



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, 2017-September 30, 2018



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UNIVERSITY

I ILLINOIS

PHLIL External Advisory Council:

Dr. Robert Zeigler, Chair

- Retired, internationally respected plant pathologist; Director General Emeritus of the International Rice Research Institute.

Dr. Nathaniel Pitts

- Retired, National Science Foundation. Included in his various roles was overseeing many cross-foundational activities, including Science and Technology Centers.

Dr. David Priest

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

Brett Rierson

- Head of the World Food Programme's Global Post-Harvest Knowledge & Operations Centre (KNOC).

See their full bios at <https://www.k-state.edu/pbl/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 and a previous Mission Buy-In in Afghanistan.

Program Partners

United States

Advanced Manufacturing Institute
Fort Valley State University
GrainPro, Inc.
Helica Biosystems, Inc.
John Deere
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 Post-harvest 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 University
Bhai Bhai Engineering
Department of Agricultural Extension, Government of the People’s Republic of Bangladesh
Jagorani Chakra Foundation
Kamal Machine Tools
Uttaron Engineering

Ethiopia

Ethiopian Institute of Agricultural Research
Bahir Dar University
Hawassa University
Mekelle University
Hiwot Agricultural Mechanization P.L.C.
Sesame Research Center at Humera

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
Council for Scientific and Industrial Research-Crops Research Institute (CSIR-CRI)
Kwame Nkrumah University of Science and Technology
Ghana Grains Council
Ministry of Food and Agriculture (Northern and Upper West regional offices)
Pens Food Bank Enterprise

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

Vestergaard Frandsen (Switzerland)
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (Germany; in Ghana, Ethiopia)
Mars Global Food Safety Lab (China)

Acronyms

ADRA – Adventist Development Relief Agency
AMPLIFIES – Assisting Management in Poultry Layer Industry by Feed Improvement and Efficient Strategy
BAU – Bangladesh Agricultural University
DAE – Directorate of Agricultural Extension
DICE – Dry, Inspect, Clean, Examine
EIAR – Ethiopian Institute of Agricultural Research
FGD – Focus Group Discussion
KNUST – Kwame Nkrumah University of Science and Technology KNUST
KSU – Kansas State University
ME – Management Entity
MoFA – Ministry of Food and Agriculture
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
SAWBO – Scientific Animations Without Borders Organization
SBD – Solar Bubble Dryer
SBHD – Solar Biomass Hybrid Dryer
STR – a low cost dryer made locally in Asia (acronym based on Vietnamese)
Uof I – University of Illinois, Urbana Champaign
USAID – United States 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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2018 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 fifth 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.

With a focus on end users and building partnerships with scaling organizations, the fifth year of the Innovation Lab's existence was intentionally designed with activities moving from full implementation to synthesis, targeted stakeholder discussions and reporting, progressing through the fiscal year.

With the completion of the engagement phase, the program has formed strategic partnerships and enhanced human and institutional capacity in its core countries. PHLIL has now successfully characterized and gleaned insights into various post-harvest losses in chickpea, dried fruits, maize, nuts, rice, sesame seeds and wheat and used the information gathered. This information has set the foundation for and has begun making a positive impact in the livelihood of producers and other target beneficiaries in each country. Further, a more advanced understanding of the socioeconomic, gender and nutrition context is coming into focus through surveys, trainings, workshops and focus group discussions. Overall, this has produced a matrix of adapted and validated post-harvest interventions, which were effectively moved from research into piloting and technology transfer. Building partnerships with strategic actors ensured that each innovation kept the end users in mind, increasing the buy-in of important actors: those who are continually faced with post-harvest challenges that lead to economic and nutritional losses.

The activities and outcomes of the last 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 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. To tackle these questions and others, USAID granted PHLIL a three year extension to continue post-harvest loss reduction research for development through December 31, 2021. A fully detailed scope of PHLIL Years 6-8 is being finalized.

II. Program Activities and Highlights

The Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss (PHLIL) entered its fifth year of programming starting January 1, 2018. Through the second year of the “engagement phase,” we have disseminated our research findings in both academic and practical settings with researchers, farmers, extension networks, governmental leaders, private sector actors and non-governmental organizations working in the post-harvest space. Our country programs have trained 4,399 people in post-harvest loss reduction techniques during Fiscal Year 2018. PHLIL also adapted intervention packages ranging from moisture meters and BAU-STR dryers in Bangladesh to the Post-Harvest Loss Prevention Manual in Guatemala. Each intervention package was developed using our research findings from Years 1-4 to ensure the package was contextualized to meet the needs of each community.

In addition, a holistic assessment was conducted for each of our program countries on progress-to-date, existing gaps, opportunities, future priority areas and key partnerships. PHLIL enlisted Humanitas Global to do this exercise (see Appendix C), which has been an incredibly useful tool to gather lessons learned and establish a forward-looking approach to reducing post-harvest loss and improving livelihoods in our program countries.

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

1. Further enhancing national capacity to conduct post-harvest loss and food safety research. This included increased visibility through presentations and publications in national and international fora, formal integration of post-harvest into university curricula, and development of materials for trained trainers to in turn use downstream of the project.
2. Communicating research findings and intervention options with stakeholders, through measured communications plans, including through training of potential end-users of the promising technologies.
3. Forging and leveraging partnerships and engagement with private sector, policy makers, civil society and other strategic stakeholders to propel innovations down the pathway to impact.

III. Key Accomplishments

In all four core countries, post-harvest loss innovation packages coalesced and were presented to next-users along the pathway to impact. Through these interactions with key stakeholders, technology and knowledge were fine-tuned as packages, as an iterative process to diversify and improve them for subsequent engagement rounds.

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

- A total of 4,399 short-term, and 12 long-term trainees (degree-seeking) directly supported by the program in FY2018.
- A total of 11 research publications.
- A total of 3 technologies transferred and/or ready to scale.
- 12 public-private partnerships along the pathway to scaling and impact.

Selected key accomplishments by country include *(note that this is a subset of key accomplishments, for brevity; more detail is provided in subsequent sections)*:

Bangladesh

The additional testing of the BAU-STR Dryer for parboiled rice indicated the process to be financially unsuitable in the present condition of the dryer; however the local development process of the blower has created a prototype blower that weighs 17 kilograms, a significant decrease from the 40 kilogram prototype previously being developed. This lighter weight is more appropriate for the mesh wiring (a key piece of the affordability and portability of the dryer) to hold the blower, and also for women to operate the dryer.

Ethiopia

Triplex and filter cake, which are innocuous currently discarded in-country industrial by-products, have been shown to effectively manage major insect pests associated with smallholder farmers' storages. These products represent an inexpensive, transformative option for use by farmers, as a replacement for the toxic pesticides often used/misused that are health and environmental hazards.

Ghana

Sesi Technologies, a Ghanaian enterprise recently founded by young graduates of Kwame Nkrumah University of Science and Technology (KNUST), began local production of the GrainMate Moisture Tester (developed by PHLIL), and has produced nearly 200 meters for customers. The start-up business has been gaining attention in the media and at various international conferences in the region.

Guatemala

The PHLIL-developed Post-Harvest Loss Prevention Manual and suite of training materials has been shared and is being utilized by several local partners and other organizations. Their enthusiasm to use these materials in their own program training activities is a key indicator of the manual's efficacy and realistic impact for smallholders in the Western Highlands.

IV. Research Program Overview and Structure

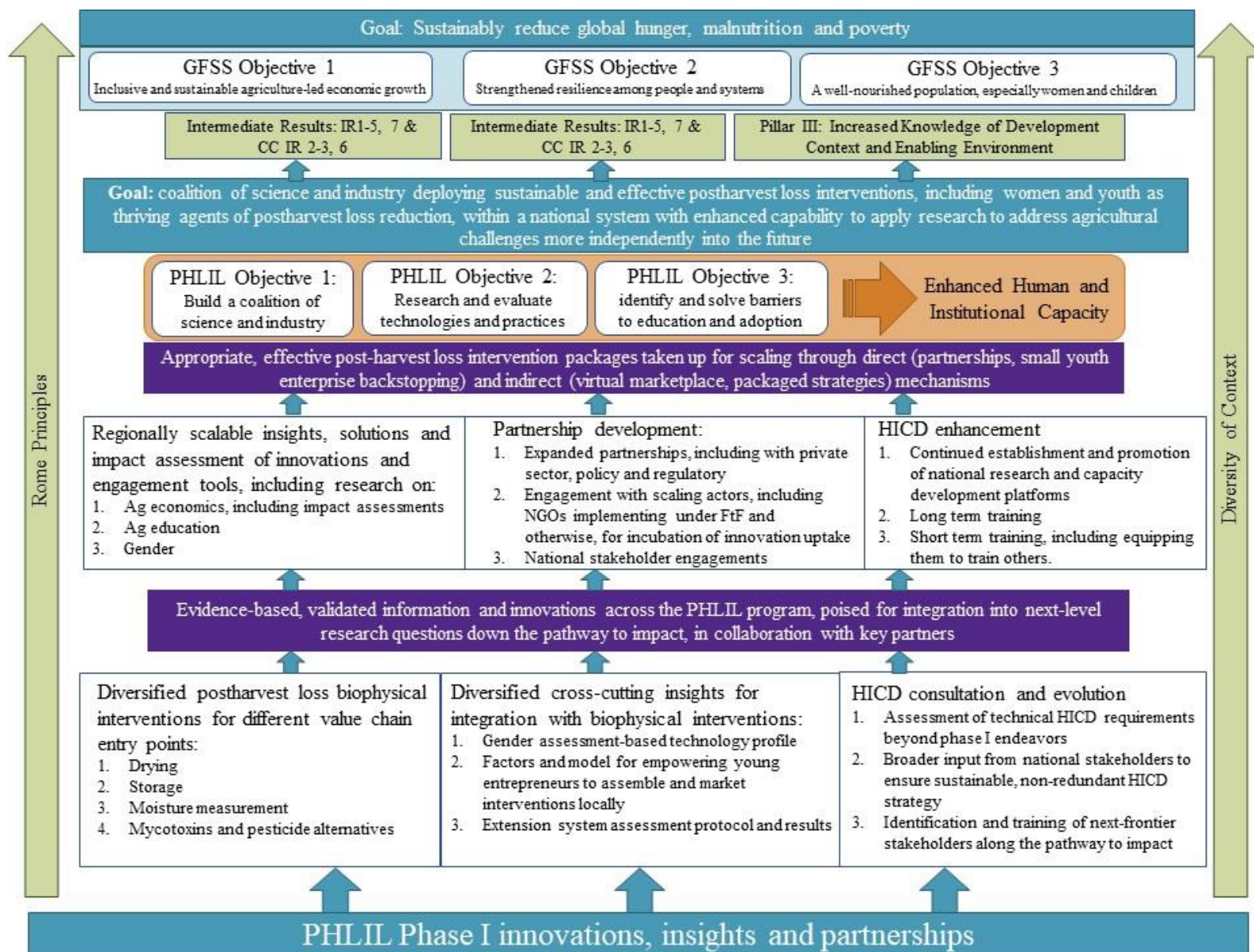
PHLIL focuses on several key areas with significant post-harvest challenges: **drying (included moisture measurement), storage, insect pest/pesticide alternatives** and **mycotoxin contamination**, as well as working with fumigation management and other issues. The program takes a phased approach to building 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 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).

