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, 2018–September 30, 2019

USAID
FROM THE AMERICAN PEOPLE

KANSAS STATE UNIVERSITY

PHLIL External Advisory Council:

Dr. Robert Zeigler, Chair

- Director General (Emeritus) of the International Rice Research Institute

Dr. David Priest

- Chief Executive Officer of Farm Input Promotions Africa, Ltd.

Brett Rierson

- Managing Director of African Harvest Ventures

See their full bios at https://www.k-state.edu/phl/about-the-lab/advisory.html.

Where we work:

The Post-Harvest Loss Innovation Lab has comprehensive post-harvest programs in our four core countries of **Bangladesh, Ethiopia, Ghana** and **Guatemala**.

In addition, PHLIL has current Mission Buy-In projects in Nepal and Honduras, with supplemental funds from the USAID Bureau for Food Security, and a previous Mission Buy-In in Afghanistan.

Phase II (2019-2021) Program Partners

United States

Feed the Future Innovation Lab for Livestock Systems
Feed the Future Innovation Lab for Nutrition
Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (Appropriate Scale Mechanization Consortium)
Helen Kellerr International
Iowa State University
Kansas State University
Michigan State University, Scientific Animations Without Borders
Oklahoma State University
Piestar
Purdue University - Purdue Improved Crop Systems (PICS) project
Romer Labs
South Carolina State University
University of Illinois at Urbana-Champaign, ADM Institute for the Prevention of Postharvest Loss
University of Kentucky
University of Nebraska – Lincoln
United States Department of Agriculture – Agricultural Research Service (USDA-ARS), Center for Grain and Animal Health Research

Bangladesh

ACI Motors, Ltd.
Bangladesh Agricultural Development Cooperation, Government of the People's Republic of Bangladesh
Bangladesh Agricultural University
Bhai Bhai Engineering
Department of Agricultural Extension, Government of the People's Republic of Bangladesh
GH Electronics
Jagorani Chakra Foundation
Kamal Machine Tools
Uttaron Engineering

Ethiopia

Ethiopian Institute of Agricultural Research
Bahir Dar University
Mekelle University

Ghana

Adventist Development Relief Agency (ADRA)
Agri Commercial Service Ltd.
American Soybean Association World Initiative for Soy in Human Health – Assisting Management in Poultry Layer Industry by Feed Improvement and Efficient Strategy (AMPLIFIES) project
Kwame Nkrumah University of Science and Technology
Ministry of Food and Agriculture (Northern and Upper West regional offices)

Guatemala

Asociación de Organizaciones de Los Cuchumatanes (Asocuch)/International Maize and Wheat Improvement Center (CIMMYT) – Buena Milpa project
Fundacion para Desarrollo Integral de El Tejar (FUNDIT)
SHARE Guatemala

Universidad del Valle

Additional Partners

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (Germany; in Ghana, Ethiopia)
Mars Global Food Safety Center (China)
Nepal Academy of Science and Technology (Nepal)
Vestergaard Frandsen (Switzerland)

Acronyms

ADRA – Adventist Development Relief Agency
AMPLIFIES – Assisting Management in Poultry Layer Industry by Feed Improvement and Efficient Strategy
ASMC – Appropriate Scale Mechanization Consortium
BAU – Bangladesh Agricultural University
BADC – Bangladesh Agricultural Development Corporation
BDU– Bahir Dar University
DAE – Department of Agricultural Extension
EIAR – Ethiopian Institute of Agricultural Research
FAO – Food and Agriculture Organization of the United Nations
HKI – Helen Keller International
KNUST – Kwame Nkrumah University of Science and Technology
KSU – Kansas State University
LPG – Liquefied Petroleum Gas
LSIL – Feed the Future Innovation Lab for Livestock Systems
ME – Management Entity
NAST – Nepal Academy of Science and Technology
PHL – Post-harvest loss
PHLIL – Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss
PICS – Purdue Improved Crop Storage
PMP – Performance Management Plan
RCT – Randomized Control Trial
SAWBO – Scientific Animations Without Borders Organization
SIIL – Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification
STR – a low cost dryer made locally in Asia (acronym based on Vietnamese)
Uof I – University of Illinois at Urbana-Champaign
USAID – United States Agency for International Development
USDA-ARS – United States Department of Agriculture – Agriculture Research Service

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2019 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 global food security by reducing post-harvest losses in stored product crops, such as grains, oilseeds, legumes, root crops and seeds. The Lab's efforts are focused in four Feed the Future countries: Bangladesh, Ethiopia, Ghana and Guatemala. Projects in each country are led by a U.S. or in-country Principal Investigator (PI) and in-country coordinators and overseen by the Lab's Director, with input from local and international academic, private sector, governmental and non-governmental organizations. In its sixth year, the program has continued making significant advances towards scalable innovation packages and cultivating the necessary capacity to reduce post-harvest losses at scale in our target countries.

The activities and outcomes of the first five years have placed PHLIL in a strategic position to address the next stage of critical research questions. These include expanding research into areas such as kernel sorting to reduce mycotoxin contamination, safe alternatives to pesticide use and addressing market needs in drying technologies, while still addressing critical questions around barriers to adoption, effective extension and education and sustainable scaling, including gender and youth considerations in all of these areas.

From developing new research questions and designing research plans to building upon previously existing and new partnerships, the Post-Harvest Loss Innovation Lab's sixth year of operation was focused on continuing to reduce post-harvest losses across our four core countries. National partners continue to be empowered to characterize and address key post-harvest loss factors along target value chains. The research program in this second phase of activities (2019-2021) now extends down the pathway to scaling to understand and remove potential barriers for inclusive and resilient improvements for target beneficiaries. Moving forward, the program continues to cultivate targeted and inclusive partnerships to substantially contribute to global efforts to reduce post-harvest loss, promote agriculture-led growth, strengthen resilience of people and systems, and contribute to a well-nourished population.

II. Program Activities and Highlights

In the first quarter of FY2019, PHLIL completed its initial five-year phase of programming (2014-2018), and on January 1, 2019, entered its sixth year of operation. This marked a period of transition to our second phase of research, adapted and outlined in the Revised Program Description that formed the basis of the 2019-2021 program extension from USAID (referred to as Phase II herein). Adaptations to the PHLIL program were informed through an extensive and iterative process of formally gathering the perspectives of a range of stakeholders, subject matter experts and potential partners along the pathway to scaling and resilient impact. The process also included in-depth discussions with USAID's Bureau for Food Security and partner country Missions over the course of the last two years of PHLIL's first phase. An important focus of Phase II is on packaging innovations that have been developed and validated to reduce post-harvest loss issues at key intervention points, and fostering their transition to scaling with strategic partners. This is accomplished through adaptations to the Phase I research program, such that research continues filling technology and information gaps as they emerge, as well as following Phase I innovation packages down the pathway to scaling to understand and remove potential barriers for inclusive and resilient improvements for target beneficiaries.

The first half of this year was primarily focused on setting up partnerships, agreements, and logistical operations to fully operationalize Phase II of the research plan. Research efforts continued as post-harvest innovation packages continued to be piloted, presented to and transferred to end users along the value chains. PHLIL innovation packages include drying, storage and moisture measurement technologies, coupled with locally illustrated and expert-informed extension and training materials, informed by Phase I PHLIL post-harvest loss research surveys and evidence-based adaptation and validation of technologies. The next two years of PHLIL seek to continue enhancing national agricultural system research and extension capacity.

In Phase II, PHLIL has enhanced our efforts focused on empowering women, youth, government and the private sector, across the areas of gender, youth, engagement and agricultural economics. The addition of youth as a focus area involved PHLIL partnering with AgReach at the University of Illinois. Additionally, our engagement team now includes an engagement PI, as well as a new team member at Iowa State University to collaborate in implementing their research. To better understand economic barriers to adoption, we have dedicated research dollars to agricultural economics faculty at Kansas State University. Given that fungal toxins can accumulate in grains during adverse years despite best efforts, kernel sorting is a new area of research we have integrated into our work in Ghana, to identify and remove specific kernels contaminated with mycotoxin. These enhanced and new research capacities will cross-fertilize insights and new innovations to more sustainably and inclusively reduce post-harvest losses for resilient, agriculture-led growth to inclusively foster a well-nourished population.

Year 6 activities have successfully built on the momentum and successes of PHLIL Phase I. Achievements include: formation of a National Post-Harvest Loss Advisory Committee including high-level officials in the Ethiopian National Agricultural Research System that is informing policy and government agricultural programming activities; graduation of the first cadre of PhD and MSc researchers from PHLIL-supported, new post-harvest graduate programs at Mekelle University and Bahir Dar University in Ethiopia; uptake of 184 PHLIL-developed BAU-STR dryers at Government of Bangladesh Department of Agricultural Extension farmer field schools in 21 upazillas of 6 districts; establishment and catalysis of new private sector adoption and scaling pathways for PHLIL-supported post-harvest interventions in Ghana, including by Isaac Sesi, a young, award-winning entrepreneur who was named one of MIT's Top 35 Innovators Under 35 globally; exploratory discussions to underpin adaptation of locally illustrated post-harvest manuals from the highlands to the lowlands of Guatemala; and continued engagement and leadership by PHLIL in the broader Feed the Future and post-harvest research for development communities. Additional successes across two active Buy-In awards, in Honduras and Nepal, are covered in other reporting.

Moving forward, the program continues to cultivate targeted and inclusive partnerships to substantially contribute to global efforts to reduce post-harvest loss, promote agriculture-led growth, strengthen resilience of people and systems, and contribute to a well-nourished population.

