A Report on Assessment of Maize Postharvest Losses in Northern Ghana

December 8-19, 2014

A Summary Report Prepared by

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Provided in partial fulfillment of a Grant with

USAID

Submitted April 24, 2015

TABLE OF CONTENTS

Overview

A two-week in-country assessment of postharvest losses (PHL) in the Ghana maize value chain was conducted in Northern Ghana by seven experts in communications and agricultural education, post-harvest engineering technology, and stored-products protection from four different U.S. Land-Grant Universities (Oklahoma State University, Kansas State University, University of Kentucky, and University of Illinois at Urbana-Champaign); the USDA-ARS Center for Grain and Animal Health Research (CGAHR); Kwame Nkrumah University of Science and Technology (KNUST); and University of Ghana – referred to hereafter as 'Team' (Appendix A). The assessment covered the period December 8-19, 2014 (in country).

The Team visited stakeholders in Accra and traveled to Northern Ghana (Northern Region and Upper West Region), a major maize growing part of Ghana. During visits to these areas, the Team acquired knowledge on postharvest losses that occur along the value chain. Stages of the maize postharvest system such as harvesting, pre-drying in the field, threshing (shelling), drying, cleaning, bagging, and storage were discussed. Additionally, the capacity and operations of grain storage systems in these regions and maize losses that occur in them were assessed. The Team observed current grain handling and pest management tactics, stored-product insect activity, drying systems, and post-harvest grain losses in small-, medium-, and large-scale storage warehouses. The ultimate goal was to identify researchable areas in PHL that are perceived "critical control points" where breakthroughs in research and development could lead to significant improvements in grain quality and food security. Important stakeholders in the maize value chain such as nucleus farmer aggregators, government and parastatal entities, the private sector, non-governmental institutions, research institutions, universities, etc. were visited as part of the second PHL assessment. Specific activities of the Team are listed in Appendix B, Table 1. Appendix C, Figures 2-8 highlight some of the activities of the team.

A Summary of Major Findings of the PHL Assessment of the Maize Value Chain in Northern Ghana

Major findings of the PHL assessment of the maize value chain in Northern Ghana were:

- There are multiple tactics in use for monitoring of insects and moisture at both the on-farm storage level as well as in warehouses. Many of these are not effective or reliable. Methods for monitoring moisture content are not widespread, so this is an area ripe for introduction of simple low-cost technologies that are more reliable than traditional methods. As new more effective air-tight storage systems are introduced, the use of reliable moisture detection techniques will become more critical to reduce losses due to molds.
- Farmers are not patronizing warehouse storage systems except when agricultural production-related service packages of pre-harvest mechanization, fertilizers, pesticides, and other inputs are offered by the storage provider. These arrangements tend to establish stronger working partnerships with farmers and as a result, warehouses offering the

referenced services enjoy greater patronage from farmers for storage. A common risk with this system is that collection (recovery) of cash or in-kind payment at harvest time for input or service expenses is sometimes difficult. Another risk is the timely provision of services when service providers are dependent on governmental entities for financing or release of inputs.

- Farmers are resistant to investing in new technology to produce quality grain when there is no economic reward for increased input costs. A lack of affordable credit facilities with ease of access adds another obstacle to farmer adoption of capital investments in postharvest technologies.
- We identified several organizational entities for delivery of training that could assist farmers to adopt new technologies. These organizations include nucleus farmers and agricultural inputs and production service packages providers such as Masara N'Arziki Farmer Association (MAFA), as well as other smaller farmer based organizations (FBOs). We found women's groups, nucleus farmers, and other service providers to be good models for delivering new methods and scaling them up. Women's groups were cited by multiple sources as tending to be relatively more honest, reliable, and more willing to follow protocols and objectives addressed through training than are male farmers. The connections established on this trip will allow us to expand our reach.
- Aflatoxin-related issues can be exacerbated most by current handling practices such as: harvest timing mismatched with maize maturity (early or late), heaping maize ears in the field until a sheller is available, and the lack of proper drying facilities during harvest. Promising aflatoxin mitigation techniques including Aflasafe™ currently in development offer an affordable method to reduce aflatoxin levels. We have initiated working relationships with Africa Research in Sustainable Intensification for the Next Generation (Africa RISING); International Institute of Tropical Agriculture (IITA); Strengthening Partnerships, Results and Innovations in Nutrition Globally (SPRING); Resiliency in Northern Ghana (RING); Agricultural Development and Value Chain Enhancement (ADVANCE), Agriculture Technology and Transfer (ATT), and Council for Scientific and Industrial Research - Savanna Agriculture Research Institute (CSIR-SARI) that will enable us to deliver training and scale up to make progress on the aflatoxin issue in the near term.
- Current local and on the shelf technologies exist that may address identified problems while capitalizing on private sector partnerships. These include ZeroFly® bags, Purdue Improved Crop Storage Bags (PICS bags), and plastic silos. Adoption of these technologies will require accurate measurement of grain moisture content and proper drying. We are implementing field-based pilot testing of a low cost moisture meter that could address the moisture measurement issue. We are also exploring approaches to more rapid and cost efficient means of drying via an improved solar dryer model.
- We identified potential partners for engagement and for assisting us in data collection . These include the previously listed organizations in addition to Kwame Nkrumah University of Science and Technology (KNUST), Ministry of Food and Agriculture (MoFA), Pen's Food Bank Ent., Wienco, and a number of other postharvest handling and storage service (PHHS) providers.

- Training is needed on PHHS, aflatoxin-related issues, stored-product pest identification, and correct pesticide use and handle. Based on results of the first Postharvest Loss Assessment, we have initiated development of training materials and scientific animations. We are also exploring training of stakeholders with the PICS bag providers in 2015. We have identified multiple players throughout Northern Ghana and the Middle Belt who are eager and willing to facilitate the implementation of training.
- The lack of reliable storage facilities in close proximity to farms coupled with the lack of available shellers and ill-timed harvest are key contributors to postharvest loss.
  - Community warehouses appear to be a viable model if operated by the private sector, and if they offer production inputs and services.
  - The mechanized shelling business model appears lucrative, but entrepreneur investment is limited due to lack of affordable credit, issues with supervision and maintenance, and a shortage of trustworthy sheller operators.
- Women play a major role in the PHHS system and therefore have a significant role in the adoption of new technologies. Women-based organizations have been demonstrated to be a good vehicle in the adoption and scale up of new technologies and for obtaining financing. Multiple sources indicated women are more reliable, better able to follow prescribed protocols, and more likely to repay extended credit. We identified key seasons and times of day to maximize women's participation in future training offerings.
- Collaboration with RING and SPRING can have an impact on gender and nutritional aspects of our project and theirs.
- There is an opportunity to reduce environmental and health impacts due to over-reliance on pesticide use via the new technologies we are investigating for potential scale up.

Research to be Conducted in 2015 and 2016 Within the Scope of the Existing Award

- Collecting baseline data on moisture levels, insect infestations, aflatoxin levels, and losses during maize harvesting and storage. Project protocols for two graduate students at KNUST have been developed and their research was initiated early this year (2015).
- Evaluation of improved protection of maize from insect infestation using ZeroFly bags compared to forms of traditional storage bags. A graduate student at Oklahoma State University has initiated this research, and is assisted by the two graduate students at KNUST.
- Investigating means of refining the solar tent dryer, moisture meter (refining and scaling up), and on-farm and warehouse storage methods (ZeroFly bags, PICS bags, and plastic silos). Additionally, investigating the solar tent dryer as a means of managing stored-product pest infestations. Solarization is already being used in some parts of Northern Ghana for disinfesting grains. Therefore, managing stored-product pests using solar dryers has great potential.
- Collecting data on stored-product insect pest species and their population dynamics for on-farm storage and in warehouses.

- Measuring efficacy of improved monitoring tactics for moisture content and insect infestation.

Critical Research, Demonstration, and Capacity Building to be Conducted Using Supplemental Funding / Associate Awards

- Africa RISING is in the process of developing an Aflasafe formulation for use in Ghana. We want to partner with them and link them to SPRING, RING, ADVANCE and ATT to demonstrate the effectiveness of this technology under Ghanaian production and storage conditions. This will enable our team to raise awareness that aflatoxin is a soil-borne nutrition issue and that aflatoxin is both a pre and postharvest concern. In addition, our focus on maize will raise awareness that aflatoxin is prevalent in this staple crop in addition to the more conventionally viewed aflatoxin-containing commodities of concern such as groundnuts. Aflasafe has been proven to be an effective technology for use in Nigeria.
- The PICS program is rolling out training for the expanded use of their bag for other commodities including maize and has requested our partnerships to explore the use of the low-cost moisture meter and the role it could play in enhancing the effective use of their storage technology.
- Solar dryers are currently under-utilized as a means of mitigating the timely drying problem in maize. The efficacy of models in use in Ghana could be enhanced through improved design. Research work, training, and scale-up for a more broad adoption of this promising technology are needed.

Five-Year Plans for PHL-IL Ghana

A number of institutions and professionals comprise the Ghana Project Team, namely, Oklahoma State University, Dr. George Opit, Entomologist and Team Leader; Kansas State University, Dr. Shannon Washburn, Professor of Communications, and Dr. Venkaat Reddy, Project coordinator; Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana, Dr. Enoch Osekre, Entomologist; USDA-ARS Center for Grain and Animal Health Research (CGAHR), Manhattan, KS, Drs. James Campbell and Frank Arthur, Entomologists and Dr. Paul Armstrong, Agricultural Engineer; University of Kentucky, Dr. Samuel McNeill, Agricultural Engineer; Fort Valley State University, Dr. G. Mbata, Entomologist; and Vestergaard Frandsen SA, Lausanne, Switzerland, Dr. Oana Baban and Isaac Ola Ayobami, Entomologists. Current key cooperators in Ghana include Pens Food Bank Enterprise, Ejura, Ghana, Mr. Evans Nsiah, Managing Director; Masara N'Arziki Farmer Association, Tamale, Ghana, Mr. Luuc Smits, General Manager; and Agri Commercial Services, Wenchi, Ghana, Mr. Kwabena Adu-Gyamfi, Managing Director. During the first year (2014), the Ghana Project Team assessed grain handling and pest management tactics, stored-product insect activity and post-harvest grain losses on-farm and in small-, medium-, and large-scale storage warehouses in the Middle Belt and Northern Ghana and identified researchable areas in postharvest loss that are perceived "critical control points" where breakthroughs in research and development could lead to significant improvements in food security.

In the second (2015) and third year (2016), the Ghana Project aims to conduct research on topics identified as researchable areas in postharvest loss where breakthroughs in research and development could lead to significant mitigation of PHL in the maize value chain in the Middle Belt and Northern Ghana.

In the fourth (2017) and fifth year (2018), the Ghana Project aims to conduct education and training meetings in the Middle Belt and Northern Ghana to share proven practices and information learned during assessment and research activities to reduce PHL of grains at the household and village level. The target audience will include farmers, aggregators, local NGO's, warehouse owners and/or managers and other stakeholders including women's groups.

After five years, the Ghana project hopes to achieve the following:

1. An assessment through documentation and field research, of current practices, constraints, and critical control points that will identify improved technologies and management options for PHL mitigation in warehouses.
2. New postharvest technologies and management options that have been verified and piloted to suit local conditions in small-, medium-, and large-scale storage warehouses. This will include improved, low cost grain moisture content monitoring, practical pest monitoring and management approaches and technologies, and improved maize drying and storage technologies.
3. Improved capacities and awareness of warehouse owners and/or managers engaged in grain storage regarding sources of PHL and remediation options.
4. Scale up of successfully adopted technologies in other regions.
5. Data collected from field research will be disseminated to stakeholders and policy-makers regarding warehouse losses and needs with proposed interventions and policy recommendations.
6. Capacity building through the training of:
    a. 3 MS graduate students. Emphasis will be placed on training at least 2 female graduate students.
    b. 15 professionals in 2 train-the-trainer workshops.
    c. 50 farmers, farmer association members, and agribusiness customers in 2 annual symposia.
    d. 1,350 smallholder farmers in 90 local Extension workshops.
7. Made available downloadable educational materials and videos/audio files on demand via cell phones, Internet, etc.
8. Seek additional funding to support related research that targets the mitigation of insect infestation and aflatoxin contamination in maize.
9. Measurable evidence and impact that postharvest loss has been reduced because more smallholder/subsistence farmers, producer cooperatives and agribusiness enterprises are linked/integrated with market-based value chains from seed to end-user.

10. Measurable evidence and impact that postharvest loss has been reduced based on lower insect pest infestation levels and reduced aflatoxin levels.
11. Measurable evidence and impact that food security has improved because more people, at more 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.

Introduction

Northern Ghana has 30% of Ghana's land mass equivalent to 7 million ha. The area of arable land is 4.9 million ha but only 900,000 ha are cropped. Northern Ghana has great potential as a breadbasket with almost all crops grown in the country capable of being grown here with the exception of yams and palms. Priority crops targeted for commercial agriculture in Northern Ghana are rice, soy, and maize.

