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

Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification

Annual Performance Report FY 2019



Collaborative Research on Sustainable Intensification
FEED THE FUTURE INNOVATION LAB

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Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification
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Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification

Annual Performance Report FY 2019

This annual performance report for FY 2019 is made possible by the generous support of the American people through the United States Agency of International Development (USAID). The contents are the responsibility of Kansas State University and do not necessarily reflect the views of USAID or the United States Government.

Program activities are funded by the United States Agency for International Development under Cooperative Agreement No. AID-OAA-L-14-00006.

Cover Photos
Top left: A choice experiment where farmers were able to choose among bean varieties and technologies (seed treatment) was partially supported by SIIL in Tanzania on bidirectional approaches. *Photo credit: Stephen Morgan.*
Top right: Taken at the market in Phnom Penh and Battambang. *Photo Credit: David Ader*
Bottom left: New operator power tiller training in Khulna, Bangladesh. *Photo credit: Md. Mottalib*
Bottom right: Local women training in aviculture practices in Malicounda, Senegal. *Photo Credit: Bineta Dieye*

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Feed the Future Sustainable Intensification Innovation Lab

A. Management Entity Information

The Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL) is housed at Kansas State University in Manhattan, KS. The management entity staff includes the following individuals:

Dr. Vara Prasad – Director
Email: vara@k-state.edu

Vara Prasad, University Distinguished Professor of Crop Ecophysiology, serves as the Program Director of SIIL. He earned his B.S. and M.S. in agronomy from Andhra Pradesh Agricultural University in India, and his Ph.D. in crop physiology from The University of Reading in England. He has extensive international experience in both Africa and Asia, and has had significant involvement with several USAID projects in these regions. His research focuses on understanding the response of food-grain crops to changing environments and management practices; developing strategies for management of crops, soil, water and nutrients for the efficient use of resources; and using farming-system approaches to provide food and nutritional security to smallholder farmers. Prasad provides leadership to SIIL and oversees all of the research, capacity building, and knowledge-sharing and communication activities of the program. He administers technical and financial aspects of SIIL and serves as the primary contact for donors, advisory groups and partner organizations.

Dr. B. Jan Middendorf – Associate Director
Email: jmiddend@k-state.edu

B. Jan Middendorf serves as the SIIL Associate Director. She earned her B.S. in business administration at the University of Rhode Island, her M.S. in international affairs at Ohio University and her Ph.D. in curriculum and instruction and evaluation practice at Kansas State University. Her primary interests are institutional and program improvement through strategic planning, change management and evaluation. She has more than 25 years of experience in project development, management, implementation and evaluation of multi-institutional, interdisciplinary programs and projects in national and international settings. As Associate Director, Middendorf serves as the administrative officer alongside the Program Director and oversees the Management Entity (ME) in organizing activities to facilitate technical and administrative goals of the SIIL program. She conducts research and leads SIIL's impact assessment, monitoring and evaluation efforts. She is responsible for establishing and maintaining effective partnerships with other U.S. and international institutions, industry, USAID Missions and developmental partners.

Dr. Manny Reyes – Research Professor
Email: mannyreyes@k-state.edu

Manuel Reyes, Research Professor, has more than 30 years of experience working with water quality modeling, natural resources management and conservation agriculture. He is an agroecological engineer, designing food production systems that mimic nature. Reyes has extensive expertise across the globe in research, extension, teaching and project implementation. Reyes will focus his efforts in Cambodia, working with the Royal University of Agriculture and University of Battambang to enhance human and institutional capacity to conduct research and training of scholars and youth. He will facilitate partnerships with other Feed the Future Innovation Labs, international organizations and private industry in Cambodia.

Dr. Jessie Vipham – Assistant Professor
Email: jessiev@k-state.edu

Jessie Vipham is a Food Microbiologist by training, and serves as the SIIL faculty hire in Global Food Systems and Nutrition. She is an Assistant Professor in the Department of Animal Science. She holds a B.S. in Agriculture Business from Kansas State University, as well as an M.S. and Ph.D. in Animal Science from Texas Tech University. While at Texas Tech, Jessie was involved with faculty members of the International Center for Food Industry Excellence (ICFIE). She is experienced in international food security research, and has spent a significant amount of time strengthening food systems in Latin America.

Dr. Zachary Stewart – Assistant Research Professor
Email: zachstewart@k-state.edu

Zach Stewart serves as the SIIL Program Manager. He is a Research Assistant Professor in the Department of Agronomy. He earned his M.S. in Control of Infectious Diseases from the London School of Hygiene and Tropical Medicine and his Ph.D. in Agronomy from the University of Nebraska-Lincoln. He has done extensive research on crop physiology and production as well as worked with smallholder farmers in East Africa on agronomic and human health topics. The 2008 recipient of the John Chrystal Award from the World Food Prize Foundation, Zach has been able to use his multidisciplinary background to advance agricultural production while keeping in mind the well-being of those impacted. As part of the SIIL management entity, Zach leads knowledge management and sharing efforts and conducts research related to global food and nutrition security for smallholder farmers.

Andra Williams – Program Administrator
Email: ajolenew@k-state.edu

Andra Williams serves as the Program Administrator for the SIIL. She collaborates with the Lab's domestic and international partners to help manage the program's monitoring and evaluation, communication, reporting, and knowledge management needs. Andra received a B.A. in French, with a minor in Community Nutrition, from the University of California, Davis, and a Master's in International Development and Sustainability from the Université Grenoble-Alpes in France. She served as a Peace Corps health volunteer in Senegal from 2013-2014 and has worked in both Senegal and Guinea as a part of USAID projects. Andra was most recently employed with the Horticulture Innovation Lab at UC Davis prior to coming to the SIIL. She speaks fluent French and passable Seerer.

Jessica Burden – Business Manager
Email: jess522@k-state.edu

Jessica Burden serves as the Business Manager for the Sustainable Intensification Innovation Lab. She is responsible for the financial management of all grants, including post-award accounting, travel planning, distribution of funding for sub-awards, and working with pre- and post-award services. Jessica holds a B.S. in Business Administration – Accounting with a minor in Leadership Studies, as well as a Masters in Accountancy, both from Kansas State University. Additionally, she has previous experience as an auditor, providing her with much grant compliance and financial experience and prior university experience at Kansas State, Oklahoma State, and University of North Texas.

Jovin Lwehabura – Regional Coordinator, East Africa
Email: j.lwehabura@cgiar.org

Mr. Jovin Lwehabura has more than 10 years of experience working on applications of geospatial science and technology in sustainable management of natural resources. He holds an M.S. degree in Geographic Information Systems from the University of the Redlands, California as well as a B.S. in Geomatics from the University of Dar es Salaam. Mr. Lwehabura is a member of Global Society for Conservation Geographic Information Systems (SCGIS). He has developed several GIS databases, guide mapping, and support implementations of land use planning for more than 50 local communities in Tanzania. Mr. Lwehabura currently works for the International Center for Tropical Agriculture (CIAT) under the Sustainable Intensification Innovation Lab. He is the SIIL's Coordinator in East Africa and lives in Arusha, Tanzania.

Dr. Aliou Faye – Country Coordinator, Senegal
Email: alliouselbe11@yahoo.fr or aliou.faye@isra.sn

Aliou Faye has two decades of research experience with the Senegalese Agricultural Research Institute (ISRA), the French Institute of Research for Development and the International Centre for Cooperation in Agricultural Development (CIRAD). Faye worked also for 5 years as Chief of Agency of a Saudi group dealing with non-timber forest products in the Tambacounda and Louga regions of Senegal. Faye holds a B.S. in Tropical Forestry, an M.S. in Agronomy, and a Ph.D. in Plant Biology from the Cheikh Anta Diop University of Dakar, with field experience at the Tropical Soil Biology and Fertility (CIAT) in Nairobi, Kenya. Faye has published at least 20 research articles in different scientific journals. Dr. Faye is currently the head of the Soil-Water and Plant Laboratory of the Centre National de la Recherche Agronomique (CNRA) of ISRA in Bambey, Senegal and serves as the Country Coordinator of the SIIL in Senegal.

Dr. Hamidou Traore – Country Coordinator, Burkina Faso
Email: hamitraore8@yahoo.com

Dr. Hamidou Traore has more than 25 years of research experience in the field of agronomy. Dr. Traore holds a Ph.D. in Weed Science from the University of Montpellier II, Sciences and Techniques of Languedoc, France, and a Diploma of Rural Development Engineering in Agronomy from University of Ouagadougou. Dr. Traore currently serves as Director of Institut de l'Environnement et de Recherche Agricoles (INERA), Burkina Faso. He previously held the position of Regional Director of the Eastern and Sahelian Environmental and Agricultural Research Regional Centers. Dr. Traore was also a Fulbright Scholar at the Agronomy Department of Purdue University.

B. External Advisory Board

The External Advisory Board (EAB) is chaired by Jules Pretty. The EAB was actively engaged in evaluating the proposals for focus country research subawards and was responsible for making final decisions on project selection.

Professor Jules Pretty – Chair
University *of Essex*

Dr. Jules Pretty is Deputy Vice-Chancellor at the University of Essex, and Professor of Environment and Society. His 18 books include *This Luminous Coast* (2011), *Nature and Culture* (2010), *The Earth Only Endures* (2007), and *Agri-Culture* (2002). He is a Fellow of the Society of Biology and the Royal Society of Arts, former Deputy-Chair of the government's Advisory Committee on Releases to the Environment, and has served on advisory committees for a number of government departments and research councils. He was a member of two Royal Society working groups that published Reaping the Benefits (2009) and *People and the Planet* (2012), and was a member of the UK government Foresight project on Global Food and Farming Futures (2011). He is the founding Chief Editor of the *International Journal of Agricultural Sustainability*. He received an OBE in 2006 for services to sustainable agriculture, and an honorary degree from Ohio State University in 2009. More details can be found at www.julespretty.com.

Dr. Deborah Bossio
The Nature Conservancy

Dr. Deborah Bossio is the Lead Soil Scientist for The Nature Conservancy, where she is an integral member of the Global Lands team and an active member of the Science Cabinet, a collaborative group of Conservancy Lead Scientists contributing topical expertise to cross-cutting science issues for the organization. In this role she integrates new soil science expertise to support and advance existing climate, agriculture, forestry and conservation priorities, and to better understand how we can scale our impact through improved soil management.

Dr. John Dixon
Australian Centre for International Agricultural Research

Dr. Dixon has more than 30 years of developing-country experience with agricultural research and development, including cropping systems, economics and natural resource management in South, South-east and East Asia, Africa, Latin America, and the Middle East, working for the CGIAR system and the FAO. He has served as Director, Impacts, Targeting and Assessment at CIMMYT, leading activities on impact assessment, value chains, impact knowledge sharing, systems agronomy and conservation agriculture; and also in various capacities with FAO in their global, regional and country programs. He also led ACIAR international program and is currently an Adjunct Professor at Queensland Alliance for Agriculture and Food Innovation, The University of Queensland. Dr. Dixon is a graduate from the University of New England with a Ph.D. (agricultural economics), Masters (natural resources), Masters (economics) and Bachelor in Rural Science.

Dr. Cornelia Flora
Iowa State University

Dr. Cornelia Flora is an Emeritus Distinguished Professor in the Department of Sociology at Iowa State University. Her research interests include international and domestic development, community, and the sociology of science and technology, particularly as related to agriculture and participatory change. Socio-technical regime changes and capitals transformations (natural, cultural, human, social, political and financial/built capitals) guide her current research includes work on the community development, sustainable agriculture and natural resource management, with particular attention to how class, gender, and ethnicity influence and are influenced by technology and policy.

Dr. Jemimah Njuki
Canada's International Development Research Center (IDRC)

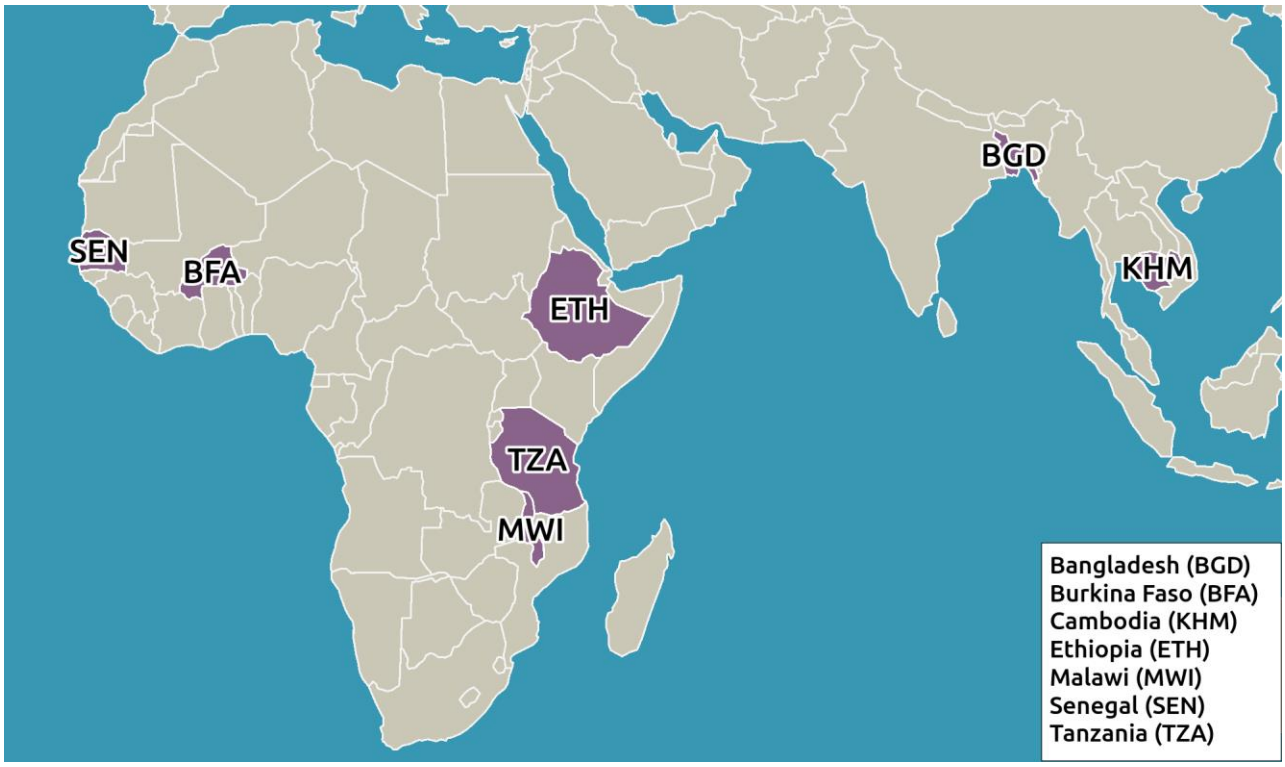
Dr. Jemimah Njuki has fifteen years of experience overseeing gender-responsive and women-targeted research and development projects that link women smallholder farmers to markets, integrate gender in cooperatives, apply participatory gender-responsive research, and more. As senior program officer at the International Development Research Centre (IDRC), she manages the Cultivate Africa's Future program.

Dr. Peter Thorne
International Livestock Research Institute (ILRI)

Dr. Peter Thorne coordinates the Africa RISING project in the Ethiopian Highlands. He completed his Ph.D. at the University of Nottingham in animal nutrition, with a part of his research conducted at the University of the Philippines in Los Banos. His career has allowed him to work in both public and private sectors, focusing largely on the evolution of mixed farming systems in Africa and Asia. Prior to joining ILRI, Dr. Thorne was responsible for the national dairy benchmarking service in Britain.

C. Focus Countries

The Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification works in West Africa, East Africa and Asia. The six focus countries are listed and shown below, along with the Malawi Subaward that was initiated in FY 2017.



D. List of Program Partners

United States
ADM Institute for the Prevention of Postharvest Loss
American Soybean Association (ASA)
Feed the Future Innovation Lab for Horticulture
Feed the Future Innovation Lab for Collaborative Research on Nutrition in Africa
Feed the Future Innovation Lab for Small Scale Irrigation
Feed the Future Innovation Lab for the Reduction of Postharvest Loss
Kansas State University
Michigan State University
North Carolina A&T State University
Oakland University
Pennsylvania State University
Stanford University
Texas A&M University
Tillers International
University of California, Davis
University of Florida
University of Illinois at Urbana-Champaign
University of Maryland
University of Tennessee Institute of Agriculture (UTIA)
University of Wisconsin – Madison

Bangladesh
ACI Motors Limited
Bangladesh Agricultural Research Council (BARC)
Bangladesh Agricultural Research Institute (BARI).
Bangladesh Agricultural University
Bangladesh Rice Research Institute
BRAC
International Maize and Wheat Improvement Center (CIMMYT)
International Rice Research Institute (IRRI)
Khulna University

Burkina Faso
Association pour la Promotion de l'Elevage en Savane et au Sahel (APESS)
Institut de l'Environnement et de Recherches Agricoles (INERA)
International Livestock Research Institute (ILRI)
La Fédération Nationale des Groupements Naam (FNGN)
Polytechnic University of Bobo-Dioulasso (UPD)
The International Union for Conservation of Nature (IUCN)

Cambodia
Agricultural Development Denmark Asia
AVRDC – World Vegetable Center
Conservation Agriculture Service Center (CASC)
Department of Agricultural Engineering (DAEng)
ECHO Asia
Institute of Technology of Cambodia (ICT)
Kasetsart University

Ministry of Agriculture Forestry and Fisheries (MAFF)
Ministry of Education and Youth (MoEY)
Royal University of Agriculture – Phnom Penh
University of Battambang

Ethiopia
Africa Research in Sustainable Intensification for the Next Generation (Africa RISING)
Bahir Dar University / Bahir Dar Institute of Technology
International Food Policy Research Institute (IFPRI)
International Livestock Research Institute (ILRI)
International Water Management Institute (IWMI)
University of Twente

Senegal
Institut Sénégalais de Recherches Agricoles (ISRA) – Centre National de Recherches Agronomiques de Bambey (CNRA – Bambey)
ISRA – Laboratoire National de Recherche sur les Production Vegetales (LNRPV)
ISRA – Laboratoire National d'Élevage et de Recherches Vétérinaire (LNERV)
University of Thies – College of Agriculture
Institut de Technologie Alimentaire (ITA)
Agence Nationale de Conseil Agricole et Rural (ANCAR)
Réseau des Organisations Paysannes et Pastorales du Sénégal (RESOPP)
Institut de Recherche Pour le Développement (IRD)
Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)
Conseil ouest et centre africaine pour la recherche et le développement agricoles (CORAF)

Tanzania
Sokoine University of Agriculture (SUA)
Wageningen University and Research Center
International Center for Tropical Agriculture (CIAT)
Nelson Mandela African Institution of Science and Technology (NM-AIST)
International Institute of Tropical Agriculture (IITA)
Africa Research in Sustainable Intensification for the Next Generation (Africa – RISING)
International Maize and Wheat Improvement Center (CIMMYT)
N2Africa

Additional Partners or Collaborators
International Institute for Applied Systems Analysis (IIASA)
ITC – Netherlands
Kifiya Financial Technology Plc.
One Acre Fund
Quantitative Engineering Design
Swisscontact
Taking Maize Agronomy to Scale in Africa (TAMASA)
Wageningen University and Research Center
World Agroforestry Center