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)



This theory of change reflects the updated objectives for the upcoming second phase of PHLIL.

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; *NGOs:* Jagorani Chakra Foundation; *Private-sector:* Bhai-Bhai Engineering, ACI Motors Ltd., Uttaron Engineering, Kamal Machine Tools, GH Electronics

Achievements:

Objective 1: Research into Practice- Expansion of Post-Harvest Intervention Technologies

Twenty-nine villages in seven districts (Bogra, Jessore, Khulna, Sherpur, Mymensingh, Naogaon, and Netrokona) were selected and training & demonstrations were conducted for scaling up drying and storage technologies. These 29 villages were selected in addition to the 46 villages previously reached with post-harvest training and demonstrations, bringing the total villages reached to 75 in the first five years of the PHLIL Bangladesh programs.

Objective 2: Develop Capacity of PHLIL Stakeholders

BAU-STR Dryer: Twenty-nine hands-on trainings on the moisture meter, BAU-STR Dryer & Hermetic bags and awareness of mycotoxin development were conducted in Bogra, Naogaon, Jessore, Khulna, Sherpur, Mymensingh and Netrokona districts.

The trainings focused on operation and maintenance of the BAU-STR dryer for seed and grain. Trainees also learned how to use hermetic bags and measure the moisture content of the grains/seed using the moisture meter. Information on mycotoxin awareness and prevention and their effect on human health was also integrated into the training. As part of the training, 750 hermetic GrainPro bags were distributed among the participants.

BAU-STR Dryer Evaluation for Parboiled Paddy: BAU-STR dryer was evaluated for parboiled paddy from March 13 to 23, 2017 and February 4 to June 7, 2018 at Moti auto rice mill in the Netrokona district. The dryer was evaluated with four treatments using BRRI dhan28 variety. The treatments and results are described in Appendix B, Figure One. The operating costs of all four treatments were higher than traditional sun drying treatment. The benefit cost ratio (BCR) was less than one (1.0) in every treatment. Milling recovery of rice dried in BAU-STR dryer was satisfactory, but head rice yield was not up to the standard level. It is evident from the financial analysis that BAU-STR dryer for parboiled paddy is not economically viable in the present situation.

Drying loss for BAU-STR dryer and open sun drying: Drying losses for open sun drying method and the BAU-STR dryer were measured and compared during Aman season (Nov-Dec 2017) in Tangail, Mymensingh, Netrokona and Jessore districts of Bangladesh. The results displayed in Appendix B, Figure 2, showed that the average drying loss of paddy using BAU-STR dryer was found 0.43% in laboratory and 0.39% at the field level while the drying losses using open sun drying method at the farmer's field level were between 2.41 % and 3.95% across five districts. The BAU-STR dryer would be an effective alternative drying technology to save 1.4 million MT of paddy by reducing 2.7% losses of national production (51.87 million MT in the year of 2016), thus combating hunger and improving food security in Bangladesh. However, the

research indicated the BAU-STR dryer would not be suitable financially for drying parboiled paddy in the present condition of the dryer.

GrainPro and PICS Bags: An experiment was conducted on properties of hermetic bags, and two locally available polythene bags, the puffed rice bag and the Grameeni bag. Thickness, tensile, seal strength and water vapor transmission rate were determined using micrometer, universal testing machine, seal strength testing machine and a water vapor transmission rate testing machine. O₂ and CO₂ concentrations of stored paddy during Aman 2017 were also measured. The details of the experiment are found in Appendix B in Figure 3.

Mycotoxins: Twenty-five stored paddy samples were collected from farm households of Phulpur, Mymensingh district in October 2017 and analyzed in the laboratory. Additionally, during Boro 2018, one hundred paddy samples were collected from four districts, Mymensingh, Netrokona, Bogra and Jessore. One kg paddy samples were collected from each farmer and will be tested for aflatoxins using the ELISA method by November 2018.

Objective 3: Develop Dissemination Materials

Posters and leaflets on the moisture meter, BAU-STR dryer and storage bags were prepared in Bangla and English for training purposes. These materials focus on moisture measurement, paddy drying technique in BAU-STR dryer, paddy storage, awareness on mycotoxin and gender issues. The trainers indicated that these materials facilitate more effective communication between the trainer and training participants. Additionally, Scientific Animation Without Borders (SAWBO) is preparing video animations on the BAU-STR dryer and the hermetic GrainPro bag.

Objective 4: Develop Market Linkages

Entrepreneurs: Several potential entrepreneurs for commercializing the BAU-STR dryers were identified and supported in different intervention areas, and their business plans are being prepared. Additionally, Kamal Machine Tools and Bhai Bhai Engineering workshop employees were trained on manufacturing, selling and servicing of the BAU-STR dryer and were linked to ACI motors for the appropriate parts. ACI Motors imported 50 blowers from Vietnam to be used in manufacturing of the dryers. A local small electronics company, GH Electronics, has also developed a prototype of a blower for the BAU-STR dryer that can be produced locally.

Objective 5: Workshops and Symposia

Policy Dialogues & International Implementers: PHLIL Bangladesh is in discussions with public and private organizations regarding promotion of the BAU-STR dryer and hermetic bags. The in-country coordinator is a member of the agricultural mechanization committee of the Department of Agricultural Extension (DAE), and the PHLIL team is seeking to add the BAU-STR dryer in a government subsidy program. Palli Karma-Sahayak Foundation (PKSF) is launching a pilot program for disseminating the BAU-STR dryer along with other important agricultural machineries.

The BAU-STR dryer was exhibited in a national agricultural machinery fair in February 2018 at the Krishibid Institution in Dhaka. The BAU-STR dryer was highlighted in the keynote presentation at the inaugural session of the Machinery Fair. The Minister of Agriculture, Begum Matia Chowdhury, and Minister of Local Government and Rural Development, Engr. Khondokar Mosharraf Hossain, were present and expressed interest in the BAU-STR dryer being available at the farmer level. A National Symposium jointly organized by PHLIL Bangladesh and the Appropriate Scale Mechanization Innovation Hub (ASMIH)-Bangladesh project is scheduled for October 24, 2018 in Dhaka involving policy makers, national and international post-harvest

loss project implementers in Bangladesh, farmers, NGOs and agribusiness enterprise customers.

Objective 6: Engagement Activities

Post-Harvest Loss Integrated into the Classroom: A group of relevant faculty members of the Department of Farm Power and Machinery at Bangladesh Agricultural University was formed to discuss incorporating post-harvest loss information into relevant courses. Two advanced undergraduate and graduate level courses (FPM 403 Agricultural Process Engineering and FPM 509 Advanced Agricultural Process) revised their course syllabi to include post-harvest processing of horticultural crops, as well as material on the BAU-STR dryer and hermetic storage technologies.

Objective 7: Gender and Cross-cutting Issues

Gender issues were incorporated into training modules for post-harvest technologies. Participants were deeply engaged in discussions about gender and post-harvest loss. A gender sensitization training was conducted in Dumuria, Khulna involving male and female participants.

Objective 8: Capacity Building Overseas

PHLIL Bangladesh met with researchers in Bihar, India in March at the ADM Institute for the Prevention of Post-harvest Loss's program village and shared information with farmers on drying and storage. Additionally, PHLIL team members attended the 2018 American Society of Agricultural and Biological Engineers annual meeting in Detroit, where two abstracts were accepted.

Objective 9: Preparation of Scientific Manuscripts and Interim and Final Reports

Five abstracts were presented and published in national and international conferences. Two conference papers were published in the proceedings of 2018 ASABE annual meeting in Detroit, Michigan. One paper was published in an international journal "Heat and Mass Transfer" and two manuscripts were submitted in peer reviewed national and international journals.

Lessons Learned:

Though the target was 25 household farms in each training, there were more participants than expected due to growing interest in the new drying and storage technologies. Including posters and leaflets in the trainings helped to communicate with trainees and reinforce the information on proper drying, storage, and causes and effects of mycotoxin contamination. The team also found that scheduling trainings in the afternoon is effective at reaching more men and women, as they are usually both finished with their farm and household work in the afternoon.

PICS and GrainPro bags are found effective in controlling moisture, CO₂ and O₂ concentration exchange of stored paddy in hermetic bags with outside atmosphere.

Both the BAU-STR dryer and hermetic bags are necessary for reducing post-harvest loss; however, large-scale intervention is necessary for national level impact. Unfortunately, delays in blower imports prevented the BAU-STR dryer from being available for interested farmers during Aman 2017.

The Government of Bangladesh is providing a subsidy on selected agricultural machinery such as transplanting, harvesting, and conservation agricultural machines of 50 to 70% to popularize them among farmers. There is great need of drying and storage technologies, and the BAU-STR dryer and hermetic bags should be included in this subsidy program to increase wide-scale adoption. They have been considered and

we expect them to be included in the next subsidy cycle.

The research indicated the BAU-STR dryer would not be suitable financially for drying parboiled paddy in the present condition of the dryer.

Publications:

Alam, M., Harvey, J., Alam, M., Saha, C. K., Bala, B. K., & Ashraf, M. A. (May 2018). Neural network modeling of drying of rice in BAU-STR dryer (pp.1-9). Heat and Mass Transfer, online, Springer-Verlag GmbH Germany. doi:<https://doi.org/10.1007/s00231-018-2368-5>

Presentations:

Hossain, M., Awal, M., Ali, M., & Alam, M. (October 2017) Quality of Milled Paddy in Different Storage Technologies. Presentation at 1st National Conference on Food and Nutrition Security in Bangladesh: Interdisciplinary Approaches, Dhaka, Bangladesh.

Alam, M. (January 2018) Combating challenges of future agriculture of Bangladesh through agricultural mechanization. Presentation at 1st International Conference on Challenges for Future Agriculture, BAU, Mymensingh, Bangladesh.

Hossain, M., Awal, M., Ali, M., & Alam, M. (January 2018) Efficacy of Diversified Paddy Storage Technologies. Presentation at 1st International Conference on Challenges of Future Agriculture, Mymensingh, Bangladesh.

Alam, M., Saha, C. K., Alam, M., Ali, M., & J. (January 2018) Role of BAU-STR dryer for strengthening food security in Bangladesh. Presentation at 1st International Conference on Challenges for Future Agriculture, BAU, Mymensingh, Bangladesh.

Alam, M., Saha, C. K., Awal, M., Ali, M., Ali, M.... (March 2018). USAID Post-harvest Loss Reduction Innovation Lab (PHLIL)-Bangladesh Component. Presentation at Annual Workshop on BAU Research Progress- 2018, BAU, Mymensingh, Bangladesh

Alam, M., Harvey, J., Alam, M., Saha, C. K., & Winter-Nelson, A. (August 2018). Scope of BAU-STR in existing paddy drying system of Bangladesh. 2018 ASABE Annual International Meeting, Detroit, Michigan, USA. doi:<https://doi.org/10.13031/aim.201800674>

Alam, M., Awal, M., Harvey, J., Ali, M., Hossain, M., & Winter-Nelson, A. (August 2018). Sustainable Alternative Traditional Paddy Storage Technology in Bangladesh. 2018 ASABE Annual International Meeting, Detroit, Michigan, USA. doi:<https://doi.org/10.13031/aim.201800755>

Ethiopia

Focus Crops: Chickpea, Maize, Sesame 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, Sesame Research Center at Humera.