A major challenge to commercial agriculture in Northern Ghana is lack of mechanization, which ultimately results in heavy postharvest losses. Machinery for shelling is especially needed. Traditional methods of shelling are inefficient yet postharvest services (commercial shelling services) are out of the reach of smallholder farmers (SHFs) because of the rampant poverty in this part of the country. Postharvest losses of 30% are suggested but the exact figure is not known. Others estimate losses to be between 5-30%. Postharvest losses are exacerbated by the fact that most SHFs view agriculture, as a way of life and not as business hence are less likely to invest in mitigation measures. Estimates of farmers who are SHFs, medium-holder farmers (MHF), and large-holder farmers (LHF) are 75, 15, and 10%, respectively. The sizes of land for each of these categories are approximately 1, 40, and 40-200 HA, respectively.

A key challenge in overcoming storage-related losses in Northern Ghana is the fact that SHFs are reluctant to store their maize outside their homes. Farmers want to store maize within the homestead and sometimes go to the extreme of storing it in their bedrooms. This is because of lack of trust in whoever is entrusted to store their maize. In their homes, they can guarantee they will not be ripped off despite the fact that storage conditions are deplorable and usually no PHL mitigation interventions are implemented hence the resulting serious postharvest losses caused by insect pests, rodents, moisture, etc. This lack of trust may explain why many community warehouses, such as those owned and/or operated by the Warehouse Receipt System (WRS), ADVANCE, and Millennium Development Authority (MIDA), are not adequately patronized by SHFs. Many of these community warehouses were supposed to serve as aggregation points but many of them are empty. The immense success of MAFA, which comprises approximately 10,000-11,000 farmers in Northern Ghana and the limited success of the WRS to date, can be explained by the agricultural inputs and preharvest and postharvest services provided by the former. The provision of inputs and services earns MAFA a lot of trust from SHFs. Because of this trust, Wienco (Ghana) Limited warehouses, used by MAFA, are well utilized. There are approximately 40-50 nucleus farmer-based warehouses in Northern Ghana that are also well patronized due to the aforementioned reason. The take-home-message seems to be that the trust of the SHFs has to be won during the production (preharvest) stage for them to have any dealings with community warehouses in relation to storage and marketing of their maize.

Irrespective of the prevailing poverty among SHF, provision of preharvest and postharvest handling and storage services (PHHS) is a lucrative business. Despite this, scarcity of PHHS services is dire. Some key reasons cited for this include lack of incentives to increase machinery and the low number of people involved in the provision of these services. Difficulty recovering maize paid for services offered has been a major stumbling block. Providers of PHHS services think that enactment of laws to facilitate payment for services would facilitate enforcement of contracts signed with SHFs prior to the maize growing season. They cite Burkina Faso as an example of where such laws exist and agricultural extension agents participate in witnessing the signing of contracts and ensuring payment by SHFs. Lastly, difficulty getting honest people to operate and/or supervise machinery operated by PHHS service providers has also prohibited the scale up of these services.

There is an increasing recognition that nucleus farmers (NFs) need to be the reference point or catalyst for agricultural development and hence PHL mitigation. It is now recognized that it is easier to work with NFs than directly with SHFs. NFs are elite (model) commercial farmers who are respected in their communities; they are usually also aggregators who provide production-related service packages of pre-harvest mechanization, agricultural inputs, and preharvest, harvesting, and postharvest services to SHFs known to them. NFs have their own warehouses and associate with SHFs in their communities whom they select based on their honesty and ability to work well with their nucleus farmer-based group. Therefore, empowerment of nucleus farmers indirectly lifts up all the associated SHFs. NFs have a genuine desire in seeing SHFs increase their agricultural productivity because it increases quantities of maize they are purchasing from them and using for their trade. SHFs on realizing feasibility of increased production would be expected to desire even higher production levels.

Description of the Northern Ghana Maize Value Chain

The Northern Ghana maize value chain is generally similar to that of the Middle Belt described in our assessment report for the Middle Belt and depicted in Appendix C, Figure 1. The assessment of maize PHL in the Middle Belt was conducted during the period May 19-30, 2014.

Losses Attributable to Insect Pests in the Maize Value Chain in Northern Ghana

Maize (*Zea mays*) is the most important cereal in Ghana and it accounts for 74 % of the total cereal production. Northern Ghana is second only to the Middle Belt (Brong-Ahafo region) in terms of maize production in Ghana. Maize has replaced sorghum as the lead staple in the north. Northern Ghana produces maize only during the minor season (June to October, although maize may be left in the field to dry until November or even December) unlike the Southern and Middle Belts that have two seasons. Over 90 % of the farmers produce white maize even though yellow maize is more marketable and attracts a higher price. This is because white maize is preferred for human consumption.

Maize production in Northern Ghana is mainly by smallholder farmers. Maize production has many challenges, namely, limited use of improved seeds, lack of fertilizer or high fertilizer prices, low levels of mechanization (including use of inefficient shellers), and inadequate availability of PHHS services. Average yields are well below potential attainable levels and post-harvest losses also are high. According to the Northern Region MoFA, maize PHL are suggested to be ≈30%, but are probably much higher in many cases. Generally, maize farmers cite insect pests, inefficient harvesting and shelling, and poor storage facilities as important contributors to losses. Delayed harvesting; temporary storage of ears on bare ground, floors or on some other inappropriate material; and transfer of infested kernels from the field to storage structures or facilities also contribute to losses. Reducing PHL has the potential to sustainably assure food security.

Key insect pests in Northern Ghana include maize weevils [*Sitophilus zemais* (Motsch.): Coleoptera: Curculionidae], rice weevils [*Sitophilus oryzae* (L.): Coleoptera: Curculionidae], larger grain borer [*Prostephanus truncatus* (Horn): Coleoptera: Bostrichidae], lesser grain borer [*Rhyzopertha dominica* (F.): Coleoptera: Bostrichidae], red flour beetle [*Tribolium castaneum* (Herbst): Coleoptera: Bostrichidae], Angoumois grain moth [*Sitotroga cerealella* (Olivier): Lepidoptera: Gelechiidae], termites [*Microtermes* spp: Isoptera: Microtermitidae] and corn earworm [*Helicoverpa zea* (Boddie): Lepidoptera: Noctuidae]. Because of the long dry spell after maize matures in the field in Northern Ghana, the ears are left in the field longer to ensure proper sun-drying period. This practice results in field infestation, which is then carried into storage causing further deterioration. There is evidence of multiple tactics in use for monitoring of insects at both the on-farm storage level as well as in warehouses. However, many of these are not effective or reliable.

A survey of storage practices, pest management, and loss mitigation measures currently in use in the Upper East Region of Ghana was conducted in 2013 by Dr. Nutsugah at SARI. Participants in the survey were from households averaging seven individuals, with majority of respondents having no formal education. Most (75%) were low-income households (less than GHS1,000 or ≈US$300). Maize was the predominant crop grown, with 1-4 ha per household. Maize was primarily grown for consumption, with only around 10% of farmers using maize production to supplement household income. Maize was typically stored in jute sacks (71-86%) compared to poly sacks due to the low cost and ready availability of jute sacks. Only 1% used PICS bags due to the high initial cost. A majority of farmers stored maize for 5-8 months, with only 1% storing for more than a year. Insects, rodents and grain mold were identified as the most critical challenges during storage. This survey reported that red flour beetle (*T. castaneum*), larger grain borer (*P. truncatus*), lesser grain borer (*R. dominica*), maize weevil (*S. zeamais*), granary weevil (*S. granarius*), and Angoumois grain moth (*S. cerealella*) were most commonly found species. However, most respondents could not provide specific names of the insect pests – the generic term, weevils, was commonly used. Pesticides were usually applied if there was going to be prolonged storage or when insect infestation in grain was noticed during storage. Not using any form of grain protection beyond re-drying if infestation was noticed was reported by 21% of respondents. Phostoxin fumigation was conducted in non-airtight bags – leading to control failures and need for repeat fumigations. Most farmers acquired agro-chemicals from non-accredited dealers and without prior training on appropriate use. This highlights the need for more training on use of insecticides.

Smallholder famers also store their maize in mostly traditional grain storage structures. These structures vary considerably and are unable to prevent insect infestation. Because of the risks associated with grain storage and the need for cash, many farmers sell their maize soon after harvest to minimize their losses. As expected, this practice causes maize glut and low prices at and near the time of harvest. Farmers could obtain a higher price for their maize if they sold it later in the season as a result of having the ability to minimize insect infestations. It is estimated that over 50% of the farmers in Ghana store their maize in mostly poly sack bags; a large percentage of such farmers then keep these bags in their rooms, >30 % in local cribs and <1 % in household metal silos.

Insect control using insecticides is mostly by the use of Phostoxin® tablets or Actellic® EC or dust. However, many SHFs lack information for proper application of insecticides and do not follow label recommendations thereby endangering themselves, their families, and consumers. Some SHFs use community warehouses for storage if they are present in their locality. However, high storage fees charged by operators of such facilities often discourage patronage. Community warehouses that loan agricultural inputs and provide preharvest and postharvest services for a fee are usually well patronized. Perhaps community warehouses need to adopt this approach to encourage more SHFs to store their maize under better conditions and to increase patronage.

Lack of sound knowledge on good maize management plagues most warehouses in Northern Ghana. This means maize storage in many of these warehouses is not done under proper management. For example, there is poor sanitation, lack of monitoring of stored-product insect pests, and a low level of technical expertise of managers. This situation contributes to significant maize losses during warehouse storage. Fumigation using Phostoxin is the method of choice for insect pest control in warehouses. However, warehouses owned by operators such as Big Ajar Enterprises, do not use Phostoxin fumigation at all. A common problem observed in most warehouses that leads to inefficient fumigations is lack of plastic sheets used to create airtight enclosures during fumigation in order to minimize fumigant leakage. Maize is usually stored in warehouses for varying periods of up to 9 months.

Areas in Warehouse Storage Causing the Most Losses where Breakthroughs in Research and Development Could Lead to Significant Improvements in Food Security

Storage of maize in warehouses is a critical part of reducing postharvest losses (PHL) in Ghana. During our first PHL assessment trip a number of critical control points and technologies with high potential to reduce PHL in warehouse storage were identified. During this second trip we focused on evaluating warehouse storage in the northern maize production regions, evaluating factors limiting adoption and scale up of warehouse PHL mitigation tactics, identifying cooperators, and refining our research approach. All of the target areas developed during the first PHL assessment trip still apply after this second trip, and in general their importance in solving PHL has been reinforced based on findings during this second trip. In addition, we have identified collaborators and mechanisms to facilitate research and technology transfer.

A critical factor in reducing PHL in warehouses is improving the quality of the maize when it comes into storage. As was pointed out by most of the people we met on this trip, many of the problems with inbound grain have to do with delay in timing of harvest and shelling. In the north there is less of an issue in terms of increasing mold and aflatoxin with delay in harvest because the grain is dryer, but delays are reported to increase insect infestation levels. Low availability of shellers at time of harvest was widely mentioned as a primary contributing factor in delaying maize getting into the warehouse. This is a complex problem to resolve with factors such as high cost of purchasing equipment and lack of access to low interest loans, mechanical breakdowns, need to have honest and reliable supervision of shellers, and not having enough shellers in an area hence not getting to fields in time.

Aflatoxin infestation of maize may still be an issue even in the north, but is definitely a problem in the middle belt. However, there is little data available on aflatoxin levels. Africa RISING indicated that traditional methods of sorting moldy kernels of maize only reduce aflatoxin levels by 40%. Maize is often stored in jute bags at harvest, and these don't provide a barrier to insect entry and don't seal in phosphine during fumigation. Collection of data on maize moisture, aflatoxin, and insect infestation levels in both Northern Ghana and the Middle Belt remains an important research objective and will provide the foundation data needed to determine the impacts of techniques to improve grain storage.

Ghana Standards Authority (GSA) has developed maize quality standards and thresholds for aflatoxin levels that are acceptable for maize (15 ppb). They also provide a testing service. There is desire for low moisture content maize, and GSA is working on producing a documentary to improve smallholder farmer awareness of maize standards. According to GSA, lack of proper drying is the biggest impediment on meeting quality standards for maize.

The development of community level warehouses was raised multiple times as a method to improve the maize storage, but these facilities often fail because farmers don't have ownership of these operations or trust that their grain will be protected, and often these warehouse operations are not maintained beyond pilot programs. Warehouse receipt system (WRS) is being encouraged by Ghana Grains Council (GGC), but farmers prefer to store at home for security, so don't patronize these warehouses. GGC has a program to build and encourage use of WRS, but this is not being used as much as desired because there is no mechanism to continue the program after the 5 years of funding ends. This remains a priority area. There is a need for a sustainable model for funding and maintaining these warehouse systems. Warehouse systems that appear to be more viable are ones associated with farmer associations (cooperatives) or nucleus farmer aggregators that provide preharvest and postharvest services in exchange for maize at the time of harvest. These systems build the trust needed with farmers and are more frequently used by farmers. Successful warehouse operations reported to depend on them providing inputs for preharvest to build a relationship with farmers. The farmers are more likely to trust storing their maize in a warehouse if they have this arrangement already.

