FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

FEED THE FUTURE INNOVATION LAB FOR THE REDUCTION OF POST-HARVEST LOSS

ANNUAL REPORT

October 1, 2015-September 30, 2016

USAID
FROM THE AMERICAN PEOPLE

KANSAS STATE UNIVERSITY

ADM Institute for the Prevention of Postharvest Loss
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

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- Dr. Rizana Mahroof – South Carolina State University: Ethiopia project co-leader; stored product pest management
- Dr. George Mbata – Ft. Valley State University: Ghana project; monitoring of pest populations
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- Dr. George Opit – Oklahoma State University: Ghana project PI; stored product insects and pests
- Dr. Gordon Smith – Kansas State University: Bangladesh project co-PI; technology transfer
- Dr. Shannon Washburn – Kansas State University: Engagement Coordinator

The Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss had active projects in five countries from October 2015 to September 2016: Afghanistan, Bangladesh, Ethiopia, Ghana and Guatemala; Afghanistan is covered in separate reports, as a Buy-In.

Program Partners

Universities

Bahir Dar University (Ethiopia)
Bangladesh Agriculture University (Bangladesh)
Fort Valley State University (USA)
Hawassa University (Ethiopia)
Kansas State University (USA)
Kwame Nkrumah University of Science and Technology (KNUST) (Ghana)
Mekelle University (Ethiopia)
Oklahoma State University (USA)
South Carolina State University (USA)
Universidad del Valle (Guatemala)
University of Kentucky (USA)
University of Nebraska – Lincoln (USA)

Companies

Archer Daniels Midland Company (ADM) (Illinois, USA)
Agri Commercial Service Ltd. (Ghana)
GrainPro (Massachusetts, USA)
Helica Biosystems (California, USA)
Hiwot Agricultural Mechanization P.L.C. (Ethiopia)
John Deere (USA)
Pens Food Bank Enterprise (Ghana)
Romer Labs (Austria)
Vestergaard Frandsen (Switzerland)
Woods End Labs (USA)

International Agencies

Ghana Agriculture Technology Transfer (ATT) (Part of IFDC)
ADVANCE (Ghana)
SPRING (USAID)

Government Agencies

Ministry of Agriculture, Irrigation and Livestock (Afghanistan)
Savanna Agricultural Research Institute/Council for Scientific Research (Ghana)
US Agency for International Development (USAID)
USDA-ARS Center for Grain and Animal Health Research (USA)

Non-Profits

ADM Institute for the Prevention of Postharvest Loss at the University of Illinois (USA)
Compatible Technologies International (USA)
Partners in Food Solutions (USA)
Practical Action (Bangladesh)
SHARE Guatemala (Guatemala)

Acronyms

ADVANCE - Agricultural Development and Value Chain Enhancement
ADRA – Adventist Development Relief Agency
Africa RISING - Research in Sustainable Intensification for the Next Generation
AMPLIFIES – Assisting Management in Poultry Layer Industry by Feed Improvement and Efficient Strategy
ATT – IFDC – Agriculture Technology Transfer – International Fertilizer Development Council
BARC - Bangladesh Agricultural Research Council BARC
BARI - Bangladesh Agricultural Research Institute
BAU - Bangladesh Agricultural University
BD - Bangladesh
BRRI - Bangladesh Rice Research Institute
DAE - Directorate of Agricultural Extension
EIAR – Ethiopian Institute of Agricultural Research
FGD - Focused Group Discussions
FtF – Feed the Future
GPP – Ghana Poultry Project
GRAMAUS - Grameen Manobic Unnayan Sangstha
KNUST - Kwame Nkrumah University of Science and Technology KNUST
KFC – Kentucky Fried Chicken
KSU – Kansas State University
MAIL – Ministry of Agriculture, Irrigation and Livestock
ME – Management Entity
MoFA – Ministry of Food and Agriculture
OSU – Oklahoma State University
PHL – Post-harvest loss
PHLIL – Feed the Future Reduction of Post-Harvest Loss Innovation Lab
PICS – Purdue Improved Crop Storage
PMP – Performance Management Plan
SAWBO – Scientific Animations Without Borders Organization
SBD – Solar Bubble Dryer
SBHD – Solar Biomass Hybrid Dryer
SPRING – Strengthening Partnership, Results, and Innovations in Nutrition Globally
STR – a low cost dryer made locally in Asia
UIUC – University of Illinois, Urbana, Champaign
USAID – U.S. Agency for International Development
USDA-ARS – United States Department of Agriculture –Agriculture Research Service
wb/w.b. – wet basis
WEAI – Women Empowerment in Agriculture index
RH – Relative Humidity

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2016 Annual Report

Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss

I. Executive Summary

The Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss (PHLIL) is a strategic, applied, research and education program aimed at improving food security by reducing post-harvest loss and food waste of seeds and durable staple crops, *e.g.*, grains, oilseeds, and legumes. The Lab's efforts are focused in four Feed the Future countries: Bangladesh, Ethiopia, Ghana, and Guatemala. Projects in each country are led by Country Team Co-Leaders and overseen by a U.S. Principle Investigator (PI) and the Lab's Director, with input from local and international academic, private sector, governmental and non-governmental organizations.

Major activities focus on the following goals:

- Increased understanding of current post-harvest loss factors and task division in rural communities and households, and the development of technologies usable by all household members.
- Validated and piloted post-harvest loss technologies, including grain dryers, storage bags, moisture meters, and mycotoxin testing procedures, with low acquisition costs and limited operational footprints that are sustainably accessible to resource-poor farmers and other actors, as appropriate.
- Develop creative animation tools that help non-literate farmers and other actors understand, value and implement technologies developed as part of the project.
- Develop strong partnerships with in-country extension agents, NGOs and local entrepreneurs to effectively scale-up and spread information on the technologies developed to farmers and other actors throughout the targeted regions.

The PHLIL program is reaching an inflexion point in the research for development pathway. The program has formed strategic partnerships and enhanced human and institutional capacity in Bangladesh, Ethiopia, Ghana and Guatemala. PHLIL has now successfully characterized and gleaned insights into various post-harvest losses in chickpea, dried fruits, maize, nuts, rice, sesame seeds and wheat. Further, a more advanced understanding of the socioeconomic, gender and nutrition context is coming into focus through surveys, trainings, workshops and focus groups discussions. Overall, this has produced a matrix of adapted and validated postharvest interventions, which are effectively being moved from research into piloting and technology transfer. Key partnerships along the pathway to impact have been forged, with strategic actors engaged. This ensures that the ultimate innovations bear the mark of their input and receive their buy-in; these actors form the long-standing front line defense against post-harvest losses, and hold the key to improved nutrition and reduced poverty.

II. Program Activities and Highlights

In each of the four core program countries, activities focused on:

1. Continuing surveys and focus group interactions to further *build contextual appreciation of biophysical, socioeconomic, gender and nutrition-related factors* in the target regions and with the target actors intended to ultimately scale up post-harvest innovations
2. Continuing validation and improvement of *drying, storage and moisture measurement interventions* through research and piloting
3. Further *enhancing national capacity* to conduct postharvest loss and food safety research; increased visibility through presentation and publication in national and international fora
4. *Communicating research findings and intervention options with stakeholders*, through measured communications plans; including through training of potential end-users of the promising technologies.

