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, 2020-September 30, 2021**

USAID
FROM THE AMERICAN PEOPLE

KANSAS STATE UNIVERSITY

## PHLIL External Advisory Council:

### Dr. Robert Zeigler, Chair

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

### Dr. David Priest

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

### Brett Rierson

- Managing Director of African Harvest Ventures

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

## Where we work:


In FY21, The Post-Harvest Loss Innovation Lab has comprehensive post-harvest programs in **Bangladesh, Ethiopia, and Ghana**.

PHLIL benefits from significant cost-share investments from our partners, including substantial investment from Kansas State University and University of Illinois' ADMI Institute for the Prevention of Post-Harvest Loss.

## Cover Photo:

Ms. Beatrice Asante Adjei, Secretary of the Women in Poultry Association, has implemented improved practices to substantially increase her poultry business, sell eggs to smallholder farmers, and increase purchase of maize for feed from smallholder farmers.

## Phase II (2019-2022) Program Partners

### United States

ADM Institute for the Prevention of Postharvest Loss, University of Illinois Urbana-Champaign
AgReach, University of Illinois
Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (Appropriate Scale Mechanization Consortium)
Feed the Future Innovation Lab for Livestock Systems
Feed the Future Innovation Lab for Nutrition
Feed the Future Innovation Lab for Soybean Value Chain Research
Fort Valley State University
GrainPro, Inc.
Global Good, a collaboration of Bill Gates with Intellectual Ventures
Helica Biosystems, Inc.
Mars Inc.
Nascent Solutions
Iowa State University
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
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.
AgroMech Development Initiatives (ADI) Foundation
Amin Electrics
Bandhu Engineering Workshop
Bangladesh Agricultural Development Cooperation, Government of the People's Republic of Bangladesh
Bangladesh Agricultural University
Bhai Bhai Engineering
Department of Agricultural Extension, Government of the People's Republic of Bangladesh
GH Electronics
Helen Keller International
Jagorani Chakra Foundation
Kamal Machine Tools
Missing Middle Initiative (MMI) project, FAO-Bangladesh
Moti-Auto Rice Mill
Uttaron Engineering

### Ethiopia

Bahir Dar University
Ethiopian Institute of Agricultural Research

Debre Zeit Agricultural Research Center
Humera Agricultural Research Center
Kulumsa Agricultural Research Center
Hawassa University
Hiwot Agricultural Mechanization PLC
Mekelle University
Ministry of Agriculture
National Post-harvest Advisory Committee

**Ghana**
Adventist Development Relief Agency (ADRA)
Agri Commercial Service Ltd.
American Soybean Association World Initiative for Soy in Human Health – Assisting Management in Poultry Layer Industry by Feed Improvement and Efficient Strategy (AMPLIFIES) project
Kwame Nkrumah University of Science and Technology
Mayor Sackey's Agriculture team (Accra)
Ministry of Food and Agriculture (Northern and Upper West regional offices)
Pens Food Bank Enterprise
Saving Grains
Sesi Technologies
Value Chain Council, Garu
Vestergaard Frandsen
Women in Poultry Association – Dormaa and East Dormaa chapters

**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**
USAID Bureau for Resilience and Food Security & Country Missions
Dassault Systemes (France)
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (Germany; in Ghana, Ethiopia)
Mars Global Food Safety Center (China)
Nepal Academy of Science and Technology (Nepal)
Vestergaard Frandsen (Switzerland)

**Acronyms**

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

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# 2021 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 currently focused in Bangladesh, Ethiopia, Ghana and Guatemala. It is notable that USDA funding under Food for Education also has PHLIL working in Malawi, under Nascent Solutions. 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 eighth year, the program has continued making significant advances towards scalable innovation packages and cultivating the necessary capacity to reduce post-harvest losses at scale in our target countries.

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

From developing new research questions and designing research plans to building upon previously existing and new partnerships, the Post-Harvest Loss Innovation Lab's eighth year of operation was focused on continuing to reduce post-harvest losses across our core countries. Given the covariate shocks presented by the onset of the pandemic, efforts to secure the harvest were more important than ever. PHLIL team members worked hard to develop innovative adaptations to workplans in the face of operational challenges associated with the COVID-19 pandemic. As a result, the program met or exceeded all Feed the Future indicator targets for the year.

**Overall:**

PHLIL has welcomed the invitation by USAID to articulate how our efforts contribute to climate change mitigation. Approximately one third of global food production is wasted or lost, contributing ~4.4 gigatons (or ~10% of anthropogenic) of greenhouse gasses annually. PHLIL contributes to reducing these losses through innovations that arrest contamination and spoilage by toxin-producing fungi and eliminate the need for using toxic chemicals to treat crops after harvest to prevent pest infestation. PHLIL researches innovations and technologies to dry, measure and control moisture content and safely store crops.

Additionally, PHLIL responded to a formal Request for Revised Application from USAID in mid-2021. This award raises the ceiling of the agreement by $1 million and extends the period of performance by one year through December 2022, a 9$^{th}$ year of operation.

# II. Focus Country Key Accomplishments

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

- 511 short-term (41.5% female), and 13 long-term trainees (degree-seeking) directly supported by the program in FY2021
- 5,230 individuals in the agricultural systems of PHLIL focus countries applied an improved management practice or technology thanks in part to USG assistance from PHLIL-related research and scaling (smallholder producers: 4,645; non-smallholder producers: 517; government employees: 19; private sector: 30, civil society: 19)
- 8 research publications
- 6 technologies transferred and/or ready to scale

**By country:**

In all four core countries, post-harvest loss innovation packages have begun scaling with next-users along the pathway to impact, followed intentionally by research into obstacles to and opportunities for scaling and impact. Selected key accomplishments by country include[1]:

## Bangladesh

- Using the BAU-STR dryer costs half or less and takes a quarter of the time compared to paying laborers to dry paddy rice, also essentially eliminating paddy losses
- The BAU-STR dryer fan is being used by farmers for winnowing
- The mid-scale dryer target product profile was developed in collaboration with major and husking mills, and a locally built prototype is being installed at Moti Auto Rice mill in a public private partnership
- Training village-level mechanics and entrepreneurs was conducted to help ensure sustainable scaling along the product life cycle
- BADC successfully stored large-scale paddy rice seed in hermetic cocoons, eliminating the need for pesticide application and other labor intensive practices associated with their traditional methods

## Ethiopia

- Both Mekelle and Bahir Dar universities piloted the Arc'teryx dryer. Adaptations were made before the next version will be sent to Ghana.
- Work continued on the national postharvest extension manual.
- National extension system took up PHLIL innovations and scaled to farmers.
- The deteriorating security situation and pandemic greatly hampered progress.

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

## Ghana

- Engagement with the Dormaa Women in Poultry Association continued, through times of low maize availability. PHLIL linked them with Farmer Based Organizations in Northern Ghana which have more maize.
- KNUST continued MSc research targeted at reducing post-harvest losses in maize food and feed, including testing elevated platforms to avoid heaping in the field at harvest, as well as trials that show poultry fed on hermetic bag-stored maize perform much better.
- Sesi Technologies continued scaling the GrainMate moisture meter, with sales continuing to increase rapidly.
- As of September 7, 2021, 9,825 ZFH bags facilitated by PHLIL have been sold in the Middle Belt and the Upper East Region of Ghana. Sesi Technologies has sold a total of 6,350 ZFH bags during the 2020 and 2021 period; 6,290 getting sold between October 2020 and September 2021.

# III. Research Program Overview and Structure

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

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

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

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

## IV. Theory of Change and Impact Pathway(s)

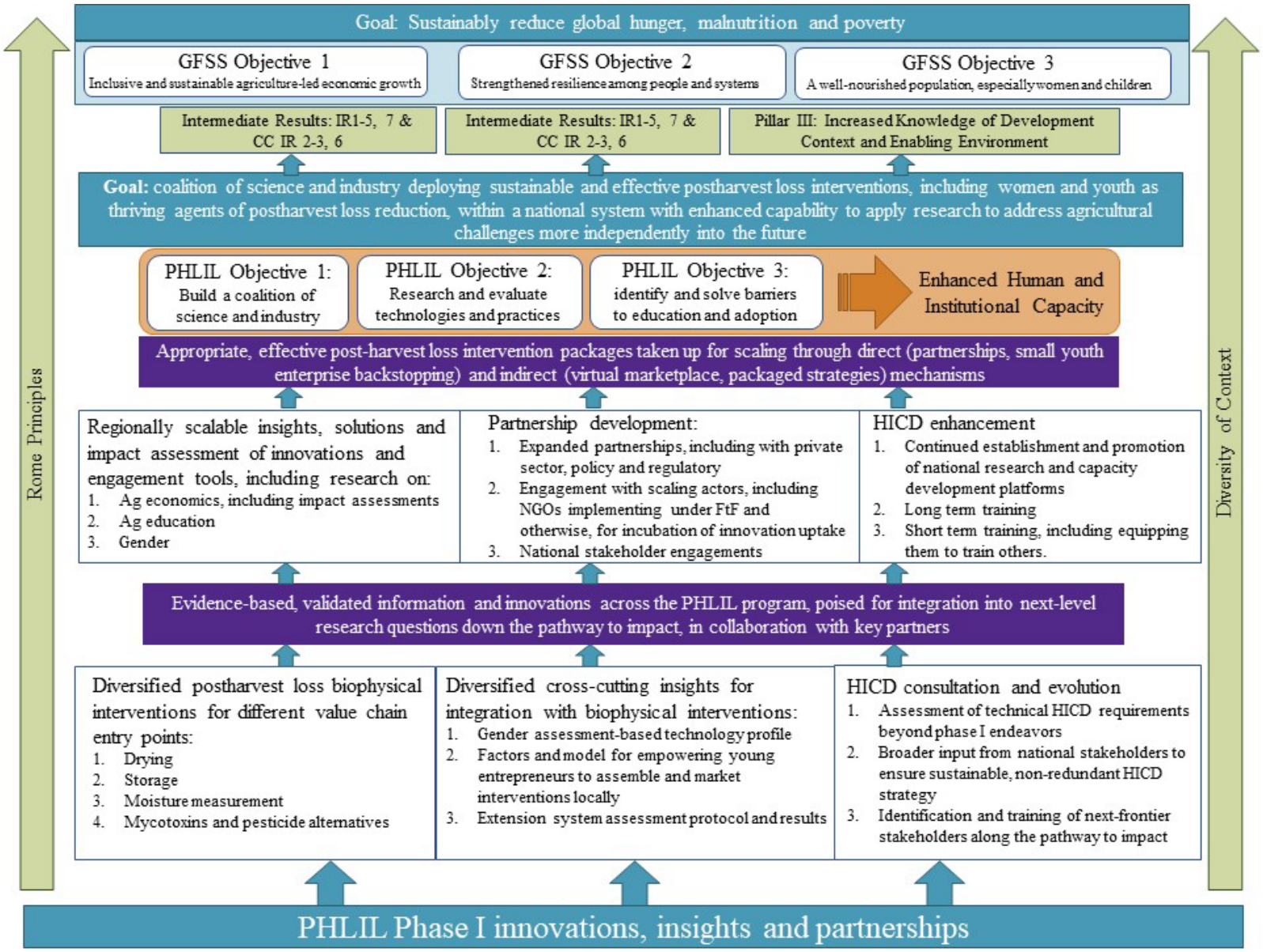


Figure 1: PHLIL Revised Program Description Theory of Change, for 2019-2021 program activities.

# V. Research Project Report

## Bangladesh

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

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

### Achievements:

#### Objective: Assessment of drying and storage technologies adaption and impact through Focus Group Discussions and Key Informant Interviews

**Progress**

PHLIL previously reported that 7-12% of paddy rice is lost after harvest in Bangladesh.

*BAU-STR Dryer*

Sun drying of paddy is traditionally practiced by Bangladeshi farmers, for either home consumption or saved seed. Since sun drying is dependent on weather, attaining proper moisture content for storing paddy or seed is challenging. A high amount of paddy is lost or quality compromised during sun drying. To solve the problem, PHLIL-Bangladesh developed and introduced the BAU-STR dryer to farmers and farmers groups, providing them with appropriate training. A survey was conducted involving users (farmers/farmers' groups) and key informants (DAE, RDA, FAO, JCF, Manufacturer, Machinery Importer sectors) to assess their experience and feedback on the BAU-STR dryer (availability, prospects & problems, operation & maintenance, business etc.), from 28 November to 14 December, 2020, at Mymensingh, Kishoreganj, Jhalakhati, Barishal, Moulovibazar and Jashore districts of Bangladesh. The survey utilized a semi-structured checklist. This study was partially supported by i2i innovation to impact survey, led by the Soybean Innovation Lab (SIL) and further funded by USAID.