We visited the maize storage operation at the Wienco warehouse in Tamale that handles maize collected by MAFA. At this location there were 6 warehouses with a capacity of 70,000-80,000 bags per warehouse. They also rent space elsewhere for extra storage. This storage operation services the communities of Tamale, Tumu, Wa, Damongo, Nawanduri, and Walewale. Wienco has procedures in place that they report results in a low level of loss (1%) during storage. The warehouses are relatively new and better sealed than many others we visited in both Northern Ghana and the Middle Belt. This facility provides a good example of how pest management strategies can be used to reduce insect infestations, but even in this warehouse insect activity was observed around cleaning equipment.

To evaluate inbound bags of maize, Wienco personnel inspect a random subsample of the bags on a truck. They inspect the outside of the bags for signs of insects, and they test maize for foreign material and measure moisture content with a commercial meter. If maize on a truck passes this random sampling then it is approved for delivery. A subsample of the bags is weighed, approximately 20-30 bags per truck. Bags are stacked in the warehouse up to 21 bags high, with one stack being 7,056 bags or 350 metric tons with 10 stacks per warehouse. Only clean bags of maize are stacked. If excessive cleaning is needed then the Technical Officer (TO) would be held accountable for the poor cleaning at the community level. They use a new bag design each year so they can track the year bags were produced. Each bag was also labeled with the farm ID and whether it was white or yellow maize. This way they can trace bags back to the farmer.

Wienco treats for insects as needed. Insect infested bags are fumigated in a separate warehouse. They fumigate at a rate of 4 Phostoxin tablets per ton and the fumigation lasts 5-10 days. They import their phosphine from Degesch in Germany to ensure good quality. They fog the warehouse or spray the walls. During storage they do spot checks every 2 weeks looking for insects and moisture, but after January or February they don't worry about checking. They use a probe to sample bags of maize for insects and moisture. They find mold occasionally but it is very rare because of the low RH levels in the warehouse and the grain during storage. They could easily implement good outside pest management because the area around the warehouses is paved and does not provide harborages for pests.

Wienco can store for up to 1 year but recent market prices have been high enough that they haven't stored for this long. High market price is also leading farmers to want to renegotiate the forward contracted price that was originally set by MAFA. The fixed price is negotiated with farmers prior to planting. Price is set by a farmer council which includes representatives from the different districts – one or two per district, that are selected by the farmers. The maize stored in Wienco warehouses is sold to suppliers such as Greater Accra Poultry Farmers Association, Flour Mills Ghana Ltd., Raanan Fish Mills, and Nestle Ghana Limited. Other companies that compete for the same market are Savannah Accelerated Development Authority (SADA), Gundaa Produce Company, Akali Farms, and Ejura Farms.

There are a number of businesses in the Upper West Region of Ghana that provide agricultural inputs and production service packages (including warehouse storage services), for example, Gundaa Produce Company (GPC) was visited on this trip. These types of businesses have many hurdles to jump to be successful. GPC works with smallholder farmers and provides tractor services (plowing only), preharvest and postharvest services. Shelling service is provided at a cost of one 100-kg bag of shelled maize for every 10 bags shelled. On the other hand, the cost of tractor services is 1 bag of maize per acre that is ploughed. GPC deals with 42 farmer groups in 10 districts. Each farmer group has at least 45 members. Only five of the farmer groups are women only groups. Altogether, GPC deals with ≈3,000 farmers. They have 80-MT community warehouses in two of the ten districts. Maize is stored at the community level for 2 weeks and then moved to the GPC 500-MT main warehouse for up to 5 months. Maize in the main warehouse could be stored for longer, but this does not happen due to concerns about shrinkage if stored beyond this period (it is extremely hot and dry in Ghana during certain times of the year). Maize comes from the field at 14-18% MC and after cleaning this drops to 12.5-13%. The GPC main warehouse is certified through GGC for sale of their maize to the World Food Program (WFP). This warehouse also issues receipts. In 2013, GPC sold 178 MT of maize to WFP under the Purchase for Progress program. Maize is also sold to Premium Foods and the open market.

Grain management (which includes pest management) at GPC involves checking bagged maize prior to being stored in the community warehouses hence no inspection for quality is necessary when transfer to the main warehouse occurs. For maize that is in jute bags, it's cleaned and then re-bagged before sale because quality is suspect. Maize is fumigated in the main warehouse after which no more maize is received. Fumigation is supervised by GGC.

All maize in GGC certified WHs has to be graded. Gundaa Produce Company categorizes its maize as low and high quality with grades from 1-5. However, the major problem is that all the maize is sold at the same price regardless of the grade – no premium for high quality (no bonus or award offered as an inducement to farmers and aggregators). The GPC maize primarily falls under Grade 3. Grade 1 or 2 maize has never been received. It is a requirement for maize to be graded if it is to be sold to WFP.

Big Ajar Enterprise (BAE) also provides agricultural inputs and production service packages to farmers and buys and stores maize in warehouses. GPC and BAE use the same model of getting payback in kind from farmers for the services provided. BAE will also buy any extra maize that farmers wish to sell. Maize MC is measured with moisture meters when maize is being bought. According to BAE, maize MC at harvest is usually ≈13%. If insects are found during inspection, the maize will be cleaned. BAE tries to avoid phosphine fumigation as much as possible. Part of their insect pest management involves application of surface insecticides around the warehouse building. Maize is stored in warehouses for 6-12 months. However, the longer the storage time, the lower the quality. For maize used for seed, they use PICS triple layer bags and where better quality seed is desired, fumigation is conducted. Maize for seed that is stored for one year is sold for food. However, maize for seed sells for a higher price. Maize for seed that is stored in PICS bags undergoes germination tests every two months because these bags have a negative impact on germination. Seed is also treated with Actellic. There is an association of ≈50 aggregators who provide agricultural inputs and production services in the Upper West Region. This could be a good group to work with for scale up of PHL mitigation technologies and methods. According to BAE, some of their major challenges are getting financing for their business, changes in government policy, and delay of government in supplying agricultural inputs.

A critical data gap identified is lack of information on pest activity in and around warehouses and the potential levels of infestation that can occur. Generally, warehouses focus on sampling insects in bags at the time of storage, with most operations not performing sampling of bags during storage for insects. However, stored-product insects can invade warehouses and grain stored in bags from outside and can persist in warehouse structures in spillage. None of the facilities visited had an active insect or rodent trapping program.

The use of plastic storage bins to help preserve stored maize at both the farm and in warehouses was identified as a potential area of research. This method of storage could reduce ability of insect populations in infested grain to grow and reduce or eliminate infestation of maize during storage and thus could results in significant PHL reduction. Earlier studies have shown that modifying plastic storage containers used for water to use for grain provided much better pest suppression than traditional methods and was equivalent to hermetic bag and ZeroFly bags (S. J. Costa, Reducing Food Losses in Sub-Saharan Africa – An Action Research evaluation trail from Uganda and Burkina Faso). Research needs to be conducted to determine how these plastic silos can be best-modified and used for grain storage and how they can fit into current grain handling and storage practices. The cost of this approach versus hermetic storage bags also needs evaluation. Dr. Stephen Nutsugah noted that only about 2% of farmers use plastic silos, but there is great potential there. Aggregators should be encouraged to own plastic silos since they would be good model adopters for this technology. Plastic silos cost around GHS70 for the 100- to 150-liter containers.

A critical finding during the visit was the importance of identifying nucleus farmers to work with in conducting research/demonstration projects and for technology transfer of our findings on warehouse pest management. Nucleus farmers are leaders in their areas and they offer services to smallholders (both preharvest and postharvest) compared to ordinary (market) aggregators that are only interested in the purchase of grain. The former are more likely to adopt new tactics and to be a model for transfer to others. The existence of an association of ≈50 aggregators who provide agricultural inputs and production services in the Upper West Region could greatly facilitate scale up of tactics and technologies.

Aflatoxin Mitigation in Maize in Northern Ghana

Aflatoxin has heretofore been commonly considered to be a postharvest problem, but significant control has recently been found in Africa by treating it as a preharvest problem. A group of plant pathologists at the International Institute of Tropical Agriculture in Ibadan, Nigeria (iita.org) have worked with USDA-ARS scientists and others to develop a new, promising product called Aflasafe™, which is comprised of up to four atoxigenic strains of *Aspergillus flavus* and when applied in the field will out compete and control toxigenic strains. Thus, the mitigation of aflatoxin can begin in the field and the effects have been shown to carry through postharvest processes to storage and further along the value chain. Aflasafe costs approximately $15 USD /ha (≈$5 to $15/t) and data indicates aflatoxin reduction is around 80% or higher. Conversations with Dr. Joseph Atehnkeng, a plant pathologist with IITA, revealed that recent field tests in Ghana have led to identification of three or four atoxigenic strains that will be produced in a mixture and tested in 2015 in 100 fields. If successful, they anticipate releasing a commercial control for maize crops in 2016. His team has successfully promoted adoption and use in other African countries by using three program pillars (training, application and testing) and targeting nucleus farmers at the village level.

An unpublished report that was shared by the scientists at CSIR-SARI near Tamale, showed results of a survey of maize producers in six districts in Northern Ghana (Upper East and Upper West Regions) that included 240 samples collected after harvest in November 2013. Samples were tested for aflatoxin contamination and found that 79% were within the EU Standard level (< 4 ppb) while 14% were above WHO Standards (15 ppb). In comparison, as stated in our PHL assessment report for the Middle Belt (assessment conducted in May 2014), Akrobortu et al. (2008) conducted a similar study in North Kwahu between 1990 and 1999 and reported average aflatoxin levels in stored maize samples to be 15.3 ppb (Stdev 7.4). More recently, a press release from the Government of Ghana (2014) reported aflatoxin levels above the permissible level (15 ppb set by the GSA) in 66 of 202 maize samples (33%) analyzed by the Food Research Institute (FRI) of the Council for Scientific and Industrial Research (CSIR). Not surprisingly, all studies showed wide variations in aflatoxin levels within and across communities, districts, varieties and years.

Other current efforts seen to mitigate aflatoxin levels are sorting during harvest, timely drying after harvest, and sorting each time grain is handled afterwards. Individual kernels that are damaged by insects, molds or rough shelling are more susceptible to mold and aflatoxin contamination during storage. Selection of maize varieties for disease resistance and Aflasafe applications will surely help reduce postharvest losses from aflatoxin in the future, but certainly not eliminate the need for rapid drying and thorough sorting practices at the source (farm level) and immediately downstream (after drying, shelling and prior to bagging). Also identified in our assessment trip in May, and subsequently in other Feed the Future countries, the use of solar dryers should be scaled up in Ghana to expand drying capacity in all production districts and regions. In combination with Aflasafe, solar drying can greatly reduce aflatoxin levels and PHL of maize in the very near future. Solar dryers also have the potential to be used for insect disinfestation.

Aflatoxin threshold level for maize and groundnuts in Ghana is 15 ppb. The current cost of aflatoxin testing is GHS150 per sample (approximately US$50), for immunoaffinity and HPLC measurement. The threshold for peanut butter is 4 ppb.

Farm Level Management Operations. As during our assessment trip in May 2014, conversations with farmers and aggregators revealed they are aware that moldy grain can at the least alter the taste of food and at worst cause illness. They also know that moisture content is critical to controlling mold. However, because smallholder farmers have limited cash resources, moisture measurement is most often done by biting kernels and/or shaking loose kernels in one hand and listening to the sound produced. Most farmers and grain merchants appear to have developed a reasonable estimate of grain moisture by using these methods, so they have a sense of when maize is properly dried. However, the need for a low cost moisture meter that could be purchased individually (by large farmers) or collectively (by groups of smallholder farmers) and used within a village or community could greatly improve traditional methods to more accurately determine grain moisture and ultimately reduce PHL in maize.

Harvest. Despite the fact that this assessment focused on Northern Ghana, we had a chance to visit some parts of the Middle Belt. We observed one maize harvest operation in a 40 ha field that was managed by several farmers near Ejura on December 17, 2015. Our guide there from Pens Food Bank, Mr. Evans Peter Nsiah, explained that 12 women would harvest the field in about two weeks while working about 10 hours each day (total cost of GHS 7,000 or GHS175/ha). A few team members participated in the harvest operation which consisted of removing ears from the stalks, bending harvested stalks to mark progress, and piling ears on the ground with husks intact. Ambient conditions were typical for the season and dominated by dry Saharan winds (Harmattan) with daily average high and low temperatures near 37 and 25°C, respectively, and relative humidity levels around 20% during the day, which combine for very rapid field drying. Surprisingly, our in-country guide, Mr. Kwabena Adu-Gyamfi, commented that he has seen maize standing in the field lose as much as two points of moisture per day in the North. Close examination of randomly selected ears during harvest revealed that most kernels were well dented, indicating the moisture to be near the stated level (18 to 22%), but others that were undented had much higher moisture (near 30%), which could be susceptible to prolific mold growth. However, all ears were thrown in a pile without removing the husks, so the relative humidity within the pile would be highly influenced by grain moisture and much higher than ambient. An estimate of this condition is indicated in Table 2 (Appendix B), which shows the equilibrium relative humidity for high moisture corn in the observed temperature range to be above 95%, which is conducive to aflatoxin production in mold infected kernels. Moreover, when conditions remain at this level, aflatoxin production can double in six to ten hours after reaching a level of 10 ppb (Wieman et al., 1986).