In addition, selected highlights by country include:

Bangladesh (rice)

- Novel, improved, affordable, efficient and effective mobile dryer developed and demonstrated in 20 villages, together with suitable storage technologies
- Discussions underway with potential private sector manufacturers for local production of low-cost technologies

Ethiopia (chickpea, maize, sesame, wheat)

- Rollouts into pilot programs and public training demonstrations
- National partners investing their own funds to expand their engagement with PHLIL, including for trainings back at Kansas State University

Ghana (maize)

- Formalized partnerships with non-governmental and private programs along the scaling pathway, including: SPRING and ATT (USAID-funded); and USDA/American Soybean Association-related entity AMPLIFIES/GPP.
- Engagement, training and technology dissemination continuing with key end users and stakeholders; training via animation videos have been chalked out in detail to include diverse focused group, ideas, and locations.

Guatemala (maize)

- Continued iterative testing and adaptation of various drying and storage technologies.
- It was determined that maize from the highlands has aflatoxin and fumonisin at levels below international guidelines, but may still be a food safety concern because of the large amount of maize consumed by highland residents.

Management Entity Level

- A new management entity team has been installed that brings broad experience working in both African and Asian Feed the Future countries, as well as experience coordinating and building programs and businesses from early phases as part of small teams.
- President of Mekelle University (Ethiopia), Dr. Kindeya Gebrehiwot, visited Kansas State University to discuss possible expansion of the post-harvest loss research outputs and possible dual degree programs between KSU and Mekelle University.
- A PHLIL team delegation, including AOR Ahmed Kablan, visited the African Union Commission's Partnership for Aflatoxin Control in Africa.

- PHLIL Director Dr. Jagger Harvey presented the Ag Sector Webinar *"Risky Business: Food Safety Concerns in Agricultural Development"* on July 13, 2016 along with two other speakers: Dr. Ahmed Kablan from USAID (USA) and Dr. Delia Grace from International Livestock Research Institute (Kenya). This webinar was subsequently re-broadcast at a post-harvest loss meeting in Malawi.

III. Key Accomplishments

Bangladesh

The strong leadership from BAU, and their broad capacity in agriculture, which our program has enhanced, were coupled with research and surveys extending from the research labs onto farms. This has included:

- Gender findings from Year 2 validated and disseminated with farmers and local NGO representatives, through workshop/training sessions. Participants emphasized relevance of study findings and trainings in their lives.
- Successfully adapted and validated interventions are being coupled with farmer training and demonstrations.
- An adapted, mobile BAU-STR dryer has been further improved and tested, which was demonstrated to 456 farmers; estimated payback period for SMEs is one year of operation.
- Hermetic bags proved significantly more effective at reducing post-harvest losses than traditional/popular technologies. This included for maintaining germination rates for seed at well above 90% - superior performance compared to commercially available seed (moving to piloting).

The recent success of this (and other) component of our program demonstrates the relative power and effectiveness of a model wherein in-country partners are equipped and backstopped to develop and deploy innovations.

Ethiopia

The contributions of the program are becoming recognized at the upper levels of partner universities and within the Government:

- The Presidents of Mekelle and Bahir Dar Universities have committed to supporting the development of a postharvest curriculum, and have invested their own university funds to expand PHLIL activities, including sending their scientists for training at KSU.
- The Ministry of Agriculture has shared their extension materials, which PHLIL team members are reviewing and adapting. According to the PHL survey, approximately 80% of farmers desire training on addressing PHL mitigation issues.

- Validation and adaptation of drying and storage technologies, including moisture meters, continued. PICS bags were found to be highly effective, and work towards deploying effective interventions to reduce PHL for targeting beneficiaries continues.
- PHLIL's work here over the past two years has brought renewed focus to post-harvest losses as an area that was neglected in Ethiopia. Findings were shared at a workshop in Addis Ababa with private producers, development agents and researchers. Thirteen presentations were given, and participants from Sasakawa Global 2000 and GTZ expressed interest in collaborating with Mekelle and Bahir Dar Universities in expanding our PHL reduction activities among farmers. Public-Private Partnership possibilities with local flour mills and Nas Foods, a private food processing company, were explored.
- Human and institutional capacity building continued to accelerate, with frequent visits and researcher exchanges featuring prominently in these efforts. Laboratory capacity continued to be enhanced at both

Ethiopian universities, through both expansion of available equipment and Standard Operating Procedures, as well as continued training of Ethiopian faculty members and graduate students.

Ghana

The efforts in Ghana have now effectively established baseline postharvest losses and associated practices, enhanced postharvest loss human and institutional capacity with both university and private sector partners, and culminated in a locally-appropriate intervention package. During the past year, strategic partnerships with targeted scaling actors have been cultivated, paving the way for research into use and downstream reduction of postharvest losses involving a range of actors. This has included:

- The PHLIL Solar Biomass Hybrid Dryer (SBHD) has proven effective at drying and disinfesting large amounts of maize, regardless of weather conditions and sunlight.
- Several scaling partners are forming downstream collaborations to incorporate the SBHD and other PHLIL-validated technologies in their ongoing private sector operations.
- Through targeting the SBHD and silos to aggregators, large groups of smallholder farmers can benefit as suppliers, as will consumers who have more, safer food.
- In terms of human capacity, the Ghana- and US-based teams have worked closely and intensively to support a cohort of graduate students at KNUST, two of whom are graduating at the end of 2016, with associated publications in the pipeline; they represent a new generation of well-trained post-harvest loss specialists, significantly enhancing Ghana's national capacity to secure a safe harvest. A third graduate student from Ghana is being trained at Oklahoma State University and will be graduating at the end of 2017.

Guatemala

A range of drying and storage technologies has been tested and adapted. Advances include:

- Appropriate storage technologies have been identified, with considerations regarding farmer preferences (e.g., silos preferred over bags due to rodent damage), adoption models for the most effective under investigation moving forward.
- Dryer tests have produced information that can be fed back to US manufacturers of drying technologies (eg, for the Solar Bubble Dryer); this could enable them to adapt their product to better suit markets with these challenges.

At a global level, linkage with the public health community and policymakers is necessary, to improve our collective understanding on how chronic exposure to "low" levels of mycotoxins, at levels well above US exposure limits, can have on stunting of these populations.

IV. Research Program Overview and Structure

PHLIL focuses on three key areas with significant post-harvest challenges: **drying, storage and mycotoxin contamination**. The program takes a phased approach to building capacity, conducting research to develop and identify suitable innovations, and effectively piloting innovation packages into adoption and use for sustainable impact. The current status is described below:

- **Initial PHL Assessment**: Following exploratory surveys in Years 1 and 2, promising in-country, "on-the-shelf" and "in the field elsewhere" technologies/best practices are being evaluated through on-farm research with stakeholder participation.
- **Project Implementation**: Year 3 shifted from small-scale testing out to broader audiences, leveraging new relationships with public and private partners in the focus countries. Our 'engagement strategy'

expands our pilot projects out to broader geographic areas and targets potential bottlenecks in adoption of these new technologies through trainings and getting these products in the hands of local entrepreneurs. Village level training workshops will be enhanced by educational videos developed by UIUC's Scientific Animations Without Borders Organization (SAWBO).