III. Key Accomplishments

Program-wide outputs, including for Feed the Future indicators, include:

- 221 short-term, and 12 long-term trainees (degree-seeking) directly supported by the program in FY2019
- 13 research publications
- 6 technologies transferred and/or ready to scale
- 12 public-private partnerships along the pathway to scaling and impact

Students, and In-Country Post-Harvest graduate programs:

Three students have graduated with MSc degrees and seven with PhDs from the PHLIL program to date. This includes the first PhD students to graduate from the Bahir Dar University post-harvest graduate program, with more to follow from there and the new post-harvest graduate program at Mekelle University. These new postharvest graduate programs are outputs of the PHLIL project, which received significant financial support from each university as a supplement to USAID funding. Many have returned to their posts in the national system, and several are involved in more senior contributing roles in PHLIL Phase II (e.g., Ethiopian students contributing to revisions of national agricultural extension manuals).

By country:

In all four core countries, post-harvest loss innovation packages coalesced and were presented to next-users along the pathway to impact. Selected key accomplishments by country include[1]:

Bangladesh

- The PHLIL Bangladesh team worked with a local engineering firm to locally design and manufacture the blower for the BAU-STR dryer, which made the blower 1.6 kilograms lighter and 34% cheaper. Consequently, the entire dryer and all of its components can be locally manufactured.

- Based on the demand of small-mid level rice traders and demand from rice mill owners for a 3-5 ton capacity dryer, the PHLIL Bangladesh team conducted a secondary review and identified international suppliers of candidate dryers. The capacity of these dryers ranges from 1 to 6.4 tons. The team is now conducting a needs assessment survey to identify the appropriate capacity(ies) of the dryer for the rice mills.

- Following scoping and planning visits by the KSU agricultural economics team, Bangladesh will serve as one of the primary countries for our ag economics research. The researchers will carry out a randomized control trial (RCT) to assess liquidity and risk constraints for the usage of hermetic storage bags for rice seed storage.

[1] *Note that this is a subset of key accomplishments, for brevity; more detail is provided in subsequent sections.*

- The burning unit of BAU-STR dryer was modified by using LPG (Liquefied Petroleum Gas) as a fuel instead of risk husk briquettes, allowing the dryer to be used in areas where risk husk briquettes are unavailable; LPG has wider availability than rice husk briquettes in some parts of Bangladesh.

- AgReach conducted a gender-based technology profiling. This led to recommendations for technologies to be more easily usable by women and helped provide context to better target engagement efforts to empower women as part of the post-harvest decisions.

Ethiopia

- The nascent National PHL Advisory Committee, which PHLIL in-country leadership and research outputs helped prompt the formation of, met twice to discuss post-harvest intervention strategies and additional researchable priorities. The Committee is chaired by the Director General of Ethiopian Research in the Ministry of Agriculture, and includes senior members from across government, as well as the PHLIL In-Country Coordinator, Professor Fetien Abay.

- A national mycotoxin conference held at Mekelle University was widely attended by regional and national stakeholders and target end-users along the value chain. PHLIL was recognized for the advances that the in-country partners have made, and connections were created and strengthened with several Ethiopian partners.

- Surveys to collect data on the effectiveness of training programs in previous years, and training's influence on farmers' adoption of new technologies, were developed by the PHLIL Engagement team at Kansas State University and Iowa State University. The surveys were piloted in Ethiopia in September.

Ghana

- Sesi Technologies and the GrainMate Moisture Meter have experienced tremendous success. Sesi Technologies' co-founder, Isaac Sesi, has won several awards, including the Generation Africa GoGettaz Agripreneur Prize (includes $50,000 capital for his company) and being named MIT Technology Review's 2019 Innovators Under 35. Under PHLIL Phase I, the initial model was developed by Dr. Paul Armstrong (USDA-ARS), and adapted by Sesi Technologies in collaboration with USDA-ARS.

- Vestergaard has begun production of ZeroFly® Hermetic Bags in Nigeria, further strengthening the distribution networks in the region, down to the village level.

Guatemala

- Funding restrictions have slowed our work in Guatemala, creating a great deal of uncertainty and instability in our partnerships.
- Discussions with Pepsico focused on partnering in Guatemala have showed positive signs, thanks to an introduction from the USAID Guatemala Mission.
- Phase II began with discussions with stakeholders in the lowlands, specifically Quiché which is part of the Feed the Future Zone of Influence.

IV. Research Program Overview and Structure

PHLIL focuses on several key areas with significant post-harvest challenges: **drying (including moisture measurement), storage, insect pest/pesticide alternatives** and **mycotoxin contamination**, as well as working with fumigation management and other issues. The program takes a phased approach to building human and institutional capacity, conducting research to develop and identify suitable innovations, and piloting innovation packages towards adoption and use for sustainable impact.

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

- **Gender:** Ensuring gender issues in post-harvest are incorporated into the research on technologies and approaches
- **Youth:** Ensuring young people are engaged in post-harvest loss prevention technologies and the appropriate scaling mechanisms
- **Engagement:** Ensuring our training materials and education strategy are supported by research
- **Agricultural Economics:** Ensuring our technologies are affordable and accessible to those that need them for their livelihoods, and assessing economic barriers to adoption

The PHLIL program establishes human and institutional capacity in every project country, empowering our national partners as innovation leaders and the champions to reduce post-harvest losses in their respective national systems.

V. Theory of Change and Impact Pathway(s)

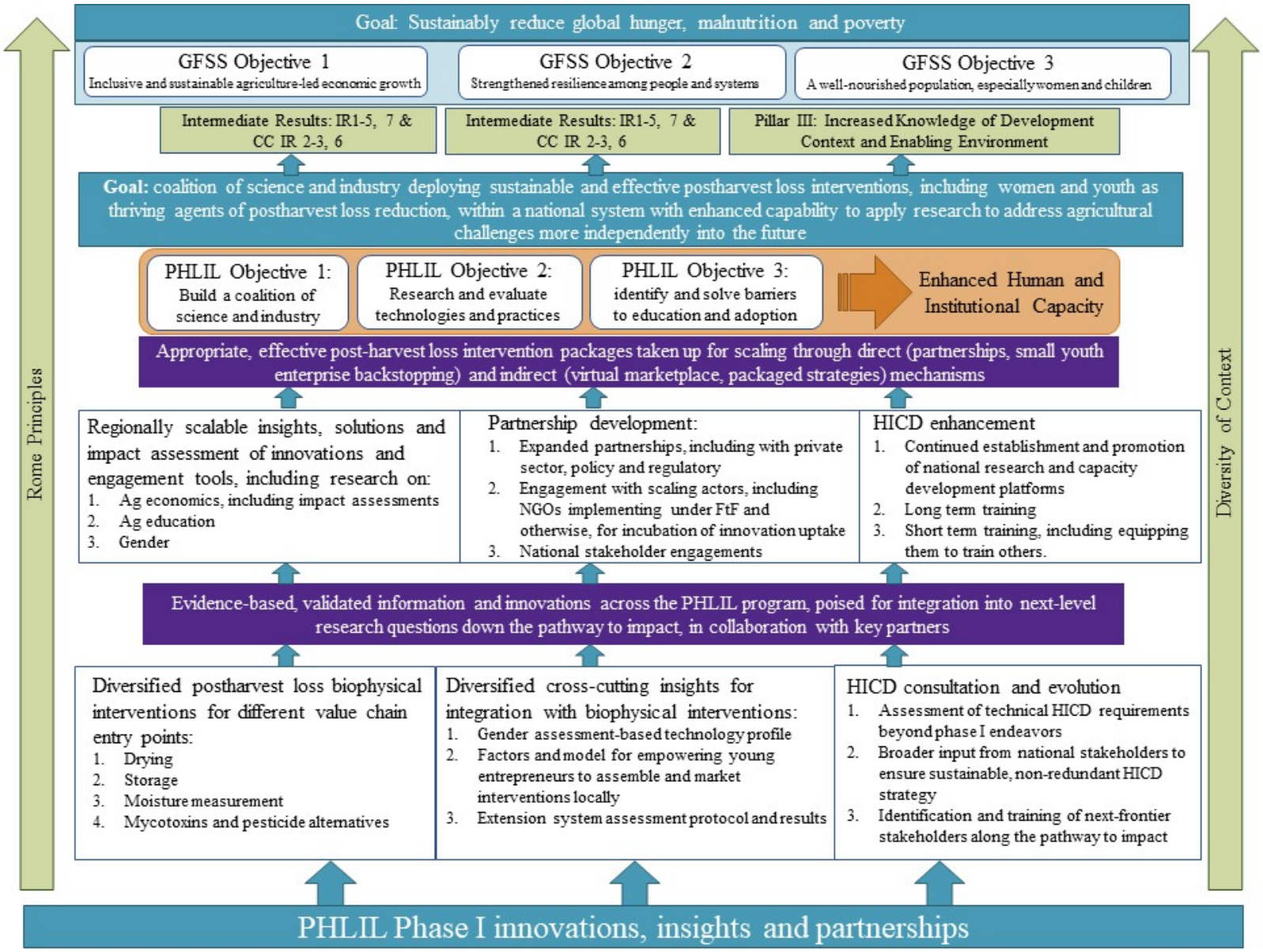

Figure 1: PHLIL Revised Program Description Theory of Change, for 2019-2021 program activities.