Mechanical threshing with PTO-driven shellers is common in the North, but can cause considerable physical damage at moisture levels above 18% because aggressive shelling is required to remove kernels that are held tightly on the cob. Delayed threshing can pose a problem of concern for corn above 20% moisture (Table 2). Only partial drying occurs when ears are piled and waiting to be threshed but mold growth is also likely to occur, especially for undented kernels with high moisture. Ears can remain in piles up to 10 days which can exacerbate the problem. An improved system may be to de-husk the ears during the harvest operation and place on a screened rack above the ground where they have full exposure to sun and wind. Although this method would require more labor and protection from wildlife and insects, the trade-off between more rapid drying, which is aimed at increasing shelf life and market value, and added harvest labor costs need to be investigated.

Threshing. Most farmers in the North used contractor-owned mechanical threshers that shell either whole or de-husked ears. We talked with several folks in the public and private sectors who confirmed that contractors are very busy during harvest, which creates delays before a thresher will arrive on site. Moreover, threshers are often not well maintained due to time constraints during the harvest rush, so poor threshing performance was often described (excess mechanical damage to the grain) and/or threshers would break down frequently which further delayed harvest. The Team concluded that more threshing machines are needed; especially those designed to improve operating efficiency and service life, as well as reduce mechanical damage over a wide range of harvest moisture levels seen in the North and Middle Belt.

Drying. As seen during our Middle Belt assessment trip in May, 2014, shelled maize is most often dried on tarps spread over the ground. Unlike the Major Season in the Middle Belt, open air solar drying in the North is faster due to abundant sunshine and low relative humidity levels. Whereas drying may take up to 5 days in the Middle Belt during the Major Season (April-August/September), only 2 or 3 days are needed in the North for the same amount of drying. Additionally, where maize may be only partially dried (to 15 or 16%) in one step in the Middle Belt, then fully dried (to 12 or 13%) in a narrow crib the second step; in the North maize is fully dried in one step, which reduces labor due to handling. Thus, rapid drying to moisture levels considered safe for storage is key to reduced aflatoxin levels seen in the North, and justifies the rationale explained by most grain merchants who source grain from this region for customers in the Middle Belt and further South, i.e. the maize from Northern Ghana is much drier and of higher quality that from the Middle Belt.

The solar drying systems seen in the Middle Belt in May 2014 could also be used in the north and would likely have more throughput capacity due to dryer environmental conditions. In fact, some lower cost solar dryers have previously been tested at the Savannah Agricultural Research

Institute in collaboration with scientists at the University of Development Studies near Tamale. These units were designed for smallholder farmers and reported to achieve similar operating temperatures (($\geq$50°C), which not only provides more rapid drying than open air drying on a tarp, but also thermal disinfestation of insects. Although these dryers were no longer in place, due to their light construction and limited funding to maintain/rebuild the structures, the scientists at both institutions remain interested in more work with similar or improved designs. In this regard, interested scientists on the Team will seek additional funding opportunities for potential collaboration with these two groups, related USAID-funded Feed-the-Future projects (RING, SPRING, ATT, and ADVANCE), and Africa RISING, scientists at KNUST, public partners (Pens Food Bank), and Ghana Standards Authority. As mentioned in our first assessment report, we believe that low-cost solar driers could have a large, immediate positive impact in mitigating alfatoxin problems. Ideally, this technology could be made portable and adaptable to the farm level, and possibly financed through a farmer-based organization. When combined with Aflasafe, this two pronged approach could offer a significant, sustainable solution to solving aflatoxin problems of maize in Ghana and elsewhere in West Africa.

Storage. Similar to our findings in May 2014, the majority of managers responsible for long term storage at small and large warehouses indicated a target moisture content of 12% or lower was preferred for maize. A spot measurement taken with our low-cost meter at one warehouse showed the moisture content to be 11%. Unlike the ambient equilibrium moisture conditions seen in May in the Middle Belt (around 10.5%), conditions were closer to 9.0% (ASABE) in December, due to the Harmattan winds. Thus, it is highly likely that maize will be over-dried in the Minor Season, which adds storage life, but reduces market weight where grain is sold by volume. Again, as in May, a study to determine the optimum storage moisture from a physical and economic viewpoint is needed.

Moisture meters. Poorly dried grain will not store well in Ghana's warm environment, so moisture measurement is critical during drying and storage processes in both the Major and Minor Seasons. The instrument developed at USDA-ARS in Manhattan KS and built with USAID Feed the Future funds is fully described in our May 2014 report. It actually measures the temperature (T) and relative humidity (RH) of the air surrounding the grain and uses these values to calculate the equilibrium moisture content (EMC) of the grain (Appendix B, Table 2). The sensors are located on the end of a long probe (0.5 m), so the instrument can be used to measure grain stored in bags or bulk as well as ambient conditions. The Team left one meter with Pens Food Bank in May 2014 for evaluation and testing and received positive feedback, so 25 more were transported to Ghana during this trip along with 9 commercial units that were donated by John Deere, one of our corporate collaborators. Our goal is to compare readings from both units at various locations. Instructions for the USDA meter and a sample data sheet developed by the Team are shown in Appendix D to record insect activity, the presence of molds, broken kernels, and other quality factors. The USDA meter was used at one site visit near Tamale to demonstrate its operation to the warehouse manager (Gundaa Produce Company, Ltd., a Ghana Grains

Council certified warehouse that was built with support by USAID Feed the Future funds). Others were distributed to interested parties with a verbal agreement that they be used to collect baseline data in each location (SARI, UDS, Weinco, Pens Food Bank, and post-harvest engineers and entomologists at KNUST [including two MS entomology students]). Data from both meters will be collected at as many farms, drying and storage facilities, and warehouses as feasible by these groups to record grain moisture. In the short term, funding from our initial grant will enable them to collect a limited amount of data to correlate grain moisture with aflatoxin levels and other attributes by location within Ghana. This information would form a firm foundation to pursue additional funding for a more detailed study. In the interim, we will pursue opportunities to meet our original goal of identifying a company in Ghana to manufacture the USDA meters.

As noted in our May 2014 report, grain aggregators often use moisture meters similar to the John Deere unit, including Dickey-John, mini-GAC; vintage Eaton capacitance meter; G-won, GMK-303; and MD7822 spear probe. An interesting project would be to compare the accuracy of these meters with the USDA meter and standard oven method. Agricultural engineers in the post-harvest group at KNUST indicated an interest in comparing the USDA and John Deere meters, which would be good first step that could lead to similar comparisons with other meters used in Ghana, provided additional funding could be identified.

Cross Cutting Issues of Gender, Nutrition, and Engagement

Gender Issues

The major objective of the Feed the Future Innovation Laboratory for the Reduction of Postharvest Loss project is to identify simple, cost-effective and readily implementable technologies that can be used to mitigate postharvest loss (PHL) caused by grain fungal infection (aflatoxins) and stored-product insect pests in on-farm storages and storage warehouses in Ghana. The PHL assessment was conducted during the period December 8-19, 2014. The Gender Consultant was with the team on December 9-11 and 17, 2014. Table 1 (Appendix B) shows dates and locations, people, groups, or organizations visited during the second Ghana postharvest loss assessment trip. Lessons learned from the visits have been categorized under design of technology, investment capacity, capacity building, market access and other issues.

Design of technology: Technologies for managing post-harvest loss of maize range from sophisticated technologies to simple tools. The storage bins, sacks and drying cribs described previously were all user-friendly and could be managed with minimum training by both male and female customers.

Investment capacity: The initial cost of purchasing, installing and using the technologies were moderate to high. The sacks cost about US$1.00 per 50-kg capacity sack. The cost of a 540-kg and 1,200-kg metal silo is US$200-250 and US$260-320, respectively. The 100-150-kg plastic silos are sold for US$20.00-36. Many small-scale farmers and traders, male and female, can co-own these storage technologies when they form associations at the community level. Otherwise, individual female-headed households may find it more difficult than male-headed households to own such technologies.

Although the initial cost of one sack appears low, many households that need a minimum of 10-20 sacks to store harvest from 1 ha of maize may not be able to invest the required US$10.00-20.00. This is because small-scale farmers may sell 50% of their grain and cannot rationalize the importance of keeping the remainder of the grain in good condition for domestic consumption.

<u>Capacity building:</u> Access of households to information and knowledge is dependent on both external and internal factors. Most female farmers are less educated in terms of number of years of formal schooling. This suggests that when training programs are designed and organized by institutions such as local governments, department for agriculture, non-governmental organizations and private sector, females should be prioritized. The situation currently is one that ensures that a majority of females are unable to participate. A key weakness is that there are no mandated percentages of males and females who should attend trainings, even for government programs. However, most of the organizations visited during the assessment ensured that females who showed interest in their projects were included. It is well known that provision of training, especially through formal schooling, eventually improves one's capacity to obtain information. The information is then used for effective on-farm decisions including exploring innovative options such as the use of modern coping strategies to mitigate postharvest loss.

<u>Market access:</u> Adoption of modern technologies depends on ease of access to technologies, finance, and information. The markets include that for the physical tools, finance, information and output disposal due to use of technology. Distance to market and bargaining power are key. Limited access to technologies due to, for example, the long distance of suppliers from end users can constrain access to technology by both genders. However, males who are heads of households usually have more power and hence greater mobility. One way females could increase access is by forming segregated or women-only groups or being part integrated groups. Both males and females have increased access to technologies when they formed integrated groups. Social capital enhances collective action and group advantage can be used to improve access to financial capital as well. Improved access to financial capital improves access to technology. During the assessment, most stakeholders we interviewed were of the opinion that women and women-only groups were more honest, reliable, better able to follow prescribed protocols, and more likely to repay extended credit. This perception bodes well for women and could be harnessed to use women for scale up of storage technologies and tactics.

In conclusion, women play a major role in the PHHS system. Therefore, they have potential to make a significant contribution to reduce PHL and scale up of new technologies. Women-based organizations have been demonstrated to be a good vehicle in the adoption and scale up of new technologies and for obtaining financing. Multiple sources indicated women are more honest, reliable, better able to follow prescribed protocols, and more likely to repay extended credit.

Engagement

In addition to helping the project team develop a broader appreciation for the postharvest loss challenges present in Ghana, the December assessment trip also enabled the team to clarify our vision and future direction for engagement with local actors for capacity building. In particular, the prospect of partnering with farm service providers who have existing relationships with farmer based organizations, including a model for training farmers in technical improvements appears to be promising for our efforts. We have identified several organizational entities for delivery of training that could assist farmers to adopt new technologies. These organizations include nucleus farmers (NF) and agricultural inputs and production service packages providers (APSP) such as MAFA, as well as other smaller farmer based organizations (FBOs). We have found women's groups, nucleus farmers, and other service providers to be good models for delivering new methods and scaling them up. Women's groups have been cited by multiple sources as tending to be more honest, reliable, and more willing to follow protocols and objectives addressed through training than are male farmers. The connections established on this trip will allow us to expand our reach via our engagement advisory teams, which will serve as the social and political face of our effort in the Middle Belt and the Northern Ghana. Several key members of our engagement advisory committee were identified during the assessment trip. Essential findings from various groups with which we met are included in this section of the report.

Agricultural Technology Transfer (ATT). ATT has a sound relationship within the local agricultural community in Northern Ghana and has established partnerships with local FBOs for capacity building efforts. While most of the attention of ATT has been focused on preharvest technology, a partnership with ATT will enable our project team to have access to farmer organizations, seed companies and APSPs who are well positioned to assist us in reaching end-users with postharvest technology training. Not only does ATT have local organization partners in key regions such as Bolgatanga, Garu and Bolay, they also have learned valuable lessons about providing non-monetary incentives such as small quantities of improved fertilizers to encourage farmers to experiment with new technology to see firsthand the potential results of more widespread adoption of technological advancements. These models and our partnership with ATT hold promise for the ultimate, sustainable success of our engagement effort.

We learnt from ATT that nucleus farmer aggregators who offer tractor services, seed, fertilizer and grain marketing services as well as occasional financial services are essential partners for engagement efforts and scale up of technologies with the greatest potential for adoption. ATT has ongoing relationships with 40 such NFs who each serve approximately 2,000 smallholders.

These aggregators are most likely available to receive training in the February to March timeframe as well as in August to September – a valuable finding for our future engagement efforts. During our assessment trip, we had the opportunity to meet with three smaller scale NFs including Gundaa Produce Company, Antika Company Limited and Big Ajar Enterprise as well as a prominent large scale service provider and farmer organizer MAFA.