E. Acronyms

ACIAR – Australian Centre for International Agricultural Research
ADDA – Agricultural Development Denmark Asia
ADS – Automated Directives System
Africa RISING – Africa Research in Sustainable Intensification for the Next Generation
AfSIS – Africa Soil Information Service
AGRA – Alliance for a Green Revolution in Africa
ANCAR – Agence Nationale de Conseil Agricole et Rural
AOR – Agreement Officer's Representative
APESS – Association pour la Promotion de l'Elevage en Savane et au Sahel
ASA – American Soybean Association
ASM – Appropriate scale mechanization
ASMC – Appropriate Scale Mechanization Consortium
AUC – African Union Commission
AWP – Annual Work Plan
BARC – Bangladesh Agricultural Research Council
BARI – Bangladesh Agricultural Research Institute
CA – Conservation Agriculture
CASC – Conservation Agriculture Service Center
CASF – Conservation Agriculture Service with a Fee
CAST – Commercialization of Aquaculture for Sustainable Trade
CE SAIN – Center of Excellence on Sustainable Agricultural Intensification and Nutrition
CGIAR – Consultative Group on International Agricultural Research
CIAT – International Center for Tropical Agriculture
CIMMYT – International Maize and Wheat Improvement Center
CIRAD – Centre de Coopération Internationale en Recherche Agronomique pour le Développement
CNRA – Centre National de Recherches Agronomiques (CNRA)
CORAF – Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles
CSA – Climate smart agriculture
CSIRO – Commonwealth Scientific and Industrial Research Organisation
DAEng – Department of Agricultural Engineering
DDL – Data Development Library
EAB – External Advisory Board
EMMP – Environmental Management and Mitigation Plan
FAA – Federal Aviation Administration
FAO – Food and Agriculture Organization
FGD – Focus Group Discussions
FNGN – La Fédération Nationale des Groupements Naam
FLMLA – Faculty of Land Management and Land Administration
FTFMS – Feed the Future Monitoring System
FY – Fiscal year
GFC – Geospatial and Farming Systems Research Consortium
GIS – Geographic Information System
GMCC – Green Manure Cover Crops
HYV – High Yielding Varieties
ICRISAT – International Crops Research Institute for the Semi-Arid Tropics
ICT – Institute of Technology of Cambodia
IDRC – International Development Research Centre
IDSS – Integrated Decision Support System
IFDC – International Fertilizer Development Center
IFPRI – International Food Policy Research Institute

IIASA – International Institute for Applied Systems Analysis
IITA – International Institute of Tropical Agriculture
IL – Innovation Lab
ILRI – International Livestock Research Institute
ILSSI – Innovation Lab for Small Scale Irrigation
INERA – Institut de l'Environnement et de Recherches Agricoles de Burkina Faso
INGENAES - Integrating Gender and Nutrition within Agricultural Extension Services
IPM – Integrated Pest Management
IRD – Institut de Recherche Pour le Développement
IRRI – International Rice Research Institute
ISRA – Institut Sénégalais de Recherches Agricoles
ITA – Institut de Technologie Alimentaire
IUCN – International Union for Conservation of Nature
IWMI – International Water Management Institute
LIVES – Livestock and Irrigation Value Chains for Ethiopian Smallholders
LNERV – Laboratoire National d'Élevage et de Recherches Vétérinaire
LNRPV – Laboratoire National de Recherche sur les Production Végétales (LNRPV)
MAFF – Ministry of Agriculture Forestry and Fisheries
ME – Management Entity
MoEY – Ministry of Education and Youth
MSU – Michigan State University
NARS – National Agricultural Research Systems
NGO – Nongovernmental organization
NM-AIST - Nelson Mandela African Institution of Science and Technology
NUS – Neglected and underutilized species
PRC – Policy Research Consortium
PI – Principal investigator
PTOS – Power Tiller Operated System
R4D – Research for Development
RESOPP – Réseau des Organisations Paysannes et Pastorales du Senegal
RHoMIS – Rural Household Multiple Indicator Survey
RUA – Royal University of Agriculture
SAR – Synthetic Aperture Radar
SBIR – Small Business Innovation Research
SI – Sustainable intensification
SIIL – Sustainable Intensification Innovation Lab
SIPS – Sustainably intensified production systems
SSA – Sub-Saharan Africa
SUA – Sokoine University of Agriculture
TAMASA – Taking Maize Agronomy to Scale in Africa
TP – Technology Park
UAV – Unmanned Aerial Vehicle
UBB – University of Battambang
UPB – Polytechnic University of Bobo-Dioulasso
USAID – United States Agency for International Development
USG – United States Government
UTIA – University of Tennessee Institute of Agriculture
WAgN – Women in Agriculture Network

I. Executive Summary

The Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL) successfully completed its fifth year since inception. All projects completed four years of active research and data collection in SIIL's focus countries (Bangladesh, Burkina Faso, Cambodia, Ethiopia, Malawi, Senegal, and Tanzania). All activities aligned with the vision of SIIL and its four main objectives.

There are several activities, accomplishments and lessons learned detailed in this fifth year report. This executive summary provides the highlights of key activities related to the overall theme from this past year: suitability, scalability, and sustainability. Project teams identified promising innovations from their research using a systems approach, actively collaborating with our strategic partners to leverage investments, and communicating our successes through our multiple knowledge management platforms has been key to successful implementation that will ensure greater impact and return on investments. The SIIL program collaborates with >80 national and international organizations (including 8 CGIAR and 13 US universities), and has supported >160 scholars to work towards common themes of increasing sustainable agriculture productivity, enhancing resilience of cropping systems and supporting nutritional outcomes.

Each of the projects have experienced important lessons and achievements. The Geospatial and Farming Systems Research Consortium supported the quantification of the SIIL's Sustainable Intensification Assessment Framework using RHoMIS data from SIIL's Subawards in Senegal and Burkina Faso, as well as the AfricaRISING Ethiopia project. The Appropriate Scale Mechanization Consortium (ASMC) developed an Agricultural Mechanization degree program within the Institute of Rural Development at the Polytechnic University of Bobo-Dioulasso in collaboration with the Institute of Technology in Burkina Faso. The ASMC also hosted numerous trainings focused on private sector enterprises to improve service business related agricultural mechanization techniques. The Bangladesh project focused on high yielding and stress tolerant rice varieties, improved productivity of rice-fish cultivation, and introduced high value rabi crops to increase farm income and improve household nutrition. Burkina Faso continued to focus on demonstrating benefits of grain and biomass yields with dual-purpose sorghum and cowpea. The Cambodia project continued to empower women and improve nutrition by promoting women's participation in the value chains for horticultural crops and rice produced via sustainable intensification (SI) practices. Ethiopia found that multiple maize crops cultivated after irrigated and fertilized vegetables or fodder increased maize yield substantially as compared to baseline conditions due to soil fertility improvement from residual nutrients from dry season cropping. The Senegal team promoted sustainably intensified production and management practices of dual-purpose millet and leguminous crops (cowpea and groundnut), with small ruminant livestock (goats and sheep) integration. The Malawi team completed their project and built geospatial tools to integrate available data sets and mapped much of the country. Lastly, the Tanzania team evaluated bidirectional learning and extension approaches to promote SI technologies among researchers, extension, agrodealers, NGOs, and farmers and analyzed household surveys.

Other highlights include: a) finalization of the Research Output Dissemination study that focused on evaluating the path from development to end-user for selected innovations produced by the Feed the Future Innovation Labs, b) launch and implementation of the SOILS consortium with the IFDC and the Policy Research Consortium with Rutgers University, c) creating an online presence to continue to promote the SI Assessment Framework, and d) development of a pilot Research, Extension, and Advisory Coordination Hub (iREACH) in West Africa in collaboration with CORAF and USAID Missions.

SIIL is committed to human and institutional capacity building as evidenced by the number of short-term trainings offered to 6,162 individuals (2,390 women, 39%, which is 4% higher than FY 2018) and the support of long-term graduate degree training to 80 individuals (35 females). Of the 80 individuals, 41 are pursuing a Ph.D. degree (37% females), 38 Masters of Science (53% females), and undergraduate degrees. In addition, the SIIL researchers produced 170 publications and presentations this past reporting period. SIIL country coordinators continued to provide support to partners on the implementation and coordination of research, capacity building activities, communication and support of ongoing research.

II. Program Activities and Highlights

A. Geospatial and Farming Systems Research Consortium (GFC)

The GFC consortium management team and their subawards made significant progress in FY 2019, including the following highlights:

- Several key surveys took place in Senegal (in collaboration with the SIIL country coordinator) and in Ethiopia with AfricaRISING, and a 2,700 household survey with the One Acre Fund in Rwanda.
- 14 papers have been published on the research conducted by the GFC.
- New studies are in preparation focusing on the quantification of the SIIL's Sustainable Intensification Assessment Framework using RHoMIS data, using the AfricaRISING Ethiopia data, the SIIL Burkina Faso data, and the new Senegal data to quantify this framework. The data science manuscript to describe the first batch of open RHoMIS data is almost complete. GFC is also engaged in a long term collaboration with the UK based iNGO TreeAID, where 5-6 new RHoMIS applications are envisaged in West Africa annually.
- GFC-supported UAV pilot, Aidara Ousmane, became the first certified UAV pilot in Senegal.

B. Appropriate Scale Mechanization Consortium (ASMC)

The ASMC continued its efforts to sustainably intensify smallholders' cropping systems through mechanization with the following highlights:

- A rice transplanter was purchased by three smallholder farmers and have been trained by ASMC Bangladesh partners in order to begin service provider operations.
- Connected the Innovation Hubs and researchers with appropriate private sector companies and actors, local entrepreneurs, and farmer organizations to enable technology design and scaling.
- Developed an Agricultural Mechanization degree program within the Institute of Rural Development at UPB in collaboration with the Institute of Technology in Burkina Faso.
- Hosted a training with Ethiopian partners in which a total of five enterprises and three groups of potential start up founders were given training on startup foundation and custom-hiring, service business related agricultural mechanization techniques. The training served as an avenue to partner with local and international partners. ASMC partnered with Digital Opportunity Trust (DOT), DOT has directly impacted more than 6,000 youth worldwide, who have gone on to reach more than 1 million of their fellow community members. More than 90% of alumni have gone on to either secure employment or start their own businesses within six months of completing DOT programming. DOT's stated mission is "to create a youth-led movement of daring social innovators who have the tools, knowledge and networks to create opportunities and transform their own communities.

C. Integrated Research Subaward Portfolio

Highlights from the six SIIL subawards include:

- *Bangladesh* – Of the 14 scholars being supported by this project, nine completed their M.S. and three completed their Ph.D. from 2017 to June 2019. The other two Ph.D. students have completed data analysis and the first draft of their theses. They are expected to complete their Ph.D.'s by end of 2019.
- *Burkina Faso* – Farmers' Field School (FFS) was conducted by APESS during the last cropping season (June to October 2019). The two focal persons for the FFS in each community were trained in improved agronomic practices. Four farmers' field schools have been established in each of the eight project communities. Each FFS is about 0.25ha for improved cowpea variety and 0.25ha also for improved sorghum variety. Each FFS consists of between 10-20 farmers, including women.
- *Cambodia* – Market-demanded tomato scions grafted onto local eggplant landraces and/or World Vegetable Center evaluated eggplant rootstock to enable rainy season tomato production and represent a potentially profitable farmer enterprise.
- *Ethiopia* – Multiple maize crops cultivated after irrigated and fertilized vegetables or fodder increased maize yield substantially as compared to baseline conditions due to soil fertility

improvement from residual nutrients from dry season cropping (i.e. vegetables or fodder). However, the highest and most consistently stable maize yield was observed when it was planted after onion and fodder, respectively.

- *Senegal* – There is a strong integration of young people (girls and boys) and women in rural activities through the development of rural entrepreneurship. Capacity building of young people in seed production, seedling, and nursery production and market gardening enhances the production environment and income diversification. This project is taking the next step by focusing on young seed entrepreneurs and cooperatives, grain producers, processing units, and end-users.
- *Tanzania* – Four graduate students (three women) continued with their graduate coursework and research proposal writing at their respective institutions. One is set to graduate at the end of 2019.

D. Associated Awards and Mission Buy-Ins

CE SAIN, supported by the Cambodia Mission, continues to build capacity, improve coordination, and strengthen partnerships as demonstrated through increased number of grants awarded beyond USAID.

The Precision Agriculture for Smallholder Systems in Africa, with support from the USAID, has mapped much of Malawi and provided information to the USAID Mission. The project completed its work on building tools to integrate data sets and began work with CIAT to push forward a pilot project related to their work, and writing a scaling proposal along with CIAT to Google. All objectives have been achieved and the project was completed in FY 2019.

The Research Output Dissemination Study (RODS) project was completed in FY 2019. The objective of RODS was to gain a better understanding of the dissemination, use and adoption of research outputs from USAID-funded Feed the Future Innovation Labs (ILs) and its predecessor program, Collaborative Research Support Projects (CRSPs). RODS was designed to explore partnership dynamics at the critical juncture at which ILs transfer an innovation to a dissemination entity (Dissemination is defined in this study as "active and planned efforts to encourage target groups to adopt an innovation"). The study focused on research outputs after they were transferred to the entities facilitating their dissemination.

The SIIL has finalized a new Associate Award from USAID-Washington focused on the improvement of policy approaches and outcomes to support the achievement of the U.S. Government Global Food Security Strategy (GFSS) objectives. Rutgers University's (RU) Feed the Future Policy Research Consortium (PRC) will lead the consortium with funding and support from the SIIL as the management entity. The activity will support the learning agenda on policy, systems analysis, and implementation and assist the initiative to report on the success of its efforts. The PRC is a grouping of universities and researchers across the U.S. and sub-Saharan Africa focused on policy research related to agriculture and food security. The award will run from August 08, 2018 through December 06, 2021.

III. Key Accomplishments

A. 2019 SIIL Annual Meeting

The SIIL fourth Annual Meeting was held during April 8-10, 2019, in Saly, Senegal. It brought together more than 100 participants and key stakeholders from the SIIL projects to report on progress, as well as activities related to the theme of the convening "Suitability, Scalability, and Sustainability". Projects and consortia had the opportunity to showcase their work through presentations, posters, and discussions. They also met with the SIIL External Advisory Board and USAID representatives to discuss the results of their projects and future plans. Site visits were included as part of the meeting highlighting projects in Senegal that have been initiated as a result of the SIIL partnerships with the ISRA, ANCAR, and Peace Corps Senegal. The site visits included engagement with a local women's cooperative working on millet flour-enrichment and improved local chicken raising enterprises, as well as a youth engagement project at a local high school showcasing improved crop varieties (e.g., millet, sorghum, groundnut, cowpea), and vegetable garden production using conservation agriculture practices (i.e., improved compost).

B. SIIL/CORAF REACH Partnership

Development of a pilot Research, Extension, and Advisory Coordination Hub (iREACH) in West Africa (WA) in collaboration with CORAF and USAID Missions. Initial discussion with partners occurred on April 11, 2019, and a plan was developed. A stakeholder workshop related to the implementation of activities within the West Africa region took place September 9-10, 2019, and a concept note was completed and circulated. The workshop was held in Senegal and organized and facilitated by SIIL with representatives from the CORAF research centers, USAID Missions, NARES, the private sector, and other key stakeholder organizations.

C. Launch of Online Web Version of the SI Assessment Framework

The Sustainable Intensification (SI) Assessment Framework web tool was developed at the beginning of FY 2019. The purpose of the web tool is to facilitate greater access and usability of the framework for the SI research community. The tool was showcased at several venues, including the American Society of Agronomy and Crop Science Society of America Annual Meeting in November 2018, and the SIIL Annual Meeting in April 2019. The SI Assessment Framework is being utilized by all SIIL projects to quantify synergies and tradeoffs of their technologies across the five domains (productivity, economic, environment, human, and social condition). These efforts will continue to be encouraged to further investigate the utility of the tool in assessing farming systems.

D. SOILS Consortium Launch and SOIL Fertility Summits

The SOILS Consortium marked their official launch and announcement of the consortium collaboration, hosted by USAID in Washington, D.C., on March 15, 2019. Additionally, they conducted two Soil Fertility Summits, one in Niger and one in Ethiopia, both in May 2019, with partners from SIIL, the International Fertilizer Development Center (IDFC) and USAID. The primary purpose of these summits was to build from previous initiatives and co-develop concrete goals and activities to develop a road map to implement a national strategy to improve soil fertility leading to improved resilience, food, and nutritional security.

E. SIIL/ASA Partnership

The SIIL has collaborated and partnered with the American Soybean Association (ASA), CE SAIN, and other development organizations in securing a $17M grant funded by the United States Department of Agriculture (USDA) Food for Progress. The project, Commercialization of Aquaculture for Sustainable Trade (CAST), focuses on creating high-quality fish feedstock in Cambodia through US Soy Producers, as well as strengthening capacity building efforts within the RUA and UBB. CAST-Cambodia held its official launch in January 2019 with support from the Minister of MAFF and the U.S. Embassy in Phnom Penh.

F. Policy Consortium Associate Award

The SIIL finalized the Policy Research Consortium (PRC) Associate Award from USAID-Washington, which is focused on improvement of policy approaches and outcomes to support the U.S. Government Global Food Security Strategy (GFSS) objectives. Rutgers University will lead the consortium to support this learning agenda on policy, systems analyses, and implementation. The PRC is composed of a group of universities and researchers across the U.S. and sub-Saharan Africa.

G. Peace Corps Youth Engagement Panel at the World Food Prize

The SIIL highlighted its youth engagement activities at the World Food Prize Borlaug Dialogue in October 2018. The side event included a panel of youth from Cambodia and Senegal – a Peace Corps volunteer, an Institut Sénégalais de Recherches Agricole (ISRA)-supported graduate student, the director of the CE SAIN in Cambodia, and a CE SAIN-supported graduate student. The event focused on youth engagement in agriculture and the transformational events that influenced their decisions to work in agriculture or agriculture-related professions. The panel also provided insights on how best to recruit, retain, and sustain youth in agricultural professions, and why their involvement is so critical in solving our global challenges related to food and nutritional security and improved livelihoods.

IV. Research Program Overview and Structure

A. The Geospatial and Farming Systems Research Consortium (GFC)

The GFC brings together leading geospatial researchers to enhance the efficiency and success of agricultural research and development. The GFC works closely with the research subaward team to enhance their capacity. Specific activities and outcomes of the members are listed separately in the next section. GFC research encompasses five thematic objectives:

- Land: To identify current patterns of intensification and opportunities for sustainable intensification.
- Inputs: To improve the resource use efficiency in crop production.
- Management: To design crop growth monitoring tools.
- Productivity: To estimate current and potential yield in the regions of interest.
- Access: To understand the impact of market socio-economic and environmental conditions on opportunities for intensification.

B. The Appropriate Scale Mechanization Consortium (ASMC)

The ASMC aims to introduce multifunctional and modular mechanized technologies that are technically, environmentally, economically and socially appropriate for use by smallholder farmers (including women) with the flexibility to accommodate different power sources. They are currently active in four countries. The specific intervention and entry point varies by country as determined by the host country partners and needs of the producers. These technologies contribute to enhanced labor productivity and increased land productivity, thus sustainably reducing poverty among smallholders. The ASMC has six key functions:

- Engage entry-point organizations to establish Innovation Hubs.
- Assess country-specific mechanization challenges, opportunities and priorities.
- Implement country-specific activities utilizing participatory research methods.
- Train and build human capacity with an emphasis on gender.
- Monitor and evaluate the impact of activities.
- Share knowledge with in-country stakeholders.