VI. Research Project Report

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

Bangladesh

Focus crop: Rice
Location: Bogra, Jessore, Khulna, Sherpur, Mymensingh, Naogaon, and Netrokona

Collaborators: *University:* Bangladesh Agricultural University (BAU);
Government: Department of Agricultural Extension, Bangladesh Agricultural Development Cooperation;
NGOs: Jagorani Chakra Foundation; *Private-sector:* Bhai-Bhai Engineering, ACI Motors Ltd., Uttaron Engineering, Kamal Machine Tools, GH Electronics

Achievements:

Objective 1: The BAU-STR dryer will further be modified to use liquid petroleum gas (LPG) as a fuel source

After stakeholder engagements revealed to PHLIL Bangladesh the need for an alternative fuel source, as rice husk briquettes are unavailable in certain areas, LPG was identified as the best alternative. LPG is abundantly distributed and used throughout the country. Modifying the BAU-STR dryer to use LPG as a fuel source will allow rice producers throughout Bangladesh access to the technology.

LPG Modification Specifications
The burning unit of BAU-STR dryer was modified by using LPG as a fuel instead of risk husk briquettes. An appropriate burner was identified by testing its heat production above 42˚C, and a high pressure regulator was installed to control LPG flow. After iterative efforts and several models being tested as a collaboration between the PHLIL in-country team and private sector partners, a suitable blower was manufactured by locally available materials; blower performance was satisfactory with the new fuel source. Technical and economic performance of the BAU-STR dryer using LPG for the heating unit were evaluated during Boro season in May 2019. The risk husk briquette dryer and the LPG dryer achieved the same moisture content, and according to these trials, the cost of operation for the LPG-based dryer is lower than the rice husk briquette-based dryer. Lastly, a germination test was done for checking the quality of seed after drying: germination rates ranged from 86% to 92%, higher than the recommended acceptable germination rate (80%) by the seed wing of the Ministry of Agriculture. The highest rate of germination was from the LPG-powered BAU-STR dryer with the locally made blower.

Objective 2: Develop an appropriate scale dryer for use on parboiled paddy rice for small-medium sized paddy traders and rice mills

Find appropriate (3- 5 ton/day) capacity dryer for small-medium paddy traders and rice mills
Members of the BAU PHLIL research team visited a rice husking mill. The mill is not operating at full capacity and is producing low quality rice, with ~8% of the rice broken. This low quality rice concerns the mill owner, who has expressed concern that his company will be unable to survive in the competitive market place without a mechanical dryer. Following a literature review, the team is now conducting a needs assessment survey to identify an appropriate capacity dryer for further intervention. In comparison to automatic and semi-automatic rice mills, the utilization capacity of the PHLIL-targeted rice mills is almost half, due to a lack of a dryer and steep competition. Without the introduction of an appropriate capacity dryer, many major rice mills will go out of business, which will also reduce farmers' ability to sell their paddy locally. If that happens, farmers may need to sell to an intermediary, which would decrease their profit.

Therefore, identifying and recommending an appropriate capacity dryer to these struggling mills will also help the local farmers maintain access to markets.

PHLIL-Bangladesh will install and adapt the appropriate capacity dryer at a rice mill, and the mill will provide the inputs such as bulk volume of paddy, rice husk as fuel and infrastructure for installing the dryer on the mill premises. There will be an MoU with the rice mill owner to allow interested paddy traders, rice mill owners, students and researchers to visit the facilities and conduct further research.

Thirty-six paddy samples have also been collected from rice mills in three districts, for mycotoxin testing at the Interdisciplinary Institute for Food Security (IIFS) Laboratory at BAU.

Objective 3: Test and promote hermetic storage for seed in collaboration with the Bangladesh Government

PHLIL is collaborating with Bangladesh Agricultural Development Corporation (BADC), the Bangladesh Government's seed producing institution which supplies 38% of rice seed in the country. The first step in the hermetic seed storage research is a literature review, which is currently underway. Additionally, a research agreement between BAU and BADC has been established, making it possible to begin experiments.

Two experiments have been set up to investigate the technical and financial performance of hermetic bags for storing seed. These experiments are taking place at BADC Seed Processing Center and Paddy Seed Storage at Balashpur, Mymensingh and Madhupur, Tangail. Using a Completely Randomized Design (CRD) with three replications, the project will compare hermetic storage (GrainPro bags) with traditional jute storage bags. Fifteen 40-kg bags are placed on wooden pallets in the BADC storage facility, and measurements are taken every 15 days (which is the standard testing interval used by BADC) for three months. Once a hermetic bag is opened, it is not used again for measurements. Moisture content, germination rate, and insect infestation rates are recorded, with data analysis ensuing.

Furthermore, the seed processing, storage, and marketing channels of BADC have been identified. The results from the two experiments determining the technical and financial performance of hermetic bags (GrainPro bag) for storing seed will be used to identify the best practices that should be used to update the processing, storage and marketing channels of BADC.

PHLIL Ag Economics team randomized control trial on liquidity and risk for hermetic bags
Hermetic storage for seeds can be used on farm as well, from which seed sales was found to be a source of income for women in Phase I. The PHLIL agricultural economics team (faculty at Kansas State University) will be testing purchase and use of hermetic bags by smallholder farmers in Bangladesh to determine the economic factors that may support or prevent adoption of these technologies for rice seed storage. Scoping visits led the team to understand that the Aman growing season is when Bangladeshi farmers grow local rice varieties and are more likely to store these seeds in their homes. Therefore, this will be the target season of the research, although Boro season will also be included as well as a randomized control trial (RCT) planned for launch in November 2019.

Scoping visits occurred in March 2019 by Dr. Ben Schwab, and June 2019 by Dr. Jisang Yu. Helen Keller International's Bangladesh Country office was identified as an on-the-ground partner to implement the RCT. The RCT and agreement with HKI are being finalized.

During the scoping visits, the ag economics team also met with the Department of Agricultural Extension (DAE), including the Director General, to discuss potential collaboration on the farmer field school scaling of the BAU-STR-dryer.

Objective 4: Ensure that opportunities are made available for women and youth to contribute to and benefit from PHLIL post-harvest interventions

Gender Dimensions and Technology Assessment
Dr. Paul McNamara (AgReach, University of Illinois) and Dr. Ismat Ara Begum, the local gender specialist, led a field-based gender technology assessment to inform the technology profile for hermetic storage bags and the BAU-STR dryer. This information will assist PHLIL Bangladesh in addressing some of the challenges to technology adoption through a gender-focused perspective. In order to explore the gender dimensions related to drying (BAU-STR dryer) and storage (hermetic bags) technologies of the study areas, both female and male household members constituted the sample for detailed survey. Simple random sampling technique was applied to select technology users, non-users, local service providers and farmers' associations as respondents for the BAU-STR Dryer (18 people) and hermetic bags (20 people).

The assessments revealed that women may not have the final decision making authority in their households, but their husbands do discuss new technologies and potentially adopting them with their wives. Developing trainings for women in parallel to men's trainings (catering to the overall knowledge of the machine/ technology, its benefits and requirement, and the financial savings in using the machine/technology) could potentially assist in the adoption of post-harvest technologies. The parallel, complementary trainings would afford both parties more details about the technology, empowering wives to have informed discussions with their husbands, and priming husbands to be more receptive. The gender based technology assessment results yielded several recommendations for awareness creation and increasing demand for the hermetic bags and the BAU-STR Dryer.

BAU-STR Dryer
The BAU-STR Dryer is a time, labor and cost saving technology. The PHLIL-Bangladesh team has worked to ensure that this technology is appropriate and usable for women, the main household members engaging in post-harvest activities. The BAU-STR dryer reduces drying-associated losses and specifically reduces time that women spend in post-harvest operations. The dryer is light weight, making it functional for women to operate alone, and can function even on rainy days.

PHLIL is working to help ensure that the dryer is available to women and youth as an entrepreneurial opportunity. The initial investment that is required is too high for many farmers, but a government subsidy for easy purchase is assisting farmers to afford the technology. The PHLIL Bangladesh team is exploring possibilities for various models of deployment including a fee for service-based model, and a farmer group-based model. The mechanization policy of the Bangladesh Government is to provide a subsidy on selected agricultural machinery for a certain period, then the subsidy is withdrawn and the market stabilized with private sector intervention. Following formal consideration and recognition that the BAU-STR dryer is a critical technology to reduce post-harvest losses in Bangladesh, the government subsidy on the BAU-STR dryer is under processing with DAE, and will soon be put into effect.

Objective 6: Implement an engagement strategy that reaches out to key stakeholders

On October 24, 2018, BAU hosted the Regional Symposium on Sustainable Agricultural Mechanization and Post-Harvest Practices, jointly organized by PHLIL and the Appropriate Scale Mechanization Consortium (ASMC) (under the Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification - SIIL). The symposium included stakeholders from universities, government, private sector and civil society, hosted representatives from India and Cambodia, and focused on private sector involvement and gender roles in post-harvest and mechanization. Various technologies from multiple countries, including the BAU-STR dryer were shared during the symposium. Representatives of partner countries and in-country development partners and institutions shared their development views in the networking session and agreed to continue sharing knowledge and technologies.

Aside from the engagement work conducted by the in-country team and described under the objectives above, the cross-cutting PHLIL engagement team will provide feedback on educational materials in FY20. The feedback will be based on their ongoing engagement research in Ethiopia as the initial focus country for that exercise.

On September 18, 2019, BAU hosted an annual workshop on Sustainable Agricultural Mechanization and Post-Harvest Practices, which was jointly organized by PHLIL-BD Phase II and the ASMC (under SIIL). The goal of the workshop was to provide an outlet for sharing knowledge relating to sustainable agricultural mechanization and reduction of post-harvest loss for attaining food security in Bangladesh. In the workshop, project activities were shared with 109 participants that included policymakers, donors, government agencies, academicians, researchers, private sector, farmers and representatives of print and electronic media. By the end of the workshop, participants recognized agricultural mechanization as a national food security need, critical for reduction of production cost and post-harvest losses, and for increasing crop production. Participant/stakeholder feedback further validated the Phase II PHLIL-Bangladesh strategy.

