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MODERN POST-HARVEST LOSS MANAGEMENT TECHNOLOGIES FOR STAPLE GRAINS BOOST RURAL FOOD SECURITY AND INCOMES IN BENIN

Introduction

Attainment of food, income and nutrition security in Sub-Saharan Africa remains curtailed by the inability of food producers, consumers, their national governments and other food value chain players to prevent staple food losses after harvest. 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). In Benin post-harvest loss (PHL) on maize is estimated at between 15 and 30% owing to precarious and archaic storage technologies. Food deficits are high in most areas of the country averaging 28.3% of food production (maize, yams, cassava, beans and groundnuts).

Post-Harvest Losses Reduce Returns to Investment in Agricultural Productivity Enhancement in Africa

Although some marked increases 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 because of costly losses, increased labour requirements, inappropriate facilities and poor product quality resulting in poor harvesting and handling systems.

Post-Harvest Losses in Staple Grains Are High and Costly but Avoidable in Benin

In Benin, PHL for maize are estimated at between 15-30% for all provinces while the ones for beans and cowpeas range between 29% and 30.6%. These losses occur from the time the crop has matured in the field, continue during the harvest, handling and transportation from the field to storage facilities, during storage, and when the food is taken from storage for processing or preparation until the food reaches the table. Significant wastage of food also occurs at the table.

The losses are avoidable through greater awareness among value chain actors, improved access to resources to adopt improved PHLM technologies and increased availability of affordable and high quality technologies. Improving methods of handling and transportation of food and better food preparation and utilization methods and practices is another way of reducing losses.

Metal Silo in use
Source: *http://maize.org/post-harvest-losses/*

Economic and Social Implications of Post-Harvest Losses

There are about 450,000 agricultural producers in Benin, dominated by small-scale farming. The production system is mainly extensive, characterized by low productivity and under-developed markets. The average area cultivated per household is 0.5 hectares in the southern region and 2 hectares in the north. The monetary value of PHL in staple grain crops is significant in Benin. Using 2015 production

totals of 1,286,059 tonnes for maize, 15-30% loss rate, and US$208.95 (XOF 126,833.33) per tonne at harvest, the value of crop loss for maize comes to between US$40.3 - 80.6 million per year, nationally. For beans with a production level of 99,106 tonnes in 2015, and price per tonne at harvest of US$571.80, losses come to between US$16.43 - 17.34 million, while for cowpeas with an output of 139,909 tonnes is of the order of US$18.47 million.

The combination of large quantities of post-harvest staple food losses, low yields and rapid population growth (of 2.75% per annum in 2016) result in high food deficits in most areas of the country averaging 28.3% of food production (maize, yams, cassava, beans and groundnuts). According to WFP, more than one third of families in Benin are food insecure annually.

Statistics on food imports for 2015 show that Benin imports US$533 million worth of rice annually (2015 actuals). Agricultural production is limited by factors including a lack of modern farming technology, inefficient and insufficient use of fertilizer, insecticides and seeds (inputs), and inadequate conditions for storing, preserving and processing food. Rural credit is in short supply.

Acute malnutrition affects 16 percent of children under 5, and 44.6 percent of the same age group suffer from chronic malnutrition. Due to these food shortages and poverty, in some rural districts, school enrolment rates are below 50 percent.

Due to sub-optimal storage infrastructure and the pressure to meet immediate cash needs a significant proportion of staple food grains produced is sold soon after harvest at low prices and shortages on the local market surface later during the lean season. Women carry the brunt of the burden for searching for food to supplement food requirements of their families. This compromises the quality of child care.

Women who provide most of the labour for farming are also deprived of opportunities to earn more income from their produce as they lose a significant share of their output to pests and disease, moisture-related spoilage, or aflatoxin contamination. Children go to school on an empty stomach or are forced to abscond school in search of casual work to augment family food supplies. Furthermore, post-harvest losses reduce the supply of high quality raw materials essential for optimal functioning of the agricultural value-chain and income maximization by actors along the chain.

A recent study conducted to estimate the costs and benefits of using hermetic bags and metal silos for storage of maize, beans and cow peas in Benin showed that farmers stand to reap significant benefits by investing in these technologies, depending on their degree of market participation and their current marketing behaviour.

The study used the following methodology. 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 based on the expected lifespans of the metal silos and hermetic bags (20 years and 2 years, respectively). 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, standardising the module (quantity stored) as 500kg. These indicators were net present value (NPV) (of the net cash flows), internal rate of return, benefit-to-cost ratio, payback period, and breakeven point.