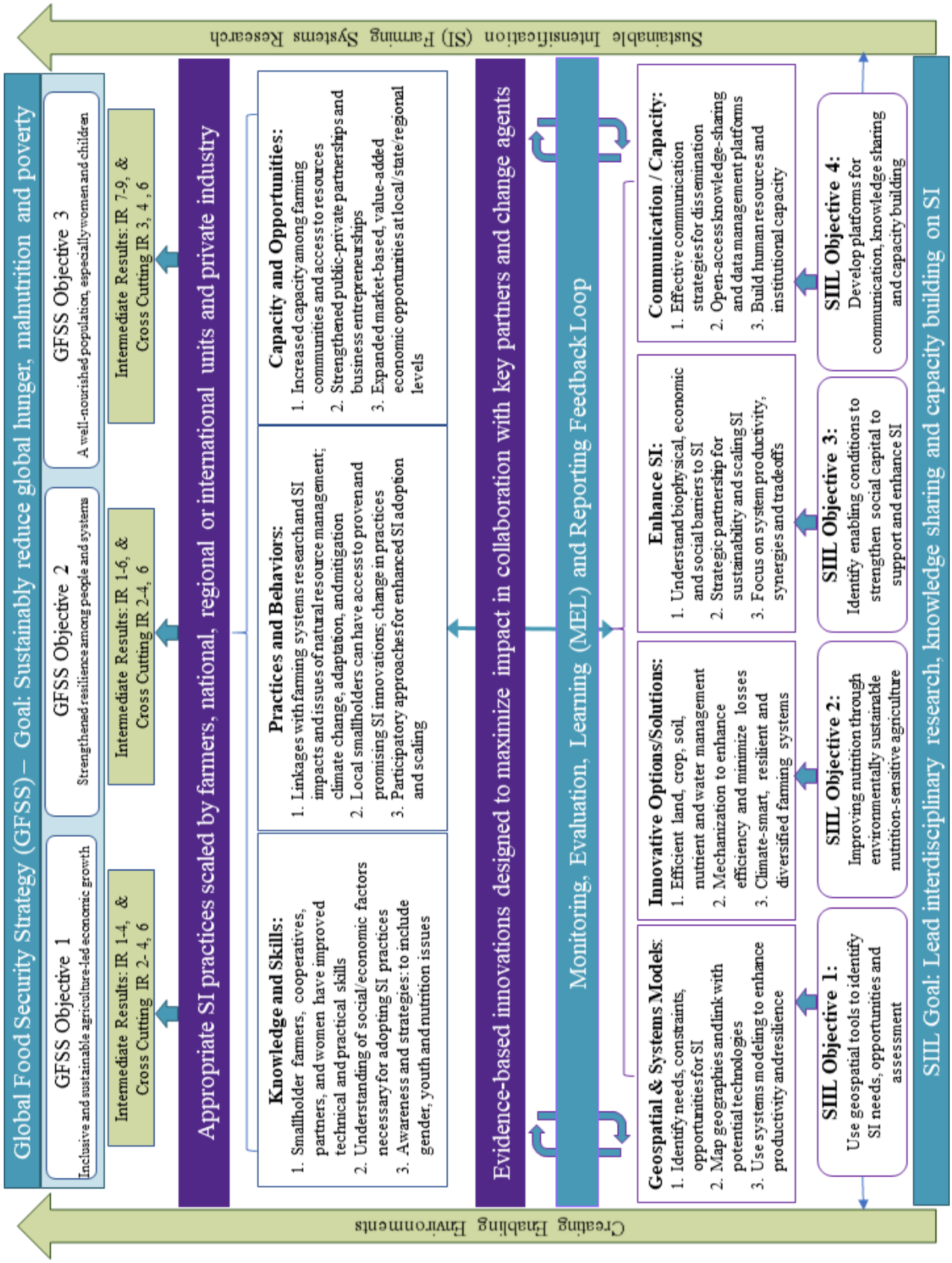
C. Focus Country Research Subawards

The SIIL is currently supporting seven country subawards. Together, the subawards investigate a diverse range of sustainable intensification practices and innovations across the SIIL focus countries. The broad focus areas are crop-livestock interaction; better management of crops and livestock to enhance resource use efficiency; diversification (integration of legumes, home gardens, and new crops); and precision and sustainable agricultural practices. The SIIL research subawards are implemented and led by collaborations between U.S. universities, NARS centers, NGOs, and CGIAR partners.

D. Developing Indicators for Sustainable Intensification

The Sustainable Intensification (SI) Assessment Framework was officially launched in October 2017 at the International Annual Meeting of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. The framework guide and manual were made available to the public at the time of the launch. The SIIL management entity led efforts to create a website to operationalize the SI Assessment Framework. The online presence of the framework will be made available November 2018. This framework will have a wide range of uses, looking at impacts of innovations across multiple domains (productivity, environment, economics, and social and human conditions) and evaluating synergies and tradeoffs. Such analysis is critical for providing options that are specific to stakeholders understanding the overall system and determining options and solution that will enhance overall productivity and resilience of a system rather than individual components. Such an analysis will aid in understanding mechanisms of scaling and adoption of innovations. This framework can also be used for improving programming and integration of gender, nutrition and human capacity.

V. Theory of Change



VI. Research Project Reports

A. Geospatial and Farming Systems Research Consortium

1. Summary of GFC activities

A. Name: Geospatial and Farming Systems Research Consortium (GFC, Principal Investigator (PI): Robert Hijmans, University of California, Davis)

B. Locations: Global – Due to the nature of the consortium's research and the incorporation of remote sensing, the projects are often not location-dependent. The locations listed for each subaward report may refer to field work locations, targeted areas for remote sensing work, or a combination of the two. However, the processes and methods can be scaled globally.

C. Description and Achievements (See FY 2019 AWP Objective 2): The GFC focuses efforts, through a portfolio of research subawards and independent research, on five primary objectives. The achievements listed under each objective refer specifically to the efforts of the GFC leadership team at the University of California, Davis. Their subawards achievements are listed separately.

(a) Identify current patterns of intensification and opportunities for sustainable intensification.

(i) The toolkit is being constantly developed. The current version is available here: https://github.com/nkoech/Targeting_Tools_10_1.

(ii) Significant progress was made with producing input predictors and analytical tools used in the framework. They also collaborated with Jovin Lwehabura, East Africa regional coordinator, for a study on targeting adoption of bean technology. The study is complete now, and the manuscript will be submitted soon.

(iii) Results for Bangladesh, Cambodia, and Tanzania are available - multi-resolution (250 m, 30 m, 20 m, 10 m) products from different remote sensing satellites were used to create cropland mask for supporting analysis at various spatial scales (plot, village, regional, and national level). Some of the products are already available in the SIIL Dataverse.

(iv) Demonstrated a new method to map paddy rice using Google Earth Engine (GEE) and the Landsat archive in Bangladesh during the dry (*boro*) season. Using GEE and Landsat, dry season rice areas are mapped at 30 m resolution for approximately 90,000 km^2 annually between 2014 and 2018.

(b) Improve resource use efficiency in crop production.

(i) Country specific WorldClim data has been uploaded into the SIIL Dataverse.

(ii) The crop models are in active development. The most recent versions of the packages can be found here: https://github.com/cropmodels. Using these packages, a study comparing various spatial prediction models for estimating crop yield potential was published. Most crop simulation models require daily weather data as input but such data are generally not available at a high spatial resolution.

(c) Design crop growth monitoring tools.

(i) The beta version of website is available here: https://weather.gfc.ucdavis.edu/ . They expect this website to remain active for future years (as long as the weather stations upload the data).

(ii) Made progress in developing R-packages and Google Earth Engine based apps to automatically download and process large number satellite data.

(d) Estimate current and potential yield in regions of interest.

(i) Collected a large number plot level yield information from Tanzania, Mozambique, Nigeria and Ghana to calibrate the remote sensing models. Estimate transportation costs at 1 km^2 spatial resolution or lower for Tanzania.

(ii) IFPRI made significant progress with new version of SPAM database on crop production. Most recent version of Global Spatially-Disaggregated Crop Production Statistics Data for 2005 and 2010 has been submitted in Dataverse.

(e) Understand the impact of market and socio-economic and environmental conditions on opportunities for intensification.

(i) Calibrated the QUEFTS model to NOT trial results in Ethiopia. Simulated blanket recommendations of available fertilizer blends in Ethiopia and Tanzania produced optimized recommendations considering spatially-variable input and output prices. Calibrated QUEFTS with the attainable yield reported from GYGA and obtained support from the Microsoft AI for Earth program to run spatially-explicit version of QUEFTS with the optimization algorithms in Microsoft servers, reducing processing time for these predictions.

(ii) The code of the R framework and the revised Shiny app are being shared through open repositories (https://github.com/spalmas/SpatialQUEFTS and https://github.com/spatial-economics/QUEFTS/tree/dev).

D. Collaborators: See GFC subaward reports

E. Capacity Building:

(a) Demonstrated a new method to map paddy rice using Google Earth Engine (GEE) and the Landsat archive in Bangladesh during the dry (boro) season. Using GEE and Landsat, dry season rice areas are mapped at 30 m resolution for approximately 90,000 km2 annually between 2014 and 2018.

(b) Started new collaboration with CGIAR and Feed the Future Innovation Lab for Assets and Market Access for collecting validation data. We also started building a website to provide easy access to remote sensing time series information to monitor the crop growth: https://anighosh.users.earthengine.app/view/biogeo-time-series-modis.

(c) Organized training events on small Unmanned Aerial Systems (sUAS) based remote sensing data collection and processing in Cambodia and Senegal. In-country partners now have a complete kit, sUAS with regular color and multispectral cameras, for near-surface remote sensing data collection. They are using the instruments to collect images of the experimental plots (or study locations) at frequent intervals during the growing seasons. sUAS equipment in Cambodia is also being used to monitor an experimental plots managed by ASMC.

F. Lessons Learned:

(a) Finding good quality ground data is challenging. Lacked sufficient funding or time to collect ground data in Bangladesh.

(b) Mapping smallholder farms in Africa proved extremely difficult due to the heterogeneity. Cloud cover often limits abilities to monitor crop growth using remote sensing data during the growing season.

(c) The project requires a specific software with high licensing cost and access to high resolution commercial remote sensing data. These two factors are often limiting the adoption of this technique for new locations.

(d) While we understand the framework could be useful to investigate scaling up potential for certain technologies, we could not find any opportunity to discuss this with other country specific projects. During the recent annual meeting, the importance of this tool was mentioned by EAB members. However, adapting this tool for other countries may require significant amount of work.

G. Peer Reviewed Publications:

(a) Riggio, J., Jacobson, A., Hijmans, R. (2019). How effective are the protected areas of East Africa? (pp.1-12). Global Ecology and Conservation, 17, Online.

(b) Smith, J. C., Ghosh, A., Hijmans, R. (2019). Agricultural intensification was associated with crop diversification in India (1947-2014). PLOS ONE

(c) Michael, M., Nelson, A., Ghosh, A., et al. (2019). Crowd-Driven and Automated Mapping of Field Boundaries in Highly Fragmented Agricultural Landscapes of Ethiopia with Very High Spatial Resolution Imagery (pp. 2082). Remote Sensing, 11(18), MDPI

(d) Hammond, J., et al. (Under Review). Next-generation household surveys to increase uptake, impact and return on investment for a nationwide NGO-led rural development program in Rwanda. Agricultural Systems

(e) Hammond, J., et al. (2019). Rapid pace of change for rural smallholders in East Africa: prosperity is driven by off farm income, in tandem with agricultural intensification. Proceedings of the National Academy of Sciences of the United States of America. - Presentation

(f) Fraval, S., Hammond, J., Wichern, J., Oosting, S.J., de Boe, F. (In Press). Making the most of imperfect data: a critical evaluation of standard information collected in cross-sectional farm household surveys. Experimental Agriculture

(g) Shew, A., et al. (2019). Rice intensification in Bangladesh improves economic and environmental welfare (pp.46-57). Environmental Science and Policy, 95, Unknown.

(h) Azzari, G., et al. (Under Review) Smallholder maize area and yield mapping at national scales with Google Earth Engine. Remote Sensing of Environment

(i) Shew, A. & Ghosh, A. (2019). Identifying Dry-Season Rice-Planting Patterns in Bangladesh Using the Landsat Archive (pp.1235). Remote Sensing, 11(10), MDPI.

2. GFC Subaward V

A. Name: Towards Standardization of Farm Household Surveys, Phase II: Moving from a Successful Proof-of-Concept to Large Application and Outscaling (Mark van Wijk, ILRI)

B. Locations: Global with specific focus on Feed the Future countries/zones

C. Description: The RHoMIS framework is a flexible digital platform built on open-source software that can be modified to meet a range of needs while collecting a core set of data that feeds into a global discussion on the success of SI. The framework has been applied in many sites and countries, and has been used in a wide-range of projects focusing on water productivity, crop-livestock integration, bean production intensification, gender equity, and climate-smart agriculture. The project aimed to further improve the RHoMIS tool, promote application in several specific contexts (including SIIL, Africa RISING), stimulate uptake of the tool, and expand analysis procedures on the identification and adoption potential of new interventions. The project will set up a new exploration type of farm household level analysis to better quantify adoption and outscaling potential of interventions and their consequences in terms of overall household level welfare.

D. Collaborators: ILRI

E. Achievements (See FY 2019 AWP Objective 2):

(a) Several key surveys took place in Senegal (in collaboration with the SIIL country representative), the AfricaRISING Ethiopia survey and a large (2700 household) survey with the OneAcre Fund in Rwanda.

(b) Several papers have been published on the work done by the project.

(c) Studies are in progress focusing on the quantification of the SI Assessment Framework using RHoMIS data with AfricaRISING Ethiopia data, and also SIIL Burkina Faso and Senegal data to quantify this framework. The data science manuscript to describe the first batch of open RHoMIS data is ready.

(d) Engaged in a long term collaboration with the UK based iNGO TreeAID, where yearly 5-6 new RHoMIS applications are envisaged in West Africa

F. Capacity Building:

(a) Web-based resources have been developed to support the understanding and utilization of the RHoMIS tool and uptake has been substantial in projects with other donors (i.e., BMGF, ACIAR, DFID, etc.). It was also adopted in SIIL's Burkina Faso and Cambodia projects along with AfricaRISING and a GFC supported project at Royal University of Agriculture, Cambodia.

G. Lessons Learned:

(a) For some users, standardization and harmonization are the key words in the RHoMIS approach, which can come at too high a cost. In such cases, users prefer to develop and use their own set of tools.

(b) Another challenge is related to current user model of RHoMIS. At the moment, GFC is in control of the applications and must make sure the applications follow the RHoMIS data label approach, and use the appropriate indicators. It is not self-sustaining.

H. Presentations and Publications:

(a) Fravel, S., et al. (Under Review). Pathways to food security in rural Burkina Faso: the importance of consumption of home-produced food versus purchased food. Food Security

(b) Fraval, S., et al. (Under Review). Nutritional gaps of rural households in East and West Africa: prevalence and determinants based on rapid indicators. Global Food Security.

(c) Tavenner, K., Van Wijk, M., Fraval, S., Hammond, J., Balte, T. (2019). Intensifying Inequality? Gendered Trends in Commercializing and Diversifying Smallholder Farming systems in East Africa (pp.1-14). Frontiers in Sustainable Food Systems, 3(10), online.

(d) Stirling, C.M., Farnsworth, C.R., Hammond, J., Chinyophir, A. (Under Review). Household Methodologies to Reduce Gender Inequality and Increase Household Resilience to Climate and Other Shocks: A Case Study from Malawi. Climate Change

3. GFC Subaward VI

A. Name: Patterns and Drivers of Land Use Change in Battambang Province, Cambodia (PI: Sanara Hor, Royal University of Agriculture, RUA)

B. Locations: The project analysis area transects through the lowland areas near Tonle Sap Great Lake (central Cambodia) to the upland area (western Cambodia) within Battambang. Additional locations include Pailin, Pursat, Kampong Thom, and Siem Reap in Cambodia

C. Description: The pattern, causes, and consequences of land use and land cover change have not been documented throughout Cambodia. In the northeastern province and other parts of Cambodia, government land policies are changing land uses and cropping systems. In this location, agricultural expansions and transitions in the farming system have had significant impacts on the forest cover. In central Cambodia, the agricultural expansion is caused by the development of irrigation systems. Given the different dynamics of land use changes across Cambodia, there is an urgent need to characterize these processes for developing land use management policies and improve the understanding of the changes in the environmental and socio-economic conditions. This study primarily focuses on land use changes of Battambang Province. The study proposes to use remote sensing image analysis and quantitative research methods to investigate the major drivers of land use and land cover changes. Medium and high-resolution imagery will be applied along with household surveys to improve our understanding.

D. Collaborators: RUA

E. Achievements (See FY 2019 AWP Objective 2):

(a) Started partnership with one of the leading UAV data processing company, Pix4D (https://www.pix4d.com/)

(b) Conducted a number of flights with UAV (DJI M100) to cover more than 1000 hectare in 5 sub-regions of the study location. Also worked with the ASMC project in Cambodia to collect data on rice experiment fields to understand the performance of the new instrument introduced. Dr. Sanara's lab will RUA will soon become a flying lab associated with WeRobotics (https://werobotics.org/).

(c) Received a USAID PEER grant to extend the project and develop crop type database. The consortium also secured additional funding from ACIAR for a project titled "Land suitability assessment and site-specific soil management for Cambodian uplands.

F. Capacity Building:

(a) Two Ph.D. students under joint supervision of the GFC were selected for this project. Both students were awarded Ph.D. scholarships from the CE SAIN.

G. Lessons Learned:

(a) Licensing issues with the software for UAV data processing delayed some of the activities in Cambodia.

(b) Fund transfer restrictions to Cambodia delayed many project activities.

(c) Data transfer processes or regular communication with Cambodia team was often affected by poor internet connections or disruptions in power supply in Cambodia.

(d) Government agencies are often reluctant to share their data (e.g. it is difficult to collect data on commune level agriculture census data for Cambodia).

H. Presentations and Publications:

(a) None to report in FY 2019.

4. GFC Subaward VII

A. Name: Updating Fertilizer Recommendations across Rainfall Gradients and Soil Fertility Levels for Improving Dual-Purpose Millet Nutrient Use Efficiency in Senegal (PI: Aliou Faye, CNRA/ISRA)

B. Locations: *Senegal* - Bambey, Kolda, Nioro, Sinthiou, and Dahra

C. Description: This project aims to improve Senegal's food security through the development of appropriate fertilizer recommendations for dual-purpose millet varieties across Senegal's rainfall and soil gradients. The project objectives include initiatives to: (1) develop a geographically appropriate fertilizer recommendation model based on millet variety, climatic conditions (precipitation), management practices such as leguminous intercropping, and soil fertility gradients in the millet cropping zone; (2) create a high spatial resolution map of soil properties; (3) improve the understanding of the relationship between seasonal and spatial price movements and climactic differences, transportation costs and other variables; and (4) build capacity of Senegalese researchers and students in statistical modelling and sUAS data collection systems.

D. Collaborators: ISRA and KSU

E. Achievements (See FY 2019 AWP Objective 2):

(a) Nitrogen fertilizer experiments (3 growing seasons) in 5 research stations and a fertilizer price survey in Senegal are all now complete.

(b) Yield response data across the 5 agro-ecologies have been compiled and analyzed. This data was used to guide the design of the third year's cropping cycle. After all three years' worth of data are complete, a final analysis and fertilizer response functions will be developed.

(c) 2500 soils samples collected across 1000 locations in Senegal. 2000 samples are being analyzed by the Cropnuts Ltd in Nairobi for wet lab and spectral analysis. The final output will be uploaded in the Dataverse at the earliest. Additional 500 samples will be analyzed by AgroCares, Netherlands.

(d) Collaboration with CropNuts and QED has continued in an effort to develop a high resolution soil map for Senegal. QED provided the locations for soil sample collections based on the framework developed by AfSIS, ISRA is collecting 2000 soil samples from the field and will provide results from a previous analysis of 500 samples and CropNuts will be responsible for providing mobile data collection platforms, barcoding and training, shipping and permits, and soil property analysis for the 2000 samples. CropNuts will also be providing soil spectroscopy.

F. Capacity Building:

(a) 4 MSc theses from different universities in Senegal (Thies, Dakar, and Ziguinchor) have been defended last December and March. 2 Ph.D. candidates are engaged in ongoing research with weather data and soil moisture information at 5 research stations across Senegal.