Objective 7: The BAU-STR dryer developed in PHLIL Phase I will continue to be promoted and scaled

During FY19, 184 BAU-STR dryers were distributed at Department of Agricultural Extension (DAE) farmer field schools in 21 upazillas of 6 districts. PHLIL will continue to collaborate with DAE to install BAU-STR dryers at as many as 3,000 farmer field schools throughout the country. Since January 2019, the work related to the BAU-STR Dryer scaling has primarily been training on the working principles, operating and maintenance of the dryer and hermetic bags for stakeholders in national institutions (DAE, BADC). PHLIL Bangladesh is also working with Palli Karma-Sahayak Foundation (PKSF), an apex NGO organization, to scale the dryer through its programs.

Members of the PHLIL Bangladesh team attended the PHLIL Nepal stakeholder workshop "Mycotoxin Mitigation for Health, Nutrition, Agricultural Productivity and Prosperity in South Asia", and the coincident official launch of the PHLIL project Mycotoxin Laboratory at the Nepal Academy of Science and Technology (NAST) in Lalitpur, on November 30, 2018. Dr. Alam delivered a technical presentation on PHLIL Bangladesh, highlighting findings and the team's drying and storage innovations. PHLIL Bangladesh also officially handed over and provided training for two new BAU-STR dryers to Nepali partners. These included Helen Keller International (HKI), a PHLIL Nepal partner. HKI also implements USAID's SUAAHARA II "Good Nutrition" project, which "aims to improve nutritional status for women and children in 40 underserved rural districts in Nepal." HKI has since been piloting the BAU-STR dryer in the field, and has requested the LPG-adapted version. This represents a successful South-South innovation handover, building regional partnerships and pathways to impact across PHLIL and broader Feed the Future countries and programs.

Possible partnership with DAE to measure the adoption rates of the BAU-STR dryer
The PHLIL ag economics team is actively working towards partnering with DAE to measure the adoption rates of the BAU-STR dryer. PHLIL is waiting on the list of locations where the dryer will be installed to determine if it is feasible to partner in this way.

Capacity Building:

PhD and MSc Students
Two graduate students were selected, a PhD student to focus on storage and an MSc fellow to focus on drying. They will complete their programs in 2021.

Two Train the Trainer programs were conducted, teaching trainers, farmers and potential entrepreneurs on

hermetic storage technology and the BAU-STR dryer. The training covered maintenance and operation of the dryer, and proper use of hermetic bags, with a total of 75 participants. This included 21 sub assistant officers who will serve as trainers at the DAE farmer field schools. Also included were 25 farmer leaders from the FAO Missing Middle Initiative, who will train others on these post-harvest loss reduction mitigation measures.

Lessons Learned:

- There is no local manufacturer of large capacity mechanical dryers in Bangladesh. However, there are a few experienced agricultural machinery manufacturers in the country who could fabricate a large capacity mechanical dryer under supervision and guidance. This will serve as another PHLIL capacity building opportunity for the private sector, as the BAU team works with local entrepreneurs to build these large capacity mechanical dryers.

- During the modification of BAU-STR dryer to use LPG, it was discovered that not every burner can produce 42°C temperature at BAU-STR drying setup. So, selection of the burner was done by checking its heating performance.

- A local electronic company has produced a lighter and less expensive blower for the BAU-STR dryer. This is a significant achievement that required persistence, having been a challenge to produce locally. This now achieves full local production of the dryer.

Conference Proceedings:

Awal, M., Hossain, M., Ali, M., & Alam, M. Economic Performance of Different Paddy Storage Technologies in Bangladesh. (July 2019) Conference Proceedings at American Society of Agricultural and Biological Engineers, Annual International Meeting, Boston, Massachusetts, USA.

Presentations:

Saha, C. K., Alam, M. Scaling up of BAU-STR Paddy Dryer in Bangladesh and Beyond. Presentation at 2019 American Society of Agricultural and Biological Engineers, Annual International Meeting, (July 2019). Boston, Massachusetts, USA.

Alam, M. Mitigation, Innovations and Interventions: BAU-STR Dryer. Presentation at the "Mycotoxin Mitigation for Health, Nutrition, Agricultural Productivity and Prosperity in South Asia" national stakeholder workshop. (November 2018) Nepal Academy of Science and Technology, Lalitpur, Nepal.

Ethiopia

Focus Crops: Sorghum and Wheat
Location: *Amhara region:* Bahir Dar Zuria, Gondor, Mecha, Wenberma 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

Achievements:

Objective 1: Formalize the inclusion of PHLIL knowledge and technologies in extension education by providing input into various nationally accessible extension materials

After PHLIL's formally requested review of the Ministry of Agriculture's Extension manuals, it was determined that PHLIL had significant, directly relevant scientific knowledge to improve the contents in the areas of mycotoxin mitigation, drying and storage. Recently graduated PhD students from Mekelle University and Bahir Dar University (from PHLIL Phase I) are reviewing and updating the manuals with findings from their research. A draft of a technical mycotoxin management training manual, translated into local language, was prepared and presented to the Ministry of Agriculture. In addition to the Extension manual edits, there is a shorter extension manual, geared towards farmers, that the PHLIL Ethiopia team is also updating with feedback from the National PHL Advisory Committee. These manuals will be available in Amharic, Oromo, and Tigrigna, with the government eager to deploy them.

Objective 2: Establish and serve on the first National PHL Advisory Committee to assist Ethiopian stakeholders in developing national post-harvest strategies

The National PHL Advisory Committee represents a major output for PHLIL, with the program's findings and in-country leadership serving as a primary impetus for its formation. The Committee is currently chaired by the Director General of Ethiopian Research in the Ministry of Agriculture, and members include representatives from the Directorate of Plant Protection, Bahir Dar University, Debre Zeit Research Station of the Ethiopian Institute of Agricultural Research, and Mekelle University (Professor Fetien Abay, PHLIL Ethiopia In-Country Coordinator). This leadership and membership demonstrates the high-level prioritization of post-harvest loss mitigation PHLIL has contributed to. The Committee met twice during FY2019 and discussed various topics. The registration process of filter cake was discussed and the group advised that toxicology research from an accredited laboratory should be a next step for the substance to be a registered pesticide. In addition to previous PHLIL research, the group also emphasized the importance of characterizing and addressing pesticide residue contamination on major grain crops; they asked PHLIL to assist in this research and adaptation of appropriate sampling and laboratory protocols. Other concerns that were discussed included food safety challenges related to mycotoxins and *Salmonella* bacteria, including in export crops. As part of the research in Ethiopia, Dr. Mekasha at Debre Zeit Research Station of the Ethiopian Institute of Agricultural Research will work to identify and adapt protocols for pesticide residue research.

Objective 3: Host various forums and events related to PHL in Ethiopia to share the knowledge gained through our research

Livestock Innovation Lab Meeting
PHLIL Director, Dr. Jagger Harvey (virtual attendee), and In Country Coordinator, Professor Fetien Abay presented at the Livestock Systems Innovation Lab "Workshop on the Prevention and Mitigation of Aflatoxin Contamination of Animal Feed and Animal-Source Foods" in Addis Ababa, Ethiopia on March 26,

2019. Dr. Harvey focused on empowering national systems with risk communication capacity/strategies and Prof. Abay focused on PHLIL results achieved in mitigating mycotoxin and storage pests. The paired PHLIL presentations were well received by partner organizations, including the Ministry of Agriculture. They appreciated that PHLIL focused on scaling up solutions and strategic risk communications, rather than simply reiterating the problem.

National mycotoxin workshop led by Mekelle University and involving PHLIL
On May 24, Mekelle University hosted a national mycotoxin workshop in honor of the late Dr. Dereje, a mycotoxin scholar at Mekelle University who unexpectedly passed away in 2018. The workshop was designed with input from the National PHL Advisory Committee and the Ministry of Agriculture. Topics included understanding risk communication strategies and mycotoxin mitigation strategies. With over 100 participants from universities, research centers, donor agencies, development projects, and the Ethiopian Government, the event was considered a success and has provided opportunities for Mekelle University to further collaborate with local and international partners. Speakers included the Director for National Crop Protection and Regulation, Dr. Ahmed Kablan (Senior Nutrition Research Advisor from USAID Bureau for Food Security), Winta Sintayehu, (Program Officer the Partnership for Aflatoxin Control in Africa, a program of the African Union Commission) and PHLIL Director Dr. Harvey.

Objective 4: Research on effective training implementation and factors contributing to or preventing adoption of post-harvest technologies

Our research for development program is scrutinizing and developing effective training implementation to help drive adoption of post-harvest loss reducing technologies. This research is being led by agricultural education and extension expert Dr. Jonathan Ulmer (Kansas State University). Surveys to collect data on the effectiveness of training programs in previous years and trainings' influence on farmers' adoption of new technologies were developed by the PHLIL Engagement team at KSU and Iowa State University (Dr. Misty Lambert). The survey was piloted with 41 Ethiopian farmers in September. The researchers realized that working with a translator will help increase the efficacy of the survey instrument, especially since they plan to use the instrument in Ghana and Ethiopia. Additionally, the pilot round provided critical insights to the engagement team, to inform their development of appropriate training materials for training enumerators later in the project.

Objective 5: Determine the prevalence of pesticides in economically important grains

It was determined that an MSc thesis for pesticide residue could not be completed due to funding, after a more detailed budgeting and prioritization exercise. The National PHL Advisory Committee recommended that a current student, with guidance from Dr. Mekasha at EIAR, focus on the establishment of pesticide residue analysis protocols as a first step.