Seven Focus Group Discussions and 9 Key Informant Interviews were conducted to gather feedback about the disseminated BAU-STR dryer. A validation Workshop on BAU-STR dryer Innovation to Impact was arranged on Wednesday, March 24, 2021 through Zoom online video conference platform to validate the users' feedback about the operation and business of BAU-STR dryer. Twenty eight participants (Male: 25 and Female: 03) attended the workshop. They included university faculty members, agriculture officers, entrepreneurs, agricultural machinery manufacturers, rice mill owners, lead farmers, and the regional coordinator officer of FAO's Missing Middle Initiative (MMI). Overall, the participants expressed their deep satisfaction about the operation and business of the BAU-STR Dryer. The majority of the farmers (78%) reported a high prospect of using the BAU-STR dryer, while only 1.44% reported a low prospect that they would use it.

In terms of operation costs, the participants expressed that, USD $10.6 - 18.8 is needed for drying 500 kg paddy with 2 laborers for minimum 2 days in case of sun drying. In comparison, only USD $4.7 - 5.9 and 4-5 hour is enough for proper drying with the BAU-STR dryer. Post-harvest loss associated with sun drying

paddy was 1.6 - 2.4%, while no loss was observed by the farmers using the dryer. Moreover, farmers are also using the blower as a winnower, further accelerating the return on investment.

The study also confirmed that the LPG heating system has solved the lack of availability of rice husk briquettes in the Southern region. Farmers, including women, reported that they did not face any difficulties in operating the dryer and never experienced any repair issues; most of the dryers have been used for more than 3 seasons without any trouble. A farmer group in Mymensingh reported saving USD $588 in would-be paddy rice losses from rainy weather in the previous Boro season, by using the BAU-STR dryer. This post-harvest loss savings almost completely recouped the cost of the dryer in a single season.

One potential area for further investigation and improvement was that users found loading and unloading paddy in the BAU-STR dryer to be a slow process (although it is noteworthy that overall time saved compared to solar drying was substantial).

*Hermetic bags*

Farmers in Bangladesh typically store rice paddy/seed in a non-hermetic gunny bag. PHLIL has demonstrated that hermetic bags yield impressive results in storing paddy, in terms of storage period, quality, weight loss and germination rate. Following on from these results, farmers were trained in the use of the GrainPro hermetic bags for seed storage. The trained farmers were provided a hermetic bag so PHLIL could follow up and assess the field performance in the Bangladeshi context. To inspect the real condition of the distributed hermetic bags, and get feedback from the field, a checklist was prepared and modified after pre-testing in the study areas. The study included 34 farmers, based on a random sampling technique, from Mymensingh, Barishal and Jashore districts. The study was deployed during the Aman-2020 season (November-December 2020).

All the participants had agreed that hermetic bag was beneficial for them and that stored paddy was of good quality. All farmers were interested in purchasing the hermetic bag. The farmers even wanted to invest about Tk. 100 (USD ~$1.12) per bag as they believe that longer period of storage can give higher price of paddy during off season. During physical inspection of hermetic bags, it was observed that the zipper of the bag was found closed, but only 52% were stored with the outer protective bag. No holes were found in 69% of hermetic bags; 12% of bags had 1 - 10 holes and 19% of bags had more than 20 holes. Overall, 74% of farmers reported that they did not face any difficulties in using the hermetic bag. Farmers reported that zipper damage, high price and the thin nature of the bags were drawbacks. Overall, 76% farmers said that their neighbors are aware about the hermetic bag, and 85% of participants recommended the bag to their neighbors. The participants expressed a desire for thicker bags and that the bags be consistently available in the local market.

PHLIL-Bangladesh team visited Shaymganj and Phulpur of Mymensingh district during June 15-28, 2021, where farmers are now using GrainPro hermetic bags for storing their *Aman* paddy-2021 seed.

**Achievements**

- Farmers were enthusiastic and eager to continue using the BAU-STR dryer with LPG-based heating
- Users of BAU-STR dryer are satisfied with its operation and found it suitable for their businesses
- Farmers' perception on the use and demand of hermetic bag at the field level has been collected and analyzed.
- Listed households are using hermetic GrainPro bag about 3-4 years after distribution.

**Challenges**

- Loading and unloading of paddy in the dryer consumes a significant amount of time

- Local manufacturers still have limited expertise in manufacturing blower for BAU-STR dryer, compared to overall demand
- Persistent motivation of farmers and BADC personnel will be necessary to ensure proper disposal of hermetic bags and cocoons.
- Farmers are interested to in purchasing the GrainPro bag, if they are made more available in the local market at an affordable price. While farmers expressed willingness to pay 100Tk/hermetic bag, they are sold by ACI Motors for 280Tk/bag. The KSU Agricultural Economics team is conducting further research around liquidity and risk constraints, to help unlock sustainable scaling strategies.
- Field survey with social distancing and other safeguards during the COVID 19 pandemic situation was found difficult to maintain.

### Objective: Appropriate scale dryer development for meso-level mills

**Activities**

- Identification of major needs and appropriate scale dryer target product profile characteristics for major rice mills
- Develop and investigate the technical and financial performance of 12 ton capacity dryer at a major rice mill
- Further modify and test the 12 ton dryer as necessary

**Progress**

*Identification of major needs and appropriate scale dryer target product profile characteristics for major rice mills*

Smallholder rice farmers rely on local mills to purchase their wet paddy rice. Of the 17,000 rice mills in Bangladesh, 15,500 are mid-sized local mills locally referred to as "major and husking" mills. Local mills are being competed out of business by a smaller number of larger mills with more sophisticated equipment including large dryers, enabling them to produce "glossy fresh-looking" rice, compared to the discolored rice produced by mid-scale mills. Faced with this existential threat, mid-scale millers approached PHLIL previously, requesting that an appropriate scale dryer be developed for local manufacture and purchase.

An assessment of 20 mid-size mills was conducted in November 2020 in Mymensingh, Sherpur, and Netrakona districts. The study team used the snowball sampling technique to help select mills, which were categorized into four groups: Major (8), Husking (4), Automatic (4), and Semi-automatic (4). Technical, financial, and demographic data were collected. Either the owner or manager of each mill was engaged to gather financial data. Paddy drying cost and associated Cost-Benefit Ratio were considered as the financial performance indicators. Operators overseeing drying were engaged to collect technical data, including capacity utilization, milling recovery, head rice recovery, percentage broken, and bran percentage. From this study, PHLIL found that unreliable, slow, laborious and expensive solar drying is the critical rate-limiting step of Major and Husking mills, also resulting in lower quality products, hampering their ability to compete.

| *Mill type:* | *Major* | *Husking* | *Semi-automatic* | *Automatic* |
|---|---|---|---|---|
| **avg. number of workers** | 34 | 25 | 45 | 102 |
| **avg. number of drying workers** | 19 | 16 | 6 | 7 |
| **tons dried in the past year** | 1,351 | 1,390 | 4,381 | 11,880 |
| **avg. operational days per year** | 210 | 195 | 223 | 278 |
| **drying cost per ton (Taka)** | 674 | 505 | 708 | 422 |
| **avg. capacity utilization** | 29.2% | 24.0% | 64.3% | 72.6% |

**Table 1:** PHLIL study of capacity utilization and rate limiting aspects of post-harvest management practices at each type of mill in Bangladesh.

Other aspects considered in the mill survey included:

- In the rice processing sector, the presence of female worker was nearly half (31%) in compared to the male worker (69%) and were engaged in paddy drying, winnowing and cleaning. The rice mills had no child labor. Only 11% young labors were engaged in the rice mill under the study. Middle age laborers were dominating in the paddy processing sector with 89% contribution of total workforce. Adoption of improved, non-solar technologies by the major and husking mills will increase the production hours and employment opportunities.
- Automatic and semi-automatic rice mills' increased efficiency, due to their drying technologies, translates to more days of the year they are operational and lower drying cost per ton.
- To dry boil rice, major and husking mill required 48 hours to 96 hours (2 to 4 days) while automatic and semi-automatic rice mill only required 8 hours to 12 hours. For aromatic rice, 48 hours to 72 hours (2 to 3 days) was required in major and husking mills, whereas 16 - 22 hours was enough for automatic and semi-automatic rice mills.
- Longer drying time of aromatic rice versus parboiled rice was the main reason for high drying cost of paddy in semi-automatic rice mills.
- Head rice, broken rice, milled rice, and bran percentage of major, husking, automatic, and semi-automatic rice mill were found 60.3%, 2.6%, 62.9%, 10.6%; 56.5%, 1.5%, 57.9%, 7.9%; 61.5%, 1.4%, 62.8%, 5%; and 54.2%, 2.9%, 57.1%, 9.8%; respectively. Highest head rice recovery was found in automatic rice mill. Bran recovery was highest in major rice mill.

*Develop and investigate the technical and financial performance of a 12 ton capacity dryer at a major rice mill*

Extensive analysis of temperature, design and drying/parboiling process for seven existing mechanical dryers found at four automatic and one semi-automatic rice mills. The PHLIL team resolved an innovative strategy to synchronize air temperature with exposure time, so that the new dryer can now be used to dry both parboiled and aromatic rice using a prescribed six step process. In calculations and discussions with product life cycle partners, PHLIL ascertained that a 12 ton capacity mechanical dryer would be appropriate, estimated to increase capacity from 29.2% (major mills) and 24% (husking mills) to 72.5% or higher (Saha et. al., 2021), notably similar to the current 72.6% capacity of automatic mills outcompeting them. To achieve this capacity, PHLIL also recommends adoption of a rubber roller rice huller with at least 2.5 ton/hour capacity and two worker shifts per day.

In a public-private partnership, PHLIL is working with Moti Auto Rice Mill to pilot a mid-scale dryer prototype. PHLIL worked with local manufacturers to produce the 12 ton dryer. Moti has now used their own capital to purchase and install the pilot dryer for ~$30,000 (a significant cost savings since previously the

only option was to purchase separate dryers for paddy and parboiled rice). The research team is visiting Moti Auto Rice mill regularly to monitor dryer construction. Research validation and training will be conducted in Fiscal Year 2022. The dryer manufacturer has agreed to provide service into the future.

Mid-sized millers able to purchase these dryers will be targeted as early adopters. Meanwhile the program will discuss potential subsidies with the government and explore other avenues for adoption

**Table: Capacity utilization of major* (M) and husking* (H) rice mills**

| Rice mill | Paddy processed last year (no of batch) | Paddy processing potential of rice mill in a year (no of batch) | Present capacity utilization (%) | Dryer capacity (ton/batch) | Paddy can be processed in a year with dryer (no of batch) | Future capacity utilization with dryer (%) |
|---|---|---|---|---|---|---|
| M1 | 133 | 400 | 33.3 | 12 | 290 | 72.5 |
| M2 | 200 | 500 | 40.0 | 15 | 340 | 68.0 |
| M3 | 75 | 251 | 29.9 | 14 | 179 | 71.3 |
| M4 | 85 | 280 | 30.4 | 12 | 202 | 72.1 |
| M5 | 100 | 265 | 37.7 | 15 | 182 | 68.7 |
| M6 | 60 | 320 | 18.8 | 16 | 210 | 65.6 |
| M7 | 40 | 192 | 20.8 | 16 | 127 | 66.1 |
| M8 | 65 | 270 | 24.1 | 16 | 180 | 66.7 |
| H1 | 105 | 420 | 25.0 | 16 | 210 | 50.0 |
| H2 | 120 | 360 | 33.3 | 15 | 190 | 52.8 |
| H3 | 80 | 380 | 21.1 | 12 | 195 | 51.3 |
| H4 | 40 | 240 | 16.7 | 28 | 125 | 52.1 |

***** Note: major and husking Rice Mill: These mill categories both dry paddy on concrete drying floor under open sun and have no mechanical dryer. They may have a rubber roller rice sheller or a traditional Engelberg huller (or both), with capacity of no more than 4 ton/hour. The major rice mills have storage facilities and can thereby operate in the off-season. However, husking rice mills do not have storage facilities, so operating days are limited to seasonal availability of paddy in the market.

Mid-sized millers able to purchase these dryers will be targeted as early adopters. Meanwhile the program will discuss potential subsidies with the government and explore other avenues for adoption. Alternatively, some millers may choose to purchase one or more of the already available BAU-STR dryers (0.5 ton capacity) as a more modest investment as they build drying capacity over time.

**Achievements**

- The appropriate size of the paddy and parboiled rice dual-use dryer was identified as 12 tons per batch. The dryer will optimize the capacity utilization of both major and husking mill to 72.5% when paired with huller capacity of at least 2.5 tons/hour.
- A six-step integrated paddy drying method suitable for both parboiled and aromatic rice has been developed for 12-ton dryer.
- The main structure of the 12-ton dryer has been erected and the installation work of the dryer nearing completion for research and training.