Gundaa Produce Company. GPC provides services in 10 districts to 42 Farmer Based Organizations (FBOs) reaching approximately 3,000 farmers. Nearly 400 of the farmers with whom they work are women – some of whom are members of five women's FBOs. The 500-MT GPC main warehouse is certified through GGC for sale of their maize to the WFP. In addition to providing technical production-focused training, GPC has recently started providing FBOs with training on how to seek micro-finance support from Sinapia Bank, which will extend lines of credit to farmers or groups of farmers who open savings accounts. GPC has been actively promoting this concept in partnership with Sinapia Bank. We were encouraged by the positive response received from GPC to the idea of working with our research findings and partnering on training the FBOs they reach. We learned that postharvest training and technology is desperately needed and an area in which GPC feels they have a lack of training expertise.

Antika Company Ltd. The business model for AC is similar to that of GPC in that they provide tractor services, seed and fertilizer sales, shelling services, and aggregation and marketing of harvested grain in exchange for a portion of the harvest. Similarly, AC is also engaged with providing smallholder capacity building – primarily provided to FBOs by their five employed technical field staff. In addition to face-to-face training on their own demonstration plots, AC also utilizes more mediated information transfer approaches. Their distribution of printed materials, creation of memorable "jingles" to reinforce best practices and most importantly their use of radio programming will serve as effective models upon which we will base our capacity building efforts. Their partnership with Esoko to offer radio programing timed to the agricultural seasons with call-in programs for farmers holds great promise for our future efforts to broaden the reach of our engagement efforts.

Masara N'Arziki Farmers Association (MAFA) and Wienco. MAFA comprises approximately 10,000-11,000 farmers in Northern Ghana. MAFAs success can be attributed to the fact that it provides agricultural inputs, preharvest, and postharvest services on credit to members. Credit extended is usually repaid in terms of 50-kg bags of maize equivalent to the value of the credit extended. The provision of inputs and services earns MAFA a lot of trust from SHFs. MAFA is also encouraging members to purchase maize shellers by extending credit to them to make this possible. To encourage SHF to view agriculture as a commercial activity, MAFA conducts Farmer Business School (FBS) trainings during the periods of April 1-30 and June-July.

MAFA maize is stored in Wienco's six 4,000-MT warehouses. During the assessment, Wienco agreed to let PHL-IL Ghana use their warehouses for evaluating insect activity during storage and to test new methods developed.

The large membership of MAFA, their current involvement in scaling up of various agricultural production tactics and technologies (shellers), and their involvement in training farmers makes them a great partner for PHL-IL Ghana. MAFA could greatly facilitate the scale up of PHL mitigation tactics and technologies in Northern Ghana.

In addition to the valuable findings received from our contacts with private sector actors, essential findings were also derived from public sector assessment visits including the MoFA Regional Director in the Upper West as well as USAID funded programs operating in Northern Ghana such as SPRING and RING. Findings from these discussions are presented in the following section.

MoFA Regional Office, Northern Region (Mr. William Acheampong – MoFA Regional Director). Mr. Acheampong has over 30 years of experience in agriculture and is keenly aware of the importance to reduce PHL and provide food security. He strongly endorsed the notion that a regional development strategy coordinated by a public/private/producer partnership was the key to reducing PHL. He believes that private investors possess more flexibility to make funding available to SHFs when it is needed compared to less nimble governmental entities. After years of effort to establish community-based storage solutions, the director was doubtful that government-owned solutions involving community warehouse systems would be effective in the short term due to the lack of cultural acceptance and other barriers to such systems. He elaborated that large groups of mostly illiterate farmers were unlikely to store their harvested grain and family food supply in a pooled community warehouse where they could not see it on a daily basis. Furthermore, he had concerns with farmer's lack of reliable transportation to deliver grain to community centers. The director encouraged us to engage with private partners who were more likely to establish stronger trust relationships with farmers due to their ability to interact more regularly.

Strengthening Partnerships, Results and Innovation in Nutrition Globally (SPRING). Due to their focus on farmer capacity building, SPRING serves as a logical partner for our engagement efforts. Their emphasis on serving women and children, their need for access to technical information related to grain storage best practices and aflatoxin detection/prevention, and their desire to partner with other Feed the Future ILs has our project team eager to further develop a relationship with SPRING administration to form a collaborative partnership. During our visit, we gained valuable insight regarding strategies to most effectively reach women farmers who frequently also have family obligations that may prevent their participation in capacity building efforts. We will utilize lessons learned from SPRING in creation of educational materials and training programs as well as in the seasonal timing and timeframes within the day when we will seek to serve women's groups with capacity building programs. The potential to pool resources with our SPRING partners to extend our mutual reach will be further explored in the near future.

Resiliency in Northern Ghana (RING). It is evident that a positive working relationship exists between SPRING and RING leadership, which is greatly facilitated by the fact that their offices are in the same building compound in Tamale (along with ATT). We view this existing relationship as another avenue to broaden our reach while assisting SPRING and RING in accomplishing their objectives. RING has an expressed need for additional expertise in aflatoxin mitigation and aflatoxin prevention information. It appears that RING is somewhat dependent on other organizations to provide them with technical information and educational materials. We believe our materials will integrate effectively into their efforts to serve Northern Ghana's most vulnerable populations. We also believe their full-time presence in the region and the relationships they are establishing with communities, community leaders and organizations serving the very poor will assist our IL in accomplishing project outcomes – particularly those related to nutrition, serving women and mitigating aflatoxin impacts through improved storage practices.

Maize Standards in Ghana

One of the key issues hindering PHL mitigation and the production of high quality maize in Ghana is the lack of adherence to maize standards established by the GSA. According to GSA, if the market demanded quality, then standards will be implemented. For example, despite having mycotoxin and residue labs accredited to GSA, stakeholders rarely utilize the services offered by these two labs. The key reason cited for lack of demand for quality maize is lack of collaboration among various stakeholders in the maize supply and value chains in demanding high quality maize.

Clearly, it is the Ministry of Health (MoH) that is responsible for the regulation of grain standards. The Ghana Food and Drugs Authority (FDA) under MoH is the agency charged with regulation of standards. According to the FDA website "The Food and Drugs Authority is the national regulatory body under the Ministry of Health with the responsibility of implementing Food and Drugs Law of 1992, (PNDCL 305B) to regulate the manufacture, importation, exportation, distribution, use and advertisements of food, drugs, cosmetics, medical devices and household chemicals with respect to ensuring their safety, quality and efficacy. In exercising this mandate, the Food and Drugs Authority ensures the safety and wholesomeness of foods we eat." [(http://www.eservices.gov.gh/FDB/SitePages/FDB-Home.aspx) (accessed on 1/18/15)]. However, despite FDAs clear mandate, the regulation is not backed by law hence the lack of adherence to grain standards. It is also surprising that the regulatory role of FDA was not clear to many officials in government, GSA, and others associated with the maize value chain. To some of these officials, it was not clear among MoH, Ministry of Food and Agriculture (MoFA), and Ministry of Trade and Industry (MoTI), as to which ministry was responsible for the regulation of grain standards. This is despite the fact that it is clearly MoH through FDA that regulates grain standards.

Scale Up of PHL Mitigation Methods and Technologies

For any technology to be successfully scaled up, it must be capable of improving performance (results) and it must save labor. The process of scaling up technologies requires proper planning. Scale up of PHL mitigation technologies is usually most successful if demand driven. For example, local organizations can initially be used to create demand for technologies. However, effort then needs to be placed on working with the private sector to develop supply channels. Most past technology scale up projects in Ghana have not moved along with the private sector and have failed after the departure of the project sponsors. During scale up, communication of scientific evidence regarding the technology is extremely important.

Demonstrations are critical in creating demand for technology. It is vital to involve local organizations that already work with farmers in conducting demonstrations. It is not wise to conduct demonstrations with opinion leaders only. If this is done, ordinary SHFs may get the impression that technology only works for the well to do. Nucleus Farmer Aggregators (NFAs) are good players to use to conduct demonstrations. They are elite farmers who assist SHFs in their communities with land preparation, agricultural inputs, and preharvest, harvest, and postharvest services. Because they are also maize traders (aggregators), they assist SHF with storing and marketing their maize. SHFs usually pay NFAs in kind (bags of maize). NFAs are progressive and well respected in their communities hence any new technology adopted by them will likely have a greater chance of being adopted by SHFs as well. On the other hand, Market Aggregators are probably not a good group to use for demonstrations because they are difficult to pin down and are as not interested in improvement.

Storage technologies need to be simple and affordable in order to be easily scaled up. Farmers are sophisticated. Therefore, good information, education, and training greatly enhance the chances of them adopting new PHL mitigation technologies.

Not all SHF have interest and capability of adopting new storage technologies. Scale up needs to be targeted at reliable SHFs and NFAs. These are the ones to be educated and trained. In interaction with SHF in relation to scale up issues or other matters, carefully consider information collected from them because they desire free things and usually give misleading information.

One of the key challenges to scale up is lack of awareness. People who are aware are more likely to seek solutions. For scale up, it wise to target areas where people are more serious and perceive agriculture as a business. For example, MAFA is moving into the Tumu area in the Upper West for the following reasons:

1-It is comparatively more fertile
2-SHFs have a good work ethic
3-Treat farming as a business and not a way of life
4-SHFs are more dedicated
5-Tumu lacks other opportunities hence farming is the only profitable thing

Overall, challenges to scale up of technologies in Northern Ghana can be related to both socio-economic and institutional factors.

Socio-economic

1) Large numbers of both male and female farmers do not view agriculture as a business
2) Lack of curiosity and desire to acquire information on improved agricultural methods and technologies
3) Lack of social capital stemming from dishonesty, unreliability, and non-adherence to agreements such as in contract schemes
4) Low capacity to access credit

Institutional

1) Inadequate household and community level storage facilities
2) Inadequate simple and affordable preharvest and postharvest services
3) Inadequate medium to long-term credit facilities for resource-poor entrepreneurs
4) Nonexistent demand-driven research
5) Lack of transparency in terms of engagement
6) Low desire by communities to change and try new ideas but preference to maintain the traditional gender division of labour concept

Based on the insight gained from the PHL assessments and what has been stated above, PHL-IL Ghana Team is of the view that only certain groups such as NFAs and other APSPs be targeted for scale up efforts. Additionally, PHL-IL Ghana will work collaboratively with ATT and other USAID-funded programs in Ghana, namely, ADVANCE, Africa RISING, RING, and SPRING to facilitate scale up efforts.

Potential Research Locations and Cooperators/Collaborators

In addition to the contacts and research locations identified in the first PHL assessment trip report (focused on the Middle Belt), the following groups are potential collaborators:

<u>Tumu, Upper West Region:</u> Tumu in the upper northwest part of Ghana is a new region with maize production and might be a good research or demonstration location if local contacts can be

made. It was reported that farming tends to be treated as a business in that area, soil is a little more fertile, and the farmers have a great work ethic.

Wienco and MAFA: these entities have tentatively agreed to collaborate in evaluating insect activity during storage and to test new methods developed. Dr. Abudulai Mumuni at CSIR-SARI is a potential researcher in the north that could direct the collection of insect and moisture monitoring data from the Wienco warehouses. Pens Food Bank and graduate students from Kumasi University of Science and Technology could help with the collection of data in the Middle Belt. Tentative agreements were made during this trip and the research projects were initialized. Pens Food Bank was also identified as a collaborator on the scale-up of using plastic silos compared to traditional bags.

Agriculture Technology Transfer (ATT): "The Feed the Future USAID Agriculture Technology and Transfer Project (ATT) targets an increase in the availability of appropriate and affordable technologies to improve the competitiveness of the maize, rice and soya value chains in northern Ghana in a sustainable way. USAID/Ghana is funding the project for a period of five years with an anticipated budget of $22 million."
http://www.ifdc.org/getattachment/Projects/Current2/North_West_Africa/FTF-USAID-ATT/Press-Release/USAID-Feed-the-Future-ATT-Project/ATT-factsheet-A4-page.pdf

We had a fruitful discussion with Mr. Musa Salifu Taylor, the ATT Organization Development Advisor, on the scale up of the ZeroFly® Storage Bag and the USDA-ARS low cost moisture meter. Follow up will involve preparing and signing a memorandum of understanding between ATT and PHL-IL.

University for Development Studies (UDS): UDS is working in the area of postharvest and has a mandate to work with the communities. One researcher is working with University of Georgia on aflatoxins in peanuts. He suggested that we work in parallel with them and use their connections with the farmers. UDS sends students to the field for 6-8 weeks for community development projects. These students could be a beneficial resource for PHL-IL activities in Northern Ghana because the students could collect data and/or provide some technology transfer. Student involvement in community development projects is paid for out of fees from Third Trimester Foundation Practical Training Program.