Achievements:

Objective 1: Conduct Training Programs and Transfer Knowledge and Technology on Integrated PHL Practices (Drying, Moisture Measurement, Mycotoxin and Insect Management)

Training Programs and Transfer of Knowledge and Technology: Two November workshops hosted by Mekelle and Bahir Dar universities used lectures and hands-on sessions on moisture measurement and drying, molds and mycotoxins, and insect pest management to educate farmers, government employees, researchers and vocational instructors. The trainings were facilitated by professors and graduate students from Kansas State University, Mekelle University and Bahir Dar University, and addressed nutrition, gender and effective teaching methods in post-harvest loss. Hermetic storage bags (PICS and GrainPro) were demonstrated, and wheat stored in polypropylene and jute bags was compared to wheat stored in PICS and GrainPro Bags. In addition, trainings on the solar bubble dryer and the moisture meter were held in late November to early December.

In collaboration with the Integrated Seed Sector Development Program (ISSD), training was delivered in January to seed producer cooperative leaders from the Amhara region on post-harvest seed handling with special emphasis on seed storage in PICS and GrainPro bags. Bahir Dar University PHLIL team members conducted a practical training aimed at introducing PICS bags for grain storage to reduce post-harvest loss and prevention of grain/seed deterioration in mid-January. They also participated in a National Agricultural Exhibition and Trade Fair, organized by the Feed the Future Ethiopia Value Chain Activity on January 27-28, 2018 in the Amhara Region.

In partnership with the East Africa Trade and Investment Hub and Eastern African Grain Council, the Feed the Future Ethiopia Value Chain Activity organized a 3-day training program on “Grain Standards and International Export Procedures” in March in Adama where PHLIL experiences with farmers on demonstration of hermetic bags were also discussed and shared.

The PHLIL Ethiopia team at Mekelle University delivered two additional trainings, a workshop for post-graduate students on proper moisture measurement and a training of trainers workshop focused on storage and pest management. From June 11 – 13, twelve post-graduate students from the Plant Protection program learned about present on-farm grain storage problems, proper moisture measurement using various methods and the health and environmental risks associated with improper use of insecticides. The training of trainers workshop was held July 28 - 30 in Humera and primarily focused on insect pest in stored products, mold and mycotoxins in storage and how to manage the challenges of insects and storage. Both of these trainings incorporated practical demonstrations of three storage technologies (PICS and GrainPro bags, and metal bins) compared to traditional storage containers (jute and polypropylene bags) on post-harvest losses in sesame and chickpea.

Bahir Dar University also delivered two additional trainings, a two day regional training workshop on Food Safety and Post-harvest Loss Management and a one day field day/stored grain exhibition day. The Food Safety and Post-harvest Loss Management workshop was conducted at Assala Agricultural Research Center April 27 -28, 2018. The participants included academics, government representatives, and agricultural experts. The one day field day/stored grain exhibition day, held at Kudmi Kebele, Merawi was organized to share successful intervention technologies and experiences from farm level post-harvest loss reduction research. The participants included fourteen selected model farmers from different Woredas, four agriculture professionals working at Farmer Training Centers and at the Woreda level, two Feed the Future value chain experts, and ten BDU staff members. Finally, a 500 kg capacity, improved large scale force convection solar cabinet dryer was constructed and installed in Kudmi Kebele Quality Seed Growers Association. The farmers’ feedback was mostly related to the cost and availability of PICS bags and other dryers. The farmers specifically asked about the possibility of using the solar bubble dryer for drying maize cobs.

Objective 2: Roll-out of PHL Mitigation Strategies at Household Level

A total of fifty PICS bags were distributed to fifty farmers in Bahir Dar district representing five kebeles. Researchers surveyed farmers to gauge their perception about the utility of PICS bags for proper grain quality management. Karta Kalsa, a graduate student at Bahir Dar University, initiated a project to assess stored grain pesticide use, practices and safety hazards to smallholder farmers in Northwestern Ethiopia (West Gojjam, Awi, and East Gojjam). The survey includes twenty-six households across sixteen to eighteen districts that use pesticides on stored grains.

Objective 3: Develop Educational Materials by the Extension/Engagement Advisory Committee

A comprehensive fifty-five page extension bulletin, “Integrated protection of stored maize and wheat,” written by three PHLIL PhD students, was shared with each participant at the trainings at Bahir Dar University. The text was in English and Amharic and has techniques for proper grain storage and monitoring of grain during storage. A similar publication was produced by Mekelle University. These publications have been translated into local languages.

Objective 4: Finalize and Summarize Research Data Collected in Years 2-3

Three graduate students from the PHLIL Ethiopia research team presented research at the 1st National Conference on Post-harvest Loss Management for Improved Livelihood and Sustainable Development in Bahir Dar, Ethiopia. Their topics included “Major insects and associated losses in stored wheat in Ethiopia,” “Occurrence of Mycotoxins in Farm Stored Maize in Ethiopia,” and “Thermal Performance of Solar Bubble and Cabinet Dryers for Maize Grain Drying.” Additionally, the PHLIL in-country coordinator, Dr. Fetien Abay, presented PHLIL Ethiopia’s work to two audiences, The International Tigray Scholars Grand Conference in Mekelle, July 18-22 and the CGIAR Collaborative Platform for Gender Research 2nd Annual Scientific Conference and Capacity Development Workshop in Addis Ababa, September 25-28. Three research papers were published in academic journals: two in *The Journal of Stored Products Research* and one in *World Medical & Health Policy*. The PHLIL team from Bahir Dar University participated in the Amhara Agriculture Forum held January 19, 2018, in Bahir Dar. Research results from BDU students were shared at this forum.

Presentations

Abay, F. 2018. The role of seed management and post-harvest handling for farmers and consumers: experience of Ethiopia. International Tigray Scholars Grand Conference, Mekelle, Tigray, Ethiopia. 18-22 July 2018.

Abay, F. 2018. CGIAR Collaborative Platform for Gender Research 2nd Annual Scientific Conference and Capacity Development Workshop. Addis Ababa, Ethiopia, 25-28 September 2018.

Kalsa, K. 2018. Major insects and associated losses in stored wheat in Ethiopia. 1st National Conference on Post-harvest Loss Management (PHLM) for Improved Livelihood and Sustainable Development. Bahir Dar, Ethiopia, 10 May 2018.

Fanta, A. 2018. Occurrence of Mycotoxins in Farm Stored Maize in Ethiopia. 1st National Conference on Post-harvest Loss Management (PHLM) for Improved Livelihood and Sustainable Development. Bahir Dar, Ethiopia, 10 May 2018.

Molla, A. 2018. Thermal Performance of Solar Bubble and Cabinet Dryers for Maize Grain Drying. 1st National Conference on Post-harvest Loss Management (PHLM) for Improved Livelihood and Sustainable Development. Bahir Dar, Ethiopia, 10 May 2018

Publications

Petros S, Abay F, Desta G & O'Brien C (2018) Women farmers' (dis)empowerment compared to men farmers in Ethiopia. *World Medical & Health Policy*. **10**(3): 220-245.

Tadesse, M. T. and Bh. Subramanyam (2018) Efficacy of filter cake and Triplex powders from Ethiopia applied to concrete arenas against *Sitophilus zeamais*. *Journal of Stored Products Research* **76**: 140-150.

Tadesse, M. T. and Bh. Subramanyam (2018) Efficacy of filter cake and triplex powders from Ethiopia applied to wheat against *sitophilus zeamais* and *sitophilus oryzae*. *Journal of Stored Products Research* **79**: 40-52.

Karta, K., Bh. Subramanyam, G. Demissie, R. Mahroof, A. Fanta, and N. Gabbiye (2018) Comparative evaluation of alternative post-harvest strategies of bread wheat (*Triticum aestivum* L.) seed in Ethiopia. *Journal of Stored Products Research* (in press).

Objective 5: Complete Pending Insect and Mycotoxin Research

Parallel to manuscript preparation for publication, the PHLIL Ethiopia PhD students are refining their experimental works. The students are working on mold identification in mycotoxin research, simulation and CFD modeling of the solar bubble dryer, and test for prevalence of insecticide resistance in storage are under investigation and near completion.

Objective 6: Build Capacity at Bahir Dar University and Mekelle University

Bahir Dar University: Bahir Dar University has established a Post-harvest Technology Program through the support of PHLIL and from internal university support. Currently, there are 13 PhD students in the program, three of whom are supported by PHLIL will be completing their degrees in 2018-19. In addition, one Ethiopian student supported by PHLIL at Kansas State University will graduate this December with a PhD degree.

One Master's student, not directly supported by PHLIL Ethiopia, studying post-harvest technology at Bahir Dar University finished his thesis with the support of PHLIL team. His research was an evaluation of traditional and improved storage structure with and without a plastic liner. An additional PhD student was sent to KU Leuven in Belgium for three months (May 14 - August 14, 2018) as a visiting researcher at the Bioscience Engineering Research Group. The student successfully developed a realistic CFD model and validated the simulation of the solar bubble dryer result with the experimental results. Apart from the positive student experience, the visit brings opportunities for additional collaboration with the research group in Belgium.

ACDI/VOCA provided Charm Science mycotoxin testing laboratory equipment and additional mycotoxin testing kits to complete mycotoxin research on feed, for the PHLIL Bahir Dar University mycotoxin group to provide sample analysis for a Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet and Feed the Future Innovation Lab for Livestock Systems project. This laboratory equipment and testing kits enhanced the available testing capacity of the PHLIL Ethiopia team by further expanding the range of options for analyzing a wider range of commodity types. The mycotoxin kits and equipment previously purchased through PHLIL Ethiopia were validated for corn and maize, while this new equipment

is validated for use in partly extracted seeds such as oil-seed cakes and wheat bran. Through this partnership one of the PHLIL PhD students at Bahir Dar University, has analyzed four types of mycotoxins on 234 feed samples as an in-country service the SMIL-LSIL project.

Mekelle University: A similar post-harvest technology program is being explored at Mekelle University, and with the construction of new laboratories such a program will be valuable to strengthen their teaching and research capacity.

One of the graduate students from Mekelle University was presented with a scholarship to conduct a molecular analysis on the sesame genotypes with which he has worked in Humera, through a six month research trip to China. Since his PhD study program at Mekelle University is "Plant Breeding and Systems" this activity was determined as an important enhancement to his studies and research.

Objective 7: Continue Work on Nutrition and Gender Topics as They Relate to Post-harvest Issues

Gender and nutrition training was integrated into the post-harvest food safety workshop in November. A manuscript on the focus group surveys carried out was accepted and published by the World Medical and Health Policy Journal. The paper outlines findings of PHLIL surveys, including that: women's role in agricultural activities increases to as much as 80% in post-harvest, poor storage technologies resulting in fungal/pest infestations and chemicals in stored grains pose serious health risks for women, and poor women consume grains with up to 50% damage (a factor for increased risk of mycotoxin contamination).