Benefits of Investing in PHLM

Maize and the Hermetic Bag and Metal Silo

- A farmer or trader who produces (or buys) and sells maize at harvest needs not invest in hermetic bags to store and defer selling to the lean season because the price increase is not enough to offset the investment cost in hermetic bags. However, if they invest in metal silos to store their maize they stand to increase their income over 20 years by 31 percent. The results apply to a farmer (or trader) who stores 500 kg of maize per year but 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.
- The cost-benefit analysis results also show that a farmer or trader who has a culture of producing or buying and storing for later sale or consumption can increase his or her income by 95 percent if they invest in the use of hermetic bag technology over a 20-year period. He or she can

recover the total investment cost for 20 years within 7 years. The returns are even higher for a farmer who has this practice of storing and selling later if that farmer invests in metal silos rather than hermetic bags. For every XOF1.00 invested in metal silo, the farmer stands to earn XOF3.87 more income. Such farmers can breakeven even with about half of the benefit (that is, even those who lose only 7.8 percent instead of 15-30 percent 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.

- The findings also 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 maize farmers and traders who will adopt and use it for shorter periods than the projected lifespan of the silos because the payback period is very short (2 to 4 years depending on assumptions of risk).

Beans and Hermetic Bags

- Farmers or traders who invest in hermetic bags for storage of beans stand to benefit more than those who store maize in them. For every XOF1.00 invested in the hermetic bag technology over 20 years, the farmer or trader gains an additional XOF2.39 in income if they store beans in them and defer use or sale of the beans to the lean season (instead of soon after harvest). For farmers or traders who were storing beans for sale or use later in the season and were using non-improved PHLM technologies, when they switch to hermetic bags, they stand to earn an additional income of XOF10.62 for every XOF1.00 invested in purchasing and using the bags.

Beans and the Metal Silo

- Even when benefits are reduced to 80 percent of the current level, the investment remains viable for beans with a payback period of 2 years and return of XOF8.10 per XOF1.00 invested in the improved PHLM technology. 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.

Cowpeas and the Hermetic Bag

- Similar results were obtained for cowpeas. For a farmer or trader who has no tradition of storing, but sells immediately after harvest, an investment in hermetic bag technology to store and sell later would leave the farmer/trader better off, with an additional income of XOF46,866.00 per 500 kg stored annually for 20 years. The farmer would stand to earn XOF1.61 per every XOF1.00 invested. 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.

- A farmer who is able to produce and store cow peas but has a practice of selling his crop at harvest time, will stand to benefit if he/she changed the practice to storing using hermetic bags and selling later in the season. The value of the additional benefits of the technology outweighs the incremental cost of the improved storage technology (hermetic bags) by about three and a half times.

- For the one who invests in hermetic technology and already has a practice of storing cowpeas for use or sale in the lean season and continues this practice after switching the technology to the improved bags, the incremental benefits are much higher, as they earn an addition income of XOF5.60 per every XOF1.00 invested in this improved PHLM technology.

- Further analysis of returns to investment in hermetic technologies for cowpea farmers shows that breakeven point can be reached with just 18 percent 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 further revealed that the incremental benefits will always exceed the incremental costs by a factor of at least 300 percent (Benefit-Cost Ratio (BCR) ranges from 4.48 to 6.73).

- The returns for cowpeas 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 but the metal silo technology should be the eventual graduation pathway for farmers who are doing well in reducing PHL.

Cowpeas and the Metal Silo

- A farmer who invest in metal silo to store cowpeas and change their practice from selling at harvest to selling later in the consumption season stand to earn XOF2.20 per XOF1.00 used to acquire the technology, while those who maintain their practice of selling in the lean season but switch to metal silo storage infrastructure would benefit even more by earning an additional XOF7.76 per XOF1.00 invested. The costs over 20 years will be recouped in the first year or two of adoption of the metal silo.

- If incremental income from improved storage of maize, beans and cowpeas is aggregated, the study estimates that 3.19 percent of agricultural GDP will be preserved through PHLM investments every year. The agricultural GDP preserved from storage of maize, beans and cowpeas can contribute to growth in the other sectors that are closely integrated with agriculture.