Africa Research in Sustainable Intensification for the Next Generation (Africa RISING):
Dr. Joseph Atehnkeng is the regional coordinator for the Aflasafe project in Ghana. This is a promising preharvest treatment that could have significant impact on the reduction in postharvest aflatoxin levels. Aflasafe can reduce aflatoxin levels by up to 80% and continues to work even postharvest during storage. In addition to marketing Aflasafe they also do a lot of education, and work with nucleus farmers for early adoption. Africa RISING focuses not just on Aflasafe, but also other ways to reduce infestation levels such as drying and storage. There is a good potential for developing collaborative project with Africa RISING and other groups such as SPRING,

ATT, and ADVANCE to evaluate this product (Aflasafe) through demonstration projects and also for technology transfer and information dissemination.

Strengthening Partnerships, Results, and Innovation in Nutrition Globally (SPRING): Focuses on reduction in stunting and works in partnership with other organizations at the community and household level. They are interested in postharvest handling and aflatoxin reduction. They work in 15 districts in the Northern Region and Upper East Region, and plan to have two officers in each district, although they are still trying to fill all these positions. They work in partnership with Ministry of Health, MOFA, Social Welfare and Community Development, and Environmental Health and collaborate with ADVANCE and Dr. Mumuni at CSIR-SARI. SPRING is planning to conduct a survey of aflatoxin levels in maize, but they are still at the stage of obtaining ELISA test strips that can detect 15 ppm. This would be good baseline data for PHL-IL Ghana project and the focus on the nutritional impact of PHL is a good linkage to our project objectives. There is potential for collaboration in sharing knowledge and information and having access to their farmers and extension officers. They are currently preparing training materials. Therefore, good opportunities exist for obtaining help with disseminating information and developing demonstration projects.

Resiliency in Northern Ghana (RING): Focuses on nutrition of women of reproductive age and children under five. They are focused more on input supply and training, while SPRING focuses on capacity building. They work to support beneficial activities to reduce PHL and have done some work with triple bags. They do not currently work on maize but focus on cowpea, groundnuts and soy because these are, commercial, low external input crops and it is traditionally the responsibility of women to cultivate these crops. There may be some potential for collaboration in conjunction with SPRING on information dissemination. Also, there is a potential collaboration in documenting the current nutrition deficiencies and the impacts of new tactics for reducing PHL and aflatoxin on nutrition.

Savanna Agricultural Research Institute (CSIR-SARI): CSIR-SARI's mandate is to provide small scale farmers in the Northern, Upper East, and Upper West Regions of Ghana with appropriate technologies to increase their food and fiber crop production based on a sustainable production system which maintains and/or increases soil fertility. There is potential for PHL-IL to collaborate with CSIR-SARI in evaluation of PHL mitigation technologies, monitoring stored-product insect populations in warehouses, and collection of baseline aflatoxin, MC, and insect infestation level data.

Ghana Standards Authority (GSA): Develops standards and provides aflatoxin testing service based on HPLC. The cost of testing is GHC150 per sample and a 1-kg minimum of the sample is required. GSA also conducts outreach activities and would be a good collaborator for both activities.

Esoko: Provides a platform to connect with farmers. It is a for profit company with a mission to make agriculture profitable for smallholder farmers. It provides market price information for commodities by cell phone. Through SMS or voice messages, information about market, weather, and best practices is disseminated by Esoko. It can also conduct surveys and polls through smartphones and tablets or SMS messages and have forms for field agents to upload collected information in real time. They also have a system to deliver extension information and technical data to tablets and smartphones.

Immediate Next Steps for PHL-IL Ghana

A key focus of the year two-project plan is conducting the research described in pages 5 and 6 above. The two assessment trips afforded PHL-IL Ghana the opportunity to identify potential members of the advisory teams that will provide grassroots stakeholder input to inform development of our engagement programming curriculum, strategies, and target recipients, i.e. Engagement Advisory Teams (EA Teams) for the Middle Belt and Northern Ghana. The assessments also enabled identification of potential members for our Technology Research Implementation Team (TRI Team) for Ghana. In fact, in March 2015, two members of PHL-IL Ghana and the Ghana In-Country Coordinator met with members of the EA and TRI Teams, formalized the teams, and discussed plans for collaboration in years 2 - 5 of our project. PHL-IL Ghana will now embark on conducting research, piloting storage technologies, and scaling up these storage technologies in collaboration with other USAID funded projects in Ghana.

People/Locations/Groups/Organizations/Government Entities Visited During the Second Postharvest Loss Assessment trip or Referenced in the Report

Africa Research in Sustainable Intensification for the Next Generation (Africa RISING)

The Africa RISING program comprises three researches for development projects supported by USAID as part of the U.S. government's Feed the Future initiative. Its aim is to transform agricultural systems through sustainable intensification projects in three regions of Africa. Sustainable intensification of mixed crop livestock systems is a key pathway towards better food security, improved livelihoods and a healthy environment. As part of the US government's Feed the Future initiative to address hunger and food security issues in sub-Saharan Africa, USAID is supporting three multi-stakeholder agricultural research projects to sustainably intensify key African farming systems. (http://africa-rising.net/)

Agricultural Development and Value Chain Enhancement (ADVANCE) Ghana

“The Ghana Agricultural Development and Value Chain Enhancement (ADVANCE) Project is a 4-Year USAID sponsored project awarded to ACDI/VOCA and being implemented in partnership with a team of agencies including ACDEP as the lead implementer in the Northern Sector. Starting in late 2009, ACDEP is working on three commodity value chains (maize, rice and soybean) and has opened regional offices in Wa, Bolgatanga and the Head Office in Tamale to ensure effective implementation of the program” (http://acdep.org/wordpress/acdep-development-programs/value-chain/advance/).

Agriculture Technology Transfer (ATT)

The ATT project addresses Ghana’s complex value chain issues, focusing on using technologies to improve the seed sector. The project also focuses on identifying sustainable solutions that will lead to increased competitiveness in the rice, soybean and maize value chains. The expected outcomes are increased availability and use of agricultural inputs and technologies to increase and sustain agricultural productivity in Northern Ghana.
(http://www.ifdc.org/projects/current2/north_west_africa/ftf-usaid-att)

Council for Scientific and Industrial Research (CSIR)

The CSIR mission is “To generate and apply innovative technologies which efficiently and effectively exploit Science and Technology (S & T) for socio-economic development in the critical areas of agriculture, industry, health and environment and improve scientific culture of the civil society. Technologies developed will be commercialized for Private Sector Development in Ghana and abroad”. (http://www.csir.org.gh/index1.php?linkid=79).

Farmer Based Organizations (FBOs)

The key goals of FBOs are bringing SHF together to facilitate: 1) transfer of agricultural production knowledge and technology for improved yields; 2) linkage to finance - provision of credit facilities to member SHF at acceptable interest rates usually not exceeding 10% (banks charge up to 45% interest); and 3) facilitate implementation of agriculture-related projects that would be too difficult for one or a few SHF to accomplish.

Financing Ghanaian Agriculture Project (USAID-FinGAP)

“The USAID Financing Ghanaian Agriculture Project (USAID-FinGAP) is a five-year project that addresses access to finance for agribusinesses while increasing the competitiveness of rice, maize, and soy in northern Ghana by using technical assistance and incentives to unlock significant financing for agribusiness”. (http://www.carana.com/projects/subsaharanafrica/919-financing-ghanaian-agriculture-project-fingap)

Ghana Grains Council (GGC)

Has a vision "To become the leading industry association representing and advocating for the interests of all participants and service providers in the grain industry to create a more competitive, productive and efficient agricultural sector." GGC mission is to: 1) advocate for and facilitate sustainable improvements and increased efficiency in the grain industry through strategically targeted interventions along the grains value chain; 2) contribute to the establishment and enforcement of transparent rules, regulations and standards; and 3) ensure a competitive industry while protecting the public interest. (http://ghanagrainscouncil.org/index.php/who-we-are/vision-mission).

Ghana Standards Authority (GSA)

The Mission of GSA is to promote standardization for the improvement of the quality of goods, services and sound management practices in industries and public institutions in Ghana. (http://www.gsa.gov.gh/home/)

International Institute for Tropical Agriculture (IITA)

The IITA is one of the world's leading research partners in finding solutions for hunger, malnutrition, and poverty. IITA's award-winning research for development (R4D) addresses the development needs of tropical countries. IITA work with partners to enhance crop quality and productivity, reduce producer and consumer risks, and generate wealth from agriculture. (http://www.iita.org/iita-ibadan-nigeria)

Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

KNUST has carefully categorized academic departments into six colleges, a state of the art library complex housing a modern Information and Communication Technology Centre, several educational resource centres, modern laboratories, research facilities and a host of other facilities. KNUST delivers a high standard of education, which reflects the pedigree of a University poised on attaining a status of being No. 1 in Africa. Academic related issues; especially on studying and research has never been this convenient. This hallmark is evident in their ever-increasing affiliate institutions. They claim to be the home of academic excellence. (http://www.knust.edu.gh/academics). Academic department personnel visited during our assessment trip included faculty and staff from Agricultural Economics, Agricultural Engineering, Agronomy, Entomology, and Plant Pathology.

Masara N'Arziki Farmer Association (MAFA)

Masara N'Arziki (meaning "Maize for Prosperity") is headquartered in Tamale and covers the entire Northern part of Ghana (i.e Nortern Region, Upper East and Upper West Regions and parts of Brong-Ahafo Region [mapsofworld.com/ghana/]). MAFA is the culmination of

Industrial Maize Program initiated in 2005 by Wienco (Ghana) Limited. Masara N'Arziki's vision is to help maize farmers do what they are doing much better, and receive more income through the use of improved technology that increases productivity of their farms. The program package consists of the provision of fertilizers, hybrid seeds, herbicides, insecticides, spaying equipment, innovative farm implements and technical advisory and training services to farmers on credit. (http://www.yaraghana.com/Support-Services/Masara-N-Arsiki-Farmer-Association.aspx).

Millennium Challenge Corporation (Millennium Development Authority (MiDA)

"Agriculture is the backbone of Ghana's economy accounting for about 40 percent of the country's gross domestic product, employing 60-70 percent of the labor force and generating more than 55 percent of the foreign exchange earnings. The program proposed under the compact would operate in the northern area, the central Afram Basin area and the southern horticultural belt area. Overall poverty rates in the target areas are generally above 40 percent. In the north, as well as in parts of the central Afram Basin area, poverty among the rural population is as high as 90 percent.

Through an act of its Parliament, the Government of Ghana created the Millennium Development Authority (MiDA), a public corporation that serves as the accountable entity for the implementation of the five-year program. MiDA is governed by an independent board of directors consisting of representatives of key government ministries, the private sector, and the non-governmental organization (NGO) community, with observers from the target areas and the environmental community. The program focuses on improving the productivity of agriculture, increasing production of high-value commercial and basic food crops, and fostering greater private investment in agriculture. To that end, the program aims to improve the physical and institutional infrastructure in this critical sector of Ghana's economy. The program was designed through a consultative process that included input by farmers, agricultural processors and marketers, NGOs, government ministries, international donors and others.

Agriculture ($241 million): The largest of the three components is designed to enhance the profitability of commercial agriculture among small farmers. It includes:

- Training for farmer-based organizations (FBOs) and agricultural enterprises to accelerate the development of commercials skills;
- Irrigation improvements with the building of a limited number of retention ponds and small dams requested by FBOs whose success requires access to water;
- Improved land tenure security and transaction support;
- Facilitation of strategic investments by FBOs and other businesses in post-harvest infrastructure, including cold storage and processing facilities, supported by enhanced compliance with international food protection standards;
- Improved access to credit provided by commercial and rural banks, and non-traditional financing channels; and

- Rehabilitation of up to 950 kilometers of single-lane roads in order to reduce transportation costs and time to major domestic and international markets, and social service networks (including, for instance, hospitals, clinics and schools)." (http://2001-2009.state.gov/p/af/rls/fs/68866.htm).

Ministry of Food and Agriculture (MOFA), Republic of Ghana

MoFA's Mission is to promote sustainable agriculture and thriving agribusiness through research and technology development, effective extension and other support services to farmers, processors and traders for improved livelihood. (http://mofa.gov.gh/site/#).

Pens Food Bank Enterprise (PFB) – Mr. Evans Peter Nsiah

Pens Food Bank is strategically located within the Middle Belt (a.k.a. transitional zone), the heart of maize production, and connects many different active players involved with the maize value chain in the Middle Belt of Ghana. Therefore, PFB is a focal organization in the Ghana maize value chain. PFB is a private and profit-oriented organization that has a lot of social interventions that benefit stakeholders in the maize value chain in the Middle Belt. Mr. Evans Peter Nsiah is the Managing Director of PFB. In order to ensure regular supply at harvest time, PFB helps to prepare farmers' lands for planting on a credit basis. Farmers pay cash or in-kind during harvest time. PFB also organizes trainings in Good Agricultural Practices (GAP) for Farmer Based Organizations (FBOs) to facilitate production of healthy and high quality crops and to enhance yields. PFB accepts maize from producers, traders and aggregators for cleaning, drying and storage for a fee. PFB uses its trade network, locally and within the West Africa sub-region to market grains for traders and farmer groups who request for volume sales on commission.