Objective 6: Determine the impact of previously researched PHL technologies within integrated mitigation strategies

A Mekelle University MSc student was identified to focus on food safety issues. The Bahir Dar University team is still in the process of identifying an MSc student for an integrated on-farm study, which will take grain from drying to storage to mycotoxin testing. Identified students are being selected from a pool of existing MSc students, who need funding for the research component of their studies, to reduce funding requirements and abbreviate their graduation timeline. This ensures that the students' work will be completed by the end of PHLIL programming.

Objective 7: Support the establishment of a distribution system for PHL technologies

Filter Cake

Inert dusts that are industrial byproducts in Ethiopia (including filter cake) were identified as highly effective, low toxicity pesticide alternatives in Phase I PHLIL research. As with any such product, filter cake must go through a government approval process prior to commercialization and distribution. A batch certificate of analysis at a certified toxicology laboratory, locally generated efficacy data from independent recognized research organization, environmental impact information, and a manufacturing license in the country of origin are all requirements. These are all prerequisites before a memorandum of understanding (MOU) can be signed with the filter cake producer. The Ethiopia team is considering partnership with a private sector partner interested in doing the further research and trials for commercialization, given the costs involved in the next steps.

Lessons Learned:

- Engaging in the National PHL Advisory Committee has been very useful when the program required clarification on government requirements related to the next steps of pesticide registration. The research necessary to register filter cake with the Ethiopian Government is beyond what the scope of this program can currently support, so private sector partnership is being explored.

- The engagement pilot survey assisted researchers in learning ways to improve their survey instrument before deploying it in Ghana in December.

- While pesticide residue research is very important to the stakeholders in Ethiopia, due to lack of funding (the laboratory analysis in this research is relatively expensive) and lack of established protocols with partner institutions, the research was shifted from identifying pesticide residues in grains to identifying and validating the protocols necessary to do so.

Publications:

Tadesse, T. M., and Bhadriraju, S. (2019) Efficacy of Filter Cake and Triplex Powders Against Three Internally Developing Stored-product Insect Species. *American Journal of Entomology* **3(1):** 15-23.

Worku, A., Kalsa, K. K., Abera, M., and Nigus, H. G. (2019) Effects of storage strategies on physicochemical properties of stored wheat in Ethiopia. *Agriculture and Food* **4(3):** 578-591.

Kalsa, K., Bhadriraju, S., Demissie, D., Mahroof, R., Fanta, A., and Habtu, N. (2019) Evaluation of postharvest preservation strategies for stored wheat and seed in Ethiopia. *Journal of Stored Products Research* **81:** 53-61.

Kalsa, K. (2019) Farmers' attitudes and practices towards variety and certified seed use, seed replacement and seed storage in wheat growing areas of Ethiopia. *African Journal of Science, Technology, Innovation and Development* **11(1):** 107-120.

Kalsa, K., Bhadriraju, S., Demissie, D., Fanta, A., and Habtu, N. (2019) Major Insect Pests and their Associated Losses in Quantity and Quality of Farm-Stored Wheat Seed. *Ethiopian Journal of Agricultural Scienc*es **29(2):** 71-82.

Kalsa, K., Bhadriraju, S., Demissie, D., Mahroof, R., S., and Habtu, N. (2019) Mortality of *Sitophilus granarius* (L.) and *Rhyzopertha dominica* (F.) Adults Exposed to Different Concentrations of Filter Cake in Stored Wheat. *Ethiopian Journal of Agricultural Science* **29(1):** 99-107.

Fanta, A., Abera, M., Kalsa, K., Bhadriraju, S., and Habtu, N. (2019) Occurrence of Mycotoxins in Stored

Maize in Ethiopia. *Ethiopian Journal of Agricultural Science* **29(2):** 31-43.

Kalsa, K., Bhadriraju, S., Demissie, G., Mahroof, R., Worku, A., Gabbiye, N., Workneh, S., and Abay, F. (2019) Susceptibility of Ethiopian wheat varieties to granary weevil and rice weevil infestation at optimal and sub-optimal temperatures. *Journal of Stored Products Research* **83:** 267-274.

Conference Proceedings:

Lapiso, S., Abay, F., Ayimut, K., Assefa, D., and Challa, D. (September 2019). Evaluating Different Hermetic Storage Technologies to Arrest Mold Growth, Prevent Mycotoxin Accumulation and Preserve Germination Quality of Stored Chickpea in Ethiopia. Book of Abstracts at 2nd All African Postharvest Congress and Expo, Addis Ababa, Ethiopia.

Ulmer, J., Lambert, M., Bhadriraju, S., Washburn, S., and& Tadesse, T. (April 2019). Needs of Ethiopian Wheat Farmers. Association for International Agricultural and Extension Education, Port-of-Spain, Trinidad & Tobago.

Presentations:

Abay, F. (March 2019) PHLIL Ethiopia findings and recommendations. Livestock Systems Innovation Lab "Workshop on the Prevention and Mitigation of Aflatoxin Contamination of Animal Feed and Animal-Source Foods", Addis Ababa, Ethiopia.

Kalsa, K., Fanta, A., Bhadriraju, S., Demissie, D., Mahroof, R., Habtu, N., & Abay, F. (September 2019). Reducing postharvest losses of cereals due to storage insects: A case study of wheat and maize in Ethiopia. Presentation at 2nd All African Postharvest Congress and Expo, Addis Ababa, Ethiopia.

Ghana

Focus crop: Maize
Location: Dormaa area (Dormaa East and West 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:* Poultry farms in Dormaa, Agri Commercial Service Ltd., Vestergaard Frandsen, Sesi Technologies ; *USAID/USG Project Partners:* AMPLIFIES

Achievements:

Objective 1: Work to increase awareness, enhance demand, and help establish efficient distribution channels to increase adoption of GrainMate moisture meters and hermetic technologies by stakeholders in the agriculture sector

Ghana's PHLIL Phase II objectives build upon their success in our first five years of research working with Sesi Technologies, poultry producers, and Kwame Nkrumah University of Science and Technology (KNUST) to scale up the GrainMate moisture meter and the PICS and ZeroFly® hermetic bags. These are Phase I PHLIL innovations. The first version of the moisture meter was developed by Dr. Paul Armstrong at USDA-ARS. Vestergaard collaborated with PHLIL Ghana PI Dr. George Opit at Oklahoma State University to validate the efficacy of the slow-release Deltamethrin-embedded ZeroFly® hermetic bags, resulting in joint peer-reviewed technical publications. With these technologies in hand in Phase II, the PHLIL Ghana team

shifted their focus to the Dormaa region, a hub for poultry production in Ghana, complemented by an enhanced focus on engagement, youth and gender, and agricultural economics. Several members of the PHLIL Ghana team, including Colette Powers from the AgReach team at University of Illinois at Urbana Champaign and Dr. Misty Lambert from the Engagement team at University of Iowa, held the Kick-off meeting for Phase II in Sunyani, Ghana in March 2019. The meeting included strategic discussions around research objectives and program plans and a review of key policy guidance for the team. The team also spent time with poultry producers to gain insights into effective strategies to improve training capacity and engage women and youth in distribution channels for scaling up hermetic storage bags and other post-harvest technologies.

During the March 2019 trip, poultry farmers and feed millers in Dormaa were trained on the use of the GrainMate moisture meter, ZeroFly® Hermetic bags, and the importance of good sanitation for proper storage of maize for poultry feed. The training on these post-harvest technologies involved both talking about the technologies and setting up a demonstration of hermetic technologies at each poultry farm. Once the training was completed, technologies were available for sale. As a result of the training conducted during this trip, at least five GrainMate moisture meters were purchased by the poultry farmers. Additionally, one female poultry farmer in Dormaa is now working with Sesi Technologies, the local company assembling GrainMate moisture meters, to become a sales agent for the meters in Sunyani and Dormaa. Three months after this pilot demonstration exercise was started, maize stored in the polypropylene and ZeroFly® hermetic bags in the farms visited was opened by PHLIL team members in the presence of poultry farmers and their staff, to assess and compare insect infestation levels and maize weight loss. On average, maize stored in polypropylene bags lost 5–10% of the initial weight whereas weight of maize in ZeroFly® hermetic bags did not change. ZeroFly® hermetic bags have a slow release insecticide-incorporated outer bag ensuring no insects can attack the stored grain or seed for up to 24 months. Additionally they include an inner bag, which when sealed will cause death to insects that had infested grain pre-harvest. Therefore, ZeroFly® hermetic bags are more effective than other available options because they have these two mechanisms for mitigating insect pest infestations; other products in the market (including other hermetic bags) have only one mechanism.

Objective 3: Assess the use of low-cost, locally built elevated platforms to mitigate high mycotoxin levels that are usually associated with heaping maize on the ground in the field

Mr. Bismark Opoku was identified as the prospective MPhil in Entomology student and started his graduate studies at Kwame Nkrumah University of Science and Technology (KNUST) in September 2019. Bismark will be instrumental in achieving PHLIL Ghana's objectives over the next two years. He and his major Advisor, Dr. Enoch Osekre, have completed designing experiments on using low cost locally built elevated platforms to mitigate mycotoxin levels in the field and will conduct experiments in 2020. The study on elevated platforms will have a randomized complete block design (RCBD). Under this design, farmers' fields will be the blocking factor. Maize ears in the elevated platform treatment will not be allowed to contact soil but be evenly spread out on the platforms immediately after harvesting. Through this approach, similar ears of maize will be in both treatments, in each field — ground heaps (a standard practice, which PHLIL Phase I research identified as a factor promoting aflatoxin accumulation) and platforms. Other experiments to assess the effects of PHL mitigation technologies on stored maize quality in poultry farms will have a RCBD.