**Challenges**

- COVID-19 situation delayed execution of the survey.

## Objective: BADC Seed Storage Trials

**Activities**

- Continue identifying and adapting best seed management practices for BADC as necessary (Hermetic bags and Cocoons)
- Develop best paddy seed management module for public sector BADC

**Progress**

In the study, efficacy of a 30 ton capacity hermetic cocoon for large-scale storage of Boro and Aman paddy seed was evaluated along with traditional storage practices with gunny bags. For storage of *Boro* 2020 (July-November, 2020) and Aman 2021 (January-May 2021) paddy seed, 3 hermetic cocoons (30-ton capacity each) were set up for comparing technical and financial performance with traditional (30-ton stack of gunny bags) large-scale seed storage system at BADC seed processing center, Madhupur, Tangail. Indoor temperature and relative humidity were measured at 1 hour intervals; O2 and CO2 level were monitored twice a day for the first 31 days. Moisture content, germination rate and insect infestation of traditional storage system were also measured in 15 days intervals. However, moisture content, 1000-grain weight, germination, purity test, physical inspection of seed for hermetic storage were conducted at the days of storage and final opening. Technical parameters for Boro 2020 and Aman 2021 experiments are shown in Tables 1 & 2. In traditional storage, BADC had to apply several rounds of insecticide, fumigation, re-drying and re-stacking which are labor intensive and risky for human health. Hermetic cocoon reduces labor and operator/technician costs as it eliminates the need for intermittent activities between storage and final retrieval of seed for distribution. The estimated payback period of cocoon was found about one year, and 5% germination loss was saved by hermetic cocoons over traditional storage. This study reveals that non-duty (at present 26% tariff and duties on import) hermetic cocoons would be a useful paddy seed storage technology for large-scale seed storage in BADC.

**Table 1: *Comparison of technical parameters in Boro* 2020 (July-November, 2020)**

| Parameters | Moisture Content % | | Insect Infestation | | Germination rate % | | Storage loss, % | $O_2$ & $CO_2$ | |
|---|---|---|---|---|---|---|---|---|---|
| | Storage day | Opening day | Storage day | Opening day | Storage day | Opening day | | $O_2$ (%) | $CO_2$ (%) |
| Traditional Gunny Bag | 11.37 | 11.67 | None | None | 89.0 | 84.25 | 0.65 | Ambient | Ambient |
| Hermetic Cocoon | 11.37 | 11.37 | None | None | 89.0 | 91.0 | 0.067 | 19.86-3.70 | 0.44-11.24 |

**Table 2: *Comparison of technical parameters in Aman* 2021 (January- May, 2021)**

| Parameters | Moisture Content % | | Insect Infestation | | Germination rate % | | Storage loss, % | $O_2$ & $CO_2$ | |
|---|---|---|---|---|---|---|---|---|---|
| | Storage day | Opening day | Storage day | Opening day | Storage day | Opening day | | $O_2$ (%) | $CO_2$ (%) |
| Traditional Gunny Bag | 12.57 | 12.01 | None | None | 89.83 | 91.47 | 0.343 | Ambient | Ambient |
| Hermetic Cocoon | 12.47 | 12.23 | None | None | 89.83 | 92.94 | 0.0175 | 20.53-6.09 | 0.35-12.02 |

Based on the BADC practices documented by PHLIL during these experiments, the team is producing extension materials on best management practices of paddy seed storage to be transferred to BADC soon.

**Achievements**

- Performance of hermetic cocoons and GrainPro bags were compared with traditional current practices at the BADC large-scale paddy seed storage facility at Madhupur as well as at BADC's seed production center in Mymensingh.
- Hermetic storage technology omits the need for intermittent activities during seed storage, including fumigation, spraying, re-drying and re-stacking, periodic moisture contents measurement and germination tests. This reduces the cost of associated labor, including operators and technicians. This also helps safeguard the health of BADC staff, since they would no longer need to handle insecticides.
- Hermetic storage is a technically feasible, environmentally safe and pollution free storage technology. It will be financially more attractive over traditional storage if it is made available as a duty- free agricultural commodity and/or becomes locally produced.
- Hermetic cocoons can be prescribed for use in storing large-scale paddy seed in the tropics and Feed the Future countries like Bangladesh.

**Challenges**

- Quality of stored paddy seed is subject to potential changes when stored in traditional jute bags and at ambient room conditions due to the variation of temperature and relative humidity.

## Objective: Engagement and Policy Advocacy

**Activities**

- Engagement advisory team meeting
- Development and application of virtual dissemination tools (video clip) of drying and storage technologies.
- Policy dialogues for post-harvest technologies adaption and dissemination issues

**Progress**

*Product Life Cycle partnerships and strategies*

PHLIL-Bangladesh has conducted several knowledge sharing and policy dialogue meetings with different public and private organizations. PHLIL-Bangladesh PI Professor Dr. Md. Monjurul Alam and Research coordinator Professor Dr. Chayan Kumer Saha have engaged in discussions with Md. Benozir Ahmed,

Project Director of the Government of Bangladesh's Department of Agricultural Extension (DAE) Farm Mechanization project, in which the BAU-STR dryer has been included for Government-subsidized scaling. Dr. Saha has also been appointed as a member of the Farm Mechanization project's technical committee. Key DAE personnel visit to the PHLIL Advanced Labs at BAU on April 3, 2021. The PHLIL team updated them on the effectiveness and farmers' eagerness to adopt the BAU-STR dryer, as well as other post-harvest loss interventions. Attendees included: DAE mechanization program Director and Deputy Directors and high-level DAE officials. On September 6, 2021, former Education Secretary and present curator of the Father of the Nation Bangabandhu Sheikh Mujibur Rahman Memorial Museum Md Nazrul Islam Khan (NI Khan) also visited the PHLIL-Bangladesh Advanced labs to be apprised of post-harvest loss challenges and interventions.

In terms of new scaling partners and pathways, beyond the Farm Mechanization program: BAU has signed an MoU with CIMMYT-Bangladesh. Discussions are also underway to strengthen linkages with other USAID funded projects, with scaling of the BAU-STR dryer as a key objective.

In terms of formal scaling partnerships that have evolved: In 2021, a tri-party agreement was signed, between PHLIL-Bangladesh project, AgroMech Development Initiative (ADI) Foundation and ACI Motors Ltd. According to the agreement: ADI will manufacture the BAU-STR dryer, and during the manufacturing process the PHLIL-Bangladesh project team will supervise production quality of the production and testing of the final product. ACI Motors Ltd. will conduct nationwide marketing of the BAU-STR dryer for the Government subsidy program through their extensive, established marketing channels. ADI and ACI are responsible for manufacturing and selling at least 350 BAU-STR dryers per year. ACI will also provide after-sales servicing through their service centers for large scale dissemination. These partnerships represent critical scaling pathways down the product life cycle, to ensure that PHLIL scaling is sustained beyond the lifespan of the project.

**Achievements**

- Mass production of BAU-STR dryer has been started locally

**Challenges**

- Strict supervision will be required to maintain the quality of the dryer

*Product Life Cycle engagement activities*

PHLIL-Bangladesh has continued to lead a series of trainings and other engagements, with key scale-up partners and end-users. This included:

1. Post-harvest technology (drying and hermetic storage) knowledge sharing meetings for BADC personnel at Madhupur, Tangail on November 3, 2020.

2. Online-based knowledge sharing meeting with the Deputy Director and Assistant Director of BADC Mymensingh and Tangail (respectively) seed processing centers on June 15, 2021.

3. Professor Saha delivered a virtual presentation on the BAU-STR dryer for paddy rice at the Institution of Engineers, Bangladesh (IEB) on January 24, 2021. The 77 attendees included leading engineering professionals and policy level stakeholders.

4. Professor Alam contributed to a seminar about "Agricultural Mechanization in Bangladesh: Present Status and Future Strategy" as a special discussant on January 7, 2021. Agriculture Minister Dr. Mohammad Abdur Razzaque was present as chief guest. Dr. Alam talked about the post-harvest loss reduction technology with the minister and convinced him to take necessary measures to disseminate the BAU-STR dryer and hermetic bags in the country.

5. The Government of Bangladesh Agriculture Information Service (AIS) has been engaged to develop extension documentary films. They will use scripts that PHLIL has developed for the BAU-STR Dryer and hermetic storage technologies. Video shootings will be starting as soon as the COVID-19 pandemic situation permits.

**Achievements**

- Public and private organizations have been informed about PH technologies through several meetings and knowledge sharing activities.
- Several agreements have been formalized with scaling-level private sector product life cycle partners.
- Video scripts are ready for video shooting. These training modules will enable extension to be conducted during the COVID-19 pandemic, given their online nature.

**Challenges**

- Video shooting of the technologies are delayed due to COVID-19 pandemic situation.

### Objective: EMMP compliance

**Activities**

- Maintain log book to track the hermetic bags and cocoons
- Record details of disposal of hermetic bags and cocoon

**Progress**

One hundred seventy eight (178) hermetic bags were used and distributed during Aman 2021 where in BADC, 90 hermetic bags were used for the experiment and 88 hermetic bags were distributed among the selected farmers for storing their paddy seed. The damaged bags were collected in project office from the field and disposed according to the standard procedure. A log book has been maintained.

**Achievements**

- A log book has been maintained to track the collection, distribution and damaged hermetic bags.

**Challenges**

- Sustained engagement is necessary to ensure motivation of farmers and BADC personnel for proper disposal of hermetic bags and cocoons.
- Monitoring of cocoons and hermetic bags during the COVID 19 pandemic was challenging and sometimes slightly delayed in terms of collection of on-farm information.

### Objective: Ag Reach-BAU conduct a gender technology assessment

**Activities**

- Finalize Gender-Based Technology Profile
- Co-development of entrepreneurship (business proposition model for gender and youth engagement) strategy on BAU-STR dryer and hermetic storage technologies
- Training on gender dimensions and sensitization on drying and storage technologies

**Progress**

PHLIL partner AgReach previously developed a Gender-Based Technology Assessment tool to identify opportunities and help address challenges to scaling technologies with women. A survey was conducted at Phulpur, Mymensingh and Monirampur, Jashore, districts of Bangladesh to develop two gender-based technology profiles. Based on this, gender based technology profiles of BAU-STR dryer and hermetic bag have been developed. A draft report on literature review has already been developed.

Outputs and findings include:

1. Literature review on co-development of entrepreneurship on BAU-STR dryer and hermetic storage technologies.
2. Women are responsible for post-harvest activities including winnowing, parboiling, drying, storing and sometimes threshing in rice fields. By using BAU-STR Dryer and Hermetic Bags, women's time invested in these activities has been greatly reduced.
3. Because the BAU-STR Dryer effectively dries paddy, even in inclement weather, women feel less anxiety about drying and storage. Furthermore, hermetic bags eliminate the need for women to conduct any intermittent drying, cleaning and re-storing during the seed storage period.
4. Both paddy and seed quality remain intact, so women can sell it for a fair price.

Short term trainings on gender dimensions and sensitization were done in Phulpur of Mymensingh district and Monirampur of Jashore district, in person before the Covid-19 pandemic. Subsequently, virtual trainings were conducted in Maria Village, Sajahanpur, Bogura district (32 participants, M: 11, F: 21); Kathaltola Village, Dumuria, Khulna district (32 participants, M: 13, F: 19); and Rakudia Village, Babuganj, Barishal district (30 participants, M: 12, F: 18) in December, 2020. The objective of those trainings was to build awareness among the female household members. But in reality we found that most of the female household members are neglected though their contributions are great in their family; most of their contributions are not recognized. Since they are unpaid workers, men fail to recognize the value of their contributions. Even the subset of women who inherit land are likewise neglected, and they receive the least productive land. While women recognize and report this disempowerment themselves, they have not felt empowered to raise the issue with their husbands. PHLIL gender sensitization training is helping with this issue.

**Achievements**

- By effectively reducing post-harvest losses and labor requirements using the BAU-STR Dryer and Hermetic Bags, women have gained confidence in adopting new technologies.
- Male partners have realized the importance of women labor in managing post-harvest activities through gender sensitization training.
- Women have realized that their family contributions are also important, and to secure their appropriate family positions they must be empowered along with their husbands. They have resolved to convince their husbands for enhanced recognition by seeking gradual empowerment.

**Challenges**

- More sensitization training will be required for building awareness and driving women's empowerment.
- Women's labor in the family is always considered as an unpaid job, going unrecognized in terms of monetary value.
- Though, post-harvest activities are mainly conducted by women, they lack social recognition due to lack of proper education and social prejudices.
- Even though women do hard work for the family, they are deprived of many fundamental rights like nutritious food.
- Due to COVID 19 pandemic, further interaction and gender sensitization training was not possible.