(b) GFC supported UAV pilot in Senegal, Aidara OUSMANE, became the first certified UAV pilot in Senegal.

(c) Fertilizer dispersion and price study are complete in the 5 regions of the country and 4 Master students are currently finalizing their thesis on economics at ENSA University of Thies.

G. Lessons Learned:

(a) Dedicated personnel (e.g. postdoc) and adequate time needed to conduct research that requires specialized skills.

(b) Has been extremely difficult to coordinate activities involving multiple agencies from different countries. Due to a number of reasons, the project was delayed by more than a year.

(c) Some of the sensor components of all weather stations are having some problems and needed to be replaced. The additional cost of parts replacement is a major concern beyond the duration of the SIIL project. So far ISRA has supported the replacement cost.

H. Presentations and Publications:

(a) None to report in FY 2019.

5. GFC Subaward VIII

A. Name: Sustainable Intensification of Millet-Based Agrosystems Using Cowpea in the Groundnut Basin of Senegal (Laure Tall, LNRPV/ISRA)

B. Locations: Louga, Fatick, and Kaolack, Senegal

C. Description: Cropping systems involving different plant species can be strong assets for the development of SI of agriculture. However, due to the lack of technical references (most of them being established for monocrops), the evaluation of their management is difficult. Indeed, interactions between crops can change depending on the field's management scheme (density of sowing, varieties and fertility management), environment (soil, or plot type) and climate. Thus, there is a need for dynamic modelling tools to evaluate how wide ranges of soil conditions, various weather sequences and different management schemes, modify the yield and environmental impact of intercropped systems. This project aims to better understand the beneficial mechanisms involved in millet-cowpea intercropped systems, and estimate their yields in various situations of the Groundnut Basin in a context of climate variability with erratic and short rainfall periods.

D. Collaborators: *Senegal* - CNRA/ISRA, LNERV/ISRAI; *France* - RD, CIRAD

E. Achievements (See FY 2019 AWP Objective 2):

(a) Multiple equipment items (LiCOR plant canopy analyzer) and instruments (weather station, SPAD chlorophyll meter) essential for this project were procured.

(b) Trials and networks of plots for data acquisition were established. Trials are located in 3 sites in the center of Senegal: 1) in the research station of CNRA Bambey (Region of Diourbel, N 14°42'47.5" W 16°28'46.6"), 2) on farmers plots in the village of Sob (region of Fatick, N 14° 29' 44.268" W 16° 27' 16.056") and 3) in the research station of Sinthiou Malème (Region of Tambacounda, N 13°49'49.6" W 13°54'43.0"). A network of 28 farmers' plots is also being monitored in the village of Diohine in the area of the IRD observatory.

(c) As mentioned in Subaward VII achievements, collaboration between the projects is occurring to leverage research results for both projects.

F. Capacity Building:

(a) Two Ph.D. candidates have been hired to work on the project.

(b) A mid-term workshop of the SIMCo Project (Sustainable Intensification of Millet and Cowpea) was conducted to share results with research team on crop modeling and specialization.

G. Lessons Learned:

(a) The equipment and instruments were not directly purchased by ISRA. GFC and IRD had to purchase and ship them to Senegal. This caused significant delay in the project.

(b) Fund transfer delays and other difficulties in financial reporting caused data collection delays.

(c) Project has not received any update from the PI of this project, Dr. Laure Tall, over the last of couple of months and been informed that she is not well and taking some time off. However based on earlier communication, it is believed that there has been significant progress in this project.

H. Presentations and Publications:

(a) None to report in FY 2019.

B. Appropriate Scale Mechanization Consortium (ASMC)

1. Summary of ASMC Activities

A. Name: Appropriate Scale Mechanization Consortium (PI: Alan Hansen, University of Illinois at Urbana-Champaign)

B. Locations: Bangladesh, Burkina Faso, Cambodia, and Ethiopia

C. Description: The ASMC facilitates the introduction of multifunctional and modular mechanized technologies that are technically, environmentally, economically and socially appropriate for use by smallholder farmers. The overall objective of the project is to sustainably intensify smallholder farmers' cropping systems and on-farm operations through mechanization. The ASMC utilizes a user-centric systems approach through an Innovation Hub model in each of their four focus countries. The Hubs identify specific mechanization needs, leverage ASMC resources accordingly, and implement innovative solutions.

D. Collaborators: *United States* - Kansas State University, Michigan State University, and North Carolina A&T State University, ADM Institute for the Prevention of Postharvest Loss (Illinois). Additional international collaborators are listed under each ASMC country report.

E. Achievements (See FY 2019 AWP Objective 3):

(a) Focus country achievements are reported separately to capture the range of activities.

(b) The initial toolkit has been refined and adapted for ASMC's unique context of working with early-stage technologies. New presentation training modules have been created, tested in ECHO FL, Cambodia and Bangladesh. A new questionnaire developed for assessing the technologies has been tested and refined in Cambodia and Bangladesh.

(c) There has been great progress in Burkina Faso with the team attempting to test the planter with donkeys that are more accessible to both women and men farmers.

(d) Drip irrigation evaluated in Ethiopia. BiT has implemented along other partners, testing the water-lifting technologies and conservation agriculture (CA) by growing a local variety of onions at 34 on-farm locations in Dangishta during the dry season (December to March) with participation of both male and female farmers.

F. Capacity Building:

(a) Trained 17 participants to conduct gender technology assessments through a 1.5 day training in Bangladesh in January 2019. The 12-member team consisted of BAU staff and a gender specialist.

(b) Trained 12 participants to conduct gender technology assessments through a 1.5 day training in Cambodia in January 2019. The team consisted of RUA staff, DAE gender staff, CASC team, and a UBB staff.

G. Lessons Learned:

(a) Capacity of some countries to maintain equipment is lacking.

(b) It was very challenging travelling to two countries back to back to conduct assessments. The time frame was extremely short for the level of effort and work required to train staff, conduct quality assessments, and author reports.

(c) There were not enough women on the team in Bangladesh. The male dominated teams are good for capacity building, however, it posed a barrier in a conservative society with men interviewing female farmers. Project tried to ensure that there was one woman in each team, however, in an effort to conduct as many interviews as possible, teams sometimes split into pairs with just men, which did not yield to good information on gender dynamics within households.

(d) Coordination within country proves difficult at times.

(e) Qualitative interview skills are lacking. In an effort to counteract this gap, the questionnaire was made as detailed as possible. However, this meant that per interviewee time increased to almost two hours. Many team members found that challenging and some farmers found that challenging. Furthermore, since there is already reduced time in country and kept LOE down to minimum, it further complicated the learning and conducting of the assessment.

H. Presentations and Publications:

(a) Faulkner, P. E., Jefferson-Moore, K., Begum, S., SOCHEATH, O., Bougouma-Yameogo, V., & Abate Fenta, F. (2019). Addressing Gender Inequality: Reports from Women Farmers in Bangladesh, Burkina Faso, Cambodia, and Ethiopia. - *Presentation*

(b) Jefferson-Moore, K., Faulkner, P. E., Begum, S., SOCHEATH, O., Bougouma-Yameogo, V., & Abate Fenta, F. (2019). Integrating Gender-Sensitive Participation in Sustainable Intensification and Nutrition Research. First International Sustainable Agricultural Intensification and Nutrition Conference, Royal University of Agriculture, Phnom Penh, Cambodia. - *Presentation*

(c) Jones, M. (2019). Assessing early-stage agricultural technologies for gender sensitivity. Women and Gender in Development, Blacksburg, United States. - *Presentation*

(d) Jones, M., Moore, A., & Rivera, A. (2018). Assessing technologies for gender sensitivity. Presentation at ECHO Conference, Fort Myers, Florida. - *Presentation*

(e) Jones, M. (2019). Assessing technologies for gender sensitivity. Presentation at International Food Security symposium, Urbana- Champaign. - *Presentation*

(f) Rendall, T. & Jones, M. (2019). Making Extension and Outreach Trainings Gender Sensitive: A three part Webinar Series.

(g) Srivastava, A. (2019). Solar-powered drip Irrigation Project in Burkina Faso. ASABE Annual International Meeting, Boston, MA, USA. - *Presentation*

2. *ASMC – Bangladesh*

A. Name: Appropriate Scale Mechanization Innovation Hub (ASMIH) - Bangladesh

B. Locations: Innovation Hub location: Bangladesh Agricultural University, Mymensingh (Bangladesh)
Field locations: Dumuria and Wazirpur (Bangladesh)

C. Description: The goal of the ASMIH - Bangladesh project is promote appropriate-scale agricultural mechanization for sustainable intensification focusing on smallholder farming systems in Southern Delta region of Bangladesh. The target equipment interventions include: Rice transplanters; rice reapers, mini-combine rice harvesters, strip-tillage planters, no-tillage planters, bed planters, and axial flow pumps

D. Collaborators: Bangladesh Agricultural University (BAU), Bangladesh Rice Research Institute, Bangladesh Agricultural Research Institute, and ACI Motors Ltd.

E. Achievements (See FY 2019 AWP Objective 3):

(a) Kubota NSP-4W model rice transplanter performance was evaluated in Subarnachar, Noakhali; and Wazirpur, Barishal in Boro-2019 season. The average effective field capacity, fuel consumption and field efficiency of the transplanter were found 0.18 ha/hr, 4.34 lit/ha, 69.04%, respectively.

(b) Leaflet of rice transplanter was printed, which included the brief description on seedling raising, transplanter benefits, operation, troubleshooting, and business scope. Training module has been developed to conduct training. The training manual consists of seedling raising techniques, transplanter technical parameter, and maintenance of the transplanter and general troubleshooting of the transplanter during operation in detail.

(c) Experiments were conducted for hybrid variety rice at the BAU farm, Dumurlya, and Khulna for estimating seed rate and evaluating performance of rice transplanters in both puddled and unpuddled soil conditions.

F. Capacity Building:

(a) Forty-one women participated in field days in Wazirpur, Barishal; and Dumuria, Khulna on the seedling raising process, tray/mat preparation, and operations like irrigation and pest management.

(b) Multiple field days, demonstrations, and training programs were conducted for operators, mechanics, local engineering workshop owners, and farmers on harvesting machines seedling raising, and rice transplanter operations (see short-term trainings for complete list).

(c) Developed and finalized training manual for both reaper and mini-combine harvester in English and Bengali, which will be printed as a booklet for distribution among the stakeholders at field-level. Two leaflets for both reaper and mini-combine harvester have already been printed.

(d) Three farmers each from ten different sites around Bangladesh participated in field days and were trained in operating, maintaining and troubleshooting CA and irrigation machinery.

(e) Research findings were presented in various international and national conferences and workshops.

G. Lessons Learned:

(a) Availability of good mechanics and spare parts in the locality is a challenge.

(b) Developing entrepreneurship for seedling nursery and transplanter custom hire business is difficult as the machine use is seasonal.

(c) In some intervention areas, drainage is a problem during heavy rain. Therefore, suitable lands for transplanting in the areas are limited.

(d) Student idea competition is a good practice for engaging academia and creating innovative ideas in agricultural mechanization.

H. Presentations and Publications:

(a) Hasan, M., Ali, M., Kumar Saha, C., Alam, M., & Hossain, M. (2019). Assessment of paddy harvesting practices of Southern Delta Region in Bangladesh (pp.57-64). Progressive Agriculture, 30, Mymensingh, Bangladesh. ISSN: 1017 - 8139

(b) Ali, M., M., Kumar Saha, C., & Alam, M. (2019). Custom Hiring Service of Reaper for Harvesting Paddy. International Conference on Sustainable Agriculture 2019, Bangladesh Agricultural University, Mymensingh. N/A - *Presentation*

(c) Sarkar, S., M., Basir, M., Hossain, M., Saha, C. K. (2019). Determination of seed rate for mechanical transplanting of hybrid paddy variety in Bangladesh. 2019 ASABE, Annual International Meeting, July 07-10, 2019, Boston, Massachusetts, USA. doi: https://doi.org/10.13031/aim.201901177 - *Presentation*

(d) Mottalib, M. A., Hossain, M., Hossain, M., Amin, M., Saha, C. K., & Alam, M. (2019). Techno-economic performance of conservation agriculture machinery for planting soybean in the south east coastal region of Bangladesh. 2019 ASABE, Annual International Meeting, July 07-10, 2019, Boston, Massachusetts, USA., Boston, Massachusetts, USA. doi: https://doi.org/10.13031/aim.201900574

(e) Hasan, M., Ali, M., Saha, C. K., Alam, M., & Hossain, M. (2019). Technical Performance and Benefit of Mini-combine Harvester in Southern Delta of Bangladesh. Journal of Agricultural Mechanization in Asia, Africa & Latin America. 00845841

(f) Mottalib, M. A., Hossain, M., Hossain, M., Amin, M., Saha, C. K., & Alam, M. (2019). Enhancing economically and eco-friendly jute production through appropriate conservation agricultural tillage cum seeding methods in the southwestern coastal region of Bangladesh (pp. 27-46). International Journal of Engineering Inventions, Volume 8(Issue 1), India. http://www.ijeijournal.com/papers/Vol8-Issue1/E08012746.pdf

(g) Sarkar, S., Hossain, M., M., Saha, C. K., & Alam, M. (2018). Financial performance and adaptation of rice transplanter in southern delta of Bangladesh. - *Presentation*

(h) Ali, M., Hasan, M., Kumar Saha, C., & Alam, M. (2019). Losses of Paddy in Harvesting Practices in Bangladesh. An ASABE Meeting Presentation, Boston, Massachusetts - presentation

(i) Basir, M., Sarkar, S., M., Hossain, M., Saha, C. K., & Alam, M. (2018). Performance evaluation of rice transplanter in puddled and unpuddled soil condition for hybrid rice variety. - *Presentation*

(j) Basir, M., Sarkar, S., M., Saha, C. K., Hossain, M., & Alam, M. (2019). Mechanical transplanting of hybrid variety rice for sustainable food security. International Conference on Sustainable Agriculture-2019 - *Presentation*

(k) Sarkar, S., M., Saha, C. K., Hossain, M., & Alam, M. (2019). Seedling raising nursery business for sustainable mechanical rice transplanting in the Southern delta of Bangladesh. - *Presentation*

3. ASMC – Burkina Faso

A. Name: Appropriate Scale Mechanization Innovation Hub (ASMIH) – Burkina Faso

B. Locations: Innovation Hub location: Polytechnic University of Bobo-Dioulasso, Bobo-Dioulasso (Burkina Faso); Field locations: Koumbia, Burkina Faso

C. Description: The main objective of the project in Burkina Faso was to increase maize productivity through appropriate scale mechanization using animal draft for smallholder farmers. The targeted equipment interventions included: a refined ox yoke, single row ox-driven planter, conservation ripper (chisel plow), and an animal-drawn crop cultivator. Other tools include forage/fodder chopper and solar-powered irrigation systems.

D. Collaborators: *Burkina Faso* - Polytechnic University of Bobo-Dioulasso; *United States* – Tiller's International

E. Achievements (See FY 2019 AWP Objective 3):

(a) Organized a cascade training of farmers on oxen nutrition and health. The aim of this activity will be to reach 1000 farmers in the project area. Farmers will be selected from baseline data.

(b) Chopper made by the project will be used for demonstration and forage seed storage building will be set up.

(c) Dr. Kéré and Dr. Millogo traveled to the US (Michigan State University) to learn the diet formulation software.

(d) The project developed a small drip irrigation system affordable by small holder farmers and especially women to produce vegetables.

F. Capacity Building:

(a) 492 farmers were trained on animal nutrition with 115 women from six locations in the Hauts-Bassins Region.

(b) Three master's students have completed their projects on solar drip irrigation systems to grow crops during the dry season.

(c) A master student is currently studying the sociological and economic aspects of the project, including all gender aspects related to the project's innovations.

G. Lessons Learned:

(a) The project must find a place close to UNB (former UPB) to set up as the main demo site for mechanization.

(b) The limitation of the scalability is the need for extra funds to train more farmers on how to use various technologies and innovations created by the project.

(c) A postharvest issue was found by stakeholders as very big issue for food security. A specific budget is needed to amplify this training beyond the Hauts-Bassins Region.

(d) Project must find/innovate a cost effective pump for solar drip irrigation.

H. Presentations and Publications:

(a) Srivastava, A. (2019). Solar Drip Irrigation Project in Burkina Faso. ASABE Annual International Meeting, Boston, MA, USA. - *Presentation*

(b) Millogo, V. (2018). Technical paper on the use of planter made by ASMC in Burkina Faso. National forum for research and technology (FRSIT) in Ouagadougou, Ouagadougou (Burkina Faso). CNRST/INERA/FT/2018-0051 - *Presentation*

(c) Millogo, V. (2019). Evaluation of the traction force and speed of draught oxen using a digital dynamometer at the beginning of the agricultural season in Burkina Faso. Tropicultura

(d) Harrigan, T. M. (2019). The Role of Mechanization in Agro-Ecosystems. Presentation at Frontiers in Soil Health, East Lansing, MI, USA. - *Presentation*

4. ASMC – Cambodia

A. Name: Appropriate Scale Mechanization Innovation Hub (ASMIH) – Cambodia

B. Locations: Innovation Hub location: Royal University of Agriculture, Phnom Penh (Cambodia)
Field locations: Banan district (Battambang province), Puok district (Siem Reap province), and Stung Chinit (Kampong Thom province)

C. Description: The main objectives of the ASMIH-Cambodia include:

(a) To design and assess conventional and direct-seeding, mulch-based cropping systems.

(b) To assess the performance of appropriate scale machinery while preserving soil capital.

(c) To adapt and train smallholder farmers, service operators, field technicians, and students on the use of ASM and conservation agriculture (CA)-based cropping systems.

(d) To support multi-stakeholder initiatives.

(e) To initiate a negotiation process between farmers for the individual or collective management of fodder sources or crop diversification after wet-season rice.

D. Collaborators: *Cambodia* - Institute of Technology of Cambodia (ITC), Royal University of Agriculture (RAU), Conservation Agriculture Service Center (CASC), Ministry of Agriculture Forestry and Fisheries (MAFF), University of Battambang (UBB); *France* - CIRAD

E. Achievements (See FY 2019 AWP Objective 3):

(a) There was a testing on planting maize by CASC/CIRAD in Battambang province for experimental comparison to the Brazilian no-till seeder and conventional Thai KID seeder. Results showed lower efficiency and quality than the Brazilian, but similar to the conventional Thai KID seeder. This year, CASC/CIRAD conducted the testing again after the machine was modified. The testing was conducted on farmers' lands with the participation of farmers, service providers, project partners, students, and other partner groups (CamSID, Australia).

(b) A manual was created for the seed drill and a short-term training related to this was provided to local manufacturers and students.

(c) The 4WT broadcast seeder was tested and demonstrated to farmers in Battambang with group discussion on its operational performance. After the demonstration, it was modified again based on input. The newly developed prototype has tested to compare with other seeding machines to sow rice with farmers in Battambang.

(d) The 2WT broadcast seeder was tested with farmers in Kampong Thom province and demonstrated to nearby farmers and high school students. The 2WT broadcast seeder was applied in 100ha of paddy fields in Kampong Thom province.

F. Capacity Building:

(a) A service manual of the bucket scraper prototype has been written.

(b) A bucket scraper was delivered to RUA for student use in field testing, researching, and studying. Last month, DAEng performed the last field testing and demonstration of the modified bucket scraper for laser land leveling.

G. Lessons Learned:

(a) The broadcast seeder is heavy. There is lighter weight broadcast seeder import from abroad recently might be a competitive to the local manufacturing.

(b) The service cost of laser land leveling is often too high for farmers to afford.