Challenges Confronting Farmers and Other Value Chain Actors

With the high post-harvest losses staple food grain supplies only last for a few months after harvest, after which the food deteriorates in quality due to poor storage conditions. Most small-scale farmers especially in the Alibori, Borgou, Donga, Atacora, Collines, Zou, Couffo, and Mono Plateau provinces that use traditional PHLM technologies for maize and beans, such as jar, gourd and clay granaries will be forced to sell most of their crop within three months of harvest in order to avoid physical losses. The large cereal harvests in the Alibori, Atocara and Borgou Provinces contribute to the glut on the local markets at harvest time thereby depressing prices. Unscrupulous traders also take advantage of the desperation of poor smallholder farmers to sell and earn an income to meet immediate household needs. Such farmers have little internal organization to wield sufficient power for price arbitrage. Farmers who sell their crops at harvest time lose the opportunity to sell at higher prices later in the year. For maize the price at harvest time is equivalent to US$208.95 but rises sharply (by 50%) to US$315.90 during the lean season. For beans prices increase from about XOF347,083.30 per tonne to XOF512,500 during the marketing season.

The prices rise during the lean season when commodities become scarce on the local markets partly due to post-harvest losses that will have reduced the quantities saleable. Both traders and consumers (including farmers) will access the same commodities which they would have sold cheaply earlier in the year at much higher prices.

While a wide array of modern and improved PHLM technologies have been introduced to smallholder farmers in Benin through various initiatives of the Government, donor agencies, NGOs, universities (e.g., Purdue University), farmer organizations, the private sector and local governments, in a number of provinces, adoption rates remain subdued at around 40-69% for hermetic bags due to non-availability and limited awareness by farmers and traders on their existence and where to purchase them, and 70% for metal granaries or tanks due to high cost, beyond the reach of smallholder farmers. Both metal silos which cost between US$22 (for silo with capacity of 30 kg) to $116.00 (for 1,000 kg silo) and hermetic bags are costly to farmers.

Hermetic bags are also costly (US$3.21 per bag that stores 50 kg weight of crop) and have a short lifespan (2 years) which implies that the bags have to be replaced with new ones every second year in order to maintain effectiveness of storage.

Low literacy, inadequate access to information sources and suppressed and variable farmer incomes dependent on rain-fed agriculture affects demand for metal silos. The income is inadequate to provide the needed capital to meet the initial investment costs incurred by farmers to adopt the new technologies that are more effective in preventing crop damage from postharvest insect pests and resultant quantitative losses of food and monetary value.

Untimely supply of hermetic bags is a major barrier affecting adoption by smallholder farmers. Awareness among private sector partners has been limited and this has compounded supply gaps. Efforts are therefore needed to help them understand the technology, quality requirements, potential market, and challenges in reaching smallholder farmers with a new product.

Due to these and other challenges, the use of archaic technology for storage is keeping a large section of smallholder farmers in Benin in a poverty trap characterized by low productivity, high post-harvest losses, low incomes, food deficits, and low innovation potential.

Some of the metal silos that are manufactured are of poor quality as a result of raw materials that are of inferior quality and artisans that lack the requisite skills, tools and financial resources to procure high quality metal.

Micro-finance facilities which could be used by farmers to secure the much-needed capital to purchase hermetic bags and metal silos are not widely available in rural Benin. Access to finance by smallholder farmers in Benin is particularly curtailed by low viability of subsistence and semi-subsistence farming. A large proportion of smallholder farmers are engaged in crop production with low investment in improved agronomy, resulting in low productivity, and low marketable surplus (hence returns). They fail to raise the money needed to invest in innovations. This situation is often described as low equilibrium poverty trap (Barrett and Swallow, 2006; Barrett, 2008).

Agriculture-lending banks and MFIs have a limited branch network and outreach potential due to high transaction costs which they face in lending to smallholder farmers and small traders. These transaction costs are driven by under-developed transport and ICT infrastructure, and a compromised credit culture, whereby farmers have become used to handouts from the Government or credit schemes that were not strict on loan recovery.

Financial instruments such as the warehouse receipt system which offer opportunities for farmers to store maize safely, whilst having a facility to access credit to invest in improved post-harvest technologies and blending financial instruments which reduce the risk of commercial banks and MFIs lending to smallholder farmers and traders, are innovative but not yet fully developed or widely understood among stakeholders at policy and programme levels in Benin.

Challenges in market participation also affect innovation among farmers. Farmers do not have adequate access to information on demand and supply, prices, and quality of agricultural inputs and outputs and this encourages opportunistic behavior among traders. Therefore, most smallholders are price takers and face low prices for their produce yet being exposed to high prices for inputs. Weakness of farmers' organizations which affect aggregation potential and farmer voice on prices due to inadequate information on market conditions causes farmers to sell their produce at farm gate or local markets that offer low prices. The low output prices and the high input prices dampen operating margins and hence incentives to commercialize production and invest in modern technologies for storage.