Objective 4: Contribute to increased success (in sales and efficiency) of Sesi Technologies, serving in an advisory role to increase assembly efficiency, continue to make upgrades to the GrainMate, etc.

Dr. Paul Armstrong (Co-PI, ARS) chose to use funds allocated for his 2019 activities to purchase materials and supplies that will facilitate more efficient assembly of GrainMate moisture meters in Ghana.

Objective 5: Conduct research into effective training methods

Previously, Dr. Jon Ulmer (KSU Ag Education Associate Professor) has participated in PHLIL Ghana trainings, and given feedback that led to adaptations in the engagement/training approach used by the team. To build on this previous work, an instrument to survey the previous year's training participants has been developed and piloted in Ethiopia. There will be adjustments made to ensure cultural transferability to Ghana. The engagement team plans to collect data on previous trainees, and comparing one-on-one versus group educational experiences, in December 2019 as a basis of further adaptations to PHLIL engagement strategies.

Objective 6: Through research, evaluate impact of use of GrainMate moisture meters and hermetic technologies, including positive strategies to promote awareness and adoption by women and youth-focused stakeholders in the agriculture sector

Representing AgReach, Colette Powers visited in Accra and Sunyani/Dormaa areas in March 2019, engaging in one-on-one interactions with maize and poultry value chain implementers. This established a contextual understanding of potential distribution channels, and is informing associated research activities related to scaling-up of hermetic storage bags, and other promoted PHL practices with women and youth in Ghana.

Objective 7: Test small-scale kernel sorting as an avenue to remove mycotoxin-contaminated maize from the food supply

Even in the U.S., corn (maize) can become contaminated with aflatoxin despite best efforts, when environmental factors and agricultural practices are conducive; developing country farmers and other value chain actors can face an even more daunting challenge. Dr. Matthew Stasiewicz at University of Illinois began discussions with the Ghana team to adapt and validate a single-kernel sorting technology, initially designed by USDA-ARS, which he previously adapted in Kenya. His team is engaging with collaborators on the PHLIL Ghana team to integrate their work into existing sampling collection and analysis activities. (Guatemala was the initial focus country of his work, however given the funding uncertainty, there has been a strategic shift to include Ghana.)

Lessons Learned:

- Better coordination between the engagement and the AgReach team will be a priority moving forward. AgReach chose to shift some of their work for the KNUST MSc student to a later date to accommodate his schedule.

Publications:

Manu, N., Osekre, E. A.,Opit, G. P.,Arthur, F. H.,Mbata, G., Armstrong, P., Danso, J. K.,McNeill, S. G. and Campbell, J. (2019) Moisture content, insect pests and mycotoxin levels of maize on farms in Tamale environs in the Northern Region of Ghana. *Journal of Stored Products Research* **83:** 153–160.

Danso, J. K., Osekre, E. A.,Opit, G. P.,Arthur, F. H.,Campbell, J. F.,Mbata, G., Manu, N., Armstrong, P., and McNeill, S. G. (2019) Impact of storage structures on moisture content, insect pests and mycotoxin levels of maize in Ghana. *Journal of Stored Products Research* **81:** 114–120.

Manu, N., Opit, G. P.,Osekre, E. A.,Arthur, F. H.,Mbata, G., Armstrong, P., Danso, J. K., McNeill, S.G., and Campbell, J. (2019) Moisture content, insect pest infestation and mycotoxin levels of maize in markets in the Northern Region of Ghana. *Journal of Stored Products Research* **80:**10–20.

Guatemala

Focus crop: Maize
Location: Playa Grande, Municipality of Ixcan, Department of Quiché, Guatemala
Collaborators: *University:* Universidad del Valle; *NGOs:* SHARE, *Project Partners:* Buena Milpa

Due to political uncertainty around funding for Guatemala, the ME created a bifurcated modular plan for Guatemala. The adapted plan allows for either research and other activities to finish by March 2020 or to continue as originally planned if funding is released.

Achievements:

Objective 1: Further investigate regionally-relevant post-harvest interventions and management practices to reduce post-harvest losses in Guatemala

In the first phase of PHLIL Guatemala, maize surveys in the Western Highlands revealed higher levels of aflatoxin contamination in maize coming from lowland areas. As such, it was determined that the lowland maize should be investigated for mycotoxin contamination and mitigation options. This geographic shift was affected in consultation with the Mission. To determine our focus area within the lowlands, FY19 began with maize stakeholder discussions in the lowlands of Guatemala, preceded and informed by Mission recommendations. This assessment was conducted via 20 interviews with recognized actors across the different regions, representing academia, private sector and local nonprofits. From this initial assessment and available literature, a resulting priority list identified three zones with higher potential PHLIL impact. Playa Grande, Municipality of Ixcan, Department of Quiché, Guatemala (within the Feed the Future Zone of Influence) was selected for Phase II activities.

Following an introduction by the Mission, the PHLIL Guatemala team has been engaged in discussions of a partnership with Pepsico. However, nothing has been finalized due to the uncertainty surrounding funding.

A desk exercise to catalogue and prospect for best off-shelf drying and storage technologies was developed and presented by Alejandro Morales. He reviewed the technologies developed and used by PHLIL in Guatemala and other program countries, as well as by other development projects including other relevant Feed the Future Innovation Labs. This exercise will contribute useful information to the nascent Feed the Future Innovation Exchange.

Due to U.S. Government policy uncertainty, funding and travel have been restricted for work in Guatemala. As a result, activities have been delayed and held until further guidance is received. As a result, Dr. Matthew Stasiewicz at University of Illinois has shifted most of his single-kernel sorting technology research to Ghana. However, his team had reached out to collaborators on the Guatemalan team to integrate their work into existing sampling collection and analysis activities. As a starting exercise, Dr. Stasiewicz's team analyzed 576 single kernels from 12 individual samples of maize from the Guatemalan Highlands (previously published work from this project) provided by Dr. Andreia Bianchini (PHLIL Honduras PI and Guatemala co-PI, University of Nebraska, Lincoln). These had bulk aflatoxin levels of 0-12 ppb and fumonisin 0-2.5 ppb, based on subsamples tested at UNL. No individual kernels from the subsample passed through the sorter tested positive for aflatoxin, while 17 of 576 tested positive for fumonisin. Differences in aflatoxin measurement illustrates the challenges presented by sampling/sub-sampling issues in aflatoxin measurement. Notably,

12ppb is also a relatively low concentration of aflatoxin that can lend itself to difficulty in detecting across sub-samples, so the likely higher level Ghanaian maize should provide better material for sorting optimization.

Objective 2: Understand agricultural and socio-economic factors that may hinder the adoption of the identified post-harvest technologies and management practices in the lowlands

In August 2019, the ag economics team and the Guatemala team began to develop the agricultural economics module for the upcoming survey to assess stakeholder's willingness to pay for a post-harvest reducing technology or mycotoxin testing. The survey is currently being prepared for deployment in late October, 2019.

Objective 3: Based on outcomes of Objective 1 and 2, resolve barriers to education and adoption of interventions through effective delivery of information to different stakeholder categories

The outputs of objective 1 and 2 are forthcoming and will be used to update the post-harvest loss mitigation training manual suite for conditions in the lowland region. This tool will then be disseminated to stakeholders in the lowlands.

Lessons Learned:

- Continuing to work in Guatemala has proved difficult with political uncertainty surrounding funds intended for Guatemala. SHARE have commendably and generously paused, shifted and adapted project plans despite challenges and uncertainty.

VII. Human and Institutional Capacity Development

a. Short term Training

Country of Training	Brief Purpose of Training	Who was Trained	Number Trained		
			M	F	Total
Bangladesh	Training on Use of BAU-STR Dryer at Bangladesh Agricultural University (BAU), *Mymensingh* (May 4, 2019)	Rice Producers, Civil Society Actors	19	6	25
Bangladesh	Training on Use of BAU-STR Dryer and Hermetic Bag at BAU, *Mymensingh* (May 27, 2019)	Government Employees, Civil Society Actors	39	0	39
Bangladesh	Training on Gender-Based Technology Assessment *Mymensingh* (August 28, 2019)	Civil Society Actors	5	4	9
		Bangladesh Subtotals	*63*	*10*	*73*
Ghana	Poultry Farmers and Feed Millers Training (One on One), *Dormaa* (March 8- April 12, 2019)	Producers, Private Sector Actors,	21	1	22
		Ghana Subtotals	*21*	*1*	*22*
Guatemala	Local Network or Organizations formed by Local Associations and Farmers from *Playa Grande Ixcán* (May 16, 2019)	Maize Producers, Government Employees	18	5	23
Guatemala	Post-harvest workshop for small farmers of *San Marcos* (June 21, 2019)	Maize Producers, Government Employees, Civil Society actors	36	29	65
		Guatemala Subtotals	*54*	*34*	*88*
Ethiopia	Training of Experimenters and Technology Adopters *Mekelle, Amhara Region* (June 27, 2019)	Grain Producers, Government Employees	8	5	13
Ethiopia	Training of subject matter specialists and grain store managers from farmers' cooperative unions in ANRS *Amhara Region, Agew Awi Zone* (June 24, 2019)	Government Employees	20	5	25
		Ethiopia Subtotals	28	10	38
		Overall totals	166	55	221

b. Long term Training

We are continuing to support graduate students at our partner institutions in Bangladesh and Ethiopia. In FY 19 PHLIL supported 3 graduating graduate students at Bangladesh Agricultural University, 2 PhD students at Mekelle University, and 3 PhD students at Bahir Dar University. In Bangladesh, 2 new graduate students, one an MSc student and one a PhD student, joined the team. One additional PhD student graduated with his PhD in Grain Science and Industry from Kansas State University. Lastly 1 MSc student at Kansas State University was funded through the PHLIL Nepal Buy In.