In addition, PHLIL recognizes and works to address and incorporate three cross-cutting components into our programming:

- **Gender** – All four core countries have a local gender specialist who assesses and documents relative roles by gender in the villages where new technologies are to be piloted. Deployment strategies for interventions are informed by insights into current and potential gender dynamics related to perturbed post-harvest practices and outcomes.
- **Nutrition** – Aspects related to human nutrition are considered, including both direct (e.g., reduced mycotoxin exposure) and secondary (e.g., increased dietary diversity due to increased household income).
- **Environment** – Research programs and activities adhere to USAID's Environmental Compliance Procedures in Title 22 of the Code of Federal Regulations, Part 216 (22 CFR 216).

V. Research Project Report

This section details research progress across the focus areas in each core PHLIL country.

Bangladesh

Focus crop: Rice
Location: Mymensingh, Netrokona and Jessore districts.
Collaborators: *University:* Bangladesh Agricultural University (BAU); *NGOs*: Jagorani Chakra Foundation, Grameen Manobic Unnayan Sangstha (GRAMAUS); *Private-sector:* Bhai-Bhai Engineering, ACI Motors Ltd.

Drying Technology and Implementation

The in-country team at BAU successfully adapted, validated and compared an off-the-shelf dryer that had been identified as promising for the local context: the STR dryer (originally from Vietnam). The PHLIL-adapted BAU-STR dryer, capable of working rain or shine, outperformed both the Solar Bubble Dryer and traditional sun in testing done both at BAU and in on-farm field trials. The PHLIL team's adaptations to the BAU-STR dryer were effective in improving its efficiency, cost and mobility, and removing its reliance on the national electrical grid. These included replacing the bamboo mat bins with wire mesh and the addition of a diesel generator for running the blower. The adapted BAU-STR dryer was demonstrated to reduce rice breakage and improve the time to drying to an efficiency level feasible for use by SMEs looking to provide drying services to small farmers. The payback period for the purchase of an BAU-STR dryer, which costs approximately $500 USD, is estimated at less than one year.

The SBD design was found to have significant shortfalls for use in the typical context in Bangladesh, including higher cost, lower efficiency under non-ideal weather, and large size relative to harvest size and available space.

Grain Storage Technology

Quantitative post-harvest losses were measured for improved hermetic bags (GrainPro and PICS) and traditionally-used storage technologies (Dole, Motka, plastic drum and plastic bag). In BAU-controlled experiments and in pilots with farmers, both hermetic bag technologies outperformed all of the common technologies. For example, GrainPro bags reduced post-harvest losses by 2-25 times compared to the commonly-used Dole storage containers. In a cost-benefit analysis, GrainPro bags were best, followed by PICS

bags and then plastic drums. GrainPro and PICS bags were also found to preserve germination capacity better than traditional containers. Eight additional strategic locations were selected in Jessore and Netrokaona districts to scale up adoption efforts of the GrainPro bags at a farmer level. Education and outreach to promote the use of hermetic bags and the EMC moisture meters was conducted. Follow-up assessments were done with the trained farmers, which suggested between 70 and 97 percent of farmers were correctly packing the GrainPro bags.

Testing for mycotoxins and related factors
An initial screen for presence of aflatoxin and fumonisin was conducted. Given the highly-skewed distribution of mycotoxins, survey results should be regarded as a preliminary indication of whether a given mycotoxin occurs in the study areas rather than as an estimate of the overall mycotoxin levels during the period surveyed. Moisture content, grain discoloration (a proxy for potential fungal contamination), and aflatoxin and fumonisin levels were tested in paddy rice from samples from 72 households, from the Boro season. Analysis is ongoing, but samples tested so far showed the presence of aflatoxin above the tolerance limit in some cases. Fumonisin was also detected but not above tolerance levels. Further validation of results and testing are underway.

Gender
The findings of Year 2 gender surveys were developed into a report that was disseminated and discussed with farmers and NGOs through workshop/training sessions. These sessions sensitized the participants to women's unrecognized roles in agriculture and problems women encounter during post-harvest activities. Women confirmed project activities/outputs are highly relevant to their lives and livelihoods.

Lessons Learned
1) An earlier strategic shift in partner roles was effective in empowering the BAU team to successfully regain time lost in establishing program activities in Bangladesh and highlighted the importance of strategic partnerships with national partners.
2) Farmers in general expressed keen interest in the innovations, so long as an appropriate price point can be met. This implies that a scaling strategy should consider elements of variably sized bags, reduced cost, financing options, and phasing in new technologies over multiple seasons to reduce the investment burden.

Ethiopia

Focus Crops: Chickpea, Maize, Sesame and Wheat
Location: *Amhara region:* Gondor and Bahir Dar Zuria districts; *Tigray region:* Mekelle and Almata districts; *Oromiya region:* Kalumsa district.
Collaborators: *Universities:* Bahir Dar University, Mekelle University; *Research Centers:* Ethiopian Institute of Agricultural Research, Sesame Research Center at Humera.

Drying technology and implementation
During the 2015-2016 dry season, testing was done using three different types of dryers – a solar bubble dryer, cabinet solar dryer, and traditional, open sun drying – in varying climatic conditions and drying loads. Climate challenges – cloudy days and rain, especially for at Meher crop harvesting time – did present some limitations to the solar technologies in the first round of testing (December 2015). Additional testing at Bahir Dar University April 2016-September 2016 proved more promising, with higher solar radiation and lower humidity rates leading to more effective drying. The team also designed and built a larger cabinet solar dryer (estimated to be 150kg capacity – validation underway) to address the load issues of a smaller dryer (80 kg capacity) designed and produced by the universities for vegetable/fruit drying. A demonstration was provided to the public on the functionality of the solar bubble dryer in two locations, Axum and Mehoni, with attendance of 300 and 90, respectively. The team also participated in a three-day workshop and exhibition in Axum city, where 25,000 people were expected to attend, and several hundred having been exposed to the solar bubble dryer and its potential through its showcasing. This forum was an opportunity to

educate the public about the issues of post-harvest loss and to inform the public about current projects on the ground in Ethiopia. Two faculty members from Mekelle University traveled to Kansas State University in August 2016 to attend the Extrusion Processing: Technologies and Commercialization short course. Mekelle University provided the funds for the researchers to attend.

Grain storage technology
Laboratory experiments begun in Year 2 continued into Year 3 to measure the effectiveness of selected storage technologies. The PHL team also began moving storage and drying technologies into demonstration and piloting phases. Two hundred bags (100 PICS and 100 GrainPro) were provided to lead farmers for on-farm testing following demonstrations of PICS and GrainPro bags in Axum in April 2016 attended by 1,019 farmers and aggregators. However, only 12 women were in attendance. Train-the-trainer workshops were held in September 2016 in the Tigray and Amhara regions for 25-30 participants comprised of investors, smallholder farmers, other value chain participants, policy makers and implementers. The trainings focused on sesame and chickpea with a goal of empowering smallholder farmers to improve the quality of sesame and chickpea in order to help them improve their incomes from sales to higher quality markets.

Mycotoxin surveys and intervention
Analysis of farm samples of sesame and chickpea taken in 2015 were analyzed in early 2016. *Extended validation of the testing method and results is underway for sesame and chickpea, to ensure that there are no confounding matrix effects in these sample types.* A second round of sampling for sesame and chickpea took place in Year 3, with 180 samples coming from the same regions and 180 samples being collected from new regions. Sampling for wheat and maize was also conducted in Year 3, with 180 samples of each commodity being collected. Analysis from these surveys are forthcoming and will inform future programming to address the prevalence of these mycotoxins.