Objective 8: Pathway to Impact Partnerships

A regional technical meeting held on July 12, 2018 brought together major partners from Bureau of Agriculture, Fintrac's Feed the Future Value Chain Project, AGP coordinators, regulatory departments and private seed/grain producers to provide an opportunity for their input and feedback on the national post-harvest loss strategy, for which PHLIL is providing significant input. The collaboration with the Feed the Future Value Chain Project has allowed PHLIL Ethiopia researchers to be actively involved in capacity building and orientation pieces of the project. From June 28 to 30 the Value Chain Project distributed 65 PICS and Grain ProBags in the Asgede Isimbla district.

Collaboration with the Integrated Seed Sector Development (ISSD) project has also given PHLIL researchers the opportunity to participate in the training and capacity building of farmers and agricultural experts. The ISSD project purchased 400 PICS and GrainPro bags and distributed them to 6 districts (Adwa, Kilte Awlalo, Enderta, Hagereselam, Alamata, Asgede Tsimbla) to contribute towards quality seed distribution.

Meeting with H/E Eyassu Abraha, Deputy Minister of Agriculture, and Mr Esayas, Director of Crops allowed PHLIL researchers to be engaged in strategic discussions focused on attitudes toward post-harvest technology adoption, integrating post-harvest loss solutions across the entire value chain. These conversations helped PHLIL Ethiopia researchers and policy makers realize the importance of having a national core team interact with high-level experts in the Ethiopian ministries.

Representatives from the USAID Ethiopia mission visited Bahir Dar University on August 27, 2018 with the purpose of evaluating the community impact of PHLIL, Appropriate Sale Mechanization Consortium (ASMC), and the Feed the Future Innovation Lab for Small Scale Irrigation Ethiopia team at Bahir Dar University. The PHLIL team, together with representatives of the other teams, presented the achievements of the programs to the USAID team. USAID stressed the need for scaling up the results and making reasonably priced improved storage structures and solar dryers available. They were supportive and mentioned they would incorporate our achievement in their Global Food Security Strategy considerations.

Additionally, one of the PHLIL Ethiopian graduate students participated in the community piloting of post-harvest handling and preservation of fruit, vegetable, and animal products in collaboration with the USAID-funded Growth through Nutrition project. The activity included solar cabinet drying experiments for fruits and vegetables and evaluated a traditional fermented milk product called “Metata Aybi”.

Lessons Learned:

With the research from FY18 illustrating the safety and efficacy of Triplex and Filter Cake, PHLIL Ethiopia looks forward to promoting the use of these non-toxic powders that are locally available.

As we move further into mainstreaming PHLIL innovations into building national research and extension capacity, US Land Grant extension and agricultural education research and implementation capacity can be transformative in its support and insights.

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, Agri Commercial Service Ltd.; *USAID/USG Project Partners:* AMPLIFIES

Achievements:

Objective 1: Complete Writing and Submitting Manuscripts on Research Data Collected in Years 2-4 to Peer Reviewed Journals

Writing and Publications: The Ghana PHLIL team conducted analysis and wrote manuscripts for various research studies using data collected in Years 2-4 of the program. Four papers have been published in the *Journal of Stored Products Research*, and one paper has been published by the American Society of Agricultural and Biological Engineers. Two additional papers are submitted and awaiting responses from journals, and two papers are in the final stages of preparation for submission. Please see below for citations of the aforementioned publications.

Presentations

PHLIL Ghana PI, George Opit, attended the West and Central Africa Post-Harvest Congress and Exhibition (WCAPHCE) 2018 in Abuja, Nigeria to present research from PHLIL’s Ghana program. He also had a very productive meeting with Mr. Isaac Ola Ayobami of Vestergaard SA to discuss the delivery of ZeroFly[®] Hermetic bags to Ghana. Members of the PHLIL Ghana team will also attend the Partnership for Aflatoxin Control in Africa Partnership Platform Meeting to present research findings, promote technologies and connect with other international agriculture players.

Published:

Manu, N., G. P. Opit, E. A. Osekre, F. H. Arthur, G. Mbata, P. Armstrong, J. K. Danso, S.G. McNeill, and J. Campbell (2018) Moisture content, insect pest infestation and mycotoxin levels of maize in markets in the Northern Region of Ghana. *Journal of Stored Products Research* (in press).

Armstrong, P. R., S. McNeill, S., Manu, N., Bosomtwe, A., Danso, J. K., Osekre, E. A., & Opit, G. (2017) Technical Note: Development and Evaluation of a Low-Cost Probe-Type Instrument to Measure the Equilibrium Moisture Content of Grain. *Applied Engineering in Agriculture Journal* **33(5)**: 619-627.
<https://doi.org/10.13031/aea.12266>

Danso, J. K., Osekre, E. A., Manu, N., Opit, G.P., Armstrong, P., Arthur, F. H., Campbell, J. F., & Mbata, G. (2017) Moisture content, insect pests and mycotoxin levels of maize at harvest and post-harvest in the Middle Belt of Ghana. *Journal of Stored Products Research* **74**: 46-55.

Manu, N., Osekre, E. A., Opit, G. P., Arthur, F., Campbell, J. (2018) Population dynamics of stored maize insect pests in warehouses in two districts of Ghana. *Journal of Stored Products Research* **76**: 102-110.

Danso, J. K., Osekre, E. A., Opit, G. P., Manu, N., Armstrong, P., Arthur, F. H., Campbell, J. F., Mbata, G., McNeill, S. G. (2018) Post-harvest insect infestation and mycotoxin levels in maize markets in the middle belt of Ghana. *Journal of Stored Products Research* **77**: 9-15.

Presentations

Opit, G. P. 2018. Food Safety: The Battle Against Contamination. The 1st West and Central Africa Post-Harvest Congress and Exhibition (WCAPHCE). Abuja, Nigeria, 17–21 September 2018.

Opit, G. P. 2018. The Innovation Lab for the Reduction of Post-Harvest Loss: Facilitating Improved Food security in Ghana. The 1st West and Central Africa Post-Harvest Congress and Exhibition (WCAPHCE). Abuja, Nigeria, 17–21 September 2018.

Opit, G. P., S. K. Ajao, K. O. Popoola, M. O. Omobowale, A. A. Ala, and G. V. Bingham. 2018. Evaluation of the suitability and optimal use of post-harvest storage bag technologies and a combination thereof for maize storage in Nigeria. The 1st West and Central Africa Post-Harvest Congress and Exhibition (WCAPHCE). Abuja, Nigeria, 17–21 September 2018.

Opit, G. P. 2018. Food Safety: The Battle Against Contamination. The 1st West and Central Africa Post-Harvest Congress and Exhibition (WCAPHCE). Abuja, Nigeria, 17–21 September 2018.

Opit, G. P. 2018. The Innovation Lab for the Reduction of Post-Harvest Loss: Facilitating Improved Food security in Ghana. The 1st West and Central Africa Post-Harvest Congress and Exhibition (WCAPHCE). Abuja, Nigeria, 17–21 September 2018.

Opit, G. P., S. K. Ajao, K. O. Popoola, M. O. Omobowale, A. A. Ala, and G. V. Bingham. 2018. Evaluation of the suitability and optimal use of post-harvest storage bag technologies and a combination thereof for maize storage in Nigeria. The 1st West and Central Africa Post-Harvest Congress and Exhibition (WCAPHCE). Abuja, Nigeria, 17–21 September 2018.

Opit, G. P. 2018. Talk: Ghana PHLIL: Activities, Accomplishments, Challenges, and Priorities for the Future. The 2018 PHLIL Annual Meeting. Urbana-Champaign, IL, USA, 1–2 May 2018

Objective 2: Continue Supporting Scale Up of Promising Post-harvest Loss Mitigation Technologies

Identifying Collaborators & Obtaining Funding: The PHLIL Ghana team partnered with the Assisting Management in the Poultry and Layer Industries by Feed Improvement and Efficiency Strategies (AMPLIFIES) project to obtain funding. Additionally, the Ghana team worked with USDA/FAS Scientific Cooperation Research Program, the Ghana Grains Council, the Adventist Development and Relief Agency

Ghana, and the WFP Enhanced Nutrition and Value Chains project to transfer knowledge and meet scaling and uptake goals related to ZeroFly© Hermetic Bags, PHLIL Moisture meters and Solar Biomass Hybrid Dryers. The AMPLIFIES project is independently funded by USDA, with complementary outputs leveraged across this program and PHLIL.

Solar Biomass Hybrid Dryer: While the Solar Biomass Hybrid Dryers were built in previous years, the poultry farmer in Jamasi has continued to repay for the dryer to support the revolving loan fund, where the poultry farmer repays the cost of the dryer on a monthly payment schedule, which will provide funds for the construction of an additional SBHD. Ghana PHLIL worked with USDA/FAS Scientific Cooperation Research Program (SCRIP), which contributed funds for the construction of a second SBHD for a maize seed producer in Wenchi. The Enhanced Nutrition and Value Chains (ENVAC) project funded by WFP is in the process of placing an order for three SBHD for their 87 Farmer Based Organizations (FBOs).

The GIZ-funded Green Innovation Center has submitted a procurement request, awaiting approval formalities by the Ghana Government, for the construction of 20 mobile 1-MT SBHDs.

PHL Moisture Meters: Sesi Technologies, a Ghanaian enterprise founded by young graduates of Kwame Nkrumah University of Science and Technology (KNUST), has further improved (in collaboration with PHLIL team member, EMC moisture meter developer Paul Armstrong, USDA-ARS) and is selling PHLIL-developed EMC moisture meters, now called the GrainMate Moisture Tester, for about \$100 each. These young entrepreneurs lowered the production cost through component changes and by assembling the moisture meter in a local lab at KNUST, making this extremely important technological advance for maize management in Ghana even more affordable and readily available.

Nearly 200 meters have been produced and distributed by Sesi Technologies in Ghana, with production starting to ramp up. AMPLIFIES purchased 120 meters for use in their poultry project activities. With funding from the Green Innovation Center, 16 meters are being used by the Ghana Grains Council to conduct moisture measurement training for farmers; another 34 were purchased by AMPLIFIES for the same purpose. Sesi Technologies has also demonstrated the GrainMate Moisture Tester for Ghanaian Vice President Dr. Mahamudu Bawumia and German Chancellor Angela Merkel. Sesi Technologies will attend the Partnership for Aflatoxin Control in Africa Partnership Platform Meeting as a vendor to engage with other post-harvest researchers and experts in October.

PICS, ZeroFly©, and Zerofly© Hermetic bags: In March 2018, the PHLIL Ghana team catalyzed a channel for the distribution of ZeroFly© Hermetic Bags from Lagos, Nigeria to Kumasi, Ghana. Sesi Technologies became a private sector dealer/distributor of Zero Fly© Hermetic bags, receiving 1,500 bags through this channel. Another 5,200 Zero Fly© Hermetic bags are now en route to the port of Tema in Ghana from Vietnam for the purpose of ensuring availability of bags for stakeholders who need them and establishment of distribution channels.