### Objective: Workshop and Symposium

**Activities**

- Arrange post-harvest and ag mechanization symposium for national and regional level stakeholders (partner with Sustainable Intensification Innovation Lab's Appropriate Scale Mechanization Consortium)

**Progress**
Post-Harvest Loss Reduction Innovation Lab (PHLIL) Bangladesh team, Department of Farm Power and Machinery, Bangladesh Agricultural University organized the 2020 PHLIL Bangladesh Virtual Annual Workshop on "Appropriate Postharvest Practices: A Key to Reduce Postharvest Loss in Bangladesh." The virtual meeting was held on September 9, 2020, attracting a total of 167 participants.

The workshop was divided into inaugural, panel discussion and closing sessions. In the inaugural session of the workshop, Honorable Secretary Md. Nasiruzzaman, Ministry of Agriculture, Government of the People's Republic of Bangladesh was present as the Chief Guest; Honorable Vice-Chancellor Professor Dr. Lutful Hassan, BAU, Mymensingh was present as the Chief Patron; Professor Alex Winter-Nelson, Director, ADM Institute for the Prevention of Postharvest Loss, University of Illinois at Urbana-Champaign, was present as the Special guest; and Dr. Jagger Harvey, Director, Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss, KSU, chaired the inaugural session. Dr. Alam delineated PHLIL Bangladesh activities, outcomes, achievements and future plans through his keynote presentation.

The theme of the panel discussion session was "Securing Food for Millions by Post-Harvest Loss Reduction". In this session distinguished panelists included: Dr. Md. Abdul Muyeed, Director General, Department of Agricultural Extension (DAE), Bangladesh; Professor Alam, Principal Investigator, PHLIL-Bangladesh, Bangladesh Agricultural University; Engineer Subrata Ranjan Das, Executive Director, ACI-Motors Limited, Bangladesh; Dr. M. A. Matin, Former Director General, Rural Development Academy (RDA), Bangladesh; and Mr. Md. Nurunnabi Sarder, Member Director (Seed and Horticulture), Bangladesh Agricultural Development Corporation (BADC). The session was moderated by Professor Dr. Chayan Kumer Saha, Research Coordinator (Drying), PHLIL-Bangladesh, BAU.

In the closing session, Professor Dr. Md. Nurul Hoque, Dean, Faculty of Agricultural Engineering & Technology, and Convener of the Dean Council, BAU, Mymensing; and Professor Dr. Md. Jasimuddin Khan, Pro-Vice Chancellor, BAU, Mymensingh, Bangladesh were present.

**Key messages from Product Life Cycle stakeholders at the workshop include:**
*"BAU-STR dryer is the appropriate drying solution at the farmer's level as well as small trader's level and larger capacity re-circulating batch dryer at the husking mill level. Hermetic cocoons will be the best options for bulk seed storage at the BADC seed processing center. Post-harvest loss reduction of fruits and vegetables is needed to be focused on and collaborating partnership among the researcher, public sector and private sector to disseminate and scale up of those technologies is essential."- Professor Dr. Md. Monjurul Alam*

*"The feedback of disseminated BAU-STR dryer is good. For scaling up of the technology, promotional activity is very much essential."- Dr. Muyeed*

*"Though hermetic bag/cocoon is [more] expensive than jute bag but Return on Investment (RoI) and positive impact is much higher than the jute bag."- Engineer Subrata Ranjan Das*

*"Local manufacturers must be strengthened so that they can produce quality machinery. Research lab like the PHLIL-BD project should create new business opportunities."- Dr. M. A. Matin*

*"Appropriate storage system is needed for BADC so that time to time seed sample can be collected easily for testing."- Mr. Md. Nurunnabi Sarder*

*"The use of BAU-STR dryer is simple and easy."- Khudeza Begum, female lead farmer, Mymensingh.*

*"BAU-STR dryer reduces cost and time of drying."- Md. Humayun Kabir, Seed trader, Comilla*

*"The results and ideas shared in this workshop will help in achieving food security in Bangladesh." - Dr. Md. Nurul Hoque*

*"The workshop has provided a useful platform to exchange knowledge and ideas about post-harvest loss reduction."- Dr. Md. Jasimuddin Khan*

A virtual Symposium is being organized during 3rd week of November, 2021. The symposium will comprise the post-harvest and agri-mechanization issues for national and regional level stakeholders (partners with ASMC and SIIL). The best innovative ideas of students regarding smart technology in agriculture will be highlighted in the symposium.

**Achievements**

- The workshop participants received a clear, research evidence-based message about the suitability of BAU-STR dryer in drying multiple grains (paddy rice, maize and wheat) from trusted leaders in national agriculture.
- The performance of BAU-STR dryer & hermetic storage bags, and the reflection of the field level users (including lead farmers) have drawn the attention of participants and dignitaries.

**Challenges**

- Hermetic bag/cocoon is considered as a plastic product in Bangladesh and is subject to a 26% import duty. This is the main reason for its high price at the field level. Hermetic bags should be considered as essential tools for agricultural productivity, translating to waiving the import duty.

### Objective: Preparation of scientific manuscript(s) and interim and final reports

**Progress**

Journal papers:

- M. A. Hossain, M. A. Awal, M. M. Alam, M. R. Ali, M. T. H. Howlader and A. Zahan (2021). Prevalence of insects in traditionally stored rice at farmhouses in Bangladesh. Aust. J. Eng. Innov. Technol., 3(3), 34-44.
- M. A. Hossain, M. A. Awal, M. M. Alam, M. R. Ali, F. A. Huda, and A. Zahan (2021). Do hermetic storage technologies significantly abate losses of rice over time? An economic evaluation. *Int. J. Manag. Account.* **3**(3), 52-59.
- M. A. Hossain, M. A. Awal, M. R. Ali, Machbauddin and M. M. Alam (2020) Prediction of Paddy Germination Stored in Different Technologies Using Artificial Neural Network. International Journal of Statistical Sciences, 20 (2), pp 267-276.
- Roy, D., Saha, C. K., Alam, A., Sarker, T. R., Alam, M. (2020) Evaluation of S4S Solar grain dryer for drying paddy seeds, CIGR Journal, 22(4), 200–210.

Conference paper/presentation/abstract:

- Saha, C.K., Ahamed, S., Sarkar, S., and Alam, M.M. (2021). Identification of Appropriate Size and Operating Parameters of Recirculating Paddy Dryer for Major and Husking Rice Mill of Bangladesh. 2021 ASABE Annual International Virtual Meeting 2100768. doi:10.13031/aim.202100768.
- Gope, S.N., Ali, M.R., Awal, M.A., Alam, M.M., Nelson, A.E.W. (2021). Efficacy of Hermetic Cocoon for Large-scale Paddy Seed Storage in Bangladesh. A presentation at the ASABE Annual International Meeting.
- Alam, M.M., Saha, C.K., Md. Abdul Awal, M.A., Md. Rostom Ali, M.R. and Begum, I.A. (2021). Sustainable paddy drying and storage technologies in Bangladesh. An abstract submitted at the BAURES.

Blogs

- Saha, C.K. (2020) On and Off-Farm Mechanization in Bangladesh: A Sustainable Approach to Ensure Food Security. A blog post published in the ADM Institute for the prevention of Post-harvest Loss, University of Illinois, https://postharvestinstitute.illinois.edu/bangladesh-virtual-workshops/

Magazine:

- Saha, C.K. and Alam, M.M. (2021) BAU-STR Dryer: A Sustainable Grain Drying Technology in Achieving Food Security. Special Publication of an Atlas on the Occasion of Bangabandhu's Birth Centenary by BAURES.

**Achievements**

- Published 4 journal articles, 1 conference paper, 1 conference presentation, 1 workshop abstract, and 1 blog post
- Submitted 1 abstract and 1 magazine article
- Research activities highlighted in the ADM Institute Newsletter

**Challenges**

- In spite of the COVID-19 pandemic, the field survey and laboratory research work was conducted maintaining social distancing and other precautions, resulting in publication of peer-reviewed research articles.

### Objective: Capacity Building

*In-country leads' involvement in capacity building:*

**Activities**

- Attendance and knowledge sharing in national/international conferences/seminar/workshop
- Management visit for sharing ideas and planning research

**Progress**

The PHLIL BAU team delivered the following additional presentations to convey progress to Product Life Cycle stakeholders:

- Recent research findings of PHLIL-Bangladesh project were presented virtually in the Bangladesh Agricultural University Research System (BAURES) Annual workshop on the theme "Transforming Agricultural Research to Offset COVID-19's Impacts on Bangladesh" on May 29, 2021.
- Two presentations were delivered at the 2021 ASABE annual international meeting on July 14, 2021. The presentation on "Efficacy of Hermetic Cocoon for Bulk Paddy Seed Storage in Bangladesh" was given by Professor Dr. Md. Monjurul Alam and the presentation on "Identification of Appropriate Size and Operating Parameters of Recirculating Paddy Dryer for Major and Husking Rice Mills of Bangladesh" was given by Professor Dr. Chayan Kumer Saha.

**Achievements**

The suitability of BAU-STR dryer and hermetic storage technologies were conveyed to the public and private sector stakeholders.

- Suitability of hermetic storage technology (Cocoon) for large scale paddy seed storage at BADC seed center and meso scale paddy dryer was shared with the international research community.

**Challenges**

- In the context of the ongoing pandemic, where in person meetings are more challenging or not possible, these professional seminars were found to be the most effective practical means of developing awareness and helping to inform policy changes.

### *Drying-related capacity building:*

**Activities**

- Demonstration and monitoring of BAU-STR dryer in selected areas
- Development of entrepreneurship modules, particularly focused on youth, to encourage private-sector scaling of the BAU-STR dryer
- Development of Training modules for the 12 ton dryer
- Capacity building of the meso scale dryer manufacturing workshop on improved design and manufacturing

**Progress**

A total of 207 individuals (110 Male and 97 Female) of Mymensingh, Jhalokathi, Barishal, Jashore, and Kishoreganj districts were trained on the proper use of the BAU-STR dryer, through demonstration. All the participants completed and accomplished the goals of the short-term training.

Training modules of BAU-STR Dryer (in English and Bengali) have been prepared and are in the final review stage to prepare the final materials. Business modules of the BAU STR dryer are also being prepared to encourage youth to start drying businesses centered around the BAU-STR Dryer.

**Achievements**

- 207 individuals trained about the operation of BAU-STR dryer, with a focus on including youth trainees
- Participants reported finding the installation and operation of the dryer very simple and easy

### *Storage-related capacity building:*

**Activities**

- Demonstration and monitoring of hermetic bags in selected areas
- Capacity building of BADC paddy seed storage (ToT, demonstration)

**Progress**

Four training programs on demonstration of hermetic bags and benefit of hermetic cocoons were conducted at Phulpur, Mymensingh; Horina, Jashore; Wazirpur, Barishal and Nalchity, Jhalokati. Both male (44) and female (50) farmers participated in the trainings. They are now able to effectively use hermetic bags for storing their paddy seed. Capacity of BADC personnel at Madhupur, Tangail and Balaspur, Mymensingh seed processing centers has also been built on how to use hermetic cocoons for bulk seed storage.

In addition to previous trainings, a hands-on training on importance and use of improved hermetic storage technologies was conducted for village-level mechanics (31 Male). This training was organized by DAE at their Horticulture Center in Mymensingh.

Training manuals on improved storage technologies (in Bangla and English) are in press.

**Achievements**

- Effectiveness of hermetic bags and cocoons were conveyed through five training programs at different locations of Bangladesh.
- These trainings enhanced understanding level and skill of farmers and relevant stakeholders on hermetic bag and cocoon.
- Village-level mechanics were engaged as an important Product Life Cycle group that will be important as the BAU-STR dryer scales.

**Challenges**

- Due to the COVID 19 pandemic situation, appropriate health and safety precautions were taken during training programs.

### Objective: Provide Logistical support to KSU Agricultural Economics Team for Designing and Implementation of the Randomized Control Trial on Hermetic Seed Storage Adoption

**Major activity:**

- Preparation of Midline survey report

**Progress**

- The PHLIL-Bangladesh team worked as a liaison between the local agricultural extension officers and the HKI-BD team. Communication bridge between HKI and DAE personnel was established so that, the HKI personnel can easily identify the farmers in the Sherpur sadar, Nakla, Nalitabari, Narail sadar, Kalia, and Lohagara upazila of Bangladesh.
- For conducting endline survey smoothly, a letter was given to DAE officials on January 26, 2021 for the field level cooperation in introducing enumerators from HKI.