Lessons Learned – Gender
Reaching women farmers continues to be a challenge in our Ethiopia programming. Gender survey results in Year 3 indicated that women have a greater role in post-harvest activities but are less empowered than men in several areas. A manuscript is being prepared to discuss the results of the gender survey and recommended next steps. A forthcoming survey on gender and nutrition will provide further insight into the roles of women in post-harvest practices and how effective programming can be targeted to serve women farmers.

Ghana

Focus crop: Maize
Location: Ejura, Wenchi, Tamale and Kumasi districts.
Collaborators: *University:* Kwame Nkrumah University of Science and Technology (KNUST); *Government:* Ministry of Food and Agriculture (Northern and Upper West regional offices); *NGOs:* Adventist Development Relief Agency, *Private sector:* Ghana Grains Council, Pens Food Bank, Yedent Agro Group, Sahel Grains, Antika Co. Ltd., Masara N'Arziki Farmers' Association, Antika Co. Ltd., Masara N'Arziki Farmers' Association, Takhilla Farms Ltd.; *USAID/USG Project Partners:* Africa RISING, ATT, AMPLIFIES, SPRING.

Drying Technology and Implementation
Traditional open sun drying, which leaves maize susceptible to birds, insects and rodents, as well as mycotoxin contamination and other food safety concerns. PHLIL conducted research and facilitated improvement of the Solar Biomass Hybrid Dryer (SBHD) as an alternative. Testing of the SBHD found it to be both technically and cost effective. It effectively disinfests and dries maize, with a batch of 3–5 tons taking 8 hours. The dryer was placed adjacent to the main market where much of the maize produced from the middle belt of Ghana passes through to serve as an aggregation-point post-harvest loss intervention. The 5-MT capacity SBHD unit costs approximately $18,000; give its scale and efficiency, it is estimated that this cost can be recouped in 1.5-3 years.

Grain Storage Technology
Storage technologies have now been successfully adapted and validated. These include options for a range of actors, from on farm use to adoption at aggregation points (e.g, cooperatives or SMEs adjacent to markets). Two aggregation point-scale storage technologies have been adapted and validated at PENS: a 6 MT Kikapu bulk storage bin donated by Kepler Weber (Brazil), and storage bins constructed from Ghanaian-made plastic water tanks (the two at PENS can store 7 MT each). Smaller scale bags have also been tested, including deltamethrin (DM) incorporated 50-kg polypropylene (PP) bags (ZeroFly® Storage Bags made by Vestergaard Frandsen). Results are under preparation for submission to peer-reviewed journals, and for sharing with key stakeholders.

Public and private sector actors are showing great eagerness to partner as we pilot the tested interventions into use. They recognize postharvest losses as a critical issue, wherein reduced losses can lead to increased food, feed and profits for farmers, and more sustainable and profitable avenues for SMEs. Scale up and testing of ZeroFly bags was one of the key item from Africa RISING and ATT partnerships. ATT may provide financial support in this process specific to seed warehouse locations. SPRING has agreed to collaborate in conducting testing of ZeroFly and PICS bags and 150–200 kg plastic silos, specifically for groundnuts. These tests should facilitate scale up of ZeroFly and PICS bags.

Mycotoxin surveys and interventions
The team is in the final stage of publishing grain moisture content data from USDA-PHL and John Deere moisture meter performance. Results indicated that the USDA-PHL meters performed better and are more versatile compared to the John Deere meters. Collection of mycotoxin baseline data in stored maize by KNUST continues in the Middle Belt and in Northern Ghana. The AMPLIFIES project is planning to purchase and utilize the moisture meters.

Gender
Dr. Irene S. Egyir has been hired by the project as a gender consultant. Quarterly interactions with PIs/Co-PIs and farmer groups have begun, as has a review of methodology and training curricula to ensure gender sensitivity. In-country gender sensitization training for the Ghana co-PIs was undertaken. Students at KNUST included more than 50% female farmers and traders in their insect and moisture monitoring research.

Guatemala

Focus crop: Maize
Location: Huehuetenango, Chiantla and Todos Santos districts in the Western Highlands
Collaborators: *University:* Universidad del Valle; *NGO:* SHARE

Drying Technology and Implementation
Given the challenging conditions for drying in the highlands of Guatemala, three different dryers were tested to look at cost and efficiency:

- AlfaSTOP furnace-type dryer (constructed based on plans from their program) that acts as a heat exchanger by burning corn cobs and wood with forced air, with capacity of 500 kg and drying rate of 0.1% per hour. The cost of the tested version is low at $800, but so is the efficiency. (*Note: AflaSTOP has since developed a model that is more efficient than the one tested in our program)*
- Modified BAU-STR dryer with heat exchanger; similar to AlfaSTOP, but with a capacity of 150-500 kg and drying rate of 0.8% per hour. While more efficient, it is also more expensive at $1,500.
- Combined solar and furnace dryer. A dryer designed by the students of Universidad del Valle, it is powered by a solar panel with a furnace back up for cloudy days (which are frequent). The cost is $400 with a current capacity is of 50 kg with drying rate of 0.7%.

Grain Storage Technology

Storage technology trials are being conducted on farms in Chiantla and Todos Santos with GrainPro® Super Bags, PICS bags, 1-tonne capacity metal silos, 170-liter plastic drums and triple bagging with the locally produced "arrobera" bag (suggested by the Legume Innovation Lab). Each storage technology is tested for 90 days after harvest with maize dried following a local protocol or by a dryer developed for this project. The efficacy of the storage technologies will be assessed on the quality of the maize after storage, the levels of mycotoxins and insects present and the cost to use each technology.

Mycotoxin surveys and intervention

An assessment of the quality of maize harvested (Nov. 2015-Jan. 2016) by smallholder farmers in Chiantla and Todos Santos after 30, 60 and 90 days of storage is in process with results to be compared with a similar assessment conducted the preceding year. In the first assessment aflatoxin averaged 7.9 ppb for aflatoxins and 3.4 ppm fumonisins, which is lower than values previously reported in the literature. Given the strong effect of climate and management on mycotoxin risk, there are often discrepancies between studies conducted during different seasons – or even within the same season. Sampling and testing procedures can also lead to these differences. Several means of checking this are being considered.

Identification of additional insects and fungi in stored products is also in progress.

Gender

Workshops organized by the gender consultant were conducted in Chiantla and Todos Santos to assess items in the Women's Empowerment in Agriculture Index (WEAI). The in-country gender specialist Ms. Ada Chavarria is using analysis of the results to help inform her ongoing gender sensitization sessions in the target region. Due to lack of English language proficiency Ada was unable to attend the Gender workshop in Manhattan in August. The chief gender specialist Dr. Cheryl O'Brien and Guatemala PI and Co-PIs are well versed in Spanish and hence, we expect that one-on-one interactions with Ms. Chavarria will be equally fruitful.

Lessons learned

1) Furnace dryers require electricity to power a high capacity fan to create the airflow necessary to dry the maize in a timely matter. The cost of electricity and poor maintenance of electrical connections can limit the ability of smallholder farmers to use this type of dryer. Solar dryers in the Western Highlands in Huehuetenango are difficult to use due to extensive cloud cover. The direct solar energy available in the Western Highlands is less than in other locations in Guatemala. Continued adaptation and piloting will continue to improve drying outcomes.