PFB activities span across the Middle Belt comprising places such as Ejura, Sekyedumas, and Mampong Municipalities. Its operations impact on an average of 40,000 farmers in about 62 Farmer Based Organizations (FBOs), 200 aggregators, 300 traders, and 150 processors.

Resiliency in Northern Ghana (RING)

This USAID project focuses on vulnerable families, helping to improve the health status of families and enabling them to better resist unforeseeable shocks, such as droughts, floods, and fluctuating food prices. The initiative is under implementation in 17 districts in the Northern Region, which USAID and its partners in district and regional government have identified through an assessment process. (http://ghana.usembassy.gov/pr_072913.html)

Smallholder Farmers (SHF)

Ghana's agricultural sector is primarily subsistence-based. According to the Ministry of Food and Agriculture Sector Development Policy (FASDEP II), family-operated smallholder farms account for nearly 80 percent of the country's total agricultural output. Approximately 51% of the labor force is directly or indirectly engaged in agriculture with most holdings averaging less than two hectares. These figures imply there is a lot of on-farm storage.

United States Agency for International Development (USAID) – Accra, Ghana
(http://www.usaid.gov/what we do)

"In an interconnected world, instability anywhere around the world can impact us here at home. Working side-by-side with the military in active conflicts, USAID plays a critical role in our nation's effort to stabilize countries and build responsive local governance; we work on the same problems as our military using a different set of tools. We also ease the transition between conflict and long-term development by investing in agriculture, health systems and democratic institutions. And while USAID can work in active conflict, or help countries transition from violence, the most important thing we can do is prevent conflict in the first place. This is smarter, safer and less costly than sending in soldiers.
USAID extends help from the American people to achieve results for the poorest and most vulnerable around the world. That assistance does not represent a Democratic value or a Republican value, but an American value; as beneficiaries of peace and prosperity, Americans have a responsibility to assist those less fortunate so we see the day when our assistance is no longer necessary.

USAID invests in ideas that work to improve the lives of millions of men, women and children by:

- Investing in agricultural productivity so countries can feed their people
- Combating maternal and child mortality and deadly diseases like HIV, malaria and tuberculosis
- Providing life-saving assistance in the wake of disaster
- Promoting democracy, human rights and good governance around the world
- Fostering private sector development and sustainable economic growth
- Helping communities adapt to a changing environment
- Elevating the role of women and girls throughout all our work"

Strengthening Partnerships, Results and Innovation in Nutrition Globally (SPRING)

SPRING is dedicated to strengthening global and country efforts to scale up high-impact nutrition practices and policies. SPRING provides state-of-the-art technical support focused on preventing stunting and maternal and child anemia in the first 1,000 days (beginning at conception), linking agriculture and nutrition, and creating social change and behavior change through communication. SPRING's mission supports two major U.S. Government initiatives: Ending Preventable Child and Maternal Deaths and Feed the Future.
(http://www.jsi.com/JSIInternet/IntlHealth/project/display.cfm?ctid=na&cid=na&tid=40&id=9561)

Warehouse Receipt Program (WRP)

USAID is currently funding the establishment of the Ghana Grains Council (GGC) through ADVANCE program. GGC runs the USAID Warehouse Receipt Program (WRP). The Ghana WRP was started in March 2010 and a number of WRP are planned for West Africa with the one in Ghana being a pilot project for these. The underlying reasoning behind the program is that there will be no impetus for grain quality without the WRP or something like it. Grain trade in Ghana is currently inefficient due to lack of a WRP or a commodity exchange system. The WRP will be mostly driven by issues related to grain quality, price stabilization, and the value chain. The goal of the program is to increase grain quality by ensuring low incidence of aflatoxins in the grain value chain. Consumption of aflatoxins can lead to immediate death or chronic effects such as liver cancer. The WRP will also make grain trade more efficient by ensuring a reliable supply of good quality grain to warehouses, which will result in grain price stabilization.

World Food Program (WFP) Ghana

WFP works with the Government of Ghana to implement a development programme focusing on education, nutrition and climate change mitigation and adaptation projects. Some of WFP Ghana activities include: 1) provision of school meals; 2) nutrition - provision of nutritious food supplements to pregnant and nursing women, chronically malnourished children under the age of two, children under the age of five suffering from moderate acute malnutrition, and people living with HIV on anti-retroviral therapy; 3) resilience - building resilience of communities in Ghana through asset creation activities and training to promote sustainable livelihoods; 4) emergency operations - an emergency operation began in August 2011 to provide food to Ivorian refugees after the 2010 election crisis in Côte d'Ivoire; 5) Purchase for Progress (P4P) - the P4P initiative aims to address some of the major constraints SHFs face, including low productivity, significant PHL, poor market infrastructure and inadequate access to markets; 6) local procurement - WFP Ghana buys a minimum of 60 percent of its food needs from surplus production areas in the country, which is then redistributed in food-insecure regions; 7) United Nations Humanitarian Response Depot - Ghana hosts one of five UN Humanitarian Response Depots in the world - logistics intervention fleet - this centrally-pooled fleet of trucks is on hand for immediate dispatch to regional emergencies. (http://www.wfp.org/countries/ghana/operations).

References Cited

Akrobortu, D.E. 2008. Afatoxin contamination of maize from different storage locations in Ghana, M.Sc. Thesis. Mechanical and Agricultural Eng. Kwame Nkrumah University of Science and Technology. Kamasi, Ghana.

Government of Ghana. 2014. Aflatoxin in maize--challenges and efforts to curb it. http://www.ghana.gov.gh/index.php/2012-02-08-08-32-47/features/6921-aflatoxin-in-maize-challenges-and-efforts-to-curb-it

International Institute of Tropical Agriculture Press Release. 2014. Farmers in Ghana become more aware of aflatoxin menace. http://www.iita.org/2014-press-releases/-/asset_publisher/CxA7/content/farmers-in-ghana-become-more-aware-of-aflatoxin-menace?redirect=%2Fhome#.VNZP5C6gvkM

International Institute of Tropical Agriculture. 2014. Aflatoxin mitigation in Africa. www.aflasafe.com.

Wieman, D.M., G.M. White, J.L. Taraba, I.J. Ross, C.L. Hicks and B.E. Lanlois. 1986. Production of aflatoxin in damaged corn under controlled environmental conditions. Trans. ASAE. 29(4): 1150-1155.

Footnotes

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Appendix A

Biosketches of Ghana Project Team that Conducted the Second Maize Postharvest Loss Assessment in Northern Ghana

Julia Bello-Bravo (J.D., M.B.A., M.A., and Ph.D.), Assistant Director at the Center for African Studies at the University of Illinois at Urbana-Champaign. She is one of the co-founders of the program called "Scientific Animations Without Borders" (SAWBO). SAWBO, which is based at the University of Illinois at Urbana-Champaign, creates high-quality 2-D and 3-D animations for educational purposes and then makes them easily and freely accessible to people and organizational groups in a great diversity of languages in many different formats, ranging from DVDs, to computers, email attachments and cell phone Apps. Julia specializes in educational content appropriate for low literate learners in developing countries with an emphasis on strategic partnerships, bringing together experts from around the world, engaging local communities to share their knowledge and languages and coordinating with student's animators during the process of creation. As part of SAWBO, she has help in the development of over a dozen ongoing collaborative working relationships with African institutions and NGOs.

Her research interests lie in the intersection of social, cultural and global perspectives. She has repeatedly travelled to a considerable number of African countries and spent a great amount of time interacting with local, national and international communities on the ground. She has engaged with UIUC students in the Global Health Initiative as it pertains to Africa, including two trips with MD/PhD students to Ghana and Sierra Leone. She also serves on the admission committee for potential students at the Center for African Studies. Her research has been published in a diversity of journals, conference proceedings and multiple book chapters. At the University of Illinois, Julia has taught a course in International Development in Practice to undergraduate and graduate students. In addition, she teaches International Business at the University of Deusto (Spain) to American students in the summers.

Julia has been the Co-PI of numerous grants from different institutions, including several large USAID grants as well as the ADM Institute for the Prevention of Postharvest Loss. SAWBO is also funded by the Chancellor's office (through the Chancellor's Fund). SAWBO has received numerous awards including the 2012-2013 Campus Award for Excellence in Public Engagement at the University of Illinois and the 2012 Champaign-Urbana International Humanitarian Award. (Email: juliabb@illinois.edu).

Dr. James F. Campbell is a Research Entomologist with the United States Department of Agriculture, Agricultural Research Service, Center for Grain and Animal Health Research in Manhattan, Kansas USA. He is also an adjunct professor in the Department of Entomology at Kansas State University. His research interests include the spatial distribution and movement patterns of stored-product insects in food facility landscapes, improving the implementation and interpretation of insect monitoring programs, and determining the impact of different management tactics on pest populations within commercial food facilities. He has authored numerous peer-reviewed journal articles, given many invited presentations at national and international conferences and at stakeholder group meetings. He serves as the Secretary/Treasurer for the Permanent Committee of the

International Working Conference on Stored Product Protection and is on the Editorial Board of the Journal of Stored Products Research. (Email: James.Campbell@ars.usda.gov).

Dr. Irene Susana Egyir is a Senior Lecturer in the University of Ghana at Department of Agricultural Economics and Agribusiness, School of Agriculture of the College of Basic and Applied Sciences. She has engaged herself in a number of researches and consultancies. Her current research is concerned with productivity and profitability of organic and conventional farming. Her consultancies have focused on youth employment in agriculture, women and micro finance, post- harvest loss assessment and mitigation and contract farming and out-grower schemes. She has also collaborated with institutions like the GIZ, FAO and Ministry of Food and Agriculture to undertake capacity building programmes and studies in gender and agricultural development. Dr. Irene Egyir has performed many tasks in institutional capacity building some of which are acquisition of funding for M.Phil. Student theses since 2006, was part of the Teaching and Learning Innovations Fund (TALIF) programme in 2007-2012 and implemented the AGRA funded scholarships for 20 PhD students from 2012 to 2014.

Dr. Egyir has made a number of contributions to various book chapters and has published a number of articles in journals, and written a number of articles in Technical reports, discussion papers and also contributed to conference proceedings across the continents. She has also served as a member on various boards and committees and was the Head, Department of Agricultural Economics and Agribusiness for the 2012 to 2014 academic years. She is currently using her sabbatical leave from the University to serve as a Technical Advisor at the Agriculture and Agribusiness Unit, Ministry of Finance, where she supports staff capacity building, research and policy analysis. Dr. Egyir has founded a development NGO named Multi-Features and Capacity Enhancing Services which links urban micro-entrepreneurs to Research, Extension, Finance, Consulting and Cooperative and Media (REFCOM) Services. (e-mail: iegyir@ug.edu.gh / ireneegyir@yahoo.com).

Dr. Samuel McNeill is an Associate Extension Professor and Extension Agricultural Engineer in the Biosystems and Agricultural Engineering Department at the University of Kentucky Research and Education Center in Princeton, KY, USA. He is a registered professional engineer in the Commonwealth of Kentucky. His extension and research program focuses on post-harvest processing of grain and biomass crops for food, feed, fiber, and fuel production and he has extensive experience working with the design, operation and management of grain drying and storage facilities. He has authored numerous extension publications including topics on harvesting, drying and storing corn, canola, grain sorghum, soybean, soft red winter wheat, and aflatoxin control in corn which are available on the UK-BAE website (www.bae.uky.edu). An active member of the American Society of Agricultural and Biological Engineers since 1979, he is currently a member of several technical committees, including energy, extension, grain drying and storage, biomass products, and textbooks and monographs committees and has served as chair of the last three during his career. Recent projects have focused on reducing postharvest losses of grains in West Africa (Nigeria and Ghana). (Email: sam.mcneill@uky.edu).

Dr. George Opit is an Associate Professor of Stored Product/Post Harvest Entomology in the Department of Entomology and Plant Pathology at Oklahoma State University in Stillwater, Oklahoma, USA. His broad research interests are integrated pest management and biological control of arthropod pests. Specifically, his research is focused on investigating the biology, behavior, and population dynamics of stored-product arthropod pests and their natural enemies and in using the information acquired to optimize pest management. His research activities involve the study of pesticide resistance of stored grain pests, while extension activities are in the area of integrated stored-product pest management both of which have led to numerous speaking opportunities at national and international meetings and conferences (http://entoplp.okstate.edu/profiles/opit.html). (Email: george.opit@okstate.edu).

Dr. Enoch Adjei Osekre is a Senior Lecturer in Entomology at the Department of Crop and Soil Sciences of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. His broad research interests are integrated pest management and host plant-insect interaction with focus on population dynamics of insect pests and their application on development of integrated pest management strategies for both field and storage insect pests of vegetables, legumes and cereals. His extension activities have focused on education on safe handling and use of pesticides. He has participated in many scientific conferences. (Email: osekre.canr@knust.edu.gh).