**Achievements**

Successful partnership has been developed between HKI-BD and PHLIL-Bangladesh (BAU) team. Activities of HKI-BD will be helpful to assess the demand of hermetic bags at the field level.

**Challenges**

No challenges were found

### Objective: [AG ECON]: Implement the Endline Randomized Controlled Trials and Survey in Bangladesh

**Activities**

- Finalize the design of the RCTs and survey questions
- Implement the RCTs and survey
- Process data

**Progress**

The PHLIL-Bangladesh team worked as a liaison between the local agricultural extension officers and the Helen Keller International (HKI) team. Communication bridges between local HKI and the Department of Agricultural Extension (DAE) personnel were established so that the HKI team can easily identify farmers in the Sherpur Sadar, Nakla, Nalitabari, Narail Sadar, Kalia, and Lohagara Upazilas of Bangladesh. In order for the Ag Econ team to be able to conduct their endline survey, and to enhance field level cooperation with HKI enumerators, a letter was provided to DAE officials by BAU in January 2021.

The endline survey was significantly adapted based on preliminary observations from the baseline survey with regard to willingness-to-pay (WTP) for GrainPro bags. After finding a low WTP amongst participants from the baseline survey, the team decided to repeat the RCT of the baseline during the endline survey, among other adjustments, treatments, and changes. Additional modules were added to the questionnaire to collect information about price, utilization, and preferences around the use of GrainPro bags. During endline activities, the Ag Econ team reached 887 households and obtained willingness-to-pay estimates for 886 households. During the auction, 158 households won and received the bags. In January 2021, HKI enumerators were trained. The HKI team and enumerators completed the RCTs and survey in February 2021, and the HKI team is currently cleaning the data.

Finally, discussions are ongoing between the PHLIL Ag Econ team, HKI, and BAU regarding a late 2021 dryer survey that would assess the preliminary impacts of the BAU-STR dryer on the rural farm economy.

HKI team is currently doing the initial cleaning of the data.

**Achievements**
During the endline activities, the team reached 887 households and obtained willingness-to-pay (of a GrainPro bag) estimates for 886 households. During the auction, 158 households won and received the bags.

Data have been cleaned and ready for the analysis.

**Challenges**
Compared to the baseline, we have 8 households migrated. Also, there were some households with issues such as refusing to follow the term of the endline activities or absent due to various reasons.

### Objective: [AG ECON]: Analyze Data and Draft Manuscript(s) for the Bangladesh Study

**Progress**
Preliminary analyses have been done with the baseline data. The analyses helped develop the endline activities. The team decided to do the analyses using both rounds of the data.

**Achievements**
The team produced some preliminary results and developed the endline activities.

**Challenges**
N/A

# Ethiopia

**Focus Crops:** Chickpea, Maize, Sesame, Sorghum, Wheat
**Location:** *Ambara 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

***Overall: significant challenges were increasingly faced as the security situation in Tigray and elsewhere unfolded. This was discussed with our AOR and he stressed that safety of our partners is the primary consideration.***

### Objective: Assess existing PHL extension manual for deficiencies and finalize materials as needed.

**Progress**
The extension manual was revised and edited by the team members in two separate cycles and provided to the in-country team for further revision. The final version is pending a last round of input. Upon completing the final version, recommendations will be made to translate the extension manual into several languages.

- revisions from several team members were gathered
- so far it has been translated into Tigragna

**Achievements**
Rizana Mahroof and Jagger Harvey have revised the manual for the second time, incorporating necessary changes since the first revision.

**Challenges**
- Some critical issues addressed related to the manual were discussed during monthly meetings and recommendations were made to resolve these issues.
- Some critical comments raised the need for additional input from KSU and SCSU.

### Objective: Engage National Post-Harvest Loss Advisory Committee

Continue supporting the National PHL Advisory Committee to assist Ethiopian stakeholders in developing national strategies related to post-harvest, including continuing to serve on the committee as the Government prefers.

**Progress**
- Evaluation and monitoring of overall activities of the PHL project in Ethiopia.
- Improved, validated PHL technologies were promoted and incorporated in the regional agricultural strategies.
- Post-harvest loss of grains at various stages of production were reviewed; results on PHL improved storage, drying, and moisture meter were sensitized with the Advisory Committee, for scale up in Ethiopia.

**Achievements**
- Evaluation and monitoring of overall activities of PHL project in Ethiopia

**Challenges**
- COVID 19 restrictions and the Tigray region crises affected scheduled meetings.

### Objective: Host and attend various forums and events related to PHL to disseminate and share knowledge gained through our research

Continue holding post-harvest related trainings for farmers and Ag. extension personnel

**Progress**
Training conducted on integrated approaches for post-harvest loss reduction of maize grain. Topics covered included mechanical threshing, solar drying, hermetic storage, and samples were stored in different hermetic and PP bags for six months. The two training sessions included:

- Adet-Alway district, 35 Km far from Bahir Dar city, for small holder farmers on December 30, 2020
- Burea-Alefa district, 150 Km far from Bahir Dar city, for small holder farmers on January 30, 2020

**Achievements**
Before introducing the technologies, farmers were encouraged to raise their most significant maize post-harvest problem. In doing so, an interactive training style was employed to identify the key challenges faced by farmers during the post-harvest period of maize.

Following the identification of key post-harvest challenges common to all the farmers, the trainers practically demonstrated the technologies so that farmers' challenges were addressed.

Finally, the mechanically threshed maize was put in PICS and ZeroFly bags, using woven polypropylene and traditional gotta as controls. Those bags are kept for six months in five selected farmer's houses in Kebele, where grains are typically stored. Each type of bag is represented in each of the farmers' houses. This study is meant to enable farmers within these communities to witness the performance of the storage technologies first-hand.

**Challenges**
Lack of sufficient funds, pandemic, conflict in Tigray

### Objective: Global Linkage of PHLIL -Ethiopia: participation in conferences/tailor made meetings

**Progress**

- One oral paper presented at International Conference on Advancement of Science and Technology (ICAST-2020) on October 3, 2020 at Bahir Dar institute of Technology, Bahir Dar, Ethiopia
- One poster paper presented at International Conference on Advancement of Science and Technology (ICAST-2021) on August 28, 2021 at Bahir Dar institute of Technology, Bahir Dar, Ethiopia

**Achievements**

- Disseminating the major findings of PHLIL project for the participants

**Challenges**

- COVID-19
- Budget transfer timing

### Objective: Enhance the inclusion of women and youth in PHL decision-making technology uptake

Engage youth and women in the distribution across the value chain.

**Progress**
Gender-inclusive on-farm training on use of storage bags, the solar bubble drier, and moisture tester demonstration was conducted at the beginning of September.

**Achievements**
Telephone communication was used to target specific youth and women to participate in training and technology dissemination.

**Challenges**
- Movement restriction due ongoing crises
- Food shortage is a major challenge for women to feed their kids (shared during telephone communication)

### Objective: Integrated PHL technology MSc student graduates

Disseminate MSc student researcher results on integrated experimentation

**Progress**
Nutritional analysis: Moisture content, crude protein, crude fat, crude fiber, and ash of the sorghum grain flour were determined according to AACC, (2000) standard method at Mekelle University Food Science and post-harvest technology Biology and Chemistry Department Laboratory.

Sensory evaluation: The injera made of sorghum that was stored in PICS bag, polypropylene bag, and underground pit storage technologies at the start, three and six months of the storage experiment was evaluated by 30 sensory panels (15 men and 15 women), comprised of farmers who are familiar with sorghum injera as daily consumers, to assess the sensory quality of the product.

Physical parameters to be evaluated: The germination rate of stored seed was measured for each storage technology used. Germinated and ungerminated seeds were counted until the 7th day of the test.

At Bahir Dar University, Bahir Dar institute of Technology, one MSc student is working on thesis work, focused on an integrated post-harvest management approach that includes mechanical threshing, solar drying and different storage structures/technologies for the reduction of post-harvest loss of maize grain. The Master's thesis was successfully defended.

**Achievements**
- Impact of drying, location, and storage duration on grain nutritional, physical, and sensory quality of sorghum stored in different post-harvest preservations strategies was evaluated.
- Effect of threshing methods and storage structures on physio-chemical properties of maize grain during storage assessed.
- Effect of several post-harvest management factors on grain susceptibility to insect infestation and damage assessed, including: grain moisture content during threshing, threshing methods, cob drying, and storage structure/technology.

**Challenges**
- COVID 19 restriction was a major challenge during the sample collection from experimental sites
- cost of nutritional analysis

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

Distribution of hermetic bags and small-scale mechanization technologies.

**Progress**
- Discussions were undertaken with the regional engagement team regarding the establishment of a distribution system for PHL technologies.

- Regional research centers and agricultural officials agreed to scale up and further distribute improved PHL technologies through the extension system.
- Mechanical thresher and hermetic storage bags (PICS and Grain Pro) were introduced to smallholder farmers who lived in East and West Gojjam, Amhara Region.

**Achievements**

- High sorghum post-harvest loss due to insect and molds highlighted to key scaling partners and smallholder farmers.
- Improved storage bags, drying facilities, and moister meter issues were incorporated in the regional intervention program to address the demands raised by farmers.
- Smallholder farmers understand the advantages of mechanical thresher and hermetic storage technologies and are willing to use them.

**Challenges**

- some regional engagement team meetings were limited due new regional structural changes and conflict
- a six month extension is required to complete further activities related to scaling

### Objective: Pesticide residue in economically important grains

- Continue awareness creation & sensitization of pesticide residue protocol development
- Review the risk associated to pesticide residue in stored grains
- Finalize and distribute residue validation SOPs

### Objective: Mycotoxin analysis of economically important grains

Mycotoxin analysis and capacity building activities

**Progress**

The original plan for Dr. Bianchini's (UNL) engagement in this activity was to further enhance the capacity of these labs and technical personnel. This included an anticipated hands-on training, as well as some targeted purchase of materials (eg, a subsampling mill, Certified Reference Materials). This was to be accomplished with resources shifted when PHLIL had to close down its Guatemala activities; in coordination with our AOR, Dr. Bianchini was shifted to support the Ethiopia team.

As a first, important step, progress has been made by Dr. Bianchini's team at UNL towards validating the detection platform for the quantification of mycotoxins in the commodities of interest. This included the development of SOPs for technicians in Ethiopia.

**Achievements**

- Validation of mycotoxin detection platform (AgraQuant, Romer Labs) for quantification of aflatoxin, fumonisin and deoxynivalenol in maize and sorghum. Recoveries at two different contamination levels (low, high) have been performed. Pending: Ochratoxin
- Detailed SOPs for each mycotoxin have been developed. Pending: Ochratoxin.

**Challenges**

- Some mycotoxins (i.e. deoxynivalenol) required modifications in extraction steps to guarantee adequate toxin recovery.
- Due to the pandemic and evolving security crisis in Ethiopia, the PHLIL team made several changes to the plans for Dr. Bianchini to support Mekelle and Bahir Dar universities. A series of planning meetings and associated activity/budget scenario assessments took place between Dr. Bianchini, the

Management Entity, Ethiopian partners and Dr. Ulmer (KSU Ethiopia PI). The team shifted the plan for a possible virtual training, and changes were made to the UNL training material to be provided to personnel in Ethiopia. The ME considered the possibility of having the training hosted at the International Livestock Research Institute campus in Addis. However, given the further devolving situation, it seems unlikely this will necessarily be accomplished. The training materials are available should the opportunity for the virtual training arise, which the program is hopeful for.

### Objective: Explore Compiling Ethiopian PHLIL Project Research Output as a Book

Compile relevant material for potential inclusion in an educational reference book.

**Progress**

- several teams were established from universities, research centers, private companies
- book content development has been started
- email correspondence undertaken with different teams before internet lockout

**Achievements**

- team establishment
- book content development underway

**Challenges**

- internet lockout limited further communication with the established team

### Objective: Validation of Arc'teryx tent dryer for maize and sorghum

Explore the opportunities to pilot test the Arc'teryx dryer with locally important commodities.

**Progress**

- the Arc'teryx team in Canada built several versions of their tent dryer, with input from PHLIL
- The Management Entity liaised with Arc'teryx, Mekelle and Bahir Dar universities and arranged dryer delivery in Ethiopia via DHL
- Experimental sites were prepared for dryer trials
- In-country teams worked to procure freshly harvested maize and sorghum grain
- Validation experiments for the Arc'Teryx dryer were conducted using freshly harvested maize grain and rewetted sorghum (given the ongoing crisis, the team was unable to source fresh sorghum grain). For maize, BDU identified nearby farmers using irrigation so that fresh maize could be sourced out of season.