2) Because mycotoxin levels in agricultural commodities may vary with the growing conditions of the crops, and due to the low number of samples analyzed during the first assessment and the observed low levels of mold and mycotoxin contamination, a second assessment is being conducted to determine if weather or other unusual conditions affected the results. Longitudinal surveys such as this are always more reliable in determining whether mycotoxins are an issue, given their episodic occurrence and the role of climate in their accumulation.

3) Some of the storage technologies may not be useful for smallholder farmers because of the expense (PICS bags or metal silos) or limited commercial availability (GrainPro® Super Bags). The main maize storage concerns are rodents and the presence of mold. The relatively high low temperatures (14-18°C) in the Western Highlands result in relatively few insect infestations. Smallholder farmers need considerable training to understand the benefits of reducing post-harvest losses that can come from investing in better storage technology.

Cross-cutting: Gender

Co-organized (with Cheryl O'Brien, Gender Coordinator) a write-shop for the in country gender coordinators took place in Manhattan, Kansas from Aug 11-13, 2016. Dr. Cheryl O'Brien assisted all the gender specialist in peer-reviewed article writing based on the WEAI information collected in the core countries. Each of the in-country gender specialist presented their results on gender data and discussed future experimental designs

correlating gender and nutrition. The chief nutritionist Dr. Brian Lindshield shared his survey instrument and experimental plan with in country gender specialists from all the four core countries.

Cross-cutting: Nutrition

In-country partners have been identified in Bangladesh, Guatemala, Ghana, and Ethiopia to collect nutrition, economic, and grain quality data from small-scale farmers with direct relevance to Feed the Future nutrition indicators. The WEAI nutrition survey has been adapted to fit in the storage bag intervention technologies pilot tested in the focus counties. The training of this survey and how to it correlates with gender aspect of the innovation lab was discussed in depth in a workshop held in Kansas, Aug 11-13, 2016 with all the in-country gender specialists.

VI. Human and Institutional Capacity Development

a. Short term Training

Country of Training	Purpose of Training	Who was trained	Number (sex disaggregated)		
			M	F	Total
Bangladesh (conducted in several locations within the focused districts)	1. Validation and Gender sensitization (2 trainings) 2. Set up the dryers and operations 3. BAU-STR dryer installation and operation (04/23/2016-08/26/2016) 4. BAU-STR dryer installation and operation & FGD 5. BAU-STR dryer installation and operation (05/02/2016-05/05/2016) 6. BAU-STR dryer installation & FGD (05/07/2016) 7. Storage experiments 8. Use of GrainPro and PICS bags and moisture meter (11/14/2015 -11/28/2015) 9. GrainPro and PICS bag use and moisture meter (05/31/2016-06/09/2016) 10. GrainPro and PICS bag use and moisture meter (06/18/2016-06/20/2016) 11. Tracking mycotoxins & PHL awareness (undergraduate project report)	Farmers Students Farmers Farmers Farmers Farmers Students Farmers, government officials Farmers Farmers Students	56 3 104 45 116 38 3 119 117 119 2	32 2 20 20 95 20 2 89 110 54 1	88 5 124 65 211 58 5 208 227 171 3
Ethiopia	Awareness of post-harvest loss in Ethiopia workshop/seminar: progress-to-date and future goals for FtF PHL. Research results on storage, mycotoxin contamination, and drying in Ethiopia were discussed. Field training topics: 1.Proper use of storage bags, metal and plastic drums 2. Operation and handling of moisture meters 3. Importance of grain drying 4. Mycotoxin analysis 5. Best management practices to reduce PHL	University Researchers NGOs EIAR Ag./ Ag. Institute Private Business USAID Mission Farmers & Investors Development Agents Technical Agents Flour Milling Companies	16 5 9 5 0	4 1 1 2 1	20 6 10 7 1 150 25 25 7
Ghana **(conducted in multiple locations including the Pens Food Bank office and neighboring villages)**	Training and demonstration of USDA- PHLIL moisture meter and how to incorporate good agricultural practices after harvest. Education on use of silos for grain storage. Aflatoxin awareness with mitigation strategies and good farming practices. Monthly training session from Oct 2015 - Aug 2016 was conducted and reported to the PI. Conducted by Evans Peter Nsiah and Adu Maxwell from Pens Food Bank.	Farmer Based Organizations (FBOs) = 52. A single FBO consisted of 35 members (average). Traders= 12 Community Agents = 7	721	1012	1733
Guatemala	To discuss and address the Women's Empowerment in Agricultural Index (WEAI) Romer Mill demonstration at UVG (January 2016) Mycotoxin Proficiency Training at UVG (April 2016)	Farmers Univ. Technician=1, Faculty=1, Students=2 Students	0 1 0	30 3 2	30 4 2

b. Long term Training

Support for graduate education is an important part of PHLIL's mission to build capacity for the next generation of post-harvest experts. Graduate students are also essential in performing PHLIL's activities, including lab and on-farm research and assisting in PHL trainings. In Bangladesh, PHLIL is supporting eight graduate students at Bangladesh Agricultural University. The students are working on master's or doctoral degrees in our three key areas of drying, storage or mycotoxin analysis. There are seven graduate students involved with our programs in Ethiopia, six at Mekelle and Bahir Dar universities and one at Kansas State University. In Ghana, three graduate students from Kwame Nkrumah University of Science and Technology (KNUST) and one graduate student from Oklahoma State University are involved in PHLIL activities. In Guatemala one graduate student at the University of Nebraska-Lincoln is engaging in PHLIL research and training, through joint funding with USDA.

Institutional Development

Bangladesh

Partner: Bangladesh Agricultural University (BAU).
Description: Installation of two types of dryers; provision of sufficient hand held moisture meters, including John Deere, probe moisture meters, Fluke data logger, six 30m k-type long thermocouples, two ACR TRH-1000 data loggers with temperature and humidity measurement capability, ACR smart button sensors were provided to conduct drying and storage trials. Gas analyzer (O_2 and CO_2), Hygrometer and a hot air oven have been added in the lab of the Department of Farm Power and Machinery, Bangladesh Agricultural University. Two types of hermetic bags (GrainPro® and PICS) and a one ton capacity silo were provided for storage experiments. Ten blowers for BAU-STR dryers were imported from Vietnam and five generators were purchased for BAU-STR dryer piloting. An additional 250 GrainPro bags were purchased from ACI Motors Ltd. Renovation of drying and storage labs is ongoing. Romer Lab test kits were delivered to BAU for assessing mycotoxin contamination levels. To the best of our knowledge this is the first functional mycotoxin testing lab in the country. Planning for engagement/outreach activities continued, including: active learning, curriculum development, assessment, use of multi-media tools, and gender inclusion strategies.

Ethiopia

Partners: Mekelle University and Bahir Dar University.
Description: Equipped mycology laboratories at Mekelle and Bahir Dar Universities with ELISA readers and test kits for mycotoxin analysis – aflatoxins, deoxynivalenol and fumonisins (at both universities), and ochratoxin (only at Mekelle). A GrainPro® Solar Bubble dryer was delivered to and installed at each university. Nineteen HOBO data loggers with temperature and humidity measurement capability, 27 Button sensors, several USDA moisture sensors, and 3 John Deere moisture meters were provided for each university. In the last quarter of 2015, a team from K-State visited Ethiopia to develop relations with Hawassa University and Nas Foods Inc. to broaden the nutrition and gender portions of the Ethiopia program. Two faculty members from Bahir Dar and one PhD student traveled to Kansas State University to participate in a short course on grain extrusion and processing which built knowledge on scale-up and commercialization concepts.