Objective 3: Plan and Conduct Post-Harvest Loss Mitigation Training

Short-Term Training:

A training was held for stakeholders in Kumasi and Jamasi, Ghana on January 9-11, 2018, with a revised curriculum and training materials from the 2017 Post-Harvest Loss Mitigation Training. The training took place at the Council for Scientific and Industrial Research-Crops Research Institute (CSIR-CRI) and Sacom Farms and was sponsored by PHLIL and the AMPLIFIES project with seven additional collaborating partners from US and Ghanaian institutions of higher education and the PENS Food Bank in Ejura, Ghana. The workshop included one day of lectures and two days of hands-on exercises; this was a shift toward increased hands-on sessions, based on input from PHLIL agricultural education faculty at KSU. The goal of the workshop was to develop local capacity among Ghanaian poultry industry stakeholders (and other

participants with indirect links to this industry) in modern stored grain handling and management practices in the grain value chain (mainly maize) beginning from on-farm storage; small, medium and large warehouses; and in silos. Trainees received instruction on stored grain fundamentals, appropriate methods for handling grain on-farm, in warehouses and silos, and how to diagnose and solve issues in grain handling and storage along the grain value-chain.

Additionally, two post-harvest loss mitigation animation videos on the PHLIL moisture meter and DICE have been produced as a result of Ghana PHLIL work with SAWBO. These videos can be used by extension agents and poultry producers that have been engaged in PHLIL activities.

Long-Term Training:

The final PHLIL-sponsored MSc student at KNUST finished her graduate degree in Entomology in December of 2017. Two former PHLIL sponsored MSc students from KNUST in Kumasi, Ghana are independently pursuing PhDs in Entomology in the United States, one at Oklahoma State University and one at Kansas State University.

Objective 4: Complete Collection, Analysis and Write-up of Data to Evaluate and Improve the Solar Biomass Hybrid Dryer (SBHD) Technology & its Use for Disinfestation

The first set of data collected on the SBHD in Ejura from 2016 was processed and analyzed. The second set of data collected on the SBHD in Jamasi was completed in April 2018, and data analysis began immediately. A draft manuscript related to this experiment was completed by the end of June 2018 and submitted to a journal upon completion.

Lessons Learned:

Dissemination and demonstration of PHL mitigation technologies significantly increases demand. This is quite evident with Ghana poultry industry stakeholders.

Building on past training experience greatly facilitated the 2018 PHL mitigation training.

Clearly assigning responsibilities to various PIs on their roles in manuscript writing greatly facilitated the process.

Although still needing validation, it appears that mycotoxin levels found on maize in Ghana are lowest in the minor season maize from the Middle belt (not exceeding 4 ppb in our study samples, in the case of aflatoxin) and highest in the major season maize from the Middle belt (exceeding the 15 ppb in our study samples, in the case of aflatoxin). Levels of aflatoxin exceeding 15 ppb were found in greater than 50% of the samples of maize collected from the Northern Region — this brings to doubt the popularly held belief that maize in the northern part of Ghana has low mycotoxin levels, and warrants further investigation given the seasonal and other variation in mycotoxin contamination.

The SBHD is both effective at drying maize and disinfesting maize of stored product insect pests. The use of metal phosphides for phosphine fumigation, for disinfestation of agricultural commodities, was banned in Ghana in June 2018 due to an alarming number of accidental deaths attributed to these products. Therefore, disinfestation using the SBHD is a logical low risk alternative to metal phosphides.

Guatemala

Focus crop: Maize

Location: Huehuetenango, Chiantla and Todos Santos districts in the Western Highlands

Collaborators: *University:* Universidad del Valle; *NGOs:* SHARE, FUNDIT; *Project Partners:* Buena Milpa

Achievements:

Objective 1: Assessment of Economic, Nutrition and Gender Effects of Post-harvest Loss Mitigation Interventions

The data from the first part of the survey on economics, nutrition, and gender is currently undergoing analysis, and the second part of the survey was conducted in September 2018. A total of 102 plastic containers and 204 GrainPro bags were distributed to farming families that participated on the survey. Each family received one 250 kg capacity plastic container and two 50 kg capacity GrainPro bags, for high quality post-harvest storage for the 2017-2018 harvest season. Ten extension trainers were trained on the utilization of the post-harvest storage technologies. These extension educators then trained the farmers that are participating in the study on how to utilize the post-harvest storage technologies. All the families that participated are now storing their maize using the provided storage technologies, bringing the total amount of maize stored with the two post-harvest storage technologies to 35,700 kg. The second round of the survey is assessing the effect of using improved storage technologies in these households.

Objective 2: Continued Optimization of Drying Practices and Technologies in the Western Highlands

Due to the limitation of resources from the farmers and communities to purchase or rent the proposed dryers (STR and combined biomass and solar dryer), and the extreme weather conditions in Huehuetenango, which makes it very difficult to utilize low cost dryers, any optimization and comparison of the proposed dryers was previously discontinued in favor of adapting local practices.

The optimized drying effort focused on teaching the farmers on how to improve their current maize drying practice using direct solar drying, but with better management techniques.

Objective 3: Continuation of Best Post-harvest Strategies for Mitigation of Losses Based on Storage Technologies

The PHLIL Guatemala Post-harvest Loss Mitigation Manual was updated with the best post-harvest loss mitigation strategies and reviewed by local partners and stakeholders. The manual provides technical information in a contextualized and locally illustrated graphic design that is easy to use by the extension network. The extension network trainers were taught how to properly utilize the post-harvest mitigation manual using adult teaching methodologies. Since their training, they have already trained 204 farming families using the manual.

One of the main PHLIL Guatemala in-country partners, SHARE, attended other local agriculture-related events to disseminate the project's Post-harvest Loss Mitigation Manual and share the outcomes of the project. Several partnerships have been developed with local NGOs and organizations to promote post-harvest loss mitigation by sharing information, technology, and the manual. Additionally, students from the local university in Huehuetenango have been invited to observe and participate in the projects activities. A

train the trainer PowerPoint library with five presentations focused on post-harvest practices was also developed and disseminated in conjunction with the Post-harvest Loss Mitigation Manual.

Objective 4: Continuation of Gender and Women's Empowerment Work

Gender Considerations: The gender consultant was involved in the development and implementation of the survey, Post-harvest Loss Mitigation Manual, and the trainings conducted for extension network trainers. The gender consultant helped develop and disseminate information about the role of gender in post-harvest activities to the agricultural extension network and many community leaders.

Objective 5: Economic Impact through Building Local Capacity for Post-harvest Loss Prevention Tools

PHLIL Post-harvest Loss Mitigation Kit: A total of twenty-five 600 kg capacity metal silos have been fabricated by a local artisan for farmers participating in the PHLIL project. Additionally, a prototype of the Post-harvest Mitigation Kit was developed to provide the essential equipment needed by farmers to mitigate post-harvest losses. The kit includes a storage technology (metal silo or plastic container), a hygrometer to check for the maize moisture content and a maize sheller. A market study was conducted to determine acceptability of the kit by farmers for post-harvest loss mitigation.

The PHLIL Guatemala project staff learned about the benefits of teaching by using hands-on demonstrations. Additionally, they learned the value of monthly visits by the trainers to the farmers to follow up and answer questions, conducting monthly community meetings, utilization of the portable mycotoxin kit to analyze mycotoxin content of maize, and show videos, which are effective in helping trainers and farmers learn the best post-harvest practices. Additionally, the team noted that it is necessary to explore other methods to disseminate appropriate technical post-harvest loss prevention information to mass audiences via radio and television.

Objective 6: Engagement of Stakeholders and Collaborators

Engagement Team: An Engagement Team meeting and symposium was conducted with the local partners and stakeholders in Huehuetenango in order to validate the teaching material for the extension network trainers and the post-harvest loss mitigation material. All materials created are predominantly graphical and visual so that they are easy to understand.

Objective 7: Implementation of Engagement Strategy & Information Dissemination of Best Grain Quality Management Practices & Strategies to Foster Adoption

Engagement Strategy in Practice: Community meetings were conducted in several of the locations targeted by the project, enabling the exchange of post-harvest loss mitigation knowledge and experiences by the farmers and the extension network. The goal of this exercise was to engage farmers and families who have problems in adopting new post-harvest loss mitigation practices. Technical videos from partners, including WFP, detailing good post-harvest practices were also shared during these meetings. Additionally, extension network trainers conducted hands-on demonstrations on good post-harvest practices during technical visits to the farms.

Information Dissemination: Researchers from the PHLIL Guatemala team shared research findings by presenting at three conferences. Presentation topics included improving food security and food safety in the Western Highlands of Guatemala; post-harvest management practices in the Western Highlands as it relates to mycotoxins; and understanding the microbiota of native maize from the highlands of Guatemala. A poster presentation was given on maize storage technologies at the 2017 American Association of Cereal Chemist

International annual meeting. One article, cited below, was accepted for publication in the Journal of Food Protection.

In addition, an animation about mycotoxins was created in partnership with SAWBO for uses in Guatemala and across PHILIL project countries. Radio and television are other media outlets that the PHILIL Guatemala team would like to explore.

Publications

Mendoza, R., Sabillon, L., Calmenares, A., Rodas, A., Oliva, A., et al. (2018) Safety and Quality Assessment of Smallholder Farmers' Maize in the Western Highlands of Guatemala. *Journal of Food Protection* 71: 14-21.

Lessons Learned:

The adoption of new storage technologies and post-harvest practices to mitigate post-harvest losses has been difficult due to the strong belief in the inherited cultural practices that have been performed for thousands of years. However, the trainings and promotion of new storage technologies developed by the extension network of trainers has triggered positive changes in the post-harvest practices now utilized by the farmers.