**Achievements**

For drying of maize at Bahir Dar University:

- The medium size Arc' Teryx dryer (single chimney) was tested.
- 500kg (4cm thickness) of freshly harvested maize grain was used.
- It took 22 hours to reduce initial moisture content of 30.75% (w.b) to13% (w.b)
- A maximum temperature of 60 degree was recorded inside the dryer for 3 consecutive hours of the day.
- The dryer has a faster drying rate than open sun drying system.

**Challenges**

- Facing a problem to get funding for this validation; the Management Entity worked to address this.

- Grain shortage for experimental validation, due to COVID 19 and war crises in the region
- Lack of security to move about in the field and market to source grains

### Objective: Investigating effects of threshing and drying maize on post-harvest losses

**Progress**

- Performance of the solar bubble dryer was compared for maize, either still on cobs or threshed prior to drying. A faster drying rate was observed for solar bubble drying of maize as grain versus on the cob. It took approximately 26 hours for grain drying versus 44 hours for cob drying.
- Mechanical threshing was faster than threshing by hand, as expected.
- Insect pest susceptibility of maize grains dried before threshing (cob drying) and as grain (after threshing) was conducted. Mechanically threshed grains were less susceptible to insect pest-mediated losses than those threshed by hand.

**Achievements**

Overall, evidence was gathered showing the advantages of mechanical threshing. This includes: reduced time required to thresh; reduced time needed for drying in the solar bubble dryer; and reduced susceptibility of grains to insect pest losses compared to hand threshing.

**Challenges**

No

### Objective: Overall Activity Manuscript development from completed research projects

**Progress**

- Draft manuscript on an integrated approach (threshing, solar drying and storage) prepared
- Poster presented at an International Conference on Advancement of Science and Technology, ICAST-2021.

**Achievements**

Research finding are shared with the community

**Challenges**

No

# Ghana

**Focus crop:** Maize
**Location:** Dormaa area (Dormaa East and West districts), Northern Ghana
**Collaborators:** *Universities:* Kwame Nkrumah University of Science and Technology (KNUST), University for Development Studies; *Government:* Ministry of Food and Agriculture (Northern and Upper West regional offices); *NGOs:* Adventist Development Relief Agency; *Private sector:* Poultry farms in Dormaa, Agri Commercial Service Ltd., Vestergaard Frandsen, Sesi Technologies ; *USAID/USG Project Partners:* AMPLIFIES

### Objective: Continue creation of awareness and enhancement of demand for hermetic bags and GrainMate moisture meters.

**Activities**
PI and In-country Coordinator in the field for activities related to research, awareness, demand, and distribution of hermetic bags and GrainMate moisture meters to poultry farmers in Dormaa (Middle Belt) and smallholder farmers in northern Ghana. Cross-cutting teams will work with early adopters of ZeroFly Hermetic (ZFH) bags and GrainMate moisture meters to collect data to improve understanding of factors driving technology adoption.

Assessment of whether cargo motor trikes can facilitate aggressive marketing and taking ZeroFly Hermetic (ZFH) bags closer to customers in northern Ghana, and hence boost sales.

**Progress**
In the last 3 years, at least 12,500 ZeroFly Hermetic (ZFH) bags have been sold and the distribution channels for ZFH bags are taking shape. These 12,500 ZFH bags were for the AMPLIFIES project, but PHLIL played a major role in facilitating their increased adoption. Each ZFH bags retails for $1.6-2.2 (GHS9-12). In the case of GrainMate devices, 397 have been sold since 2018. Each device retails for $90-100 (GHS500-550). Approximately 1,700 ZFH bags were sold in the Northern regions of Ghana in 2018, 2019, and the first quarter of 2020. From April 2020 to date approximately 400 ZFH bags have been sold in the Northern Regions of Ghana.

As of September 7, 2021, 9,825 of the 20,000 ZFH bags purchased by PHLIL had been sold in the Middle Belt and the Upper East Region of Ghana. Sesi Technologies has sold a total of 6,350 ZFH bags during the 2020 and 2021 period; 6,290 getting sold between October 2020 to September 2021.

PHLIL Ghana now has 3 marketing agents for the ZFH bags in Dormaa and 4 marketing agents in northern Ghana. Discussions and planning for importation of additional bags for sale during Year 9 are underway with the Management Entity and key scaling partners.

In 2020, USAID funds were used to lease 3 cargo motor trikes (CMTs) to assess the effects of transport availability on scaling of ZFH bags in northern Ghana. The CMTs were leased in October 2020. Data collected show a total of 403 ZFH bags were sold by agents with CMTs whereas only 27 bags were sold by agents without CMTs. These numbers show that CMTs facilitate aggressive marketing and taking of bags closer to consumers. These numbers should have been much higher but the shortage of maize throughout Ghana at the end of 2020 and in 2021, and associated dampened demand for ZFH bags. Data from this study greatly facilitate future continued scaling of hermetic technologies in Ghana and elsewhere in sub-Saharan Africa. This information can be provided to bag manufacturers of (e.g., Vestergaard and Poly Sacks) and distributors and marketing agents of hermetic technologies to facilitate business.

In the case of GrainMate devices, 861 have been sold since 2018; 555 getting sold between October 2020 to September 2021. Each device retails for $90-100 (GHS500-550).

USAID funds were used to facilitate the installation of a flatbed biomass assisted dryer (FBAD) in Dormaa for the Ghana Women in Poultry Association - Dormaa chapter (WPA paid for all construction costs). This FBAD will facilitate proper drying of maize before it is stored in ZFH bags by the 50 members of the association. Members of this association are currently the biggest market for ZFH bags in Dormaa. The FBAD was completed in July 2021 and handed over to the Dormaa Women in Poultry Association.

| | GrainMates | ZFH Bags |
|---|---|---|
| **2018** | 141 | 0 |
| **2019** | 82 | 0 |
| **2020** | 152 | 477 |
| **2021** | 486 | 5873 |
| **TOTAL** | **861** | **6350** |
| **TOTAL, FY21 only** | **555** | **6290** |

**Table 3:** Sesi Technologies' overall sales numbers of GrainMates and ZeroFly Hermetic bags.

**Achievements**

- Significant increase in ZeroFly Hermetic bags distributed, with the support of the PHLIL program.
- Sesi Technologies began selling ZFH bags in 2020, seeing a substantial increase in bags sold in 2021.
- PHLIL engaged in a public-private partnership to enable the Women in Poultry Association – Dormaa Chapter to install a Flatbed Biomass Assisted Dryer, for use by their 50 members.
- Cargo Motor Trikes enhanced sales agents' effectiveness at selling bags.
- Planning underway to import more ZeroFly Hermetic bags for scaling with key Product Life Cycle partners during Year 9.

**Challenges**

The sales numbers for ZFH bags in 2020 were low because there were delays in supply of bags. The current consignment of 20,000 ZFH bags in the market in Ghana were received from Nigeria on December 5, 2020 yet these bags should have arrived much earlier in the year. These 20,000 ZFH bags had to come by sea. The delay in supplying bags in 2020 was primarily a result of the closure of Nigeria's land borders on August 20, 2019. However, COVID-19 pandemic and the End SARS protests that rocked Nigeria in October 2020 also contributed to the delay. On December 16, 2020, President Buhari ordered the immediate reopening of 4 critical land borders, and all borders will be open by December 31. With Nigeria's land borders now open, we do not expect any delays in the supply of ZFH bags in the future.

Maize shortage in Ghana from September 2020 until now (September 2021) dampened the demand for ZFH bags. Demand for bags is expected to increase towards the end of 2021.

### Objective: MPhil student at KNUST conducts research, data summarization and analysis, and manuscript writing.

**Progress**

An MPhil student sponsored by PHLIL at KNUST is currently doing course work and conducting research on some of the innovations identified during PHLIL Year 1-5 activities. In February 2021, the student presented their MPhil proposal at the KNUST Department of Crop and Soil Science. This student is supervised by Drs. Enoch Osekre and George Opit.

Student has completed data collection on all activities associated with the four objectives listed below.

- Determine moisture content, insect damage, mycotoxin and nutritional levels of yellow maize stored in ZFH, Purdue Improved Crop Storage (PICS) and PP storage bags on poultry farms,
- Assess rodent damage to maize and storage bags (ZFH, PICS and PP) over a 6-month storage period.
- Assess the performance of broiler birds raised on maize stored in ZFH and PP storage bags for 6 weeks, and
- Determine the effectiveness of elevated platforms in reducing mycotoxin contamination in heaped maize on-field.

**Achievements**
Objectives 1 and 2 experiments ended in March/April 2021. Thereafter, maize from PP and ZFH bags was used for Objective 3 which deals with assessing the performance of broiler birds raised on maize stored in ZFH and PP storage bags for 6 weeks. Objective 3 experiment was completed in June 2021.

Data collection for Objective 4 on investigating use of elevated platforms in the field for reduction of mycotoxin contamination in heaped maize has been completed.

**Challenges**
None that are noteworthy.

**Objective: Conduct experiments on assessing the use of low cost locally built elevated platforms to mitigate high mycotoxin levels that are usually associated with heaping maize on the ground in the field. Summarized and analyzed data will be used to prepare manuscripts.**

**Progress**
Data collection for the study on investigating use of elevated platforms in the field for reduction of mycotoxin contamination in heaped maize was completed on 14 September 2020. All samples collected are for the Middle Belt major season harvest. Analysis of aflatoxin and fumonisin levels has been completed in the KNUST PHLIL mycotoxin laboratory. Data indicate consistent reduction of aflatoxin levels in maize ears freshly harvested and piled on platforms over a 14-day period before shelling. Whereas aflatoxin levels increased in maize piled on the ground, levels reduced in maize piled on platforms over the 14-day duration of the experiment. Aflatoxin levels were always below 2 ppb after 14 days of maize ears being heaped on platforms. Aflatoxin levels in maize ears heaped on the ground after 14 days were in the range of 13.3–18.3 ppb. Fumonisin levels on platform-stored maize were generally below the safe threshold, but also consistently reduced over the 14-day. The Ghana Standard Authority acceptable aflatoxin threshold is 15 ppb. The fumonisin action limit for Ghana is 4 ppm. Data summarization and analyses are in progress. The mechanism for potential mycotoxin reduction during platform storage is unclear, and the research team is critically discussing this; it is clear that platforms help avoid the increases in mycotoxins during heaping on the ground, a risk driver identified in PHLIL Years 1-5 research.

Maize samples from these trials were sent to University of Illinois, for quantitative PCR assessment of Aspergillus flavus levels in each. While the work above that quantified aflatoxin is important, the qPCR assay will additionally given information about the amount of fungus in each sample, versus the toxin it produces. These data will serve to: 1) compare with toxin levels at each timepoint, and see whether there is a commensurate reduction in fungal levels over the duration of platform storage, and 2) provide information on the potential for subsequent aflatoxin accumulation in maize heaped on the ground or platforms AFTER that period of storage (ie, are some samples/practices dooming the grain to further aflatoxin contamination in subsequent storage, being loaded with fungus capable of producing toxin under poor storage conditions?).

**Achievements**
- Use of elevated platforms for storing maize at harvest successfully reduced aflatoxin and fumonisin accumulation over 14 days, compared to the standard practice of heaping harvested maize onto the soil.

**Challenges**
None that are noteworthy.

### Objective: [KERNEL SORTING]: Assess the potential reduction of aflatoxin and fumonisin due to mechanical cleaning procedures and the interaction of that with single kernel sorting.

**Activities**
Collect corn samples from poultry farms that have a cleaning system for mycotoxin contamination, located in the Sunyani and Dorma Ahenkro area.

Investigate the implementation of spectral kernel sorting techniques as a mitigation strategy to reduce aflatoxin and fumonisin contaminated corn in local poultry farms, and improve local cleaning systems for better post-harvest loss management due to mycotoxin contamination.

Conduct experiments to improve spectral classification algorithms and sorting methods that distinguish and remove aflatoxin and fumonisin contamination in corn by using a UV-Vis-NIR spectrometer.

**Progress**
The University of Illinois PhD student in the Stasiewicz lab was able to analyze the corresponding bulk levels from the imported maize from poultry farms located in Dormaa Ahenkro, Ghana. For aflatoxin 36 of the 76 bulk samples were ≥ 20 ppb, while for fumonisin only 2 of the 76 bulk samples we contaminated with ≥2 ppm. Single Kernel samples that were high in bulk aflatoxin and bulk fumonisin were used to train the mycotoxin visual risk calibration algorithm (n accept = 1000, n reject = 1000). The classification performance of the sorting algorithm based on visual contamination characteristics showed a specificity of 63% and a sensitivity of 90%. Then, 150g of the single kernel sample were sorted (n = 76), and the reject and accept stream was grinded and tested for aflatoxin and fumonisin contamination. Single kernel sorting results showed that aflatoxin and fumonisin contamination was reduced among single kernel samples. For aflatoxin, 73 out of the 76 had a reduction in contamination in the accepted maize stream. For fumonisin, all 76 samples showed a reduction in the accepted maize stream.