Ghana

Partner: Kwame Nkrumah University of Science and Technology (KNUST).
Description: MoUs between the Ghana PHLIL project and ATT (IFDC), Africa Rising, and SPRING agricultural NGOs have been completed and signed. These formalized relationships increase and strengthen the human capacity, research goals and mass-scale adoption portions of the program. These NGOs are now collaborating with KNUST to collect mycotoxin data and to enable widespread adoption of moisture meters. Kepler Werber Company (Brazil) donated a Kikapu steel storage silo sited in the middle belt of Ghana for experimental storage studies. USDA AMPLIFIES has also partnered for construction and procurement of drying and storage technologies, to improve the quality of maize used for animal feed.

Guatemala

Partners: SHARE Guatemala (a local NGO), Universidad del Valle.
Description: A mycotoxin testing laboratory at Universidad del Valle was established through working with U.S.-based PHLIL scientists. Fungal identification workshops and seminars were presented to strengthen the background of relevant university faculty and staff in this area. Solar dryers were set up at the university, where undergraduate students are helping to design, modify and construct them as a part of their senior year project.

VII. Technology Transfer and Scaling Partnerships

Bangladesh

Steps Taken and Partnerships Made: The heads of partner institutions engaged in post-harvest loss reduction activities for rice nominated members of an Engagement Advisory Team. The team met in September 2016, along with the annual workshop.
Technologies Ready to Scale: One SBD solar dryer and one modified BAU-STR dryer are installed and functional at BAU. The modified BAU-STR drier will be tested on farm before the end of project year 3. Hermetic bags (80 GrainPro® and 80 PICS bags) were supplied and are being tested for use for storing rice at the on-farm household level.
Technologies Transferred and Scaled: As planned for years 4-5 (2017-18).

Ethiopia

Steps Taken and Partnerships Made: General information gathering meetings during the first and second project years enabled the project team to identify eleven key stakeholders who now serve on the Engagement Advisory Committee and who collectively represent the public and private sectors, and governmental and non-governmental organizations. The EAT first met in July, 2015 and will meet again prior to the end of the third project year.
Technologies Ready to Scale: Scripts have been finalized in the local dialects for the SAWBO training videos. These training videos address best management practices for use of phosphine fumigants for insect control in stored grain and the use of solar dryers for grain drying. These videos are targeted for the general rural population in Ethiopia, including via cell phones, farmer training sessions; printed information is also key. Pilot scale solar dryers are installed and operational at both Bahir Dar and Mekelle Universities. Cabinet dryers at both locations have been rehabilitated.
Technologies Transferred and Scaled: As planned for years 4-5 (2017-18).

Ghana

Steps Taken and Partnerships Made: Engagement Advisory Teams (EATs) for both Northern Ghana and the Middle Belt have been formed. The EAT for the Middle Belt has 10 members and the EAT for Northern Ghana has 9 members. An eight-member Technology Research Implementation Team for the entire project also was established. MoUs with Africa RISING and SPRING, who are key partners for distribution of improved technologies, have been signed with Oklahoma State University. The names of all the members from the above three regions are listed in the 2015 PHL Annual Report. All advisory groups will meet again before the end of Project Year 3.
Technologies Ready to Scale: A Kipaku storage bin (steel) donated by Keplar Werber (Brazil) with six metric ton capacity was installed in Ejura, in the middle belt region of Ghana. Bulk plastic storage (7 metric ton capacity) and a Solar-Biomass Hybrid Dryer are now functional in Ghana, in addition to the SBD at KNUST. Scale-up efforts for USDA-PHLIL moisture meters and commercially available storage bags (PICS and GrainPro®) are planned.

Through the partner MOUs, USDA-PHL meters, ZeroFly storage bags, PICS bags, 150–200 kg plastic silos and a Solar Biomass Hybrid Dryer are being purchased for scale up. These collaborations open a wide opportunity for the Ghana team to create value to the end user, especially to the Ghana poultry industry. In conjunction, Adventist Development and Relief Agency (ADRA) has a lot of knowledge of scale-up and developing curriculum for post-harvest loss mitigation technologies including PICS bags. Such wide knowledge of scale-up and training will help the team to further intensify the scale-up process in Year 4 and 5. A USDA Scientific Cooperation Research Proposal received by program partners is providing $40,000 in funding to build a second solar biomass hybrid dryer in Wenchi.

Technologies Transferred and Scaled: As planned for years 4-5 (2017-18).

Guatemala

Steps Taken and Partnerships Made: MoUs with SHARE and Universidad del Valle remain active. These agreements add to facility and capacity of the local NGO and university through the cross exchange of technologies, training, and research results. Members of an Engagement Advisory Team have been identified, and all have agreed to serve.
Technologies Ready to Scale: Pilot scale solar dryers installed at Universidad del Valle were redesigned and improved by students who participate in their operation.
Technologies Transferred and Scaled:
As planned for years 4-5 (2017-18).

VIII. Environmental Management and Mitigation Plan (EMMP)

Most research activities do not have a significant effect on the environment as they fall outside the 11 classes of action identified in Part 216.2 (d) (1). However, the projects in Ethiopia and Ghana, which include the use of pesticides on commodities and in warehouses, must comply with procedures set forth in Part 216.3. Dr. Bhadriraju developed an Environmental Mitigation and Monitoring Program (EMMP) for the Lab that has been updated and approved. Dr. Andreia Bianchini developed a standard operating procedure (SOP) for decontaminating and disposing of materials used during mycotoxin analysis, and a set of general lab safety guidelines to follow when conducting mycotoxin analyses. An EMMP checklist was developed specific to the PHLIL for use by designated individuals in each country to be completed at least quarterly that enables regular reporting and documentation of compliance with the EMMP. These documents are available through the Piestar reporting hub and the PHLIL public website.

IX. Open Data Management Plan

The Management Entity (ME) will make information and data publicly accessible on the Innovation Lab's website. A Data Management Plan has been developed, approved and will develop a data sharing policy, abiding by all policies, for primary investigators and research teams as a matter of priority, which will address access and timelines. The ME has communicated with the country PIs regarding depositing data in the USAID Data Development Library (DDL). The ME will monitor and track the deposit of data as the program moves to year 4 and 5. The general data management plan is as follows:

A. **Data Description:** Includes work plans, travel plans, data management plans, PMPs, EMMP checklist, financial reports, annual reports, and repository of data for USAID. In addition, the ME collects individual country meeting and trip reports, along with site visit reports and reports on in-country meetings.
B. **Data Organization and Management:** A local data management company, Piestar, developed a web-based Monitoring, Evaluation, and Progress Reporting System (MEPRS). This system is customizable, accurate, reliable, user-friendly and supported by secure internet connections. A major benefit derived from this system is the ability to use components already available to other USAID Feed the Future Innovation

Labs based at K-State. Excel and Word files generated by the ME are stored in external hard drives at K-State available (locked with user permission) only to authorized users within the Dean of Agriculture's office. Piestar reporting modules interface with the USAID Digital Data Library (DDL) to enable easier uploading of PHLIL data sets to the DDL. Additional data stored on K-State servers follows the University's Policies and Standards.