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 moisture meter, BAU-STR dryer, hermetic bags use and awareness building on mycotoxin issues <i>Netrokona, Mothbaria, Dumuria, Khulna</i> (Two Trainings: Dec 10 and Dec 13, 2017)	Rice Producers, Government Employees, Private Sector Actors, and Civil Society Actors	32	42	74
Bangladesh	Training on moisture meter, BAU-STR dryer and hermetic bags use <i>Jessore, Khulna</i> (Two Trainings: Dec 12 and Dec 13, 2017)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	61	40	101
Bangladesh	Gender sensitization training <i>Dumoria, Khulna</i> (December 24, 2017)	Rice Producers	16	14	30
Bangladesh	Training on moisture meter, BAU-STR dryer and hermetic bags use <i>Hasonpur, Fotehpur, Modon, Netrokona</i> (April 23, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	28	0	28
Bangladesh	Training on Use of BAU-STR Dryer and Hermetic Bag at Bayantisri, Fotehpur, <i>Modon, Netrokona</i> (April 23, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	24	4	28

Bangladesh	Training on Use of BAU-STR Dryer and Hermetic Bag at Dakkhin Dewshahila, <i>Fatehpur, Modon, Netrokona</i> (April 24, 2018)	Rice Producers, Private Sector Actors, Civil Society Actors	27	0	27
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Uttar Dewshahila, Fatehpur, Modon, Netrokona</i> (April 24, 2018)	Rice Producers, Private Sector Actors, Civil Society Actors	28	1	29
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Kismatbarenga Pascimpara, Gohalakanda, Purbadhala, Netrokona</i> (April 25, 2018)	Rice Producers, Government Employees, Civil Society Actors	9	21	30
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Maddo Kismatbarenga, Gohalakanda, Shymgonj, Netrokona</i> (April 25, 2018)	Rice Producers, Government Employees, Civil Society Actors	24	6	30
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Dakkhin Kalduari, Gohalakanda, Purbadhala, Netrokona</i> (April 26, 2018)	Rice Producers, Civil Society Actors	6	21	27
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Alipur, Gohalakanda, Shymgonj, Netrokona</i> (April 26, 2018)	Rice Producers, Government Employees, Civil Society Actors	17	13	30
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Barabaripara, Chupinogor, Shahjahanpur, Bogra</i> (May 6, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	23	10	33
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Mollapara, Chupinogor, Shahjahanpur, Bogra</i> (May 5, 2018)	Rice Producers, Government Employees	20	12	32
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Nandogram, Madla, Shahjahanpur, Bogra</i> (May 7, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	28	5	33

Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Helenchapara, Madla, Shahjahanpur, Bogra</i> (May 7, 2018)	Rice Producers, Civil Society Actors	22	2	24
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Vandara, Kaligram, Raninagar, Naogaon</i> (May 5, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	23	0	23
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Ratual, Kaligram, Raninagar, Naogaon</i> (May 5, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	26	0	26
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Bokapur South, Mohadebpur, Naogaon</i> (May 6, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	18	19	37
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Bokapur, Mohadebpur, Naogaon</i> (May 6, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	27	7	34
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Moddonagar Uttar, Phulpur, Mymensingh</i> (May 13, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	33	0	33
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Moddonagar Dakkhin, Phulpur, Mymensingh</i> (May 13, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	27	5	32
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Bakbai Pashcimpura-1, Phulpur, Mymensingh</i> (May 14, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	8	23	31
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Bakbai Pashcimpura-2, Phulpur, Mymensingh</i> (May 14, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	32	0	32
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Ranigonj, Chandrokona, Nakla, Sherpur</i> (May 27, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	26	3	29

Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Bondoteki, Chandrakona, Nakla, Sherpur</i> (May 27, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	21	9	30
Bangladesh	Training on Use of BAU-STR Dryer, Hermetic Bag and moisture meter at <i>Baliadi, Chondrakona, Nakla, Sherpur</i> (May 28, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	22	9	31
Bangladesh	Training on Use of BAU-STR Dryer , Hermetic Bag and moisture meter at <i>Zanokipur, Chondrakona, Nakla, Khulna</i> (May 28, 2018)	Rice Producers, Government Employees, Private Sector Actors, Civil Society Actors	27	4	31
<i>Bangladesh Subtotals</i>			<i>655</i>	<i>270</i>	<i>925</i>
Ghana	Post-harvest Loss Mitigation Workshop in <i>Kumasi</i> (Jan 9-11, 2018)	Producers, Government Employees, Private Sector Actors, Trainers, Civil Society Actors	34	7	41
<i>Ghana Subtotals</i>			<i>34</i>	<i>7</i>	<i>41</i>
Guatemala	Education of Field Technical Professionals from Buena Milpa (USAID Project) in Post-harvest Management Trainees from: F Quetzaltenango, San Marcos, Totonicapan and Quiché <i>Huehuetenango</i> (Dec 5-6, 2017)	Maize Producers, Government Employees, Private sector actors, Civil Society actors	13	3	16
Guatemala	Training on the teaching methodology for the ten extension network trainers so they can learn how to effectively transmit the training modules to the 200 farmers' families <i>Huehuetenango</i> (October 17-18, 2017)	Civil Society actors	10	0	10
Guatemala	Presentation on mycotoxin during a regional expo called: Feria Regional del Cordero y Diversidad en Chiantla <i>Huehuetenango</i> (Nov 12-13, 2017)	Maize Producers	25	15	40
Guatemala	Follow-up training for extension network trainers	Civil Society actors	10	0	10

	<i>Huehuetenango</i> (Jan 10, 2018)				
Guatemala	Training on mycotoxin awareness in maize Trainees from Tres Cruces & Todos los Santos <i>Huehuetenango</i> (Jan 17, 2018)	Maize Producers	5	19	24
Guatemala	Training on mycotoxin awareness in maize Trainees from San Antonio de las Nubes, Chiantla <i>Huehuetenango</i> (Jan 18, 2018)	Maize Producers	4	39	43
Guatemala	Training on mycotoxin awareness in maize Trainees from San Francisco, Las Flores, Chiantla <i>Huehuetenango</i> (Jan 19, 2018)	Maize Producers	14	31	45
Guatemala	Training on mycotoxin awareness in maize Trainees from San Jose Las Flores, Chiantla San Jose Las Flores, Chiantla <i>Huehuetenango</i> (Jan 22, 2018)	Maize Producers	4	10	14
Guatemala	Training on mycotoxin awareness in maize Trainees from Villa Alicia y San Martin, Todos Los Santos <i>Huehuetenango</i> (Jan 23, 2018)	Maize Producers	9	27	36
Guatemala	Training on mycotoxin awareness in maize <i>Huehuetenango</i> (Jan 24, 2018)	Maize Producers	27	1	28
Guatemala	Training on mycotoxin awareness in maize. Trainees from Tica, Todos los Santos, <i>Huehuetenango</i> (Jan 29, 2018).	Maize Producers, Government Employees	12	11	23
Guatemala	Training on Post-harvest Management in the Western Highlands Trainees from the university in Huehuetenango called the University Center for the Northwest CUNOROC	Civil Society actors	27	11	38

	<i>Huehuetenango</i> (March 5, 2018)				
Guatemala	Training on Post-harvest Management in the Western Highlands Trainees from the university in Huehuetenango called the University Center for the Northwest CUNOROC <i>Huehuetenango</i> (March 12, 2018)	Civil Society actors	27	11	38
Guatemala	Training on Post-harvest Management Centro Universitario de El Petén –CUDEP El Peten <i>Huehuetenango</i> (March 1, 2018)	Government Employees, Private Sector actors, Civil society actors	11	11	22
Guatemala	Principles and Technology for Maize Storage University Center for the Northwest CUNOROC in <i>Huehuetenango</i> (March 20, 2018)	Maize Producers	21	9	30
Guatemala	Farmer focus groups to exchange experiences on post-harvest management between participating farmer families <i>San Francisco, Las Flores, Chiantla</i> <i>Huehuetenango</i> (March 13, 2018)	Maize Producers	2	11	13
Guatemala	Farmer focus groups to exchange experiences on post-harvest management between participating farmer families <i>Tres Cruces and Chicoy, Todos los Santos,</i> <i>Huehuetenango</i> (March 15, 2018)	Maize Producers	11	35	46
Guatemala	Farmer focus groups to exchange experiences on post-harvest management between participating farmer families <i>Chemal II en Todos los Santos, Huehuetenango and Yerba Buena, Chiantla</i> (March 20, 2018)	Maize Producers	5	29	34
Guatemala	Farmer focus groups to exchange experiences on post-harvest management between participating farmer families <i>Aldea San Martin and Chanchimil, Todos los</i>	Maize Producers	8	33	41

	<i>Santos, Huehuetenango</i> (March 21, 2018)				
Guatemala	Farmer focus groups to exchange experiences on post-harvest management between participating farmer families Caserio El Llano, Chiantla Huehuetenango (March 23, 2018)	Maize Producers	6	8	14
Guatemala	Farmer focus groups to exchange experiences on post-harvest management between participating farmer families <i>San Jose, Las Flores, Chiantla</i> Huehuetenango (March 26, 2018)	Maize Producers	5	15	20
Guatemala	Training on mycotoxin in maize <i>Huehuetenango</i> (Feb 10, 2018)	Maize Producers	9	16	25
Guatemala	Training on mycotoxin in maize <i>Chanchimil, Todos los Santos, Huehuetenango</i> (Feb 12, 2018)	Maize Producers	8	18	26
Guatemala	Training on mycotoxin in maize <i>Yerba Buena, Chiantla Huehuetenango</i> (Feb 14, 2018)	Maize Producers	8	21	29
Guatemala	Improvement of maize post-harvest handling practices for smallholder farmers <i>Huehuetenango</i> (Oct 24-25, 2017)	Maize Producers, Civil Society, Government Employees	32	11	43
<i>Guatemala Subtotals</i>			<i>313</i>	<i>395</i>	<i>708</i>
Ethiopia	Food Safety Training workshop in Bahir Dar (Microorganisms, Toxins, Insects and Pesticide Residues) associated with grains in Ethiopia <i>Amhara Region, Gojjam</i> (Nov 4-7, 2017)	Grain Producers, University Researchers, Ag Experts, Government Employees, Private Sector actors, USAID staff	44	13	57
Ethiopia	Post-Harvest Seed Handling Emphasizing Seed Storage <i>Amhara Region, Agew Anvi Zone</i> (Jan 1, 2018)	Grain Producers, Maize Producers	46	6	52

Ethiopia	National Agriculture Exhibition and Trade Fair: Working Principle of the Solar Bubble Dryer and Improved Techniques for moisture measurement <i>Amhara Region, West Gojjam Zone</i> (Jan 27-28, 2018)	Grain Producers, Maize Producers	Unable to disaggregate		~800
Ethiopia	Drying of maize using solar bubble dryer at farmers' site in <i>Kudmi village Mecha District, West Gojjam Zone</i> (Nov 25- Dec 3, 2017)	Grain Producers, Government Employees	20	30	50
Ethiopia	Grain Standards and International Export Procedures for 14 Farmers Cooperative Unions <i>Adama Zone</i> (March 26-29, 2018)	Grain Producers	Unable to Disaggregate		20
Ethiopia	Food Safety Training workshop in Mekelle (Microorganisms, Toxins, Insects and Pesticide Residues) associated with grains in Ethiopia <i>Tigray Region, Mekelle Special Zone</i> (Nov 4, 2017)	Grain Producers, University Researchers, Ag Experts, Government Employees, Private Sector actors, USAID staff	47	15	62
Ethiopia	Training focused on moisture measurement, hermetic bags, mycotoxin kits, health and environmental risks of improper use of pesticides <i>Mekelle University, Tigray Region Mekelle Special Zone</i> June 11-13, 2018	Post-graduate students in a plant pathology course at Mekelle University	54	0	54
Ethiopia	Training focused on moisture measurement, hermetic bags, mycotoxin kits, health and environmental risks of improper use of pesticides <i>Mekelle University, Tigray Region Mekelle Special Zone</i> May 2, 2018	Post-graduate students in a plant pathology course at Mekelle University	10	2	12
Ethiopia	Training of Trainers on Post-Harvest Loss Management including insect pest in stored product, mold and mycotoxins in storage, high quality sesame storage, and storage pest management options <i>Humera</i> July 28-30, 2018	Agricultural Experts	9	3	12

Ethiopia	Regional training workshop on Food Safety and Post-harvest Loss Management <i>Assala Agricultural Research Center</i> April 27-28, 2018	Academics, Governmental Actors, Agricultural Experts	Unable to disaggregate		33
Ethiopia	Field Day/Stored Grain exhibition Day with training on filter cake dust application	Producers, Agricultural Experts, Government Employees, Academics	13	5	30 *12 gender info unavailable
<i>Ethiopia Subtotals</i>			243	74	1182

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 PHLIL trainings. In FY2018 in Bangladesh, PHLIL directly funded three 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. In addition, one PhD student in agricultural and applied economics at the University of Illinois at Urbana-Champaign is working on PHLIL research, but direct funding for his academic program is from other sources. In Ethiopia in FY2018, there were seven graduate students directly funded by USAID through PHLIL – three at Mekelle University, three at Bahir Dar University and one at Kansas State University. Two additional master’s students are engaged in PHLIL-related research at Bahir Dar University. In Ghana, one graduate student from Oklahoma State University was funded in FY2018 and engaged in PHLIL research and activities. Three additional students at KNUST, two PhD and one bachelor’s, are engaged in PHLIL research, but are not receiving USAID funds. For the Guatemala team, one graduate student at the University of Nebraska-Lincoln who was funded jointly by USAID and USDA in FY2017 to engage in PHLIL research and training is continuing PHLIL research in a PhD program at UNL (utilizing non-USAID funds). An additional PhD student at UNL and a master’s student at Kansas State University comprised the Guatemala research team, but were externally funded.