H. Presentations and Publications:

(a) Chhoem, C., Theng, D., Mean, M. C., Mai, S., Chheur, S. (2018). Effects of two-wheel tractor mounted seed broadcaster and different seed rates on growth and yield of rice. Regional Dynamic toward an Agroecology Transition in the Mekong Region, Siem Reap - *Presentation*

(b) Vernet, P. A., Faysse, N., Suos, V., Theng, D., Oung, N. (2019). Investing in a no-till planter in Cambodia: a promising opportunity for various types of service providers. International Journal of Agricultural Sustainability.

5. ASMC – Ethiopia

A. Name: Appropriate Scale Mechanization Innovation Hub (ASMIH) – Ethiopia

B. Locations: Innovation Hub location: Bahir Dar Institute of Technology, Bahir Dar University (Ethiopia)

Field locations: Bahir Dar Zuri, Bure Zuria, Dangila, (Ethiopia)

C. Description: The Ethiopia Innovation Hub aims to develop and refine sustainable mechanization practices with draft animals and an emphasis on zone tillage, seeding, weeding, and shelling technologies for maize that will be readily transferrable to other cropping systems. The scope of activities includes prototype testing and evaluation, train-the-trainer sessions for local extension and technical service providers, on-farm evaluation and artisan training for local manufacturing and marketing of technologies, as well as tools and custom services.

D. Collaborators: *Ethiopia* - Bahir Dar University, Bahir Dar Institute of Technology; *United States* - Feed the Future Innovation Lab for Small Scale Irrigation, International Water Management Institute (IWMI), and International Livestock Research Institute (ILRI)

E. Achievements (See FY 2019 AWP Objective 3):

(a) Ph.D. curriculum in Agricultural Mechanization Engineering has been in implementation since Oct 2019. A total of six applicants applied for the program and three candidates are taking course work and have started working in the project research areas.

(b) Hub Advisory Committee was established and held its first meeting with the ASMIH team to evaluate project progress and further directions. The members of the advisory committee were selected from different government sectors, NGOs, and higher education.

(c) Study visit was organized in the three kebeles (Afefa, Danishita, and Afesa) for a total of 23 students (4 graduate and 19 undergraduate) on March, 18-19, 2019.

F. Capacity Building:

(a) 10 MSc students from different fields are getting support for their research on the project.

(b) The ASMIH-BiT has conducted a short-term training on animal-drawn yoke making, startup foundation, custom-hire service, and on the job training for manufacturers and enterprises about how to fabricate maize shellers locally. Farmer training on technology testing and evaluation is also part of the ASMIH-training scheme.

(c) Farmers trained how to manufacture yokes in collaboration with Tillers International.

(d) Three maize shellers were manufactured in collaboration with the local TVET colleges and private manufacturers and are ready for testing in the next few months.

(e) Training of trainers (extension network) on proven agricultural mechanization technologies and utilizing field demonstrations and technical information (post-harvest of maize, animal handling and yoke design and making, and majipump usage for 30 farmers where the majipumps are installed.

G. Lessons Learned:

(a) Manufacturing of maize shellers with existing facilities identified challenges related to local resources, capacity, and demand.

(b) Variation in design and actual capacity of majipumps needed as it is not able to lift water for some farmers with groundwater well depth of more than 20 m (from the surface to the bottom of the well).

(c) Challenge of commercialization and lack of seed capital from the entrepreneurs perspective.

H. Presentations and Publications:

(a) Bantelay, D., Dedimas, T., Kelemu, N., & Gebeyehu, S. G. (2019). An integrated approach to solve small farm holders' mechanization Barriers in Ethiopia. 7TH International Conference on the Advancement of Science and Technology (ICAST2019), Bahir Dar, Ethiopia. - *Presentation*

(b) Kebede, G. A. (2019). Assessment of Ergonomics of Farming Activities for Backyard Vegetable Production in the North Western Ethiopia: Case of Dangishta Community. 7TH International Conference on the Advancement of Science and Technology (ICAST2019), Bahir Dar, Ethiopia. - *Presentation*

(c) Asres, S., Schmitter, P., Reyes, M., Tilahun, S. A., Steenhuis, T., & Worqlul, A. (Under Review). Conservation agriculture saves irrigation water in the dry monsoon phase in the Ethiopian highlands. Water Journal

(d) Assefa, T., Jha, M., Reyes, M., & Worqlul, A. (2018). Modeling the Impacts of Conservation Agriculture with a Drip Irrigation System on the Hydrology and Water Management in Sub-Saharan Africa (pp.1-19). Sustainability, 10(4763), Basel. Doi: 10.3390/su10124763

(e) Degu, Y. M. & Gudie, A. F. (2018). Design, Fabrication and Testing of Animal Drawn Multiple Moldboard Plough. 6th International Conference on the advancement of Science and Technology, Bahir Dar, Ethiopia

(f) Assefa, T., Jha, M., Reyes, M., Tilahun, S. A., & Worqlul, A. W. (2019). Experimental Evaluation of Conservation Agriculture with Drip Irrigation for Water Productivity in Sub-Saharan Africa (pp.1-13). Water Journal, 11(530), Basel. Doi: 10.3390/w11030530

(g) Assefa, T., Jha, M., Worqlul, A., Reyes, M., & Tilahun, S. A. (Under Review). Scaling up field-level crop production with small-scale irrigation and conservation practice by integrating the MCE technique and the APEX model. Water Journal

(h) Bekele, E. (2019). Soil water Dynamics on Irrigated garlic and pepper crops using Hydrus –1D model in the Lake Tana-Basin, Northwestern Ethiopia. 7TH International Conference on the Advancement of Science and Technology (ICAST2019), Bahir Dar, Ethiopia. - *Presentation*

(i) Tekeste, S. & Degu, Y. M. (2019). Performance Evaluation of Motorized Maize Sheller. 7TH International Conference on the Advancement of Science and Technology (ICAST2019), Bahir Dar. - *Presentation*

(j) Gebeyehu, S. G. & Dedimas, T. (Under Review). Developing Appropriate Business Model for Maize Shelling Technologies in Small Holder Farmers in North West Ethiopian Districts. Journal of Engineering and Technology Management

(k) Assefa, T., Jha, M., Worqlul, A., Reyes, M., Doro, L., & Tilahun, S. A. (Under Review). Conservation agriculture with drip irrigation: Effects on soil quality and crop yield in Sub-Saharan Africa. Soil and Water Conservation.

C. Focus Country Research Subawards

1. Bangladesh

A. Name: Unlocking the production potential of "polder communities" in coastal Bangladesh (PI: Krishna Jagadish, Kansas State University; and Sudhir Yadav, IRRI)

B. Locations: Polder 30 in the Khulna district of Bangladesh

C. Description: The primary objective of the project is to increase farm income and nutrition security by intensifying polder (a low lying piece of land near a body of water and protected by dikes) farming systems through implementation of sustainable and economically viable practices. Specifically, the project aims to advocate for high yielding and stress tolerant rice varieties, improve productivity of rice and fish cultivation, and introduce high value rabi (spring harvested) crops to increase farm income and improve household nutrition.

D. Collaborators: *Bangladesh* - IRRI, BRAC, Khulna University; *United States* - Kansas State University

E. Achievements (See FY 2019 AWP Activity 4.4):

(a) SIIL-Polder team provided water management training for rabi crop cultivation to 434 farmers (37% women) in ten learning hubs during the reporting period. The farmers were trained on the importance of residual soil water utilization for increasing productivity of the dry season crops. In this training, efficient utilization of limited soil water through early crop establishment (by dibbling seeds on moist soil) was highlighted.

(b) Two (one male and one female) Ph.D. students have completed their data collection. They are preparing the first draft of their theses and are expected to complete their Ph.D.s by the end of 2019.

(c) The project explored potential crops, such as maize in the dry season, not only to contribute to food security or income for the farming community, but also as an alternative feed for livestock, poultry, and fish. To achieve this goal, the project has been providing training to the farmers of polder 30 on nutritional aspects of maize for human consumption directly and via animal product (milk, meat, egg, and fish).

F. Capacity Building:

(a) The project had selected nine M.S. and five Ph.D. students to conduct thesis research in the polders of Bangladesh's coastal zone. They are enrolled in four different universities in Bangladesh and University of Arkansas, USA. Of the 14 scholars, nine completed their M.S. and three completed their Ph.D. from 2017 to June 2019. The remaining two Ph.D. students have completed data analysis and the first drafts of their theses are on-going.

(b) Provided nutritional awareness training to about 300 mothers of the school children, school teachers and household members of the learning hubs to educate them on the nutritional crops introduced by the SIIL-Polder Project. Among them, 70% were women.

G. Lessons Learned:

(a) Lessons learned related to cultural, political, economic, environmental, and other conditions. The Annual Operational Plan (AOP) details these lessons and are available upon request.

H. Presentations and Publications:

(a) Mondal, M. (2019). An innovative water management approach for increasing land productivity in the polders of the coastal zone of Bangladesh. Natural Resource Management of the International Conference on Climate Knowledge, ICCCD Independent University, Bangladesh. - Presentation

(b) Yadav, S. (Under Review). Making inroads to intensify agricultural system productivity in the polders of the coastal zone of Bangladesh. Paddy and Water Environment.

(c) Bhattacharya, J. (2019). The feasibility of high yielding aus-aman-rabi cropping systems in the polders of the low saline coastal zone of Bangladesh (pp.33-46). Field Crops Research, 234, NA. doi:doi.org/10.1016/j.fcr.2019.01.007

(d) Shew, A. (2019). Rice Intensification in Bangladesh improves economic and environmental welfare. (pp.46-57). J. Environmental Science & Policy, 95, NA.

2. Burkina Faso

A. Name: Sustainable intensification through better integration of crop and livestock production systems for improved food security and environmental benefits in Sahelian zone of Burkina Faso (PI: Augustine Ayantunde, International Livestock Research Institute, ILRI)

B. Locations: Dori and Ouahigouya districts, Burkina Faso

C. Description: The overall goal of this project is to improve household food production and nutrition, and enhance ecosystem services through better integration of crop and livestock production systems in the Sahelian zone of Burkina Faso.

D. Collaborators: *Burkina Faso* - Institut de l'Environnement et de Recherches Agricoles (INERA), International Union for Conservation of Nature (IUCN), Fédération Nationale des Groupements Naam (FNGN), and Association pour la Promotion de l'Elevage en Savane et au Sahel (APESS); *United States* - University of Wisconsin, Madison

E. Achievements (See FY 2019 AWP Activity 4.5):

(a) Assessment on the variation in access to land at the village scale. Classification accuracy has been assessed with overall accuracy values high for small-scale agriculture in dryland Africa. Village "influence zones" were estimated using a "population gravity approach", whose boundaries are drawn based on the populations of each village and its neighboring villages. This represents a novel approach to evaluate resource endowments among villages with important implications for the targeting of the development initiatives.

(b) Farmers' Field School (FFS) was conducted by APESS during the last cropping season (June to October 2019). The two focal persons for the FFS in each community were trained in improved agronomic practices. Four farmers' field schools have been established in each of the eight project communities. Each FFS is about 0.25 ha for improved cowpea variety and 0.25 ha also for improved sorghum variety. Each FFS consists of between 10 to 20 farmers including women.

(c) Nutrition data collected from the eight study sites will allow the project to evaluate the distribution of access to food not only among surveyed households, but among the separate eating groups within households (often shaped by gender).

F. Capacity Building:

(a) 245 participants were trained in January 2018 by a nutrition expert.

(b) Establishment of Farmers' Field School (FFS) by APESS and FNGN. Four FFS have been established in each of the eight project communities. Each FFS is about 0.25 ha for improved cowpea variety and 0.25 ha also for improved sorghum variety. Each FFS consists of between 10 to 20 farmers including women. Two focal persons from the farmers in the FFS in each community were trained in improved agronomic practices.

G. Lessons Learned:

(a) The main challenge is the security situation in the project sites which has restricted travel to supervise ongoing project activities. Dependent on field assistants who are based in the project communities for the supervision of project activities.

(b) The quality of data being collected by a few project partners is not good enough for journal publication.

H. Presentations and Publications:

(a) Ayantunde A., Duncan A. J., van Wijk M. T., and Thorne P. (2018). Review: Role of herbivores in sustainable agriculture in Sub-Saharan Africa. Animal.

(b) Fraval et al, S.9. (Under Review). Pathways to food security in rural Burkina Faso: the importance of consumption of home-produced food versus purchased food. Food security

(c) Ayantunde, A., Oluwatosin, B., Yameogo, V., & Van Wijk, M. (Under Review). Opportunities and constraints to sustainable intensification of mixed crop and livestock systems in Sahelian zone of Burkina Faso. International Journal of Agricultural Sustainability

(d) Somda, J. (Under Review). Analyse des coûts et avantages des technologies d'amélioration de la productivité agropastorale dans la zone sahélienne du Burkina Faso. Revue Science de l'Environnement

(e) Napon, K. (Under Review) Adoption et pratique des options d'intensification durable des productions agropastorales : une analyse différenciée selon le genre dans le Yatenga et le Séno au Burkina Faso. Cahiers Agriculture

(f) Ayantunde, A. (2019). SIIL Burkina Faso project profile. CGSpace: https://hdl.handle.net/10568/99525

3. Cambodia

A. Name: Women in Agriculture Network (WAgN) Cambodia: Gendered- and Ecologically-Sensitive Agriculture (PI: Ricky Bates, Pennsylvania State University)

B. Locations: Banan district (Battambang province), Puok district (Siem Reap), and Stung Chinit (Kampong Thom province)

C. Description: The WAgN Cambodia projects aims to empower women and improve nutrition by promoting women's participation in the value chains for horticultural crops and rice produced via sustainable intensification (SI) practices. The overarching goal of the project is to provide a scientifically rigorous and comprehensive understanding of the nexus of gender and SI.

D. Collaborators: *Cambodia* - Asia Impact Center – ECHO, Royal University of Agriculture, Conservation Agriculture Service Center, University of Battambang; *Denmark* - Agricultural Development Denmark Asia (ADDA); *Thailand* - Kasetsart University; *United States* - University of Tennessee Institute of Agriculture; World Vegetable Center (AVRDC)

E. Achievements (See FY 2019 AWP Activity 4.6):

(a) Surveys, focus groups and key informant interviews have been used to identify barriers to and opportunities for women's participation in mixed-gender farmer groups and securing leadership and decision-making roles in organizations.

(b) Market-demanded tomato scions grafted onto local eggplant landraces and/or World Vegetable Center evaluated eggplant rootstock enable rainy season tomato production and represent a potentially profitable farmer enterprise.

(c) Research result from tomato grafting experiments, and information on project gender research and wild food plants have been disseminated to co-operators, students, faculty and government ministry officials.

(d) The Minister of MAFF attended a WAgN tomato grafting demonstration at the Battambang CE SAIN technology park. Demonstrations of vegetable grafting, highlighting tomato grafted onto eggplant have been established along with interpretive materials and signage at CE SAIN Technology Parks.

(e) The project has established a strong connection with the Masters of Sustainable Agriculture (MSA) program at UBB. WAgN PI, Dr. Rick Bates will begin a Fulbright at UBB Nov. 1, 2019 - May, 2020. Fulbright activities will include ongoing assistance with curriculum development to include training on appropriate SI technologies for Cambodia, assistance with graduate student research and education, and the development of a strategy and action plan to introduce tomato grafting technology as part of the secondary school curriculum.

(f) Connections were made with agriculture faculty at Mean Chey University via the Australian Centre for International Agricultural Research SI project in northwest Cambodia.

F. Capacity Building:

(a) During Dr. Bates' 2019-2020 Fulbright at UBB, three additional UBB students will be recruited to enter the MSA program to conduct research on SI topics.

(b) The WAgN project continues to address scaling activities for tomato grafting technology. Students and project technicians conducted grafting training, and the project continues to produce and/or translate tomato grafting resources.

(c) During this reporting period, experiential training was given to undergrads and graduate students at both RUA and Univ. of Battambang. 'Natural Farming', a guide to sustainable agriculture, was delivered to farmers and key stakeholders at various training meetings during this reporting period.

G. Lessons Learned:

(a) Diversification is a key to the SI of smallholder farms in Cambodia. Diversified small farm enterprises can lead to multiple income streams and can become a buffer against depressed and unreliable rice prices, and other threats such as climate change.

H. Presentations and Publications:

(a) Eissler, S., Bates, R. M., Ader, D. R., Gill, T., Brown, S., & Huot, S. (2019). Taming the Messy Fringes: Wild Gardening as a Sustainable Intensification Strategy. International Journal of Agricultural Sustainability.

(b) Trail, P., Bates, R. M., & Tivet, F. (2018). Crop Biodiversity: A Foundational Component of Sustainably Intensified Farming Systems. Presentation at Regional Agroecology Futures Forum, Siem Reap, Cambodia. - *Presentation*

(c) Huot, S. (2019). Gender and Leadership in Agricultural Cooperatives: The Case of Cambodia. Presentation at Penn State University Graduate Student Research Exhibition, Penn State University, University Park, PA, U.S.A. - presentation

(d) Ader, D., Bates, R. M., Huot, S., Eissler, S., & Gill, T. (2019). Gender and Sustainable Intensification: The Case of Wild Gardens in Northwest Cambodia. Presentation at Rural Sociological Society Annual Meeting, Richmond, VA. - *Presentation*

(e) Ader, D., Bates, R. M., Gill, T., Huot, S., & Eissler, S. (2019). Taming the Messy Fringes: Wild Gardening as a Sustainable Intensification Strategy. Presentation at Rural Sociological Society Annual Meeting, Richmond, VA. - *Presentation*

(f) Bates, R. M., Huot, S., Ader, D. R., Gill, T., & Brown, S. (November 2018). 'Wild Gardens' to Diversify Cambodian Smallholder Agriculture for Improved Nutrition and Income. American Society of Agronomy Annual Meeting, Baltimore, Maryland. - *Presentation*

(g) Bates, R. M., Ader, D. R., Gill, T., & Brown, S. (2019). Perennial wild food plants: an important tool in the sustainable intensification of Cambodian smallholder agriculture. International Conference on Underutilized Plant Species, Hoce, Slovenia. – *Presentation*

4. ***Ethiopia*** *(Project Completed)*

A. Name: Sustainably Intensified Production Systems Impact on Nutrition (SIPSIN) (PI: Neville Clarke, Texas A&M University)

B. Locations: Robit and Danghista, Ethiopia

C. Description: The project aims to evaluate the implications of sustainable intensification of crop and livestock production systems (SIPS) on human nutrition in northern Ethiopia. The existing infrastructure and ongoing research and development of the Innovation Lab for Small Scale Irrigation (ILSSI) in the Lake Tana basin of Northern Ethiopia is used as a platform to efficiently conduct research to evaluate SIPS for crop and livestock production and their environmental, economic, and nutritional consequences. This project collaborates with ASMC in evaluating the farming systems used in commercial home gardens to develop hand tools for female farmers.

D. Collaborators: *Ethiopia* - Bahir Dar University, IWMI, IFPRI, ILRI*; United States* - North Carolina Agricultural & Technical State University, Feed the Future Innovation Lab for Collaborative Research on Nutrition in Africa (Tufts University), and ILSSI (Texas A&M University)

E. Achievements (See FY 2019 AWP Activity 4.7):

(a) The water survey for both watersheds (Danghista and Robit) revealed that shallow ground water is the main water source for domestic, livestock, and irrigation purposes for ILSSI intervention (average 72%) and non-ILSSI intervention households (average 57%) followed by surface water (i.e. river) for non-ILSSI intervention households (average 34%).

(b) Anecdotal evidence suggested that when milk production increased, a family of 6 consumed about 4 kg of milk per day. The rest goes for sale. If the production was less than 4 kg/d, all were used for home consumption. This data appears to suggest that adoption of irrigated forage will have substantial direct (via home consumption) or indirect (via sales of milk) effects on nutritional security and quality.