C. **Data Access and Sharing:** The ME abides by the data sharing policies and procedures established by K-State, as well as other partner institutions. The ME bears the overall responsibility for data management over the life of the project and will monitor and supervise compliance throughout the life of the project. Data will be preserved and made available over generational shifts in technology to ensure that it remains accessible over time.

Policies: Training and regulations potentially required of or applicable to researchers participating in this project by the Research Compliance Office at K-State include:

- Human Subjects Research Institutional Review Board (IRB) - The IRB administers a comprehensive and compliant Research with Human Subjects program for researchers, students, and potential human subjects.
- Responsible Conduct of Research (RCR) - This training is an individual and an institutional requirement. All persons involved in research activities must have a working understanding of the responsible conduct of research to make the best ethical and legal choices in the face of potential conflicts involving research activities. This training develops an appreciation for the range of accepted scientific practices for conducting research, and the need to be knowledgeable about the regulations, policies, statutes, and guidelines that govern the conduct of University-sanctioned research.
- Confidential/Sensitive Research (C/SRC) - C/SRC policies govern activity(ies) proposed by K-State faculty and staff that involves information for which general access to or distribution of should be restricted, or is inadvisable, illegal, or contraindicated.
- Project staff will adhere to all federal laws and regulations for oversight of activities involving research with human subjects and will analyze, present, and communicate the results of such studies in a manner that preserves participant confidentiality and accurately portrays their views. Project staff will file the appropriate paperwork with the Institutional Review Board (IRB) at K-State. All of K-State's human subject studies, regardless of funding source, are guided by the ethical principles in *The Belmont Report: Ethical Principles and Guidelines for the Protection of Human Subjects of Research* and the *National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research*.

X. Project Management Activities

- Dr. Jagger Harvey assumed directorship of the PHLIL program on May 16, 2016.
- Ms. Catherine Hickman is the new business finance specialist as of August 2016, replacing Ms. Naaz Yasmin.
- Ms. Dena Bunnel is the new program coordinator, as of October 2016, replacing Rumela Bhadra.
- Dr. Brian Lindshield has established an operational budget and collaboration with in-country nutritionists to design surveys and research trials to assess the impact of the post-harvest loss and the reduction technologies developed by the lab.
- Dr. Gordon Smith (K-State) replaced Dr. Venkat Reddy as co-PI for the Bangladesh project in collaboration with co-PI Dr. Prasanta Kalita (University of Illinois). An operations budget for Dr. Smith was established.
- Dr. John Leslie is serving the ME team in an advisory and mentoring role, as well as a role across mycology in the program.

XI. Other Topics

XII. Issues and How They Are Being Addressed

Drs. Pittendrigh and Bello-Bravo left the University of Illinois for Michigan State University in the summer of 2016. Arrangements have been made for continued funding of their project. The funds supporting them will switch from the ADM Institute to USAID, beginning October 2016.

Projects have been slow to provide receipts for reimbursement to the ME. Improved communications between the K-State Business Office, the PIs and business offices of subcontractors have reduced this problem significantly.

Timing of field experiments: Timing for field experiments still remains a challenge, especially for solar drying experiments. In some locations, the rainy season hindered installation and operation of the solar dryers. In some cases solar dryers have been modified to incorporate mechanisms to enable drying to continue on cloudy and rainy days.

Ethiopia – supply, equipment availability and capacity building: Universities in Ethiopia have a competitive bidding process that is awkward and time consuming. Restructuring this process has been recommended to appropriate university administrators. The mycotoxin readers and test kits that were delivered last year to replace the non-functional ones are now in use. New sets of mycotoxin kits are scheduled to be delivered by the end of this year to both institutions.

Recent political unrest in the Bahir Dar region has created significant concerns relating to the safety of staff, as well as the ability to have timely data collection and reporting. However, the PI is frequently in touch with the in-country collaborators and the situation is being monitored closely.

XIII. Future Directions

- **The ME has committed to a strategic shift towards increased focus on external communications. This is in part due to the fact that the program is now transitioning from the baseline assessment and innovation development/adaptation phases, into piloting into use with partners representing targeted end users. There is much to report in terms of successes and progress on the ground to date.**
- Results from Year 1 and Year 2 gender reports are assisting the development of post-harvest loss mitigation technologies, and are providing guidance for the PI and Co-PIs as PHLIL moves towards the 'in-field' phase and more widespread adoption efforts. They also provide important insights into local culture-dependent norms and divisions of labor that extend beyond the management of post-harvest problems.
- Multiple options exist for suitable drying and storage solutions, and no one solution is likely to be the "right" one for all countries, or perhaps even for all of the communities within a country. In Year 4 PHLIL will work on developing a portfolio of potential technologies from which the best technology for a given situation can be selected.
- Identifying local suppliers and manufacturers of dryers and storage materials and partnering with them to ensure high quality products are put on the market remeins a target in all four core countries.
- An External Advisory Board (EAB) as outlined in the grant proposal will be formed in Year 4.
- The mycotoxin surveys conducted have led to the development of component of a "blueprint" that can be used in many countries to conduct baseline surveys. Using this blueprint to solicit funding from other USAID missions would increase the number of countries in which the Lab can have an impact. Through

collecting and providing baseline data to these countries, PHLIL can help inform decisions about which needed remediation approaches are most likely to succeed and be sustainable. The Lab is well-positioned to both lead and to partner with others in designing and implementing studies to reduce mycotoxin severity from on-farm plant production to post-harvest storage, sales, marketing and regulation.

Appendix: Success Stories

Success story A

Meeting Interventions at the Market:
Modified Solar Dryer and Storage Bins in Ghana

Post-harvest loss of staple crops due to insect pests and fungi in developing countries are estimated to be between 30-80 percent, representing a major threat to food security for those regions in the world. This loss can be greatest for small-scale farmers who do not have access to proper crop drying and storage facilities. Many of the crop storage methods utilize traditional storage vessels like woven baskets, pots, bamboo structures, etc., or simply in bags inside the household. These storage methods are cheap; however, they leave grain susceptible to insect damage, as well as mold infection and toxin contamination. Improved drying and storage technologies for deployment at aggregation points hold great promise to mitigate the economic and health risks associated with post-harvest loss.

Mycotoxins are metabolites of crop-infecting fungi that can cause cancer, transitory illnesses (diarrhea and vomiting), organ failure (usually kidney failure) and death; and are associated with immune system suppression (resulting in increased sensitivity to microbial and other contagious diseases), developmental stunting in children under age 5, and blocking nutrient uptake. Grain kept at a high moisture content creates a particular haven for breeding insects and fungi, so drying grains properly is vastly important for health and long-term storage of grains. Traditionally, drying is done by spreading maize on the ground (usually under a tarp or directly on the soil/roadside) in the open air. This leaves the grain open for contamination from birds, rodents, livestock, dust, etc., and susceptible to rewetting by rainfall.