For this reason, smallholder farmers are perceived as a high-risk group to lend depositors funds to by the banks and MFIs.

The focus of agricultural extension services on increasing productivity with relatively less attention being given to post-harvest loss management remains a big policy and programming gap not only for Benin but Africa as a whole. Global evidence has shown that a dollar invested in improvement of yields produces much less return (1%) than that spent on reducing post-harvest losses (15%). However, investments in yields have historically had a wider reach, been more popular with the electorate and had a better appeal in messaging than those aimed at reducing post-harvest losses. Changing this perception requires significant investments in demonstrating the differential in economic gains from investing in yield improvement and reducing losses.

In addition, most public-sector initiatives were geared towards serving the farmer directly and did not fully integrate (at times crowded out) the private sector. Promoting innovation in PHLM will require a more central role of the private sector not only in manufacturing and distribution but also social marketing reaching out to farmers to change their PHLM practices (and technologies in use) for better systems.

Another major challenge hindering wider promotion and adoption of improved PHLM technologies in Benin has historically been the policy vacuum on PHLM in general. 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, commercialization, 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 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, 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.

In addition, while a lot of research on PHLM has been done, it has been focused mainly on storage neglecting other steps of the value chain. The stakeholders interviewed in the study by Chisvo and Jaka (2017) 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.

Adoption of improved PHLM technologies is also negatively affected by a general lack of training institutions for PHLM, a weak government extension services system on the subject of PHL.

Metal Silo integrated into traditional PHM

Recommendations

Policy Recommendations

1. Government, development partners, civil society and the private sector should increase investment in post-harvest loss management technologies and give higher priority to awareness promotion, research and technology transfer on PHLM than previously done in agricultural growth promotion programmes and national budgets. Reducing post-harvest losses should be given equal if not more weight than other investments in the short-term given the 15 times higher returns to PHLM investments than those in agricultural productivity.

2. 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.

3. To sustainably increase the rate of adoption of hermetic bags and metal silos by small-scale farmers, medium-scale farmers, traders, and agro-industries, government and development agencies should strengthen the supply chain of these storage technologies 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 or domestic taxes on the metals, where applicable. The price of hermetic bags to the farmer should not exceed XOF 1,500 as it will be non-viable to farmers or traders storing maize. The lower the price of the hermetic bag the more likely that it will be that the technology will be viable even for farmers or users who incur lower PHL even without them.

Technical Recommendations

4. PHLM technology promotion programmes must be tailored to the specific context of the farmer or trader in terms of the viability of the technology. For example, they should not dissuade maize farmers who are already prudent to sell their surplus grain immediately after harvest as incremental benefits of switching to hermetic storage and selling later in the season are not justified by the economics of storing maize in hermetic bags at current market prices. They should target 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 percent of their harvest to pest and other forms of damage in storage.

5. Government 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 4 years. Those who do not have this culture of storing would need to use

the silo for at least 9 to 12 years, otherwise the investment will not be worthwhile.

6. Given the payback periods for investments in PHLM technologies of 2 to 7 years, PHLM promotion programs should be medium to long term in duration (4-7 years) with shorter periods for silos and longer periods for hermetic bags. Seeing as 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, holding all other variables constant.

7. 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-span (2 years), they are more expensive for resource-poor maize farmers in the longer-term.

8. Programmes seeking to reduce post-harvest losses can promote adoption of the hermetic bag technology for bean and cowpea producers and traders including targeting those who are selling immediately after harvest as the investment will be viable. The benefits of improved technology outweigh the incremental costs by a wide margin. The investment can recover the costs as much as 5-7 times during the 20 years of investment.

9. Given that returns to investment in hermetic bags for storage of beans are superior to those of maize by as much as 83 percent, and quantities produced and stored by farmers are lower for beans than maize, government and development agencies could consider promoting hermetic bags more for the storage of beans as opposed to maize. However, 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.

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The Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN) is an autonomous regional stakeholder driven policy research, analysis and implementation network that was formally established by Ministers of Agriculture from Eastern and Southern Africa in 1997. FANRPAN was borne out of the need for comprehensive policies and strategies required to resuscitate agriculture. FANRPAN is mandated to work in all African countries and currently has activities in 17 countries namely Angola, Benin, Botswana, Democratic Republic of Congo, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe.

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