(c) The multiple cropping of maize cultivated after irrigated and fertilized vegetables or fodders increased maize yield substantially compared to baseline condition. This is because of improvement in soil fertility due to residual nutrients from dry season cropping (i.e. vegetables or fodder). However, the highest and most consistently stable maize yield was observed when it was planted after onion and fodder, respectively.

(d) The use of irrigation during the dry season to expand cropping produced additional food and generated income. The increased income as a result of irrigated crops sales, especially fodder and tomatoes, allows the household to purchase additional food items such as animal products (milk, eggs, beef, and chicken) from the markets to complement their nutrition. Production and sale of fodder increased the availability of animal feeds at the market.

(e) Multiple cropping of rain fed teff cultivated after irrigated and fertilized vegetables or fodders increased the rain fed teff yield by 15% compared to baseline condition due to improved soil fertility as a result of residual nutrients (nitrogen) from the dry season irrigated crops. .

F. Capacity Building:

Formal training on the use and application of the integrated Decision Support System was provided to students at Bahir Dar University in March of 2019.

G. Lessons Learned:

(a) Student working with the Robit data is delayed in finalizing his thesis as he is a summer student and hence the calculations for multiple use of groundwater has not been finalized to date. His thesis is foreseen to be completed in October and submitted to Bahir Dar Institute of Technology.

H. Presentations and Peer-reviewed Publications:

The following publications will be reported in both SIIL and ILSSI reports as being jointly supported by these two Innovation Labs.

(a) Sishu, F. (2019). Effect of irrigation intensification on nutrient fluxes in ground and surface water. International Conference on Advancements of Science and Technology, Bahir Dar Ethiopia. - *Presentation*

(b) Sishu, F., Schmitter, P., Tsegaye, E., Habtu, N., Tilahun, S. A., & Steenhuis, T. (2019). Endosulfan pesticide degradation and residue levels in khat and onion in Ethiopian sub-humid region. ICAST, Bahir Dar. - *Presentation*

(c) Passarelli, S., Mekonnen, D., Bryan, E., & Ringler, C. (2018). Evaluating the pathways from small-scale irrigation to dietary diversity: evidence from Ethiopia and Tanzania (pp.981-977). Food Security, 10, Washington D.C. USA

(d) Ringler, C., Chofani, J., Mekonnen, D., Bryan, E., Baye, K., Griffiths, J., & Davies, E. (2019). Irrigation and women's diet in Ethiopia: A longitudinal study.

(e) Dersseh, M. G., Ateka, A., Tilahun, S. A., Worqlul, A., Moges, M. A. (2019) Potential of Water Hyacinth Infestation on Lake Tana, Ethiopia: a prediction using a GIS-based Multi Criteria Technique. Submitted to Water.

5. Senegal

A. Name: Adoption of Sustainable Intensification in Dual-Purpose Millet - Leguminous Crops - Livestock Systems to Improve Food and Nutritional Security and Natural Resources Management for Rural Smallholder Farmers in Senegal (PI: Doohong Min, Kansas State University)

B. Locations: Louga, Diourbel, Kaffrine, Kédougou, Kolda and Sedhiou regions in Senegal

C. Description: The main objectives of this project are to: a) ensure food and nutritional security; b) establish resilient farming systems via a holistic approach for rural smallholder farmers, particularly women, and; c) improve nutritional and socioeconomic status in particular for women and children in the identified regions. These objectives will be achieved by using sustainably intensified production and management practices of dual-purpose millet and leguminous crops (cowpea and groundnut) with small ruminant livestock (goats and sheep) integration.

D. Collaborators: *Senegal* - Institut Sénégalais de Recherches Agricoles (ISRA) – Centre National de Recherches Agronomiques de Bambey (CNRA/Bambey), University of Thies, Institut de Technologie Alimentaire (ITA), Agence Nationale de Conseil Agricole et Rural (ANCAR), Le Réseau des Organisations Paysannes et Pastorales du Sénégal (RESOPP); *France* - Institut de Recherche pour le Développement (IRD) and CIRAD

E. Key Achievements (See FY 2019 AWP Activity 4.8):

(a) Different test and trials conducted at multiple local levels showed that pearl millet varieties tested are high-yielding for both grain and fodder accept *Souna3*, with the most suitable sites for dual-purpose millet being in Sinthou, Malem.

(b) The adoption of SI technologies should be accompanied by an availability of inputs, including biomass production, and in all areas. In these cases, they are able to produce a better quality of feed, more edible and resistant.

(c) The study of infant flours prepared from the target varieties shows that the variety SL169 followed by the variety SL243 would be more recommended for local cereal processors to produce flours in order to fight against protein-energy malnutrition in children, particularly. The basis of this recommendation could be reinforced by the results of organoleptic tests conducted with an internal ITA panel.

(d) New study components assessing the five accessions for root physiology and livestock feeding suitability were initiated.

F. Capacity Building:

(a) Exchange visits to demonstration plots and radio programs aired on local radio stations were arranged in addition to dissemination of innovations through a multimedia platform using mobile phones in Kaolack, Fatick, Louga, and Kaffrine. Used by RESOPP, this platform named Jokalante meaning "to create a link", allowed thousands of farmers to access information on dual-purpose millet and directly interact with technicians and lead farmers.

(b) There is a strong integration of young people (girls and boys) and women in rural activities through the development of rural entrepreneurship. Capacity building of young people in seed production, seedling and nursery production and market gardening enhances the production environment and income diversification. For example, this project is taking the next step by focusing on young seed entrepreneurs and cooperatives, grain producers, processing units and end-users.

(c) The project has supported 9 Ph.D. students and 22 M.S. students, 12 of who are women (39% females).

G. Lessons Learned:

We expected to see some difference in bioavailability in different varieties of pearl millet. However there was no difference in bioavailability and it's not certain why. More research will need to be done regarding the nutritional aspects of the millet flour.

H. Presentations and Publications:

(a) Thierno, B., Diaw, M., & Min, D. (2018). Characterization of the nutritional value of the upper and lower parts of the stems of three potentially dual-purpose millet populations in comparison with those of varieties Souna 3 and Thialack 2 in Senegal(pp.338-349). Journal of Scientific and Engineering Research, 5(9), Rajasthan, India.

(b) Wade, C., Vayssières, J., Thiam, M., Diaw, M., Faye, A., Dieng, A., & Lecomte, P. (December 2018). Impact de l'intensification de l'élevage et de techniques améliorées de gestion de la fumure animale sur l'efficience d'utilisation de l'azote en systèmes mixtes agriculture-élevage au centre du Sénégal. Presentation at French symposium "Rencontres Recherches Ruminants", Paris, France - presentation

(c) Faye, A., Sine, B., Lucas, M., Min, D., & Laplaze, L. (2019). Development of a model estimating root length density from root impacts on a soil profile in pearl millet (Pennisetum glaucum (L.) R. Br). Application to measure root system response to water stress in field conditions (pp.18). PLOS ONE, 14(7), Malaysia.

(d) Wade, C., Vayssières, J., Thiam, M., Diaw, M., Dieng, A. (2019). Multi-criteria sustainability of three mixed crop-livestock systems with different livestock and manure management practices. Sustainable Intensification Conference - Sustainable intensification levers for agro-ecological transition of production systems in sub-Saharan Africa, Dakar, Senegal. - Presentation

6. Tanzania

A. Name: Raising Crop Response: Bidirectional Learning to Catalyze Sustainable Intensification at Multiple Scales (PI: Sieglinde Snapp, Michigan State University)

B. Locations: Babati, Iringa rural, Mufindi, Wanging'ombe, Njombe rural, Songea rural, Mbeya rural, and Mbozi districts in Tanzania, Northern and Southern Highlands

C. Description: The project aims to improve family nutrition, reduce poverty, and enhance the use of environmentally-sound farming practices among smallholder farmers in East Africa. Specific project objectives include:

(a) Generate improved agronomic knowledge of practices that sustainably raise maize and bean yields and crop response to inorganic fertilizer.

(b) Evaluate bidirectional learning and effective extension approaches to promote SI technologies among researchers, extension, agrodealers, NGOs, and farmers.

(c) Generate improved knowledge of the nutrition impacts of adoption of SI technologies through analysis of Tanzania household surveys.

(d) Provide practical guidance to governments on staple food marketing, trade, and extension policies that support adoption of organic matter and SI technologies to support broader diffusion and scaling.

D. Collaborators: *Netherlands* - Wageningen University and Research Center; *Tanzania* - Sokoine University of Agriculture (SUA), CIAT, The Nelson Mandela African Institution of Science and Technology (NM-AIST), IITA, CIMMYT (TAMASA), N2Africa

E. Achievements (See FY 2019 AWP Activity 4.9):

(a) Data sets completed from a two-year, 620 household survey conducted with CIMMYT (TAMASA) across maize-based farming systems of the Northern and Southern Highlands in Tanzania, where precipitation (remote sensing down-scaled modeled weather data), soils, grain yield, household, and farm practices have been linked, at multiple levels (farm and field plot). Preliminary findings are consistent with rainfall and soil carbon as important determinants of maize response to fertilizer.

(b) Soil properties were analyzed through lab and spectral analysis, including soil texture, soil carbon, active carbon, and cations. Further, a subset of 54 households were chosen to represent a range of soil management practices and farmer SI strategies, a detailed characterization undertaken with the LandPKS app, soil analyses, and a supplemental survey. Initial data has been analyzed and a manuscript is under revision, close to ready for submission.

(c) Soil properties from three recently initiated long-term experiments near Sokoine University of Agriculture (SUA), in collaboration with N2Africa, are being analyzed for a suite of soil C and N pools.

(d) 210 VBAAs (FIPS farmer-based extension advisors) endline survey was just completed Feb, 2019. This was a highly successful means of testing of yield-enhancing technologies was carried out using mother and baby trial approaches, including seed treatment and modern varieties of beans. The three-way combination of seed treatment + modern variety + fertilizer was most reliable at enhancing yield.

(e) An initial and comprehensive SI assessment framework was carried out. Based on a country-wide survey data a range of intensification and SI practices by location, we have completed comparisons in five domains of performance, and considered (where data was sufficient) gender of the farmer. The SI assessment was reported at the annual SIIL meeting in Senegal.

F. Capacity Building:

(a) 4 graduate students (3 women) continue with their graduate coursework and research proposal writing at their respective institutions. One is set to graduate at the end of 2019.

G. Lessons Learned:

(a) Data was not all collected in a manner that was straightforward to link up data sets, despite best efforts to ensure automatic linkages. Pigeon pea biomass data was collected on data sheets that were not uploaded on spreadsheets for more than a year, but now are being completed.

(b) Communication with FIPS (the NGO) has proved challenging sometimes with few forms being completed, and it has been unclear by what criteria yield monitoring sites were chosen. FIPS has engaged in the report back workshop and is excited about findings that indicate the bean technologies are valued by farmers, and that baby packs added to mother demos are an effective way particularly to reach farmers that live in more remote areas, and are otherwise are hard to engage, so this challenge is being addressed.

H. Presentations and Publications:

(a) Nord, A., Snapp, S., Miller, N., and Mariki, W. (2018). Assessing the Nitrogen Fixing Potential of a Multi-Purpose Legume, Lablab purpureus (L.) Sweet. American Society of Agronomy, Baltimore, MD. - Presentation

(b) Jayne, T. (2019). Changing Farm Structure and Rural Transformation in Africa. Food Security Policy Innovation Lab Reflection Conference, USAID, Washington, DC, USA. - Presentation

(c) Snapp, S. and Bekunda, M. (2018). Diversification with Multipurpose Legumes for Soil and Ecosystem Health in Rainfed Maize Production. American Society of Agronomy, Baltimore, MD. - Presentation

(d) Morgan, S. and Mason, N. (2018). Do Different Extension Approaches Affect Smallholder Farmers' Willingness-to-Pay for New Agricultural Technologies? Experimental Action Results from Tanzania. Agricultural and Applied Economics Association's Annual Meeting, Washington, DC, USA. - Presentation

(e) Kim, J., Mason, N., and Snapp, S. (2018). Does sustainable intensification of maize production enhance child nutrition? Evidence from rural Tanzania. Agricultural & Applied Economics Association's annual meeting, Washington, DC, USA. - Presentation

(f) Snapp, S. (2019). Legumes and Soil Health – Participatory Action Research. ECHO EAST AFRICA 5th BIENNIAL SYMPOSIUM ON SUSTAINABLE AGRICULTURE BEST PRACTICES, Arusha, Tanzania. - Presentation

(g) Jayne, T. (2019). Let's Not Take the Farm Out of Agrifood Systems. Food Security Policy Innovation Lab Reflection Invited talk, Washington, DC, USA. - Presentation

(h) Nord, A. & Snapp, S., Documentation of Farmer Perceptions and Site-Specific Properties to Improve Soil Management on Smallholder Farms. Land Degradation and Development (Under review)

(i) Mason, N., Snapp, S., and Kim, J. (2019). Does sustainable intensification of maize production enhance child nutrition? Evidence from rural Tanzania. Agricultural Economics (Awaiting publication)

(j) Nord, A., Snapp, S., Miller, N., and Mariki, W. (2019). Investigating the diverse potential of a multi-purpose legume, Lablab purpureus (L.) Sweet, for smallholder production in East Africa. PlosONE

VII. Associate Award Research Project Reports

Rutgers University Policy Impact Research Consortium

A. Name: Rutgers University Policy Impact Research Consortium (PI: Cary Pray, Rutgers University)

B. Locations: Global – Due to the nature of the policy work

C. Program Description: Rutgers University (RU) leads the consortium in supporting the learning agenda on policy, systems analysis, and implementation. The aims of the consortium are to develop a clearer understanding of contemporary agricultural and structural transformation, develop and utilize specific set of indicators to quantify the impact or progress of key Global Food Security goals and understand how agricultural and food policies help to enable and contribute to agricultural transformation.

D. Collaborators: International Fertilizer Development Center (IFDC), Michigan State University, Montana State University, Northwestern University, Tufts University, University of Florida, African Economic Research Center, University of Rwanda, Université de Gaston-Berger

E. Key Achievements:

(a) Synthesized research from the policy work during the previously funded initiative under the USDA from 2014-2018. Topics include the role of policy change and policy systems in transformation; relationships between food systems policy and self-reliance; nutrition transition and agricultural transformation; agricultural trade indicators; infant cereals in Malawi; seeds policy in Kenya; policy change and impacts in Rwanda; the evolution of innovative supply chains and employment in poultry and the interaction of interest groups with policies and regulations; and gender opportunity leading to policy systems change.

(b) In partnership with the USAID Bureau for Food Security and SIIL, the consortium organized a daylong session in October 2019 to report on the consortium work as a way to have a broader conversation on contemporary agricultural transformation and the use of evidence in understanding and influencing policy change.

F. Capacity Building:

G. Nothing to report for 2019.

H. Lessons Learned:

(a) Need to understand constraints to adoption of newer varieties and the reasons of slow varietal turnover.

(b) Yields have increased, but role of new varieties is unclear. New varieties likely not being adopted.

(c) Policy reforms have resulted in greater private sector participation and varietal (e.g. Kenya).

I. Presentations and Publications:

(a) Masters, W.A. (2019), Undernutrition and the dietary transition. University of California Network on Child Health, Poverty and Public Policy, 6 September 2019.

(b) Masters, W.A. (2019), Affordability of nutritious diets in Malawi, Tanzania, Ethiopia and worldwide. Partners meeting convened by the Feed the Future Innovation Lab for Nutrition, 6 August 2019.

(c) Masters, W.A. (2019), Access to nutritious diets as a policy indicator for agricultural transformation and healthy food systems. ICABR session on Food Systems, 6 June 2019.

(d) Moss and Schmitz (2019) estimate the distribution of benefits from the introduction of technological innovation

(e) Nagarajan, et al (2019) evaluate the impact of policy changes in the seed sector on productivity

VIII. 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	Understanding Roles of Gender in Technology Adoption Training	Producers, Private Sector, Civil Society	28	7	35
Bangladesh	Gender Technology Assessment Training	Civil Society	14	3	17
Bangladesh	Regional symposium on Sustainable Agricultural Mechanization and Post-Harvest Practices in Bangladesh	Producers, Government, Civil Society	103	12	115
Bangladesh	Field day on mechanical rice transplanted crop field at Baratia, Dumuria, Khulna	Producers, Government, Civil Society	28	7	35
Bangladesh	Field day on mechanical rice transplanted crop field at Mothbaria, Dumuria, Khulna	Producers, Government, Civil Society	13	25	38
Bangladesh	Field day on mechanical rice transplanted crop field at Kalapara, Patuakhali	Producers, Private Sector, Civil Society	24	0	24
Bangladesh	Field day on mechanical rice transplanted crop field at Wazipur, Barishal	Producers, Civil Society	22	8	30
Bangladesh	Field day on reaper and mini-combine harvester	Producers, Government, Civil Society	49	0	49
Bangladesh	Field day on mechanical rice transplanted crop field at Subarnachar, Noakhali	Producers, Government, Civil Society	33	1	34
Bangladesh	Field day program on mechanical harvesting of paddy using Reaper and Mini combine harvester were done at Dumuria, Khulna	Producers, Government, Civil Society, Private Sector	28	27	55
Bangladesh	Workshop on Understanding Role of Gender in Agriculture	Civil Society, Private Sector	25	8	33
Bangladesh	Training on Assessing Technologies for Gender Sensitivity	Civil Society	14	4	18
Bangladesh	Field demonstration on mechanical transplanted rice field	Producers, Government, Civil Society, Private Sector	24	6	30
Bangladesh	Field demonstration on rice transplanter to farmers	Producers, civil society	15	8	23
Bangladesh	Training on CA machinery operation and maintenance	Producers, Government, Civil Society	16	0	16
Bangladesh	Field day on CA Machinery for soybean planting	Producers, Government, Civil Society	25	1	26
Bangladesh	Field day on mechanical rice transplanter field at Kalapara, Patuakhali	Producers, Government, Civil Society	24	2	26
Bangladesh	Training on rice transplanter maintenance, basic operation, and troubleshooting at Kalapar, Payuakhali	Producers, Government, Civil Society	13	2	15

Country of Training	Brief Purpose of Training	Who was Trained	Number Trained		
			M	F	Total
Bangladesh	Field day on soybean planting using CA machinery	Producers, Government, Civil Society	26	0	26
Bangladesh	Maintenance of rice transplanter, general troubleshooting and how to keep the machine in working order in Wazirpur, Barishal	Producers, Civil Society, Private Sector	12	2	14
Bangladesh	Field demonstration on mechanically transplanted rice field to farmers at Subarnachar, Noakhali	Producers, Government, Civil Society	23	0	23
Bangladesh	Training on seedling raising on tray and mat at Subarnachar, Noakhali	Producers, Government, Civil Society	15	0	15
Bangladesh	Field day on mungbean planting using CA machinery and rest after planting	Producers, Government, Civil Society	24	2	26
Bangladesh	Hands on training on repair and maintenance of Reaper and Mini-combine harvester at Subarnachar, Noakhali	Producers, Government, Civil Society	14	0	14
Bangladesh	Field day on mungbean planting using CA machinery-2019 was done at Purbo Dhamshar, Wazirpur, Barishal	Producers, Civil Society	16	11	27
Bangladesh	Validation/Training Workshop at Subarnachar, Noakhali	Producers, Civil Society	23	24	47
Bangladesh	Field day program on mechanical harvesting of paddy using Reaper and Mini combine harvester at Kalapara, Patuakhali	Producers, Government, Civil Society, Private Sector	36	5	41
Bangladesh	Field day program on mechanical harvesting of paddy using Reaper and Mini combine harvester at Wazirpur, Barishal	Producers, Government, Civil Society	30	19	49
Bangladesh	Validation/Training Workshop at Kalapara, Patuakhali	Producers, Civil Society	18	14	32
Bangladesh	Agricultural Machinery fair conducted in Umedpur Islamia Dakhil madrasa premises to demonstrate the modern agricultural machinery to school-going children and local farmers	Producers, Government, Civil Society, Private Sector	149	54	203
Bangladesh	Hermetic Storage – community seed bank model	Producers	68	75	143
Bangladesh	Nutritional awareness (Zinc rice, sunflower, maize and mungbean)	Producers	67	281	348
Bangladesh	Traveling seminar on improved climate-resilient and nutritious HYV rice	Producers	224	215	439
Bangladesh	Mechanical harvester: use of reaper for rice harvesting	Government, Producers	164	218	382
Bangladesh	Troubleshooting agricultural machinery: reaper, axial flow pump, mini-tractor	Producers	84	20	104
Bangladesh	Cultivation procedures and residual soil-water management for rabi crops	Producers	271	163	434
Bangladesh	Safe pesticide application by battery operated sprayer	Producers	72	56	128
Burkina Faso	Sheep Fattening Training – Ouahigouya	Producers	9	11	20