Currently, the student is conducting data analysis to establish the significance of sorting results.

Dr. Stasiewicz and student were able to finish the manuscript publication of the classification algorithms for mycotoxin detection from previous work. Results showed that Stochastic Gradient Boosting best classifies single kernels by aflatoxin level (threshold = ≥20 ppb), while Penalized Discriminant Analysis best classifies single kernel by fumonisin levels (threshold = ≥2 ppm). Currently, the student is working on further adapting these algorithms to Ghanaian corn. He is collecting the required spectra for training the algorithms, by selecting single kernels from samples that tested high in bulk aflatoxin and fumonisin (n = 384). The spectral data are being collected using a UV-Vis-NIR spectrometer. Once the training data are completed, the algorithms will be used on a different set of the Ghanaian contaminated maize samples, to further improve single kernels sorting.

**Achievements**
- Sorting calibration based on high-risk features associated with mycotoxin contamination were made based on the measured bulk levels of maize samples. Sorting of single kernel samples showed a reduction in aflatoxin and fumonisin contamination.
- Results from data collected from natural contaminated corn samples showed that only one model (Stochastic Gradient Boosting) best classifies single kernels by aflatoxin level. While another model (Penalized Discriminant Analysis) best classifies single kernels by fumonisin level. These algorithms will be adapted for Ghanian corn for an improved solution for aflatoxin and fumonisin classification.

**Challenges**
Shortage in supply chains caused delays in ordering the required materials for laboratory procedures. Simple lab consumables took significant time to arrive. To improve our efficiency and adapt to these unusual circumstances and the lab improved its supply ordering system to prevent any future delays in the materials required for experimental procedures.

Given the skewed distribution of natural aflatoxin contamination in grains, there are only a few kernels that tend to be contaminated with aflatoxin and/or fumonisin. Therefore, collecting the required amount of contaminated kernels to train and create a robust classification algorithm may take more sample replication. Therefore, to improve our chances of collecting enough contaminated kernels for model training, we were able to sort kernels based on visual features associated with mycotoxin contamination in order to improve the probability of obtaining contaminated kernels and further test our sorting methods.

### Objective: [ENGAGEMENT]: Complete adoption model in application to Ghanaian poultry farmers

**Activities**
- Complete quantitative data collection
- Complete qualitative interviews

**Progress**
The engagement team has completed data collection in Ghana. A total of 147 farmers who were previously trained by PHL responded to the questions. Data analysis is still pending, and a manuscript is in process. Much has been learned about the instrument and adjustments will be made for administration in Ethiopia, should administration be possible in Ethiopia. Connections have been made with the University of Ghana to begin qualitative data collection.

### Objective: [AG REACH]: Conduct gender technology assessment of hermetic bags and moisture meters

**Activities**
- Conduct field work for gender technology assessments of hermetic bags and moisture meter with smallholder farmers around Tamale
- Write gender technology assessment of recommended technologies

**Progress**
Final drafts of two of the three technology assessments are complete and the third will be finalized by the end of October 2021.

**Achievements**
Focus group discussions have been conducted by University for Development Studies (UDS) partners in 10 beneficiary (post-AMPLIFIES) communities and 9 non-beneficiary communities.

Qualitative analysis of the results has been completed. Finalized gender technology assessments of hermetic bags and the GrainMate moisture meter have been completed. The gender technology assessment of the crop aggregation centers is in draft stage.

**Challenges**
Communication with UDS partners, particularly when they are in the field, has been a challenge. The fieldwork has also experienced numerous delays due to weather, COVID and the poor transcription/translation services.

The extension methodologies used for dissemination matter for gender equity. Extension must go beyond equality in access and efforts must be made to engage women, particularly in the north of Ghana where there are considerable barriers to access for women.

### Objective: [AG REACH]: Outreach with the Women in Poultry Association to improve postharvest practices

**Activities**
Dissemination of Scientific Animations Without Borders postharvest videos in Ashanti Twi to WPA and other groups via WhatsApp and other social media platforms

Training on postharvest practices/technologies with local chapters of WPA and facilitation of a discussion about how these technologies can advance the goals of the association.

**Progress**
Two videos have been translated into Asante Twi and distributed to WPA and other groups which focus on women and youth farmers.

**Achievements**
Translation and production of videos in Asante Twi. We also made contact with the Women in Poultry Value Chain Apex and shared the translated videos with them along with other SAWBO and Access Agriculture videos in Twi and Dagbanli.

**Challenges**
As travel was not possible during this period, we were limited to engaging with WPA via WhatsApp with some leaders who speak English and by distributing videos in Twi. We had envisioned a deeper engagement and we plan to meet with groups in person on a future trip to Ghana.

There were considerable delays with the production of videos and problems with the dialogue not matching up with the video. It took quite a while (~2 months) to resolve those problems, with SAWBO working directly with the translator.

### Objective: [AG ECON]: Implement a Randomized Controlled Trial and Survey in Ghana

**Activities**

- Design a randomized controlled trial
- Develop a survey tool
- Implement the trial and the survey
- Analyze the data
- Disseminate the findings

**Progress**
We are currently in a design phase. We are exploring a couple of design options. The research will be centered around the role of hermetic storage bags in storage and marketing decisions and/or credit uses of smallholders. We have also identified potential in-country implementing partners (Saving Grains).

**Achievements**
We have identified potential in-country partners.

# VI. 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 BAU-STR dryer and hermetic bag use (November 28, 2020), Mymensingh | Producers | 9 | 11 | 20 |
| Bangladesh | Training on BAU-STR dryer and hermetic bag use (December 2, 2020), Jhalokathi | Producers, Government, Civil Society | 19 | 8 | 27 |
| Bangladesh | Training on BAU-STR dryer and hermetic bag use (December 3, 2020), Barishal | Producers, Civil Society | 9 | 15 | 24 |
| Bangladesh | Training on BAU-STR dryer and hermetic bag use (December 4, 2020), Jashore | Producers, Civil Society | 7 | 16 | 23 |
| Bangladesh | Training on BAU-STR dryer and hermetic bag use (December 14, 2020), Kishoreganj | Producers, Government | 21 | 25 | 46 |
| Bangladesh | Gender Dimensions and Sensitization Training (December 21, 2020), Khulna | Producers | 13 | 19 | 32 |
| Bangladesh | Gender Dimensions and Sensitization Training (December 24, 2020), Barishal | Producers | 12 | 18 | 30 |
| Bangladesh | Gender Dimensions and Sensitization Training (December 28, 2020), Bogura | Producers | 11 | 21 | 32 |
| Bangladesh | Training on BAU-STR Dryer at Purba Dhamsar (April 28, 2021), Wazirpur, Barishal | Producers, Government, Civil Society | 20 | 7 | 27 |
| Bangladesh | Field day on BAU-STR Dryer at Purba Dhamsar, (April 28, 2021), Wazirpur, Barishal | Producers, Government, Civil Society | 25 | 15 | 40 |
| Bangladesh | Training on importance and use of improved storage technology at BAU, organized by DAE (June 1, 2021), Mymensingh | Producers, Civil Society | 31 | 0 | 31 |
| **Bangladesh Subtotals** | | | **177** | **155** | **332** |
| Ethiopia | Integrated approach (Threshing and hermetic storage) for post harvest loss reduction of maize grain (December 4-5, 2020), Alway district Adet Wereda | Producers, Government | 32 | 23 | 55 |
| Ethiopia | Integrated approach (Threshing and hermetic storage) for post harvest loss reduction of maize grain (February 1-2, 2021), Alefa district Burea- West Gojjam | Producers, Government | 30 | 20 | 50 |
| Ethiopia | On-farm training and Arc'teryx tent dryer demonstrations (April 20, 202), Mekelle University | Producers | 53 | 8 | 61 |
| **Ethiopia Subtotals** | | | **115** | **51** | **166** |
| Ghana* | Poultry Farmers training on drying, storage, and good sanitation (November 24-27, 2020), Dormaa | Poultry Producers | 7 | 6 | 13 |
| **Ghana Subtotals** | | | **7** | **6** | **13** |
| **FY21 Total** | | | **299** | **212** | **511** |

*Does not include trainings conducted by PHLIL partner, Sesi Technologies.
Note that 41.5% of trainees were female.

## b. Long-term Training

| Trainee Number | Sex | University | Degree | Major | Program End Date | Degree Granted | Home Country |
|---|---|---|---|---|---|---|---|
| **Bangladesh** | | | | | | | |
| 1 | F | Bangladesh Agric. Univ. | PhD | Plant Pathology | March 2022 | In progress | Bangladesh |
| 4 | M | BAU | MSc | Agricultural Engineering | March 2022 | In progress | |
| 5 | M | BAU | PhD | Agricultural Engineering | December 2022 | In progress | |
| 20 | F | BAU | MSc | Agricultural Engineering | May 2022 | In progress | |
| 21 | F | BAU | MSc | Agricultural Economics | May 2022 | In progress | |
| **Ethiopia** | | | | | | | |
| 7 | M | Mekelle University | PhD | Plant Science | July 2022 | In progress | Ethiopia |
| 8 | M | Mekelle University | PhD | Plant Science | July 2022 | In progress | |
| 23 | M | Mekelle University | MSc | Food Engineering | July 2021 | Yes | |
| 24 | M | Bahir Dar University | MSc | Chemical Engineering | February 2021 | Yes | |
| 26 | M | Bahir Dar University | MSc | Food Technology | March 2022 | In progress | |
| **Ghana** | | | | | | | |
| 13 | M | Kwame Nkrumah University of Science and Technology | MPhil | Crop Protection (Entomology) | July 2022 | In progress | Ghana |
| **Nepal Buy-In** | | | | | | | |
| 14 | F | Kansas State University | MSc | Plant Pathology | December 2022 | In progress | Kenya |

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

| Trainee Number | Sex | University | Degree | Major | Degree Granted | Home Country |
|---|---|---|---|---|---|---|
| **Ghana** | | | | | | |
| 15 | M | University of Illinois Urbana Champaign | PhD | Food Science | In progress | Guatemala |
| 25 | M | Kwame Nkrumah University of Science and Technology (KNUST) | MPhil | Agricultural and Biosystems Engineering | In progress | Ghana |
| **Guatemala** | | | | | | |
| 16 | M | University of Nebraska, Lincoln | PhD | Food Science and Technology | In progress | Guatemala |
| **Engagement** | | | | | | |
| 17 | F | Iowa State University | PhD | Ag Education | In progress | Cameroon |
| **Ag Econ Team** | | | | | | |
| 18 | F | Kansas State University | PhD | Ag Economics | In progress | Pakistan |
| 19 | M | Kansas State University | MSc | Ag Economics | In progress | Guatemala |

### c. Institutional Development

PHLIL developed and enhanced substantial human and institutional capacity in post-harvest research across all partner countries in Phase I. In the second phase of our research program, in-country capacity continues to be enhanced and elevated to influence national-level discussions, decisions and activities.

## VII. Innovation Transfer and Scaling Partnerships

### Phase I: under research as a result of USG assistance

**Training Assessment for Engagement Team**
**Category:** Management & Cultural Practices
**Description:** This training assessment takes a research-based approach to assess different models of engagement to help drive adoption of post-harvest loss reducing technologies. Surveys to collect data on the effectiveness of training programs in previous years and trainings' influence on farmers' adoption of new technologies were developed by the PHLIL Engagement team at KSU and Iowa State University.
**Steps Taken:** The tool is under development and should be deployed in Ghana and Ethiopia in the beginning of 2020.
**Partnerships Made:** Bahir Dar University, Mekelle University, Kansas State University, Iowa State University
**Countries:** Ethiopia, Ghana

### Phase II: under field testing as a result of USG assistance

**1 - Integrated Storage Technologies for Sorghum in Ethiopia**
**Category:** Management & Cultural Practices
**Description:** evidence based training on the management of post-harvest losses and mycotoxin provided to producer farmers and technicians. Besides, storage technologies (PICS bag and Zero fly bag were disseminated to producer farmers during a training conducted at four locations from May 26 to June 5, 2020). Solar bubble drier technology was tested and demonstrated on its use for postharvest management of grains and seeds
**Steps Taken:** trial experimental setups at two locations well designed and ready for sampling. Baseline samples from each location and storage strategies were analyzed for moisture contents, temperature, and nutrition content. 200 PICS bags are purchased and disseminated to sorghum grower farmers as grain preservation. The technology was purchased through the finance support of Mekelle University. Training of farmers are planned by PHIL team.
**Next Steps:** All data from the integrated experiment was collected
**Partnerships Made:** Ministry of agriculture of Ethiopia, producer Farmers in four locations of Tigray region; PICS and Zero fly manufacturing companies.
**Countries:** Ethiopia

**2 – Post-harvest preservation strategies**
**Category:** Management & Cultural Practices
**Description:** post-harvest preservation strategies including PICS bags and Zerofly bags were procured from manufacturing companies for on-farm evaluation and farmer's dissemination.
**Steps Taken:** described in supporting documents
**Partnerships Made:** the partnership was made with PHK trading PLC and Edmealem Ejigu PLC Addis Ababa
**Countries:** Ethiopia

### Phase IV: Demonstrated uptake by the public and/or private sector

**1 - Training manual and technology dissemination**

**Category:** Management & Cultural Practices
**Description:** storage technologies like PICS and super grain pro bags were disseminated selected cooperatives and private seed producers in different locations of Tigray region by our partners ISSD project at Mekelle University. Our involvement was mentoring and advising only.
**Steps Taken:** demonstration and dissemination
**Partnerships Made:** Seed cooperatives, private seed producers and integrated seed system program
**Countries:** Ethiopia

## VIII. Environmental Management and Mitigation Plan (EMMP)

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

## IX. Open Data Management Plan

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

## X. Project Management Activities

The Management Entity was fully engaged in evasive action to continue operations and activities in the face of the COVID-19 pandemic. Consultation with USAID (AOR), the IL Council, Kansas State University, and partner institutions and organizations were conducted to ensure safety (first) and deliver. Given the covariate shocks presented by the onset of the pandemic, efforts to secure the harvest were more important than ever.

