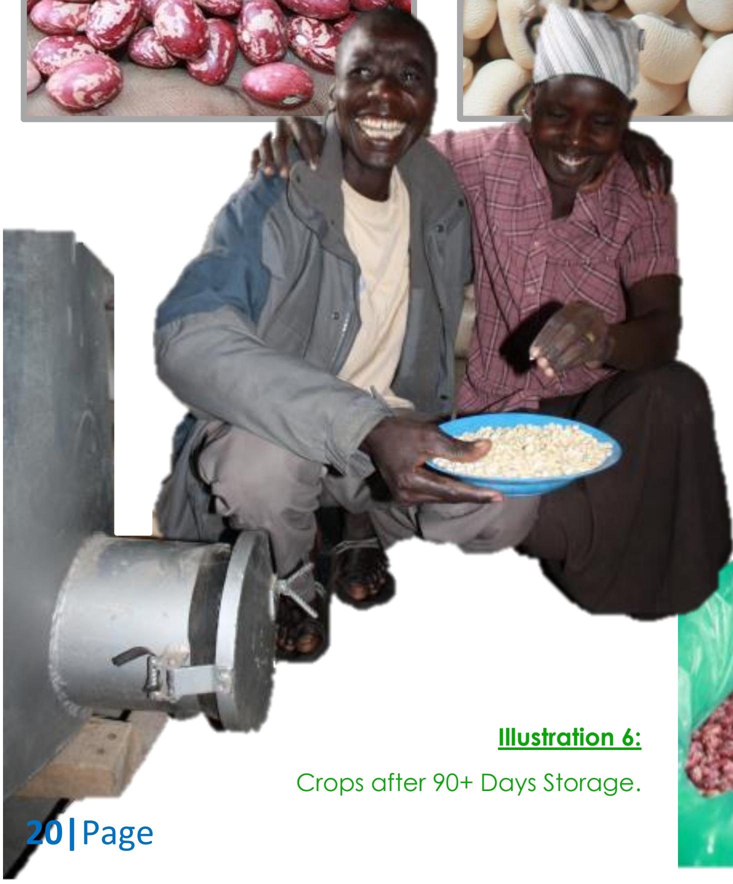


Illustration 6:

Crops after 90+ Days Storage.

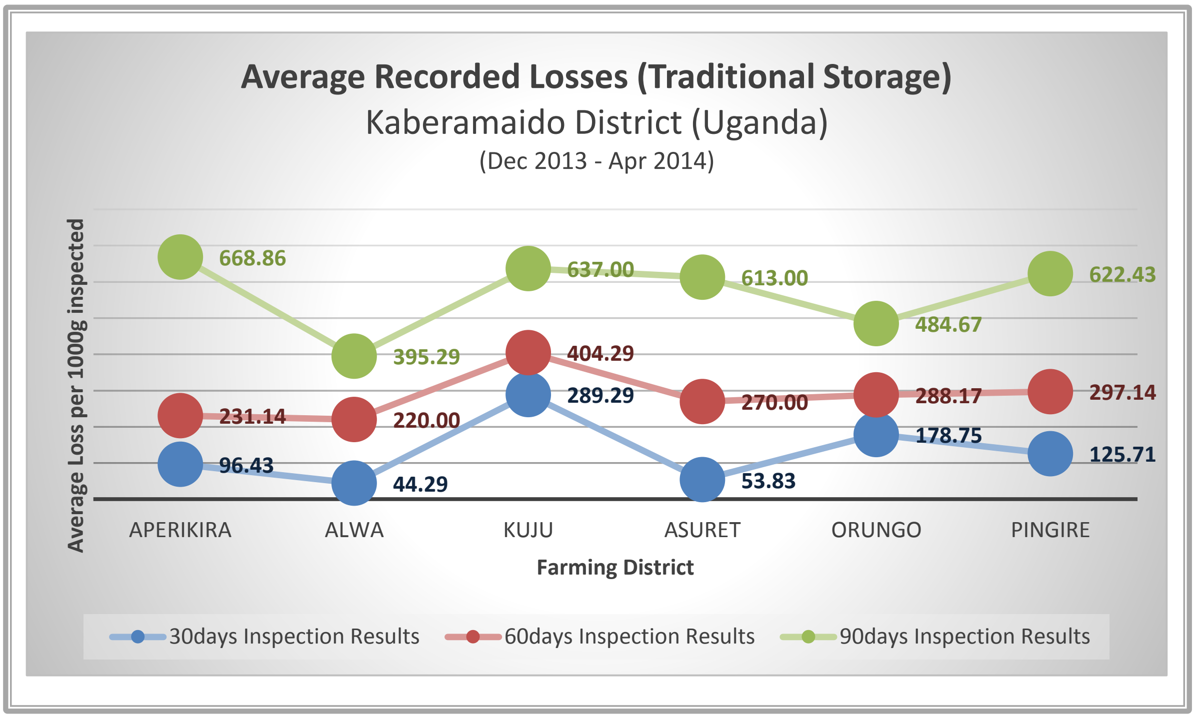


Figure 07: Example of District Average Recorded Losses

6. References and Literature Consulted

(1) Kader (2005); Kader and Roller (2004); WFLO (2010)

(2) FAO (2011); The Global Food Losses report.

(3) James Joughin (2012); The Maize Industry in Uganda.

(4) Gitonga et al. (2012); Can metal silo technology offer solution to grain storage and food security problem in developing countries.

(5) Missing Food (2011); World Bank / FAO

(6) Lawley (2013); Food Safety Watch

(7) IFPRI (2010) Aflatoxins in Mali

(8) WHO (2008); World Health Statistics.

(9) USAID; DANYA (2013); Aflatoxin: A Synthesis of the Research in Health, Agriculture and Trade

(10) Fischler (2011); 5 Year Ex-Post Impact Study Postcosecha

(11) Boxall (2002); Damage and loss caused by the large grain borer

(12) Beti et al (1995); Effects of maize weevils on production of aflatoxin B1 by Aspergillus flavus in stored corn.

(13) Bokusheva et al. (2012); Factors determining the adoption and impact of a postharvest storage technology.

(14) Proctor (1994); Grain storage techniques. Evolution and trends in developing countries.