Country of Training	Brief Purpose of Training	Who was Trained	Number Trained		
			M	F	Total
Burkina Faso	Sheep fattening training – Dori	Producers	15	5	20
Burkina Faso	Improved agronomic practices	Producers, Government	47	8	55
Burkina Faso	Awareness training on Pestes des Petits Ruminants (PPR) in sheep and goats	Producers	59	88	147
Burkina Faso	Training on production of seed in improved cowpea and sorghum varieties	Producers	40	5	45
Burkina Faso	Experimental design and data analysis	Government, Civil Society	7	8	15
Burkina Faso	Validation workshop in Yatenga province	Producers, Government, Civil Society	74	8	82
Burkina Faso	Validation workshop in Seno province	Producers, Government, Civil Society	64	5	69
Burkina Faso	Storing chopped corn silage in Burkina Faso	Civil Society	4	1	5
Cambodia	Spatial data handling with R program	Government, Civil Society	16	3	19
Cambodia	Understanding roles of gender in technology adoption training	Government, Private Sector, Civil society	19	13	32
Cambodia	Gender Technology Assessment training	Government, Private Sector, Civil society	7	5	12
Cambodia	Wild Food plants and tomato grafting	Producers	4	11	15
Cambodia	Wild foods and tomato grafting	Producers	3	15	18
Cambodia	Cambodia seed saving and soil health workshop	Government, private sector, civil society, producers	58	45	103
Cambodia	Tomato grafting workshop – ADDA 1	Producers, Civil Society	9	21	30
Cambodia	Tomato grafting workshop – ADDA 2	Producers, Private Sector, Civil Society	15	38	53
Cambodia	Tomato grafting workshop – Oxfam	Producers, Private Sector, Government, Civil Society	24	22	46
Cambodia	Tomato grafting workshop – RUA	Civil Society	18	15	33
Cambodia	Tomato grafting workshop – MAFF	Government, Civil Society	21	15	36
Cambodia	STEM+Ag: Women-friendly Agriculture	Civil Society	137	165	302
Cambodia	MAFF field research update	Government	5	0	5
Cambodia	Improving farmer adoption of SI technologies	Civil Society, Producers	6	12	18
Cambodia	World Vision International Field Day	Civil society	8	1	9
Cambodia	Improving income with rainy season vegetables, Taprom Village, Siem Reap	Producers, Civil Society	11	15	26
Cambodia	Improving income with rainy season vegetables, Thnol Chek Village, Siem Reap	Producers, Private sector, civil society	3	18	21
Cambodia	Improving income with rainy season vegetables, Doumsva Village, Siem Reap	Producers, Civil Society	2	13	15
Cambodia	Tomato grafting workshop – CE SAIN Siem Reap Tech Park	Civil Society	5	3	8

Country of Training	Brief Purpose of Training	Who was Trained	Number Trained		
			M	F	Total
Cambodia	AVIP delegate research update	Government, Private Sector, Civil Society	7	2	9
Cambodia	Business Management for CA	Government, Private Sector, Civil Society	36	8	44
Cambodia	Climate-smart agriculture workshop and farm tour	Producers, Private Sector, Government, Civil Society	26	14	40
Cambodia	WAT4CAM field research training	Government, Private Sector, Civil Society	5	5	10
Cambodia	Cambodia Seed Saving and Soil Health Workshop	Producers, Private Sector, Government, Civil Society	64	42	106
Cambodia	Seed saving for grafted tomato production, Chikreng district	Producers	3	3	6
Cambodia	ToT: Soil fertility management and climate smart agriculture	Government, Civil Society	15	7	22
Cambodia	Performance evaluation testing of broadcast seeder	Producers, Government, Civil Society	20	10	30
Cambodia	Field visit of WWF and CEDAC farmer groups	Producers, Government, Civil Society	12	11	23
Cambodia	Field visit: 2nd year FAE/RUA students to project sites	Civil Society	13	8	21
Cambodia	Field visit: FAE/RUA students	Civil Society	14	10	24
Cambodia	Technical session: engaging service providers in sustainable intensification transition	Producers, Private Sector, Government, Civil Society	64	9	73
Cambodia	Technical training on crop seed production, preservation and sharing	Producers, Government, Civil Society	54	18	72
Cambodia	Field visit of farmer network of Sustainable Rice Platform (SRP)	Producers, Government, Civil Society	8	5	13
Cambodia	Field visit: students and lecturers on straw balers and agricultural machinery	Producers, Civil Society	39	12	51
Cambodia	Field visit: 3rd year students to Battambang	Producers, Civil Society	28	10	38
Cambodia	Testing and demonstration of conventional direct seeder in Battambang	Producers, Government, Civil Society	17	10	27
Cambodia	Testing and demonstration of no-till seed drill in Battambang	Producers, Government, Civil Society	17	5	22
Cambodia	4th Hub Advisory Committee Meeting	Government, Private Sector, Civil Society	24	8	32

Country of Training	Brief Purpose of Training	Who was Trained	Number Trained		
			M	F	Total
Cambodia	Technical drawing, quality assurance and safety	Government, Private Sector, Civil Society	21	2	23
Cambodia	Field visit: delegate team from GDA	Government	5	0	5
Cambodia	Regional training on appropriate scale mechanization for CA	Government, Private Sector, Civil Society	45	12	57
Cambodia	Demonstration and promotion of ASMC project seeders	Producers, Private Sector, Government, Civil Society	25	6	31
Cambodia	ASMC for Sustainable Intensification training	Producers, Private Sector, Government, Civil Society	56	4	60
Cambodia	Final workshop for ASMIH –Cambodia	Government, Private Sector, Civil Society	32	9	41
Cambodia	5th Hub Advisory Committee Meeting	Government, Private Sector, Civil Society	17	4	21
Ethiopia	Farmer training and field demonstration on maize sheller	Government	381	165	546
Ethiopia	Novel animal drawn-yoke	Government, Private Sector	12	3	15
Ethiopia	Training on start-up foundation	Government, Private Sector	18	7	25
Ethiopia	Animal-drawn single row maize planter	Producers, Government, Civil Society, Private Sector	11	2	13
Ethiopia	Gender and Agricultural Mechanization	Government, Producers	33	33	66
Ethiopia	Understanding roles of gender in technology adoption training	Producers, Government, Civil Society, Private Sector	24	21	45
Ethiopia	Gender Technology Assessment (2-day training)	Civil Society	4	8	12
Ethiopia	Conservation effects assessment	Civil Society	7	4	11
Ethiopia	Water availability – Maji pump	Civil Society	4	2	6
Ethiopia	Yoke-making training of trainers	Producers, Government, Private Sector	15	3	18
Ethiopia	IDSS Training – Abbay Basin Authority	Government	23	7	30
Malawi	Monitoring Agricultural Productivity and Mosquito Breeding Potential via Remote Sensing and sUAS	Civil Society	13	13	26
Senegal	Biomass and nutrient flow analysis at plot, herd and farm levels	Producers	1	0	1
Senegal	Training on the use of smart phones for sampling and surveys	Civil Society	18	0	18

Country of Training	Brief Purpose of Training	Who was Trained	Number Trained		
			M	F	Total
Tanzania	Workshop: reporting out findings	Government, Private Sector, Civil Society	20	12	32
Tanzania	Training in Southern Highlands of enumerators and extension advisors	Government, Private Sector, Civil Society	7	5	12
Total			**3782**	**2390**	**6172**
			M	**F**	**Total**
			61%	39%	

B. Long-term training

Name (first, last)	Sex	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Ayele Lijalem	M	Bahir Dar University	M.S.	Mechanical Engineering	October 2018	Y	Ethiopia
Linda Zugmore	F	University of Nazi Boni, Bobo Dioulasso	M.S.	Agricultural Engineering	October 2018	Y	Burkina Faso
Sujat Ahmed	M	Sher-e-Bangla Agricultural University	M.S.	Agronomy	December 2018	Y	Bangladesh
Bishwajit Baidya	M	Khulna University	M.S.	Development Policy and Studies	December 2018	Y	Bangladesh
Jayanta Bhattacharya	F	Patuakhali Science and Technology University	Ph.D.	Agronomy	December 2018	Y	Bangladesh
Salifou Konfe	M	University of Nazi Boni, Bobo Dioulasso	M.S.	Animal Science	December 2018	Y	Burkina Faso
Nibir Saha	M	Patuakhali Science and Technology University	Ph.D.	Agronomy	December 2018	Y	Bangladesh
Arlette Toe	F	St. Thomas d'Acquin University	M.S.	Animal Science	December 2018	Y	Burkina Faso
Nazira Binte Alam	F	Bangladesh Agricultural University	M.S.	Agricultural Extension & Education	January 2019	Y	Bangladesh
Samiul Basir	M	Bangladesh Agricultural University	M.S.	Farm Power & Machinery	January 2019	Y	Bangladesh
Enguday Atalay	F	Bahir Dar University	M.S.	Hydrology Engineering	February 2019	Y	Ethiopia

Name (first, last)	Sex	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Channaty Ngang	F	University of Battambang	M.S.	Sustainable Agriculture	March 2019	Y	Cambodia
Awa Barro	F	University of Nazi Boni, Bobo Dioulasso	M.S.	Agricultural Engineering	May 2019	Y	Burkina Faso
Hafsatou Koudougou	F	Institute of Rural Development/Poly technic University of Bobo-Dioulasso	M.S.	Agriculture Engineering	June 2019	Y	Burkina Faso
Nut Nareth	M	Royal University of Agriculture	Ph.D.	Agricultural Engineering	June 2019	Y	Cambodia
Sourn Taingaun	M	Royal University of Agriculture	Ph.D.	Land Mgtt & Admin.	June 2019	Y	Cambodia
Elsabeth Tsegaye	F	Bahir Dar University	M.S.	Engineering Hydrology	June 2019	Y	Ethiopia
Sadiou Dianda	M	University of Nazi Boni, Bobo Dioulasso	M.S.	Agricultural Engineering	July 2019	Y	Burkina Faso
April Frake	F	Michigan State University	Ph.D.	Geography	August 2019	Y	United States
Brad Peter	M	Michigan State University	Ph.D.	Geography	August 2019	Y	United States
Ouda Sanfo	M	University of Nazi Boni, Bobo Dioulasso	M.S.	Agronomy	July 2019	Y	Burkina Faso
Zigale Admas	M	Bahir Dar University	M.S.	Mechanical Engineering	September 2019	Y	Ethiopia
Addis Bezabih	M	Bahir Dar University	M.S.	Water Resource Management and Engineering	September 2019	Y	Ethiopia
Meseret Cherie	F	Bahir Dar University	M.S.	Gender and Development	September 2019	Y	Ethiopia
Daniel Gelatwa	M	Bahir Dar University	M.S.	Water Resource Management and Engineering	September 2019	Y	Ethiopia
Bekelech Getachew	F	Bahir Dar University	M.S.	Food Engineering	September 2019	Y	Ethiopia
Yichalem Mulat	F	Bahir Dar University	M.S.	Gender and Development	September 2019	Y	Ethiopia
Ewentu Tefera	M	Bahir Dar University	M.S.	Mechanical Engineering	September 2019	Y	Ethiopia
Dagnew Yehualie	M	Bahir Dar University	M.S.	Water Resource Management and Engineering	September 2019	Y	Ethiopia
Senait Zegeye	F	Bahir Dar University	M.S.	Economics	September 2019	Y	Ethiopia

Name (first, last)	Sex	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Mamdou Diedhiou	M	University of Gaston Berger of Saint Louis	Ph.D.	Agronomy	September 2019	Y	Senegal
Khaly Niang	M	University of Gaston Berger	Ph.D.	Applied Mathematics	September 2019	Y	Senegal
Ayesha Sarker	F	University of Illinois	Ph.D.	Agricultural and Biological Engineering	September 2019	Y	Bangladesh
Md. Kamrul Hasan	M	Bangladesh Agricultural University	Ph.D.	Agricultural Engineering	September 2019	Y	Bangladesh
Md. Abdul Motalib	M	Bangladesh Agricultural University	Ph.D.	Agricultural Engineering	September 2019	Y	Bangladesh
Surajit Sarkar	M	Bangladesh Agricultural University	Ph.D.	Agricultural Engineering	September 2019	Y	Bangladesh
Awa Faye	F	Cheikh Anta Diop University	Ph.D.	Agronomy	October 2019	Y	Senegal
Feleke Kuraz	M	Bahir Dar University	Ph.D.	Water Resources Management	October 2019	N	Ethiopia
Chantha Thay	M	University of Battambang	M.S.	Horticulture	November 2019	N	Cambodia
Biya Chhorn	F	University of Battambang	M.S.	Sustainable Agriculture	November 2019	N	Cambodia
Sreychou Heng	F	Royal University of Agriculture	M.S.	Animal Science	November 2019	N	Cambodia
Rathana Nai	F	Royal University of Agriculture	M.S.	Agro-Industry	November 2019	N	Cambodia
Sreymey Ngoun	F	Royal University of Agriculture	M.S.	Crop Science	November 2019	N	Cambodia
Sokol Yem	F	Royal University of Agriculture	M.S.	Agricultural Sciences	November 2019	N	Cambodia
Saovanneary Huot	F	Penn State University	Ph.D.	Rural Sociology	December 2019	N	Cambodia
Melkamu Keri	M	Bahir Dar University	M.S.	Hydrology Engineering	December 2019	N	Ethiopia
Alison Nord	F	Michigan State University	Ph.D.	Agro-ecology	December 2019	N	United States
Channy Sambo	F	Royal University of Agriculture	M.S.	Animal Science	December 2019	N	Cambodia
Thierno Ba	M	University of Thies	Ph.D.	Animal Science	March 2020	N	Senegal
Ibrahima Dieng	M	Cheikh Anta Diop University of Dakar	Ph.D.	Soil Fertility	March 2020	N	Senegal
Bunseng Lam	M	Royal University of Agriculture	M.S.	Agronomy	March 2020	N	Cambodia
Aida Mangawa	F	Cheikh Anta Diop University of Dakar	Ph.D.	Food Processing and Nutrition	March 2020	N	Senegal

Name (first, last)	Sex	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Marie-Therese Mofini	F	Cheikh Anta Diop University of Dakar	Ph.D.	Soil Microbiology	March 2020	N	Senegal
E-Nieng Muth	F	Royal University of Agriculture	M.S.	Agronomy	March 2020	N	Cambodia
Ablaye Ndour	M	University of Thies	Ph.D.	Agricultural Economics	March 2020	N	Senegal
Fatou Tine	F	Cheikh Anta Diop University of Dakar	Ph.D.	Agronomy	March 2020	N	Senegal
Coly Wade	M	University of Thies	Ph.D.	Nutrient Cycling	March 2020	N	Senegal
Rufina Fredrick	F	Nelson Mandela African Institute of Science and Technology, Tanzania	M.S.	Nutrition	May 2020	N	Tanzania
Leah Mungai	F	Michigan State University	Ph.D.	Geography	May 2020	N	Malawi
Nasiba Akter	F	Bangladesh Agriculture University	Ph.D.	Agricultural Economics	June 2020	N	Bangladesh
Esther Mugi	F	University of Wageningen	Ph.D.	Agricultural Systems	June 2020	N	Tanzania
Katian Napon	F	University of Ouagadougou	Ph.D.	Geography	June 2020	N	Burkina Faso
Sisay Ares	M	Bahir Dar University	Ph.D.	Water Resources Eng. & Mgt	July 2020	N	Ethiopia
Temesgen Fantahun	M	Bahir Dar University	M.S.	Irrigation Eng. and Management	September 2020	N	Ethiopia
Solomon Kefyalew	M	Bahir Dar University	M.S.	Industrial Engineering	September 2020	N	Ethiopia
Rotha Chork	M	Royal University of Agriculture	M.S.	Agronomy	November 2020	N	Cambodia
Lyhour Hin	M	Royal University of Agriculture	Ph.D.	Agricultural Engineering	November 2020	N	Cambodia
Chakriya Norng	F	Royal University of Agriculture	Ph.D.	Agro-Industry	November 2020	N	Cambodia
Thira Pinn	M	Royal University of Agriculture	Ph.D.	Integrated Management: Agricultural and Rural Development	November 2020	N	Cambodia
Saren Ry	M	University of Battambang	B.S.	Agriculture	November 2020	N	Cambodia
Taing Aun Sourn	M	Royal University of Agriculture	Ph.D.	Land Management	November 2020	N	Cambodia
Said Hamad	M	Sokoine University of Agriculture	Ph.D.	Soil Science	December 2020	N	Tanzania

Name (first, last)	Sex	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Espoir Gaglo	M	Institut Sénégalais de Recherches Agricole	Ph.D.	Life, Health and Environmental Sciences	May 2021	N	Senegal
Deb Kumar Nath	M	Bangladesh Agricultural University	Ph.D.	Water Governance	June 2021	N	Bangladesh
Kea Prak	M	Royal University of Agriculture	Ph.D.	Animal Science	June 2021	N	Cambodia
Socheath Tong	M	Royal University of Agriculture	Ph.D.	Agro-Industry	June 2021	N	Cambodia
Bunna Touch	M	Royal University of Agriculture	Ph.D.	Agro-Industry	June 2021	N	Cambodia
Sewunet Alemu	F	Bahir Dar University	Ph.D.	Agricultural Mechanization Engineering	September 2021	N	Ethiopia
Getenet Kebede	M	Bahir Dar University	Ph.D.	Agricultural Mechanization Engineering	September 2021	N	Ethiopia
Solomon Teskeste	M	Bahir Dar University	Ph.D.	Agricultural Mechanization Engineering	September 2021	N	Ethiopia

C. Institutional Development

A. **Kansas State University – SIIL, ISRA, and Peace Corps Partnership**: In September 2019, the SIIL ME traveled to Senegal to meet with the new Peace Corps Senegal Food Security Assistant Director, Kether Hayden. An agreement was put in place to for SIIL to hold two trainings a year for the Peace Corps agriculture volunteers and a five-year Memorandum of Understanding was signed to renew the SIIL – ISRA – Peace Corps partnership. Each organization brings its own unique strength: PC Senegal has a substantial network of volunteers working as agricultural extension agents in rural and urban communities; ISRA has the regional technical expertise and provides the latest local solutions and technologies appropriate for Senegal; and SIIL brings the capacity-building expertise and the resources of a world-class research university. This collaboration forms an important link between organizations working towards the same goals of agricultural development and achieving food security in Senegal. This partnership program will support farmers in communities as they work to develop pilot farms as a space for demonstrating new technologies and trainings in collaboration with Peace Corps Volunteers (PCVs). In addition to improved diffusion of information, PCVs will collect essential feedback on technologies from smallholder farmers across Senegal and relay the information to researchers at ISRA. This partnership is designed to increase overall dissemination and increase adoption rates. Each organization: SIIL, ISRA, and PC has involved their own extended networks in the partnership. Master Farmers and PCV counterparts have been engaged through the assessment of need to identify technologies on which to train and disseminate. Senegalese graduate students have been involved through capacity building and collaboration on participatory research. PCVs are at the center of the partnership, providing that important link between Senegalese communities and ISRA researchers.