PHLIL is funding an additional graduate student through the Nepal Buy-In. She is a master’s student (transferred from Kenyatta University, Kenya) studying plant genetics from Kansas State University. There is also a Ghanaian graduate student in the Department of Agricultural Economics at Kansas State University engaged in the economics work in the Nepal Buy-In project.

PHLIL has a total of nine graduate students who are not funded by USAID but who engage in PHLIL activities.

c. Institutional Development

Bangladesh

Partner: Bangladesh Agricultural University (BAU).

Description: Two courses - agricultural process engineering in the BSc in Agricultural Engineering program and advanced agricultural process engineering in the MS in Farm Power and Machinery program, have been modified based on the research findings and experiments of PHLIL Bangladesh. The changes in the two courses have been placed before the engagement advisory committee and suggestions were incorporated. The modified courses have been submitted to the board of studies of the department of Farm Power and Machinery, BAU for approval through the university's academic council.

Ethiopia

Partners: Mekelle University and Bahir Dar University.

Description: A graduate level post-harvest curriculum has been developed at both universities to offer courses targeted specifically at post-harvest management and challenges.

Ghana

Partner: Kwame Nkrumah University of Science and Technology (KNUST).

Description: A platform was established at KNUST for the in-country assembly and distribution of the PHL moisture meters. KNUST is providing this critical incubation step, with support from PHLIL, until production can move from the university to a small enterprise. This exercise helps prime KNUST to further incubate future technology seed initiatives.

Guatemala

Partners: Universidad de San Carlos Huehuetenango

Description: SHARE's in-country coordinator gave guest lectures to students at la Universidad de San Carlos Huehuetenango to impart post-harvest knowledge and transfer the post-harvest manual.

VII. Technology Transfer and Scaling Partnerships

Bangladesh

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 desired volume of paddy sample, with one inch pipe (8/10 nos.) and one inch flat bar ring were used to fix the adjustable shape of 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 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: A BAU-STR dryer has been purchased by one farmer, Md. Humayun Kabir of Atiti village in Comilla. The BAU-STR dryer is being assembled almost entirely at local and regional engineering workshops in Bangladesh. While the blower currently must be imported from Vietnam, a version of the blower has been made in Bangladesh and will be tested over the next year. The prototype developed by a local small electronics company weighs 17 kilograms, a significant decrease from the previous prototypes that weighed as much as 40 kilograms. Training on fabrication, operation and

maintenance of the BAU-STR dryer were provided to ACI Motors Ltd, Bhai Bhai Engineering Workshop, M/S Uttaran Engineering.

Next Steps: Now that there is a prototype of a locally-produced blower in Bangladesh further research will be conducted on the efficiency and effectiveness of the dryer in the field during harvest time.

Ethiopia

Technologies Ready to Scale: *Solar Bubble Dryer*

Description: The Solar Bubble Dryer (SBD) is an off-the-shelf technology currently sold by GrainPro. It dries grain in a tunnel, protected from the elements. A solar energy-powered fan improves air flow through drying grains. The spacious and sunny environment in Ethiopia, and presence of farmer cooperatives with sizable harvests, including those supported by larger scale USAID development projects, lends itself to the effectiveness of the SBD with targeted value chain actors.

Steps Taken and Partnerships Made: University-level experiments have been conducted by graduate students at Mekelle and Bahir Dar universities. This research has shown improved drying capabilities to open sun drying of grain. Cost and size of the dryer mean that effective uptake will likely take the form of cooperatives and aggregators. SBD performance was also evaluated at the weather conditions of the farmer's surroundings in November 2017. The SBD was installed around Koga irrigation center, the place which is well known by producing wheat and corn three times per year, and showed a higher performance of drying rate than the open sun drying in the same area.

Next Steps: Partnerships down the pathway to impact are being forged for targeted uptake.

Technology Ready to Scale: *Inert Dusts, an Alternative to Pesticides for Grain Storage*

Description: Triplex and filter cake, two inert dusts that are industrial by-products from detergent and aluminum sulfate production, respectively, are locally available in Ethiopia. Effective fumigants, the two powders were tested on multiple insects with various concentrations on corn and wheat, two of Ethiopia's most important grains. Filter cake in particular was found to be highly effective in killing stored product insects. Because these products are not dangerous to human health, there is no need for specialized training (application is simple) or protective gear, making it an easy, safe, and effective technology to protect stored grain in households.

Steps Taken and Partnerships Made: Local detergent and aluminum sulfate factories outside of Addis Ababa produce Triplex and filter cake as a by-product. These experiments were conducted at Kansas State University in conditions that simulate the storage structures of Ethiopian farmers and in labs at Bahir Dar University.

Next Steps: The next step would be to 1) better understand the production process that results in these by-products, 2) work on the government clearance process for scaling up the use of these non-toxic pesticide alternatives and 3) to start creating business plans for local entrepreneurs to take the technology to scale.

Ghana

Technologies Ready to Scale: *Solar Biomass Hybrid Dryer*

Description: The Solar Biomass Hybrid Dryer (SBHD) uses a combination of solar and direct heat to dry and disinfest maize. The PHLIL team has developed both a 5 MT standing model and a 1 MT mobile model. The design is essentially a greenhouse, with translucent sides and roofing to allow for solar heat to dry the maize or other commodities inside. When solar heat is not sufficient, the dryer also has an attached furnace that can provide heat using biomass. Fans ensure sufficient airflow, with maize placed in thin layers and shelves in order to facilitate drying.

Steps Taken and Partnerships Made: PHLIL has partnered with AMPLIFIES to establish a revolving financing system. AMPLIFIES provided funding for a 5 MT SBHD to be built at an area poultry producer. As the producer pays back the dryer cost, those funds will in turn go to another producer to build a dryer on their farm. GIC has also ordered 1 MT mobile dryers.

Next Steps: Slight modifications are continuing to improve airflow in the dryer. Additional Solar Biomass Hybrid Dryers will be built in the near future.

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. GrainMate is ideal for measuring the moisture content of several commodities including corn, rice, cowpea, wheat, sorghum and soybean with the capacity to support 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 \$100. 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, a 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 \$100 each. 180 meters have been produced and distributed by Sesi Technologies in Ghana, with production starting to ramp up. The American Soybean Association's WISHH program, AMPLIFIES Ghana, purchased 120 meters for use in their poultry project activities. With funding from the German International Development Agency (GIZ) Green Innovation Center project, 50 meters are being used by the Ghana Grains Council to conduct moisture measure training for farmers.

Next Steps: Continued support of Sesi Technologies by promoting the moisture meter and providing guidance for various trade shows and research conferences to attend across the African continent.

Technologies Transferred and Ready to Scale: *ZeroFly® bags*

Description: ZeroFly® bags are a hermetic storage bag similar to PICS bags. These bags also have a pesticide-infused outer lining for enhanced pest protection.

Steps Taken and Partnerships Made: Partnering with PHLIL to provide the research basis to validate the technology, Vestergaard Frandsen, the maker of ZeroFly® bags, has developed and piloted an updated hermetic design for the bags. Sesi Technologies is now serving as a distributor of the ZeroFly® bags, and there have also been conversations about increased distribution within Nigeria with the Vestergaard regional representative in Nigeria.

Next Steps: PHLIL will work with poultry producers and Sesi Technologies, as a distributor for the bags, to increase both availability and adoption.

Guatemala

Technologies Ready to Scale: *PHLIL Post-Harvest Loss Prevention Manual*

Description: A train-the-trainer manual and suite of materials was developed for post-harvest loss prevention training. The suite of materials includes a facilitator's guide and accompanying presentation slides (will also be available in printed slides form for use without a computer); a farmer's guide, which includes mostly pictures and little text; and cards and posters with key messages.

Steps Taken and Partnerships Made: The Post-harvest Loss Prevention Manual has been published on the PHLIL website and shared with the extension network trainers, partnering organizations, and stakeholders. A partnership was developed with the USAID-funded Buena Milpa project, which is managed by CIMMYT and Asocuch, a local NGO in Huehuetenango. Their personnel were trained on post-harvest loss prevention practices and will receive all the manual materials. Another partnership is being developed with INCAP (Centroamerican and Panamanian Institute of Nutrition) to utilize the technical manual - they requested that our PHLIL Guatemala Technical Team to train their trainers. A potential partnership with Inter-American Institute for Cooperation on Agriculture (IICA) may be developed for technology transfer of the technical manual and teaching material. Additionally, a train the trainer workshop was developed using the post-harvest loss prevention manual.

Next Steps: Continue with the development of the partnerships with IICA and Institute of Nutrition of Central America and Panama (INCAP).

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, and procedures being executed accordingly. These documents are available through the Piestar Reporting Hub and the PHLIL public website.