# XI. Other Topics

None.

# XII. Issues and How They Are Being Addressed

A major preoccupation of the ME and the program was shifting operational strategy during the COVID-19 pandemic. The ME and program partners invested substantial time in adaptations to plans, ensuring safety and that the program met or exceeded all Feed the Future indicator targets for the year.

Another major challenge associated with this report was the unrest in Tigray, Ethiopia. As the report was being finalized, unrest continued to be disruptive and reporting was not the primary concern of partners, but rather their safety and security.

# XIII. Future Directions

The PHLIL team is focused on finishing strong with sustainable outcomes and innovations scaling towards resilient development outcomes in its final year (and beyond).

# Appendix A: Success Stories

## PHLIL Success Story 1:
## A women-led food system collaboration addressing a nutritional security crisis

Poultry production in Ghana is important for food and nutritional security. In 2017, approximately 46,500 tons of eggs and 59,650 tons of poultry meat in Ghana were produced (NMoFA), providing 21% of domestic livestock meat production (SRID, 2001) as well as nutrient-dense eggs. In the Netherlands' Ministry of Foreign Affairs report: "Analysis poultry sector Ghana 2019: an update on the opportunities and challenges", it was highlighted that while national poultry production has managed to steadily increase over recent years, the price of feed is a key constraint and threat; within that, maize is the largest perceived cost-driver. In August 2021, *Poultry World* reported that "According to the Ghana Poultry Farmers Association, an acute shortage of feed is threatening the survival of the country's poultry industry. 'All poultry farms in Ghana are on the verge of collapse if no drastic measures are taken… to sustain the industry,' the chairman of the association, Isaac Essiaw, told Xinhua."

The article goes on to state that "Ghana's poultry sector has, for over 2 decades, experienced a steep decline with many commercial poultry farms that were established in the late 1960s and early 1970s having collapsed or are on the verge of collapsing. The reasons for this, in recent times, is the high cost of unavailability of maize, reports Business Ghana." Small and medium farms, which are usually individual or family-owned, may face the brunt of this issue. Facing this existential threat of a severe maize shortage and exorbitant maize prices, PHLIL partners in the Women in Poultry Association have formed an alliance with farmer-based organizations in the North, where maize harvests are more reliable.

Members of the Dormaa Central chapter of the Ghana Women in Poultry Association (WPA) in the Middle Belt of Ghana have long faced challenges such as sourcing high quality, safe maize feed, sanitation and biosecurity issues, and ample access to sustainable and profitable markets for their egg and broiler production businesses. These challenges were crippling the growth of businesses while the nationally increasing demand for eggs requires *increased* production. The United States Department of Agriculture (USDA)-funded AMPLIFIES project ended in 2018, at which time AMPLIFIES members in the PHLIL project continued their engagement with the Dormaa Central WPA. PHLIL introduced the ZeroFly® Hermetic (ZFH) bag, GrainMate® moisture meter and Good Agricultural Practice innovations to facilitate storage of well-dried maize, mitigating insect infestation, aflatoxin contamination and other post-harvest loss issues that had been plaguing these businesses feed supplies.

Poultry producers quickly embraced and adopted PHLIL-introduced technologies and tactics. However, sourcing and securing maize during the current maize harvest failures in the Middle Belt remain recurring impediments to the growth and stability of poultry production. Access to maize feed has become the primary threat to WPA businesses, with many members having to reduce the size of their flocks considerably. In the search for maize to feed rather than slaughter her layers, Ms. Beatrice Asante Adjei, the Secretary of the Dormaa Central WPA, the PHLIL team introduced her to Mr. Paul Azure and Mr. Alhaji Imoru Azure. The former is a Ghana Ministry of Food and

Agriculture (MoFA) Agricultural Extension Agent (AEA) based in the Garu office (Upper East Region) and the latter the Chairman of the Garu District Value Chain Committee (DVCC). Mr. I. Azure also heads a conglomerate of Farmer Based Organizations (FBOs) with substantial women representation in each. Through contact with Mr. P. Azure, Mr. I. Azure, and the FBOs, Ms. Adjei found that maize producers experience numerous challenges in the value chain, for example, lack of lucrative markets, general mismanagement, and crippling postharvest losses typical to smallholder farmers. Ms. Zelisa Asigri, a member of one of the FBOs in Garu, has experienced maize deterioration due to insect infestation and fungal contamination, while it is in storage during the off-season when market prices are high. Consequently, Zelisa had to sell at a loss right after harvest to pay bank loans.


After weeks of negotiations among Ms. Adjei, P. Azure, Mr. I. Azure, and other key representatives of the Garu FBOs, these parties signed a working agreement. Now Ms. Adjei and the FBOs are gaining access to much needed markets and growing their businesses. This agreement especially empowers the usually marginalized women players, hence a win-win for Ms. Adjei and producers such as Ms. Asigri in a fair-trade market. Mr. I. Azure has been instrumental in setting up a lucrative off-taker market for his district's maize production. Price negotiation and fairness have been a challenge with aggregators also referred to as "middlemen" setting the price and purchasing maize using unreasonably big bowls instead of by weight. In such a "middleman" dominated market, the farmers end up feeling and actually being cheated during transactions.

In November 2020 Dr. George Opit, the Lead Principal Investigator for PHLIL Ghana, met the Garu MoFA Director, Mr. Denis Asampambila, to discuss scaling of ZFH bags and GrainMate moisture meters. A previous Canadian Government-funded project did a great job significantly increasing production of various agricultural crops in Garu, Bawku, and Zebilla districts in the Upper East Region of Ghana. However, with increased production came post-harvest loss mitigation and marketing challenges for the various crops. During the off-season, prices are high hence; farmers can potentially reap higher profits. Mr. Asampambila is pleased with PHLIL introducing ZFH bags and GrainMate moisture devices in the Northern Region of Ghana because they ensure farmers can conserve their crops well after harvest and sell at the appropriate time to earn higher profits. The market for maize provided by poultry farmers, such as Ms. Adjei based in Dormaa, also made Mr. Asampambila extremely hopeful.

The Garu MoFA office has actively sought markets for crops produced by FBOs in the district and has been a key stakeholder in scaling the ZFH bags and other PHLIL-introduced practices. "*I think it's a new trend that we are seeing that this off-taker [referring to Beatrice] is coming, I think we will do good business with her*," recounts Mr. Azure, the Garu MoFA AEA.

"*I think the off-taker [Ms. Adjei] coming to buy our maize is very good. Yeah, they use a scale to weigh our products; that is far better than sending to the market so that they use a big bowl, so at the end of it you will not get anything. So, we plead with you to continue with it so that it will help us farmers to benefit from our farming*," explained Ms. Asigri.

It is important to note that Ms. Adjei is a successful off-taker who offers a lucrative market for FBOs, mainly because the PHLIL-introduced GrainMate devices and ZFH bags that she uses permit her to purchase and store maize with little to no risk from high moisture levels or insects.

In this relationship between Ms. Adjei and the FBOs, the former purchases clean and well-preserved maize all the while providing healthy nutritious eggs to the latter, such as Ms. Zelisa and civilians in the Northern Region. Ms. Adjei and FBOs trade their commodities for the benefit of all concerned in the relationship. The sale of fresh eggs and purchase of clean maize stimulates the market systems for both of these highly desired products.

This essential link between the poultry farmers and maize value chains will create a strong economic bond between the Northern Region and the Middle Belt (Dormaa) and will surpass benefits generated from successfully marketing eggs or maize alone. Because of this collaboration, these organizations (Dorma Central WPA and FBOs) are gaining access to much needed markets and growing their businesses in a profitable and sustainable manner.

The organizations are endorsing a market system that commonly exists in the context of rural Ghana, but now it is elevated to a meso scale. This synergistic market system will generate much needed financial revenue to increase each organization's production and will support a more resilient economic system as the ripple effects of the hard work and dedication of those involved continue to bear more fruit.

## PHLIL Success Story 2:
## Public-Private Partnership to Preserve Smallholder Farmers' Local Market Access

Smallholder rice farmers in Bangladesh rely on local mills to purchase their wet paddy rice. Of the 17,000 rice mills nationally, 15,500 are mid-sized local mills locally referred to as "major and husking" mills. Local mills are being competed out of business by a smaller number of larger mills with more sophisticated equipment including large dryers, enabling them to produce "glossy fresh-looking" rice, compared to the discolored rice produced by mid-scale mills. While the major and husking mills may have threshers, they lack mechanical drying necessary to achieve significant capacity in processing. Faced with this existential threat, mid-scale millers approached PHLIL previously, requesting that an appropriate scale dryer be developed for local manufacture and purchase.

In an assessment of 22 mid-size mills, PHLIL found that these local mills operate at an average capacity of 26.6%, and ascertained that a 12 ton capacity mechanical dryer would increase capacity to 72.5% capacity or higher; unreliable and slow solar drying is the critical rate-limiting step of these operations, for capacity and quality. In a public-private partnership, PHLIL is working with Moti Auto Rice Mill to pilot a mid-scale dryer prototype. PHLIL worked with local manufacturers to produce a 12-ton dryer that will be suitable for both paddy and parboiled rice, with Moti paying for construction of the dryer. It has been estimated that with 25% of major and husking mills adopting this type of dryer, more than one million smallholder farmers in Bangladesh would benefit through preservation of their local market linkages.

BAU and Moti are collaborating on the design, research and adaptation of a 12-ton capacity paddy dryer. This recirculating batch grain dryer includes several innovations that will eliminate the need for rice mills to purchase two dryers, since it will be effective at both paddy and parboiled rice; mills typically have to install one for each type of rice. The dryer is fabricated primarily with locally available materials and matches the drying capacity of a typical major rice mill. Engineers from Bandhu Engineering worked with faculty, staff, and students at BAU to adapt and launch the construction of the 12-ton capacity dryer at Moti Auto Rice Mill. The dryer will be programmed to be fully automated, executing a six-step drying process developed by PHLIL engineers. Through a Memorandum of Understanding with Moti, the dryer can now serve as a fully operational research site which can double as a teaching and demonstration location. BAU hopes this will help springboard the design and scaling of this technology for future use in additional locations.

Despite completion timeline challenges and other constraints experienced in 2021, construction of the 12-ton dryer is complete (January 2022) and piloting exercises have begun. "Thanks to PHLIL USA and USAID for providing support and opportunity to work on this large scale dryer," expressed Dr. Md. Monjurul Alam of BAU.

Once validated, the dryer will be a game changer for major rice mills and will provide access to faster, more efficient, ways of drying paddy rice than the traditional sun drying methods. No longer dependent upon prevailing weather conditions for rice drying, Moti can now process four batches (12 tons per batch) of paddy in 3 days, or 400 batches or 4,800 tons of rice in 300 days.

Workers inspect BAU / Moti Auto 12-ton rice mill dryer

The construction of the 12-ton capacity paddy dryer is a testament of the success of a strategic Product Life Cycle Public-Private Partnership born between BAU and Moti Auto Rice Mill for the development and scaling of novel technologies, introduced with the engagement of PHLIL in developing countries. This innovative dryer has the potential to secure the harvest in Bangladesh, other Feed the Future countries and beyond.


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