Dr. Shannon G. Washburn is a professor of Agricultural Education in the Department of Communications and Agricultural Education at Kansas State University in Manhattan, KS, USA. Dr. Washburn's work revolves around educator effectiveness in agriculture and the affiliated sciences. His undergraduate and graduate courses address curriculum development, educational program planning, and professional development issues. As a State Extension Specialist in Teaching and Learning, Dr. Washburn leads secondary and post-secondary educators as well as extension educators in developing strategies to engage learners more effectively, to refine curricular expectations and goals, to improve methods of instructional assessment and evaluation, and to integrate multidisciplinary approaches to teaching technical content. As such, he has presented over 80 workshops and seminars addressing effective delivery of educational programming to secondary teachers, extension educators, and domestic and international educators. Dr. Washburn's previous international work has focused on agricultural curriculum development and human capacity building in delivery strategies in Haiti, Egypt, and Kenya. (Email: sgw@ksu.edu).

Appendix B

Tables

Table 1. Dates and locations, people, groups, or organizations visited during the second Ghana postharvest loss assessment trip.

Date	People/Locations/Groups/Organizations/Government Entities Visited
12/8/14	Ghana Standards Authority (GSA) and Financing Ghanaian Agriculture Project (FINGAP)
12/9/14	Ministry of Food and Agriculture (MoFA) Northern Region Headquarters and Mazara N'Arziki Farmers Association (MAFA)
12/10/14	Savanna Agriculture Research Institute (SARI), Agriculture Technology Transfer (ATT), and Tamale Implements Factory (TIF)
12/11/14	Gundaa Produce Company Warehouse (a GGC warehouse), University for Development Studies (UDS), and Africa Research in Sustainable Intensification for the Next Generation (Africa RISING)
12/12/14	Wienco warehouse, Strengthening Partnerships, Results and Innovations in Nutrition Globally (SPRING), and Resiliency in Northern Ghana (RING)
12/15/14	MoFA Upper West Region Headquarters, Big Ajah Enterprises (nucleus farmer aggregator), and Antika Warehouse (nucleus farmer aggregator and agricultural inputs dealer)
12/16/14	Farm harvesting in Wenchi
12/17/14	Pens Food Bank Ent., Ejura (farm harvesting and other maize field activities)
12/18/14	Exit Meeting with USAID Office of Economic Management
12/19/14	Final review meeting

Table 2. Equilibrium moisture content of maize at various temperature and relative humidity levels.

Temp.	Relative Humidity (%)								
C	50	60	65	70	75	80	85	90	95
20	11.4	12.9	13.7	14.5	15.5	16.5	17.8	19.5	22.0
25	11.0	12.5	13.2	14.1	15.0	16.1	17.4	19.0	21.5
30	10.6	12.1	12.9	13.7	14.6	15.7	16.9	18.6	21.0
35	10.3	11.7	12.5	13.3	14.3	15.3	16.5	18.2	20.6
40	9.9	11.4	12.2	13.0	13.9	14.9	16.2	17.8	20.2
45	9.7	11.1	11.8	12.7	13.6	14.6	15.9	17.4	19.9
50	9.4	10.8	11.6	12.4	13.3	14.3	15.5	17.1	19.5

Source: ASABE Data D245.6 / Average of two prediction equations.

Appendix C

The Northern Ghana Maize Value Chain and Some Pictures from the Second Maize Postharvest Loss Assessment Trip

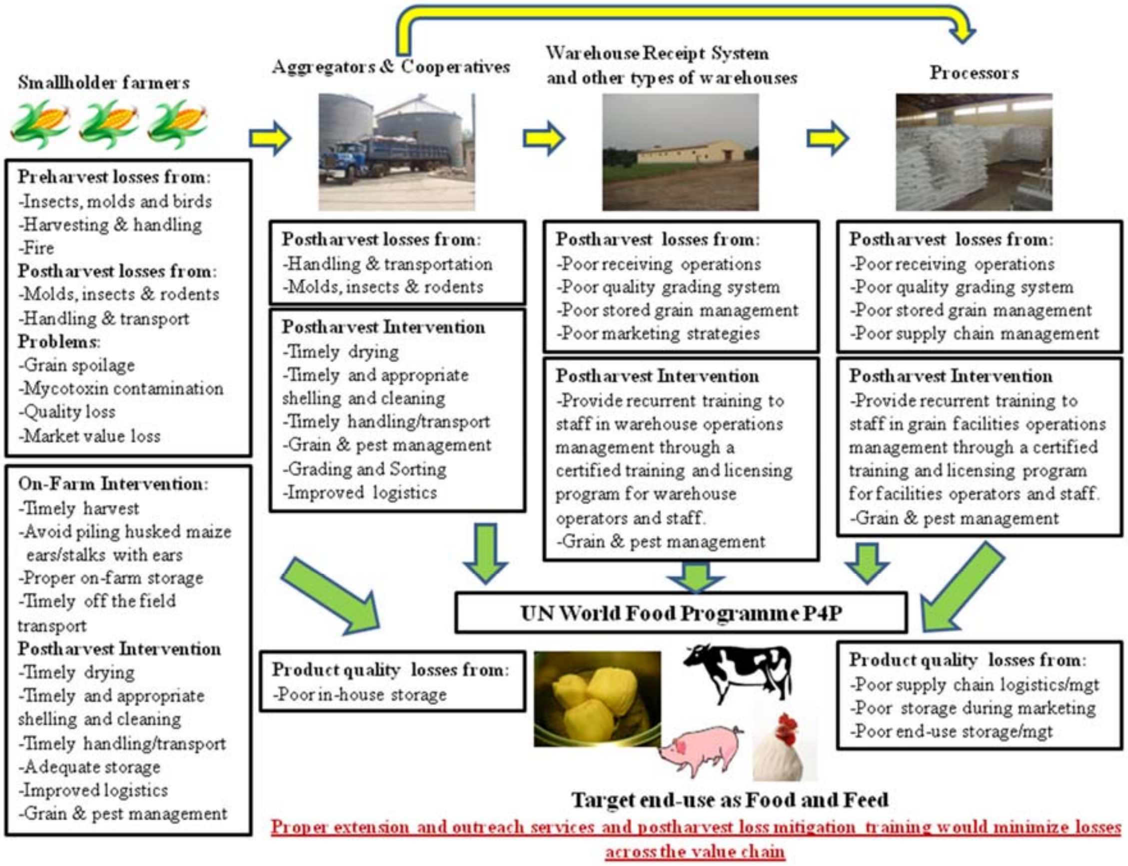

Figure 1. A diagrammatic representation of the Northern Ghana maize value chain and the types of postharvest losses that occur therein.

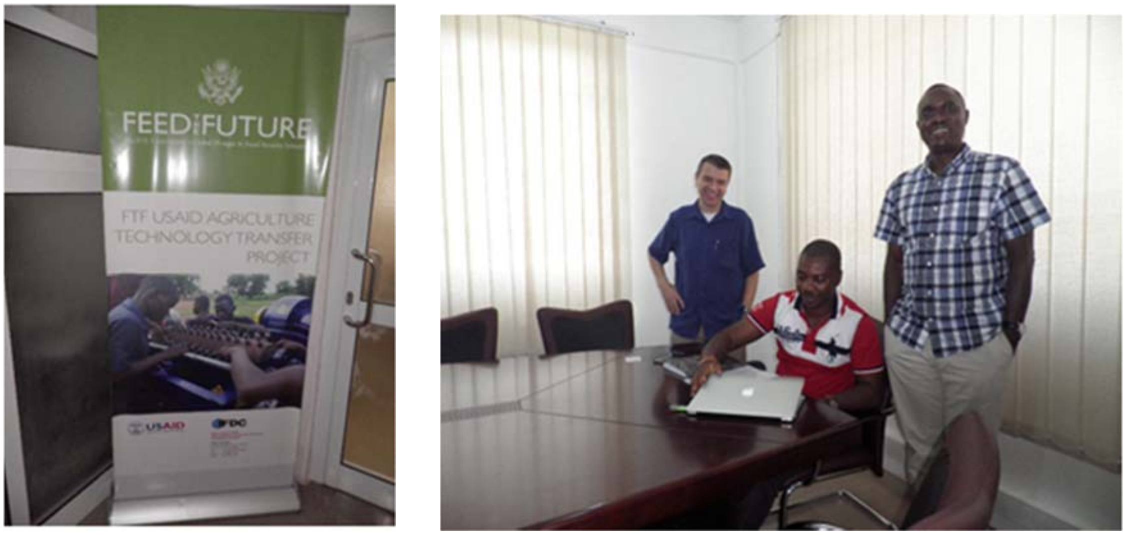

Figure 2. Members of the Ghana Project Team visited the Feed the Future USAID Agriculture Technology Transfer (ATT) Project office in Tamale, Ghana and met with Mr. Musa Salifu Taylor. ATT will be involved in large scale demos of the ZeroFly® Storage Bag as part of scale up of this storage technology.

Figure 3. Tamale Implements Factory (TIF) was visited during the second PHL assessment trip. Private sector businesses such as TIF need to be facilitated for the successful scale up of preharvest and postharvest technologies.

Figure 4. Members of the Ghana Project Team visited Antika Company Limited. The proprietor of this company is a nucleus farmer aggregator who also dealer of various agricultural inputs. Scale up of postharvest storage technologies will be successful if companies such as this one are strengthened and replicated.

Figure 5. Heaping or piling of husked ears of corn in the field prior to shelling and transportation for proper drying and storage (left) and insect infestation of maize in the field (right) are two of several factors that contribute to serious maize postharvest losses in Northern Ghana.

Figure 6. Members of the Ghana Project Team visited Masara N'N'Arziki Farmers Association (MAFA) Headquarters in Tamale, Ghana during the second postharvest loss assessment. MAFA is comprised of approximately 10,000-11,000 farmers from Northern Ghana. Business models such as MAFA and nucleus farmer aggregators who offer value chain services need to be facilitated and replicated because they have great potential as drivers of technology scale up.

Figure 7. Members of the Ghana Project Team visited Wienco warehouses in Tamale, Ghana during the second postharvest loss assessment. Wienco has six 4,000-MT warehouses in this particular location.

Figure 8. During the assessment trip, members of the Ghana Project Team held regular meetings to review information from various visits and to compare notes in order to ensure everyone was on the same page.

Appendix D

Instructions for using the USDA moisture meter
and data sheet to record grain quality factors

Instructions for using the USDA moisture meter[1]

Introduction

This meter actually measures the temperature and relative humidity of the surrounding air directly, whether it's placed in an open room or inside a bag of stored grain. When used in grain, the moisture content is calculated from equations provided by the American Society of Agricultural and Biological Engineers Standard (ASABE D245.6). An example for yellow corn is given in the table below, which shows that when the air space inside a grain bag is 27°C and 65% RH, the moisture content is 13.1% (wet basis).

Equilibrium Moisture Content of Yellow Corn (% wet basis) at various temperature and relative humidity levels.

Temperature		Relative Humidity (%)								
C	F	20	30	40	50	60	65	70	80	90
10	50	7.8	9.4	10.9	12.3	13.8	14.7	15.5	17.6	20.5
16	60	7.3	8.9	10.3	11.8	13.3	14.1	15.0	17.0	19.9
21	70	6.9	8.4	9.9	11.3	12.8	13.6	14.4	16.4	19.4
27	80	6.5	8.0	9.4	10.8	12.3	13.1	14.0	16.0	18.8
32	90	6.1	7.7	9.1	10.5	11.9	12.7	13.5	15.5	18.4
38	100	5.8	7.3	8.7	10.1	11.5	12.3	13.1	15.1	17.9
43	110	5.5	7.0	8.4	9.7	11.2	11.9	12.8	14.7	17.6
Source: ASAE Data D245.4 / Average of two Prediction Equations.										

The instrument contains a set of equations to calculate the equilibrium moisture content based on the temperature and relative humidity of the air space with a bag of grain for the following crops: yellow corn, grain sorghum, rough rice, soybean, hard red winter wheat, and soft red winter wheat.

Instructions

Step 1: press and hold the red button until numbers are shown in the LED window.
Step 2: press and hold the yellow button to select the grain type
Step 3: write the temperature, relative humidity and grain moisture level on the data sheet along with the date, location and other observations made when inspecting grain.
Step 4: repeat step 3 for other bags of grain as desired.
Step 5: press the black button to turn the instrument off.
Step 6: remove the battery when the instrument will not be used within 6 hours.
Step 7: cover the probe tip with plastic, tape or tubing to protect the sensors from moisture and dust.

[1] Meter developed by Dr. Paul Armstrong, Agricultural Engineer with USDA-ARS-CGAHR in Manhattan, KS. Tel: 785-776-2728. Email: paul.armstrong@ars.usda.gov

Grain monitoring data for Ghana.

Town:

Storage type:

GPS

Latitude:

Longitude:

Date	Location	Grain	Temp.	RH, %	MC1, %	MC2, %	Insects	Moulds	Off odor	Discolored	Broken kernels	Foreign material	Other grains	Observations	Initials