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 spent a significant portion of time preparing for and receiving a three-year program extension from USAID. Through this process, program management processes were streamlined and appropriate reporting information gathered. Additionally, the next phase of the program will expand to relevant new research areas, with questions that build upon our first five years of research.
- With streamlined management processes, we plan to institutionalize more integrated reporting from the beginning of the next phase through its completion.
- Staffing of the Management Entity has been stable, with no turnover, and additions including:
 - Ms. Caroline Kolins started as the new program coordinator in February 2018.
- The PHLIL Director presented, along with three other KSU-based Innovation Labs, to Kansas Congressman Roger Marshall in May 2018 on the value of international agricultural research to Kansans.
- A delegation of USAID representatives attended a portion of the annual Kansas Governor’s Summit on Agricultural Growth, and announced the extension of three K-State Innovation Labs, including PHLIL, at a special press conference during the summit.
- Dr. Harvey presented about the program and contributed to other meetings, including:
 - Implementing the Dry Chain to Reduce Post-Harvest Losses and Improve Food Safety, World Food Center. “Safeguarding the global harvest for all: Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss.”
 - 3/18 Global Food Security Act, US Senate expert panel, organized by the Association of Public Land Grant Universities. “Feed the Future Innovation Labs: realizing benefits at home and abroad.”
 - 3/18 World Mycotoxin Forum, Amsterdam, Netherlands. “Towards integrated approaches to mitigate mycotoxins across a changing landscape.”
 - 1/18 Plant Pathology departmental seminar, Kansas State University. “Towards integrated approaches to mitigate mycotoxins across a changing landscape.”
 - 1/18 Plant and Animal Genome Conference, San Diego. “Building transformative R4D alliances, for mutual benefit and sustainable national system empowerment.
 - 11/17 Global Good/Intellectual Ventures, Seattle, Post-Harvest Drying meeting. “Drying Innovations: designing for context.”
- Additional PHL-related publications were finalized and published:
 - Sheila Okoth, Marthe De Boevre, Arnau V Corominas, Jose D DiMavungu, Sophie Landschoot, Martina Kyalo, Joyce Njuguna, Jagger Harvey, Sarah DeSaeger (2018) Genetic and toxigenic variability within *Aspergillus flavus* population isolated from maize in two diverse environments in Kenya. *Frontiers in Microbiology* 9:57, doi: 10.3389/fmicb.2018.00057.
 - Samuel Khakata, FN Mbute, GN Ghemining’wa, M Mwimali, J Karanja, J Harvey and JK Mwololo (2018) Post-harvest evaluation of selected inbred lines to maize weevil *Sitophilus zeamais* resistance. *Journal of Plant Breeding and Crop Science* 10(5): 105-114.
- The ME enlisted Humanitas Global to conduct a broad assessment of PHLIL activities and their alignment with country and regional priorities in the focus countries. They provided valuable insights for understanding the policy landscape for post-harvest loss in our core countries, designing the

2019-2021 program plan, engaging other stakeholders including donors, and identifying strategic partnerships with an expanding set of existing programs.

- A comprehensive review of the Piestar reporting system was conducted and changes were implemented for a streamlined reporting process.
- A Memorandum of Understanding was signed between Kansas State University (through the PHLIL collaboration) and the Mars Global Food Safety Center.

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.
- Communication with the Ethiopia team has continuously been a challenge and has led to organizational issues. Part of this is caused by inconsistent internet and in-country instability, complicating the job of the in-country team. We have taken actions to mitigate the aspects of these challenges we can control by facilitating more direct interaction between key in-country team members and the ME. This has significantly improved communications in many cases. In the future we are further exploring alternative reporting platforms that do not require internet for successful completion.

XIII. Future Directions

- In August, USAID granted a three-year extension to the PHLIL program. This extension will allow us to ask critical research questions that further our “Phase I” research and contribute to the reduction of post-harvest loss. PHLIL “Phase II” will also focus on regionally- and broadly-relevant research questions around barriers to adoption and identifying and improving mechanisms to make post-harvest technologies more accessible stakeholders in the agricultural value chain. Research will also involve new, linked areas of investigation in our program’s overall objectives in agricultural economics, agricultural education/extension, physical sorting of contaminated grains, and other areas. We are currently in the process of defining specific activities to meet those objectives in an integrated manner.

Appendix A: Success Stories

Success story A Safer Way to Store Grain

When Tesfaye Tadesse was a boy in Debra-Elias, Ethiopia, he would walk two hours each morning to attend school. Many years later, his education journey would lead him to Kansas State University where he conducts research under the Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss on alternative ways to protect grains from insect pests without using pesticides that are harmful to human health.

The United Nations Food and Agriculture Organization reports that as much as 1.3 billion tons of food are lost or wasted each year – equivalent to 24 percent of all food calories produced for human consumption. In Ethiopia, farmers often lose 20 to 30 percent of their harvest due to insects, rodents and improper storage and drying techniques. Even grain that is not directly lost may not be safe if it has been contaminated by fungal toxins or dangerous pesticide residues.

In Ethiopia, farmers often purchase or receive pesticides without knowledge of the substance or training on the proper use and disposal of the chemicals. Farmers use dangerous chemicals without proper protective gear and mix unknown chemicals together. It is common to see the same containers that once held potentially toxic chemicals re-used as drinking glasses or food storage containers. Tesfaye remembers growing increasingly concerned about the poor pesticide handling practices in his home country when he witnessed a participant in a local training carrying a test tube of Phosphine, a commonly used fumigant which will ignite when it interacts with air, without any protective gear or concern for potential reactions. This experience inspired his current research on inert dusts



– mineral dusts that have little or no chemical toxicity – as safe grain protectant options for farmers. His dissertation research is testing Triplex and filter cake, two inert dusts that are industrial by-products from detergent and aluminum sulfate production, respectively, and are locally available in Ethiopia. The two powders were tested on multiple insects with various concentrations on corn and wheat, two of Ethiopia’s most important grains. Filter cake in particular was found to be highly effective in killing stored product insects. Because these products are not dangerous to human health, there is no need for specialized training or protective gear, making it an easy, safe, and effective technology to protect stored grain in households.

For this research, Tesfaye set up experiments in a laboratory at Kansas State University that simulated grain storage containers by creating mini-versions with cement in a petri dish. His findings were recently published in *The Journal of Stored Products Research*. His next step is to test them in the field using the actual storage structures widely used in Ethiopia. He also plans to convert his standard measurements into non-standard measurements traditionally used in low-resource settings, like his home of rural Ethiopia. His greatest hope is that the results in the field will be as promising as the ones in the lab and that this method of preventing post-harvest losses will improve livelihoods through fewer losses and better incomes. Tesfaye will complete his

PhD in grain science and industry this year, and he plans to return to Ethiopia and use this research to help Ethiopian farmers decrease their post-harvest losses.

¹ Tadesse, T. M., and Subramanyam, B. 2018. Efficacy of filter cake and Triplex powders from Ethiopia applied to concrete arenas against *Sitophilus zeamais*. *J. Stored Prod. Res.* **76**, 140-150.

Success Story

Sesi Technologies & The Grain Mate: A Success for Young Entrepreneurs in Ghana

Grain moisture content is one of the most important and critical factors affecting quality of maize during storage. Wet maize with a high moisture content promotes mold and aflatoxin growth, which is a serious health hazard in Ghana. Commercial moisture meters can cost hundreds of dollars (USD) and are not affordable for medium-scale farmers or aggregators.

To address this issue, the GrainMate moisture meter was developed by Dr. Paul Armstrong at USDA

Agricultural Research Service as part of the Post-Harvest Loss Innovation Lab's Ghana research. The low-cost PHL moisture meter uses equilibrium moisture content (EMC) and was designed and developed to be less costly and easier to use. It has now been extensively tested in Ghana and is comparable in accuracy to commercial moisture meters. With wide measurement range, the ability to measure moisture of multiple grains and legumes, and low power consumption, farmers and aggregators can have confidence in the moisture meter's ability to efficiently measure the moisture of their grain. Proper use of the moisture meter can help reduce post-harvest losses, which can be up or even greater than 30 percent, according to assessments by in-country partner, PENS Food Bank.

Sesi Technologies, a Ghanaian enterprise recently founded by young graduates of Kwame Nkrumah University of Science and Technology (KNUST), is selling these moisture meters for about \$100 each. These young entrepreneurs lowered the production cost by assembling the moisture meter in a

“GrainMate saved us the trouble of importing expensive grain moisture meters from overseas. We were impressed by its quality and performance.”

- Ghana Grains Council



local lab at KNUST in Kumasi, making this extremely important technological advance for maize management in Ghana even more affordable. Sesi Technologies is also a distributor of ZeroFly[®] Bags, another effective post-harvest loss reduction technology.

So far nearly 200 meters have been produced and distributed by Sesi Technologies in Ghana, with

production starting to ramp up. The American Soybean Association's WISHH program, AMPLIFIES Ghana, purchased 120 meters for use in their poultry project activities. With funding from the German international development agency (GIZ) Green Innovation Center project, 50 meters are being used by the Ghana Grains Council to conduct moisture measure training for farmers. Sesi Technologies has also demonstrated the GrainMate Moisture Meter for Ghanaian Vice President Dr. Mahamudu Bawumia and German Chancellor Angela Merkel.

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 a key component of these losses.

To address this challenges, 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 prototype. The original prototype was 40 kilograms, much too heavy to accommodate women farmers and post-harvest processors. While the blower is under development locally, the rest of 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 the growth of mycotoxins.

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 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

Appendix B: Bangladesh Research Results

Figure 1: BAU-STR Dryer Evaluation for parboiled paddy @ Moti auto rice mill

Treatment	Drying Steps*	Drying Time	Variation of Moisture from inner to outer grain	Drying Rate	Dryer Efficiency	Head Rice Yield
Treatment 1	Sun drying until moisture content reached 25% (wb) then drying in BAU-STR dryer with high temperature ($45 \pm 2.65^\circ\text{C}$).	13 hours (7.5 hours sundry) (5.5 hours in dryer)	6%	1.1%MC/hr	53.2%	45.27%
Treatment 2	Low temperature ($35 \pm 2.15^\circ\text{C}$) drying until moisture content reached 25% (wb), then drying in BAU-STR dryer with high temperature ($45 \pm 2.65^\circ\text{C}$).	7 hours	8.5%	2.0%MC/hr	62.9%	43.38%
Treatment 3	Only air flow until moisture content reached 25% (wb), then drying in BAU-STR dryer with high temperature ($45 \pm 2.65^\circ\text{C}$).	9 hours	8.6%	1.6%MC/hr	62.7%	45.76%
Treatment 4	High temperature drying until moisture content reached 14% (wb),	9 hours	3%	1.9%MC/hr	66.9%	52.47%

* Each of the drying treatment had 2 hours ambient air flow when inner grain moisture reached 18% (wb).

Figure 2: Average drying loss for BAU-STR dryer and open sun drying

Method	Location	Average Drying Loss
BAU-STR Dryer	Laboratory	0.43%
BAU-STR Dryer	Field	0.39%
Open Sun Drying	Tangail Farmer Field	3.95%
Open Sun Drying	Mymensingh Phulpur Farmer Field	3.24%
Open Sun Drying	Mymensingh BAU Farmer Field	2.98%
Open Sun Drying	Netrokona Farmer Field	2.41%
Open Sun Drying	Jessore Farmer Field	3.04%

Figure 3: Storage Method Testing Results

Storage Method	Day	O ₂ Concentration Level	CO ₂ Concentration Level
GrainPro Bag	1	20.76%	0.26%
	4	20.6%	---
	21	6.04%	10.5%
	28	3.38%	13.01%
PICS Bag	1	20.76%	0.26%
	17	18.07%	1.96%
	27	4.71%	10.26%
Seed Bag	Unchanged, no O ₂ or CO ₂ barrier		
Grameeni Bag	Unchanged, no O ₂ or CO ₂ barrier		



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