Seeking to mitigate losses at these critical points, the Ghana team of PHLIL designed the Solar Biomass Hybrid Dryer (SBHD). The SBHD looks much like a greenhouse in design, with shelving inside to hold trays of drying maize (or other commodities). The building utilizes the power of the sun for drying most of the time; however, it also has a furnace to heat the unit when drying is needed on cloudy days or after dark. This hybrid addresses these climatic challenges in a way that solar-only technologies do not. SBHD efficiency enables drying of eight tons of maize in eight hours, with drying possible around the clock. Additionally, the ability of the furnace to use crop biomass for fuel (e.g., maize cobs) reduces the reliance of coal or diesel to run the dryer. The heat produced by the SBHD dries the maize to proper moisture levels while also disinfesting insects (removing the human safety risks associated with misuse of pesticides).

There are currently two SBHDs in Ghana, one constructed within PHLIL and the other by downstream funding beyond the PHLIL program. The first was built as a central part of PHLIL activities at the facility of PENS Food Bank, a private sector partner of the PHLIL Ghana projects. The facility sits next to one of the largest markets in the region, serving as a place where farmers can dry their maize near the aggregation point with easy access to market.

The team also worked to develop modified silos at PENS Food Bank. These silos are made from Ghanaian-made plastic water tanks and have the capacity to hold up to seven tons of grain. Testing of this low-cost, locally-made storage technology has proven effective against insects after seven months of storage (based on testing so far; additional storage time capability is expected).

Leveraging funds downstream of PHLIL, there are plans to build further SBHDs and partner with poultry producers to establish a market-based system, whereby poultry producers who are sourcing poultry feed (predominantly yellow maize) from 50-70 smallholder farmers own the dryers. This supports the local poultry market both at the poultry producer and smallholder maize farmer levels and encourages best practices for

maize drying and storage. This demonstrates that PHLIL innovations have garnered interest from local and international actors for collaboration and scale-up beyond the scope of the program.

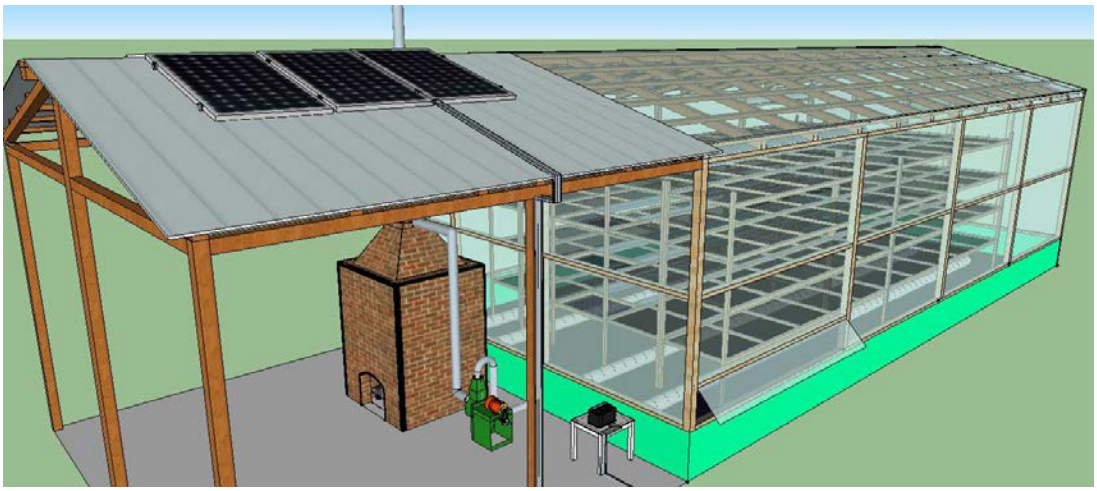

Figure 1: Schematic diagram of the biomass hybrid solar dryer set up in Ejura, Ghana.

Figure 2: Shelves stacked with maize harvest in the biomass hybrid solar dryer in Ejura, Ghana.

Figure 3: Plastic water tanks modified into silo for long term storage of maize in Ejura, Ghana (metal silos on the right was donated from a Brazilian company and additionally tested).

Success story B

Evaporating dampened prospects for food security and safety:
Low-Cost, Modified STR Dryer in Bangladesh

Rice is a crucial staple food in Bangladesh and daily serves as both a nutritional and cultural necessity. Approximately 13 million farmers are involved in rice production in Bangladesh, accounting for 75 percent of land use and 28 percent of GDP in the country. Successful harvests, driven through exhaustive efforts required for rice production, are too often undermined by a lack of proper drying and storage. Improper post-harvest practices lead to contamination with fungi and associated toxins (mycotoxins), and insect infestations reduce quality and quantity of rice, and can have significant health risks. Post-harvest drying and storage is not trivial in Bangladesh, with traditional attempts falling short of the necessary mark for food security and safety. PHLIL has cast a global net, having identified and coupled innovations from the USA and Vietnam to form the core of a promising integrated package to help safeguard farmers' harvests in this challenging environment. The STR dryer from Vietnam represents a novel innovation with potentially broad-reaching relevance across Feed the Future countries and beyond.

For the average Bangladeshi farmer, heavy seasonal monsoons and tropical humid climatic conditions hinder post-harvest drying and storage of rice below 12 percent moisture content, a critical point to avoid mycotoxin accumulation. Mycotoxins are metabolites of crop-infecting fungi that can cause cancer, transitory illnesses (diarrhea and vomiting), organ failure (usually kidney failure) and death; and are associated with immune system suppression (resulting in increased sensitivity to microbial and other contagious diseases), developmental stunting in children under age 5, and blocking nutrient uptake. Traditional drying involves laying rice out on the ground, which opens it up to contamination from birds, dust, etc., and it can take 3-5 days to sufficiently dry, climatic conditions permitting. Furnace-driven drying holds great promise to abrogate quality and quantity losses, if adapted appropriately.

Under the leadership of Dr. Md. Monjurul Alam (Bangladesh Agricultural University), Prasanta Kalita (University of Illinois, Urbana-Champaign and ADM Institute for the Reduction of Post-Harvest Loss) and others, a team of researchers from BAU has successfully adapted a low-cost drying technology for rice paddy. The team tested a few different models, including a solar dryer, but cloudy conditions during drying rendered solar technologies inadequate. The team did find promise in a technology originally developed in Vietnam – the STR dryer. The team modified to the original design, including adding rice husk briquette power as an option, beyond the original diesel and electric power design. A transformational modification for deployment and sustainability was adapting it into a mobile unit that can be carried on a motorbike from farm to farm. This feature increases the usability for farmers while also creating a market opportunity for a small entrepreneur to provide mobile drying services. The STR dryer can adequately dry 500 kg in 3-5 hours for rice paddy, and is relatively affordable at approximately $500. Based on the revenue gains from the dryer, which has been shown to reduce rice grain breakage as well as reducing losses due to fungal and insect contamination, it is estimated that a dryer purchased with credit can be paid back within one year.

The STR dryer has been deployed for training and piloting in 20 villages, with scale up to many more villages next year. Initial conversations are underway with a local entrepreneur for potential scale-up and private-sector distribution of the STR dryers in the future. The results from continuing field testing will inform future design and market-based factors (including possible cost subsidies).

Figure 1: A woman in Bangladesh spreading rice paddy for open air sun drying.
Photo by Dr. C. K. Saha, Professor of Bangladesh Agricultural University.

Figure 2: STR dryer demonstration trials in Spring 2016.
Photo by Dr. C. K.

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