PHLIL has 8 additional graduate students who are engaged in PHLIL-affiliated research activities but who are not funded by USAID. These students are enrolled and funded wholly separately from PHLIL funds; however, they are assisting in research activities, often due to their being advised by faculty on our team.

c. Institutional Development

PHLIL developed and enhanced substantial human and institutional capacity in post-harvest research across all partner countries in Phase I. As we transitioned to the second phase of our research program, in-country capacity continues to be enhanced and elevated to influence national-level discussions, decisions and activities. In one example, two PHLIL PhD graduates in Ethiopia have been elevated to play more leading roles in phase II research and engagement. These researchers are using the technical expertise developed in their PhD programs, while simultaneously learning new management and administrative skills.

VII. Technology Transfer and Scaling Partnerships

Technologies Transferred and Scaling: *BAU-STR Dryer*

Description: The BAU-STR dryer consists of an inner bin, outer bin, hot air pipe, blower and stove (chula). It is made of two perforated concentric cylinders with grains inside the annular space. The outer bin is made of two types of wire (8 to 12 mesh and 1 inch). The diameter is adjustable to hold the desired volume of paddy rice, with one inch pipe (8/10 nos.) and a one inch flat bar ring used to fix the adjustable shape of the outer bin. Air is passed from the closed-end inner cylinder to dry the grains inside the annular space. An axial flow blower sucks the hot air from the stove, through a steel pipe and forced through perforated bins. A diesel generator has been added to one version of the BAU-STR dryer, to run the blower without relying on the national electrical grid. The BAU-STR dryer has been extensively validated in the lab and the field, and is well suited and ready for drying freshly harvested paddy rice.

Steps Taken and Partnerships Made: The BAU-STR dryer is being assembled entirely at local and regional engineering workshops in Bangladesh. While previous versions of blower were imported from Vietnam, a version of the blower has been made in Bangladesh and is now locally available for manufacture. A local electronics company fabricates the new blower, which at 17 kilograms is, a significant decrease from the previous prototypes (as much as 40 kg). PHLIL Bangladesh team-led training on fabrication, operation and maintenance of the BAU-STR dryer has been provided to ACI Motors Ltd, Bhai Bhai Engineering Workshop, M/S Uttaran Engineering and government employees. The Bangladesh team is in the process of modifying the BAU-STR dryer to be powered by Liquid Petroleum Gas (LPG).

Next Steps: The BAU-STR dryer developed in PHLIL Phase I will continue to be promoted with local engineering workshops. In addition, it will be scaled via the Department of Agricultural Extension (DAE) and the Palli Karma-Sahayak Foundation (PKSF). During FY19, 184 BAU-STR dryers were distributed to DAE farmer field schools, with as many as 3,000 dryers to be installed through this partnership. Since January

2019, the work supporting the BAU-STR Dryer scaling has primarily been training covering the working principles, operating and maintenance of the dryer and hermetic bags for stakeholders in national institutions (DAE, BAD, PKSF).

Technologies Transferred and Ready to Scale: *GrainMate moisture meter*

Description: The GrainMate Moisture Meter is an effective, low-cost grain moisture meter which makes it easy to accurately measure the moisture content in grains and animal feed before storage. The initial version developed by USDA-ARS in PHLIL Phase I. GrainMate is ideal for measuring the moisture content of several commodities including maize, rice, cowpea, wheat, sorghum and soybean, with the capacity to support calibrations for up to 32 different crops. It has been tested extensively and is comparable or superior in accuracy to much costlier commercial moisture meters. GrainMate is currently being produced and sold by Sesi Technologies, a Ghanaian start-up led by young entrepreneurs, for around $80. The meter is currently targeted predominantly at the meso-level in the agricultural value chain - crop aggregators, food/feed processing companies and medium-scale producers, as well as extension agents.

Steps Taken and Partnerships Made: Sesi Technologies, an award-winning Ghanaian enterprise recently founded by young graduates of Kwame Nkrumah University of Science and Technology (KNUST), is selling these moisture meters, now called the GrainMate Moisture Tester, for about $80 each. Sesi Technologies won the Generation Africa GoGettaz Agripreneur competition is a competition for young African entrepeneurs building innovative agribusinesses. The winnings include $50,000 to jumpstart their business, which Sesi Technology plans to use to refine their products and streamline production.

Next Steps: Continued support of Sesi Technologies by promoting the moisture meter, continuing to provide technical expertise as needed, and encouraging engagement at various trade shows and research conferences to attend across the African continent (e.g., PHLIL sponsored Isaac Sesi's attendance at the Partnership for Aflatoxin Control in Africa Partner Platform Meeting in Dakar, Senegal, in October 2018).

VIII. Environmental Management and Mitigation Plan (EMMP)

The Environmental Mitigation and Monitoring Program (EMMP) for the Lab is regularly reported through the Piestar Reporting Hub and the ME maintains regular oversight, including on site review when in country. On site review is conducted regularly by PHLIL AOR Ahmed Kablan as well.

IX. Open Data Management Plan

The Management Entity (ME) makes information and data publicly available via the Harvard Dataverse. The ME has communicated with the country PIs regarding depositing data in the Harvard Dataverse. The program coordinator inputs each dataset into the USAID Data Development Library (DDL), the ME monitors and tracks data uploads into the Harvard Dataverse and uploads them into the DDL once each data set is verified. The approved Data Management Plan is available.

X. Project Management Activities

The Management Entity was fully engaged in operationalizing the adaptations to our program activities between phases of the program. Major activities included on-site kick-off meetings and priority setting in each core country, virtual team meetings (including a virtual annual meeting that focused on progress and priorities for Phase II) and the necessary administrative tasks associated with setting up Phase II. For activities, roles and partnerships that were winding down, the ME facilitated finalization. The ME also created a policy guide which was presented at kick-off meetings in Bangladesh, Ethiopia, and Ghana to further help project teams understand their role as part of the Post-Harvest Loss Innovation Lab.

As a leader and partnership catalyst within the broader research for development community, the ME also continued fostering strategic engagements as part of our impact strategy. These included delivering presentations at U.S. and international fora, and publication of post-harvest related technical publications from additional research.

Conference session organization and presentations:

- Dr. Harvey (PHLIL) organized, co-led and spoke at a technical session on Mitigating Post-Harvest Mycotoxin Contamination at the African Union Commission's Partnership for Aflatoxin Control in Africa Partnership Platform Meeting, Dakar, Senegal. The session included talks from a range of partners, including the Livestock Systems Innovation Lab and the Mars Global Food Safety Center, and involvement of Dr. Ahmed Kablan (USAID Senior Nutrition Research Advisor, Bureau for Food Security, USAID).
- Harvey, J. Resilience through reduced post-harvest loss. Presentation at the Feed the Future Innovation Labs Regional Partners Meeting. Addis Ababa, Ethiopia, May 20, 2019.
- Jagger Harvey, Nicole Lefore (Feed the Future Innovation Lab for Small Scale Irrigation) and Peter Goldsmith (Soybean Innovation Lab). Opportunities and constraints to enhancing the Feed the Future Innovation Lab brand – an initial report of the IL Council branding subcommittee. Presentation at the Annual Innovation Lab meeting, Washington DC, September 18, 2019.
- Harvey, J., Opit, G., Ulmer, J., Subramanyam, B., Abay, F., Habtu, N. and Osekre, E. Securing the Harvest: empowering national systems to inclusively and sustainably mitigate post-harvest loss issues. Presentation at the Second All-Africa Post-Harvest Congress. African Union Commission, Addis Ababa, Ethiopia, September 19, 2019.
- Harvey, J. Mycotoxin risk communication strategies: empowering national systems to be proactive and responsive. Presentation tailored and delivered at:
    - Mekelle University Memorial and National Stakeholder Workshop on Grain Mycotoxin Mitigation Technologies and Experiences. Mekelle, Ethiopia, May 24, 2019.
    - Livestock Systems Innovation Lab Workshop on the Prevention and Mitigation of Aflatoxin Contamination of Animal Feed and Animal-Source Foods. Kigali, Rwanda, April 3, 2019.
    - Livestock Systems Innovation Lab Workshop on the Prevention and Mitigation of Aflatoxin Contamination of Animal Feed and Animal-Source Foods. Addis Ababa, Ethiopia, March 26, 2019.

In addition to contributions to core PHLIL publications, additional PHL-related publications were finalized and published:

Djeugap, J.F., Ghimire, S., Wanjuki, I., Muiruri, A. and Harvey, J. (2019) Mycotoxin contamination of edible non-timber forest products in Cameroon. *Toxins* **11:** 430; doi:10.3390/toxins11070430

Temba, B., Fletcher, M., Fox, G., Harvey, J., Okoth, S., and Sultanbawa, Y (2019) Photoinactivation of conidia and hyphae of *Aspergillus flavus* using curcumin and its effect on aflatoxin B1 formation in maize kernels. *Food Microbiology* **82:** 82-88.

Niyibituronsa, M., Onyango, A. N., Gaidashova, S., l Imathiu, S., Uwizerwa, M., Ochieng, E., Nganga, F., Birungi, J., Ghimire, S., and Harvey, J. (2019) The effect of different processing methods on nutrient and isoflavone content of soymilk obtained from six varieties of soybean grown in Rwanda. *Food Science and Nutrition* **7:** 457-464.

Niyibituronsa, M., Onyango, A., Gaidashova, S., Imathiu, S. M., Uwizerwa, M., Wanjuki, I., Nganga, F., Muhutu, J. C., Birungi, J., Ghimire, S., Raes, K., De Boevre, M., De Saeger, S., and Jagger Harvey (2018) Evaluation of mycotoxin content in soybean (*Glycine max* L.) grown in Rwanda. *African Journal of Food, Agriculture, Nutrition and Development* **18(3):** 13808-13824.

XI. Other Topics

None.

XII. Issues and How They Are Being Addressed

Budget uncertainty and extended delays continue to create significant challenges to program planning and management, with challenges spanning the breadth of the program, but particularly severe in Guatemala.

XIII. Future Directions

The upcoming year will be an exciting one for PHLIL. We spent much of FY2019 finalizing Phase I activities and operationalizing Phase II activities. In FY2020 Phase II research activities will be in full swing. In Ghana and Ethiopia, we will deploy the engagement survey to understand the difference between group and individual trainings. In Bangladesh and Guatemala, we will gain more insights into the economic factors that encourage or inhibit adoption. There will be continued adaptations to the BAU-STR dryer, as the team works to find alternative fuel sources. In Ghana, there will be continued partnership with Sesi Technologies to scale the GrainMate Moisture Meter. In Ethiopia the integrated study will give PHLIL Ethiopia more information about following grains through the drying, storage, and mycotoxin testing. The ME will continue its efforts to manage and facilitate the program, and play a leading role to help affect change and achieve impact across the broader Feed the Future and post-harvest loss research for development communities.

Our team continues to await clarification for Guatemala, while maintaining a small footprint that keeps us involved in with our stakeholders.

Appendix A: Success Stories

Success story
Women's Empowerment: Josephine's Farm

The poultry industry is growing in Ghana, and Jospehine Yeboah is taking advantage, with some support from the Post-Harvest Loss Innovation Lab. After participating in a training about better post-harvest practices, Josephine decided to purchase 750 ZeroFly® hermetic bags and the GrainMate Moisture Meter, two PHLIL-technologies featured at the training. Improved post-harvest practices have allowed EvanJoes Farm, the operation she runs with her husband, to reduce their losses, and they have grown their farm from 5,000 layer hens to 25,000.

Josephine got access to this training because of a partnership with PHLIL Ghana and the AMPLIFIES Ghana project, a USDA-funded program that promotes poultry and egg production. The two programs work together to expand their reach and impact in providing training and access to technologies for poultry farmers in the Middle Belt of Ghana. These poultry producers source maize for feed from smallholder farmers in the region. As part of the approach to improving post-harvest drying and storage practices, the PHLIL Ghana team, including researchers from Oklahoma State University, the University of Kentucky, USDA-Agricultural Research Services, and Kwame Nkrumah University of Science and Technology have hosted multiple trainings on proper drying and moisture measurement, featuring the GrainMate Moisture Meter as well as hermetic storage bags, including the ZeroFly® hermetic bag.

EvansJoes farms is located in Dormaa Ahenkro, near the border with Cote d'Ivoire, and they previously struggled with weevils in their dried maize used for feed for the poultry. After training on proper drying, storage, and warehousing from PHLIL and AMPLIFIES, they started storing maize in ZeroFly® hermetic bags to reduce losses from insects and mycotoxin contamination. Josephine and her husband have fully embraced the technology on their farm, and they even plan to purchase more bags and moisture meters to sell them to other area farmers. They have also established an agreement with a farmer-based organization to supply them with 1,000 bags of maize, which they will store in the ZeroFly® hermetic bags. Now Jospehine is able to feed her poultry with maize that is both nutritious and safe for them, and expand her portfolio as a female business owner and community leader.

"Before ZeroFly® if we bought 200 bags of maize, we would lose 30% of it by the time we were ready to use it, which is a huge loss. But now with ZeroFly®, we are assured 100% recovery after storage." *-Josephine Yeboah, CEO, EvanJoes Farm*

Success Story
A Youth-led Enterprise to Reduce Post-Harvest Loss in Ghana

Since tinkering with various electronics as a boy, Isaac Sesi has had a curious and entrepreneurial spirit. The kind of energy and optimism that emanates from the innovative young people that will surely shape Africa's future.

In Isaac's home country of Ghana, 40 percent of the labor force is engaged in agriculture, and 70 percent of the value of agricultural production comes from food crops. Yet, as much as a third of cereal grains are lost after harvest. A critical cause of such post-harvest loss is a lack of proper drying and storage. The Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss (PHLIL) is working in Ghana to tackle these very issues, and in 2017 Isaac and the Lab started a partnership that is now providing farmers and people across the agricultural value chain with an affordable and effective tool to reduce post-harvest loss.

Isaac Sesi (middle right) and Dr. Paul Armstrong (lower left) discuss potential improvements to the moisture meter, while PHLIL-Ghana PI Dr. George Opit and others from the Sesi Technologies team listen in.

The GrainMate moisture meter uses equilibrium moisture content to provide information on the moisture levels of maize and other critical grains. The meter was developed by Dr. Paul Armstrong, an agricultural engineer with the USDA Agricultural Research Service and a researcher on the PHLIL team. After testing the meter in Ghana in partnership with the Kwame Nkrumah University of Science and Technology (KNUST), PHLIL was looking for an entrepreneur who could scale the moisture meter. Just completing his bachelor's degree in electrical engineering, Isaac Sesi was that entrepreneur. With a small team of KNUST classmates, Isaac learned how to assemble the moisture meters, redesigned the circuit board and built a mobile app to pair with the meter. When they were ready to start marketing, Sesi Technologies was born and the moisture meter was given its brand name as the GrainMate moisture meter.

Dr. Armstrong enjoys his continued role as an advisor for Sesi Technologies. "On a continent where it may be more common to just import technology, Isaac is trying to create it and is part of an entrepreneurial generation that says - Africa can do this too," Armstrong says.

Sesi Technologies is now an official and growing agricultural enterprise in Ghana. The GrainMate moisture meter has received pattern approval from the Ghana Standards Authority, and Isaac and his team at Sesi Technologies are working to improve the meter and streamline its production in Ghana. Originally sourcing parts from China, Sesi Technologies has since developed relationships with Ghanaian businesses to make components locally, which both creates more jobs in Ghana and reduces costs for GrainMate's production. The GrainMate sells for $80 USD, a fraction of the cost of other comparable moisture meters, making it more accessible for farmers, traders and extension personnel seeking to reduce post-harvest loss and improve livelihoods in Ghana.

People across the agriculture and tech industries are taking notice of Isaac's work, including at the university that Isaac dreamed of attending as a boy. Isaac was recently named one of the MIT Technology Review's

2019 Top 35 Innovators under 35, joining a remarkable list of past honorees including Mark Zuckerberg, Sergey Brin, Larry Page (Co-founders of Google), and Jonny Ive (Chief Designer at Apple).

This story was also published by Feed the Future at: https://medium.com/@FeedtheFuture/small-gadget-big-impact-young-entrepreneur-fights-food-loss-with-innovation-f21cb9aee513

Isaac Sesi showcasing the GrainMate at a trade fair in Ghana.

Success Story
The BAU STR Dryer: Engaging local business and farmers in post-harvest loss reduction

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.

Drying of paddy rice in Bangladesh traditionally happens in field and on farm, leaving it open to contamination from pests, dirt and dangerous fungal toxins. Post-harvest loss at the farm level is estimated to be about 14%, with drying and storage losses representing key contributors.

To address this challenge, the PHLIL Bangladesh team developed the BAU-STR dryer, modified from Vietnam, which is a small-batch dryer that is mobile and can be operated on farm. It provides an effective drying technology alternative to traditional sun drying in terms of drying rate and drying efficiency. 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. Not only has the dryer has been validated for rice, wheat, and maize, it was also recently added to the Bangladeshi Government's ag machinery subsidy program, enabling more farmers, millers and service providers to buy the dryer.

In Bangladesh, the BAU-STR dryer has been successfully adapted, validated, piloted and deployed in forty villages across six districts. Until recently the blower, was imported from Vietnam, however a small local electronics company in Bangladesh has created a 17 kilogram blower. The original blower was 40 kilograms, much too heavy to accommodate women farmers and post-harvest processors. Now the BAU-STR dryer is entirely locally manufactured and repaired by agricultural equipment manufacturing businesses.

The BAU-STR dryer can dry one-half metric ton of paddy rice in 4-5 hours and bring moisture content from 22 percent, which is often the result from field drying, to a safe 12 percent, reducing the risk of mycotoxin accumulation from contaminating fungi. While it is currently powered by rice husk briquettes, the BAU research team is currently modifying the burning unit to use Liquid Petroleum Gas as fuel, which will help farmers in regions where rice briquettes are not available have access to the technology.
The BAU-STR dryer is suitable for farmers and small traders and can be used regardless of weather conditions, presenting economic opportunities as well as ensuring a safer harvest with less post-harvest loss.

The United States Ambassador to Bangladesh, Earl R. Miller, visited PHLIL Bangladesh at Bangladesh Agricultural University on April 23. During his time in Mymensingh, Ambassador Miller met with Bhai Bhai Engineering, one of the of the local manufacturers of the BAU-STR dryer.

The dryer has been covered in the national media, highlighted in a Nature Magazine editorial, and purchased for end-use. Demand and interest are high, with business models for deployment at various points in the value chain under consideration. Recently a farmer purchased the dryer after seeing an advertisement on television.

"The BAU-STR dryer will dry paddy in less time and cost, and reduce post-harvest drying loss."

-The Daily Jugantor, a Bangladeshi news outlet

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