B. **CE SAIN Institutional Development**: The CE SAIN also continues to build human and institutional capacity at the Royal University of Agriculture in Cambodia. The CE SAIN implements its scholarship and research grant program to increase faculty teaching, research, and extension capacity through long-term training and degree enhancement. The Center, through its five Technology Parks, has also played a key role in linking RUA faculty and students and the private sector, NGOs, Innovation Labs, and other networks. These partnerships support the promotion of information dissemination and serve as a catalyst for new innovations.

C. **Institutional Sustainability**: The regional coordinators funded in Senegal and Burkina Faso have also helped with continuing some of the critical research initiated by the NARS (ISRA and INERA) and supported institutional capacity building to sustain long-term research.

IX. Innovation Transfer and Scaling Partnerships

A. Precision Agriculture for Smallholder Systems in Africa
- a. Integrating remote sensing-based crop suitability mapping with crop model simulations using APSIM
  - i. Partnerships: TBD
- b. MODIS product version comparison application for Google Earth Engine
  - i. Partnerships: Center for Global Change and Earth Observations at MSU
- c. Spatial data outlier detection and visualization using Google Earth Engine
  - i. Partnerships: Center for Global Change and Earth Observation at MSU
- d. Tracking malaria in Malawi by mapping mosquito breeding suitability
  - i. Partnerships: Center for Global Change and Earth Observations at Michigan State University, Lilongwe University of Agriculture and Natural Resources
- e. Visualizing inconsistencies among global agricultural land cover products using Google Earth Engine
  - i. Partnerships: Center for Global Change and Earth Observations at MSU
- f. Web-based GIS for spatiotemporal crop climate niche mapping
  - i. Partnerships: Center for Global Change and Earth Observations at MSU

B. Women in Agriculture Network (WAgN) Cambodia
- a. Green manure cover and relay cropping after rice
  - i. Partnerships: ECHO Asia, CIRAD, CE SAIN
- b. Tomatoes grafted onto eggplant rootstock
  - i. Partnerships: University of Battambang, World Vegetable Center, Agriculture Development Denmark Asia (ADDA), CE SAIN
- c. Wild Gardens
  - i. Partnerships: University of Battambang, ECHO Asia, World Vegetable Center, Kasetsart University, CE SAIN, CIRAD/Conservation Agriculture Service Center (CASC)

D. Raising crop response in Tanzania
- a. Bean seed treatment and modern varieties
  - i. Partnerships: Farm Input Promotions (FIPS) Africa, VBAAs, Tanzania Agricultural Research Institute (TARI) Uyole, district councils, NGOs (One Acre Fund, AGRA Tanzania, NAFAKA)
- b. Lablab variety release
  - i. Partnerships: Sahelian Agricultural Research Institute (SARI) support for on-farm training

X. Environmental Management and Mitigation Plan (EMMP)

An annual environmental mitigation activity review was conducted by the SIIL management entity across all subawards. The review entailed an evaluation of all activities outlined in the EMMP. Given the previous year's focus providing subawardees with greater knowledge and tools to improve EMMP compliance and reporting, there were no issues to highlight during this reporting period. Mitigation and monitoring activities took place in accordance with the EMMP. In cases of fertilizer and pesticide purchase and use, project partners provided appropriate personal protective equipment and training for the safe use of the materials. The SIIL ME conducted a site visit to Ethiopia and verified that safety guidelines, training, and signage were addressed in accordance to the concerns raised in the previous year.

In addition, the Piestar DPx system, which the SIIL utilizes for reporting and project monitoring, underwent significant revisions of the EMMP module to support SIIL's compliance enforcement. The Piestar DPx updates included a new fertilizer, pesticide, and microbial inoculant purchase request/approval system. The annual environmental mitigation activity review also is incorporated into the DPx system to ensure that project monitoring is streamlined and to optimize knowledge sharing within the SIIL management entity. The current EMMP module is shown below. Categories not shown in the screen shot include: a) conducting applied research not exceeding 4 ha in a single location and NOT involving support for procurement or use of chemicals, pesticides, or fertilizers; b) conducting research not exceeding 4 ha in a single location that DOES involve the procurement and use of use of chemicals, pesticides, or fertilizers; c) conducting applied research exceeding 4 ha in a single location; d) conducting applied research with microbial inoculants. Responses from investigators are reviewed semi-annually by the SIIL management entity to ensure compliance with the SIIL EMMP. All sub-award activities are currently in compliance with the SIIL EMMP.

XI. Open Data Management Plan

The SIIL management entity established the SIIL Dataverse to store and curate all SIIL subaward datasets and serve as a data repository and access hub for the SI community in general. During this reporting period, SIIL subawards and consortia reported 80 separate complete datasets have been uploaded representing 1,306 files. The complete datasets are found in the SIIL's Dataverse (https://dataverse.harvard.edu/dataverse/SIIL), hosted by Harvard Dataverse.

Each complete dataset is required to, at a minimum, include: codebooks; metadata; data dictionaries; forms, templates, and data gathering tools; explanations of redactions, when applicable (e.g. anonymization, removal/redaction/masking of personally identifiable information); notes on data quality, data limitations, or data context; and data gathering methodologies, dates, points of contact, geolocation(s).

The SIIL is in continual discussions with USAID's Data Development Library (DDL) staff to resolve issues related to the Geospatial and Farming Systems Research Consortium and the Precision Agricultural project on how to submit datasets given the excessive size of these geospatial datasets.

The SIIL also has continued to utilize CGSpace as a repository for sharing informal publications and outputs from SIIL-funded work. SIIL established this repository with CGSpace in 2017 to share SIIL-funded outputs that otherwise did not have formal publishing platforms for public sharing. To date, 44 communications materials such as presentations, videos, and other media, management documents, reports, training materials, newsletters and stories, and other communications materials have been shared on the SIIL CGSpace repository for open access.

XII. Governance and Management Entity Information

A. Regional and Country Coordinator Activity

The SIIL coordinators in Senegal, Burkina Faso, Tanzania, and Cambodia monitor in-country activities, represent various capacities, and organize SIIL-funded events. The coordinators in Burkina Faso, Senegal, and Tanzania also conduct research to address gaps or expand the scope of existing in-country SIIL subawards. Descriptions of the research and accomplishments are below:

(1) Burkina Faso: Dr. Hamidou Traore and his team's research aims to integrate available soil, water, plant, and nutrient management practices in crop rotation to enhance crop yields. Accomplishments include: a) environmental compliance visits to SIIL sites; b) characterized selected cowpea genotypes for drought, Striga, and low P/N tolerance, N fixation: dried seeds of 3 cowpea varieties were irradiated with gamma rays and M2 populations were grown in field conditions; c) organized farmer field school on Striga management; d) inventoried weeds in long-term trial on the Saria Research Station (Farako-Ba & Kamboinsé; e) implemented a long-term trial related to soil nutrient management on the Saria Research Station (long term data from this research will be shared with SIIL to produce a co-authored publication, and; f) recruited candidates for MSc and Ph.D. degrees (MSc for ASMC and Ph.D. for the long-term trial).

(2) Senegal: Dr. Aliou Faye and his team has continued the project with the GFC (see GFC Subaward VII report), which supports the work of the SIIL's subaward in Senegal led by Dr. Doohong Min. Accomplishments include: a) preparation of the rainy season activities and implementation of trials in targeted areas; b) traveled to Ghana to participate to the 2019 West Africa partners meeting of the CCAFS flagship 4 project, Capacitating Agricultural Smallholders with Climate Advisories and Index Insurance Development (CASCAID-II); c) implemented technology park at Bambey Sereer high school and organized a student visit to ISRA-CNRA in Bambey; d) organized youth training on seed production with RESOPP and poultry feed production with dual-purpose millet flour in Malincounda village, and; e) hosted Dr. Albert Baro from INERA Camboinsain in Burkina Faso for a 15-visiting scientist program.

(3) Tanzania: Mr. Jovin Lwehabura (in his last year as regional coordinator) expanded upon the mother-baby trials that are being conducted as a component of the SIIL's subaward in Tanzania, led by Dr. Sieglinde Snapp. Accomplishments include: a) harvested and processed of the lablab accessions – where from the seven tested lablab accessions (DL 1002, Dodoma white, Eldoret black 2, ILRI 6536, Karamoja red, and Q680B), Karamoja red had the highest yield weights followed by Eldoret black 2; b) supported and coordinated an end-line survey on effect of bean technologies introduced to 230 VBAAs through the RCT established back in the 2016 planting season in seven districts (Songea Rural, Njombe Rural/Wanging'ombe, Makambako, Mufindi, Iringa Rural, Mbeya Rural, and Mbozi/Momba). This is a collaborative research work between MSU, FIPS-Africa, TARI Uyole, and CIAT-Tanzania. The survey assessed if the RCT created a local demand for tested technologies and if have impacted on bidirectional learning aspects within mentioned seven districts; c) continued to facilitate a supply chain of commercialized improved seed dressed from seed producers to a network of village based agro-dealers and ultimately to the farmers (through different approaches such as a farmer's day/exhibition events and also link seed producers with seed dresser companies particularly to Apron Star (TriaChem)).

B. SIIL Personnel Changes

The SIIL hired a new Program Administrator, Andra Williams, who started in October 2018. They additionally said goodbye to their longtime Business Manager, Katy Bach, in May 2019 and welcomed her replacement, Jessica Burden, in August 2019. Finally, Dr. Jessie Vipham concluded her contract with the SIIL in August 2019, and returned to her academic home, Animal Science, to focus on her research.

XIII. Other Topics

A. Center of Excellence on Sustainable Agricultural Intensification and Nutrition (CE SAIN) at the Royal University of Agriculture

A. Project Name: The Center of Excellence on Sustainable Agricultural Intensification and Nutrition (CE SAIN)

B. Locations: Phnom Penh, Cambodia

C. Description: CE SAIN – housed in Cambodia's Royal University of Agriculture (RUA) – helps improve food and nutritional security in Cambodia by supporting agricultural research and education while fostering innovation. CE SAIN's goal is to foster private sector innovation, agricultural research, education, and training; as well as public sector capacity building through improved collaboration and knowledge-sharing that is focused on improving food and nutritional security while enhancing quality of soil, water, and biodiversity. CE SAIN's three core objectives are: a) coordinate and leverage Innovation Labs and other USAID-funded SAIN activities, b) build human and institutional capacity of the RUA, and, c) establish Technology Parks to showcase high-potential technologies and strategies to sustainably intensify smallholder farming systems.

D. Collaborators: *Cambodia* - Conservation Agriculture Service Center (CASC); Ministry of Agriculture Forestry and Fisheries (MAFF); Ministry of Education, Youth, and Sport (MoEY); Department of Agricultural Engineering (DAEng); Royal University of Agriculture - Phnom Penh; University of Battambang; and multiple Feed the Future Innovation Labs (e.g. Horticulture; Livestock Systems; Integrated Pest Management); and Swisscontact. Additional collaborators due to the ASA CAST (Commercialization of Aquaculture for Sustainable Trade) project include American Soybean Association, World Vision, and Auburn University.

E. Key Achievements (See FY 2019 AWP Activity 4.1):

(a) CE SAIN collaborated with 14 research institutions, 67 researchers and two non-profit organizations and three private sectors at the ATPs. CE SAIN hosted a field visit for Can Tho University and signed an MOU for the Commercialization of Aquaculture for Sustainable Trade (CAST) project. The role of Can Tho is to support CE SAIN in pond renovation and building technical capacity in aquaculture for RUA faculty and staff.

(b) Disseminated available data of five weather stations to researchers and students: CE SAIN has supported the FLMLA to disseminate and promote weather data use among researchers, lecturers, and students. Data will be publicly available and accessed via mobile phone, tablets, and computers. The FLMLA will continue to promote this in the state owned universities including UBB, Meanchey, and University of Kampong Cham. This data has made a huge contribution to the quality of research and extension activities in Cambodia.

(c) Twenty-five unique technologies are being demonstrated in the five ATPs, for a total of 78 technologies across all parks. Eighteen of these technologies are in Phase III of development, meaning that they are ready for scaling. These technologies are accessible throughout the zone of influence of USAID, Kandal province, Kampong Cham province, and at the Royal University of Agriculture in Phnom Penh, attracting 1,536 visitors (661 female, 43%).

(d) Thirty proposals were awarded to RUA faculty and staff that includes six international grants. These grants have contributed to improving lab facilities and purchase of consumable materials in order to increase lab activities between lecturers and students. MoAs have been signed with USDA, Can Tho University, KSU and Michigan State University.

F. Capacity Building

(a) The CE SAIN is supporting 17 scholars (9 M.S. & 8 Ph.D.; 41% female) with scholarships at RUA. The 17 scholars have finished their course work, developed their proposals and defended, 50% of them have been doing their field experiment for data collection and 4 M.S. students (1st batch) are in their final year.

(b) Funding assistance from the U.S. Service Foundation has allowed CE SAIN to recruit 9 Bachelors (4 females) from Kampong Thom, 4 students are in their 3rd year, and 4 students are in their 2nd year. CE SAIN recruited 17 interns (53% females) from Prek Leap, UBB, and RUA. The interns were trained on integrated farming systems.

(c) CE SAIN supported two high schools (one in Siem Reap and one in Kampong Thom) and one Community Development Institution of Chea Sim Kamchay Mir University in Prey Veng to establish school gardens. Five teachers (three female) and 99 students (63% female) participated. CE SAIN will bring its promising technologies to the schools so the youth can be inspired to seek an agriculture major after they graduate from high school.

(d) International and local experts provided 24 lectures as part of the CE SAIN Lecture Series program with 471 participants, 43% were females.

(e) Five short-term trainings were organized, with 132 (37% female) participants; the trainings strengthened the capacity of farmers on topics about ecology, appropriate small-scale mechanization, and USDA Crimper & Morrison seeder use.

(f) Under the partnership of PEER team from the US, RUA, CIRAD, Swisscontact and DCA, CE SAIN co-hosted the PEER Cambodia workshop on building GIS skills, along with Regional Training and Ecological training at Battambang, Kampong Thom and at RUA. These activities provide great opportunities to RUA lecturers and students, as well as farmers to learn, share knowledge, and build networks with international experts, researchers, and the private sector. Technology and innovations were showcased through the national STEM forum organized by the Ministry of Education Youth and Sport in Phnom Penh.

G. Lessons Learned

(a) Enhancement of food security, nutrition, and generating additional income for our farmers in the Zone of Influence of USAID in Cambodia, requires collaboration and defined roles and responsibilities among partners.

(b) Supporting farmers and encouraging stakeholders to assist with challenges (i.e., farming practices, access to market and finances, etc...) is critical and time intensive.

(c) Drought and flash flood continue to affect their ATPs.

H. Presentations and Publications

(a) Chay, C., et al. (2019). Total phenolic content and antioxidant activity of rice wine from waxy pigmented and non-pigmented rice varieties produced by traditional and multi-parallel fermentation. Food Research 4 (1): 199 – 206.

(b) Chay, C., et al. (2018). Quality improvement of traditional rice liquor (srasor) processing in Takeo Province, Cambodia. Food Research 2 (4): 299 – 306.

(c) Ket, P., et al. (2018). Simulation of Crop Growth and Water-Saving Irrigation Scenarios for Lettuce: A Monsoon-Climate Cast Study in Kampong Chhnang, Cambodia. Water 10 666. https://doi.org/10.3390/w10050666

(d) Le, K., et al. (2018). Evaluation of the performance of the EPIC model for yield and biomass simulation under conservation systems in Cambodia. Agricultural Systems 166:90-100. https://doi.org/10.1016/j.agsy.2018.08.003

(e) Le, K., et al. (2018). Evaluation of long-term SOC and crop productivity within conservation systems using GFDL CM2.1 and EPIC. Sustainability 10(8), 2665. http://doi.org/10.3390/su10082665

(f) Kiely, S., et al. (2019). Perceptions of Risk and Risk Management Strategies: Identifying Alternative Strategies to Promote Smallholder Vegetable Production in Cambodia. International Journal of Agricultural Extension and Rural Development Studies. Vol.6, No.5, pp. 21-43. European Centre for Research Training & Development UK www.eajournals.org

(g) Pheap, S., et al. (2019). Multi-functional assessment of soil health under Conservation Agriculture in Cambodia. Soil and Tillage Research. Volume 194 - 104349 https://doi.org/10.1016/jstill2019104349.

(h) Ritzema, R.S., et al. (2019). Household-level drivers of dietary diversity in transitioning agricultural systems: Evidence from the Greater Mekong Subregion. Agricultural Systems. 176 - 102657. Elsevier.

(i) Theng, D., et al. (2019). Production of fiberboard from rice straw thermomechanical extrudates by thermopressing: influence of fiber morphology, water and lignin content. European journal of wood and wood products. Volume 77 – Issue 1:15-32. Springer Berlin Heidelberg.

B. Precision Agriculture for Smallholder Systems in Africa *(Project Completed)*

A. Name: Precision Agriculture for Smallholder Systems in Africa (PI: Joseph Messina, MSU)

B. Locations: Malawi

C. Description: This project features an innovative approach to determine how activities can and should be scaled to promote farm productivity for millions of smallholder farmers in Malawi and elsewhere in Sub-Saharan Africa. The scope incorporates data science, machine learning and new remote sensing technologies with detailed data on farm practices, soils, climate, and production conditions in a developing economy context. The project will eventually identify site-specific opportunities for improving resource efficiency and raising farm productivity while offering innovative mechanisms for transmitting actionable, timely, and data-supported agronomic practices to farmers.

D. Collaborators: *United States* - Oakland University, CIAT

E. Key Achievements:

(a) Continued work on building tools to integrate data sets. Begun working with CIAT to push forward a pilot project related to their work, and in the beginning stages of writing a scaling proposal along with CIAT to Google.

(b) Substantial advancement on Google Earth Engine crop niche modeling software. Plans to submit it as a publication within the next few months. Recreated the work of the late Shengpan Lin and had a synopsis paper out for review by summer 2019.

(c) Innovative avenues for making these new insights actionable for policy makers, agricultural extension systems, and local agricultural advisors from private and public sectors working with smallholder farmers: this is complete, although the final manuscript is technically under review. The development of a new follow-on pilot project with CIAT is direct evidence of progress.

F. Capacity Building:

Nothing to report in FY 2019

G. Lessons Learned:

(a) There are very interesting questions related to what information is useful to small holder farmers that lead to actions with real benefits. Working with VIAMO, cell technologies, and weather/climate data has been productive, but very cutting edge.

(b) Software publications are slow to review and revise. Global error-modeling software was published this spring in IEEE-JSTARS, but software applications are more difficult to present in the traditional presses. The drone data are difficult to integrate, but critical to any operational system. The Planet Labs data are very difficult to use, but valuable.

(c) The main challenges were those typical with complex program development and integration. In retrospect, more time should have been budgeted for drone data collections, over more areas. Wind was an unexpected problem, and the project was constantly abutting the maximum operating temperature of the drone.

H. Presentations and Publications:

(a) Peter, B. (2018). Data Visualization. Lansing-Area Data Scientists Group and MSU Social Science Data Analytics Initiative. Michigan State University. - Presentation

(b) Carroll, J. W. (2019). Engaging the World: Oakland University Archaeology on Four Continents. Engaging the World: Oakland University Archaeology on Four Continents, Oakland University. https://getlocalhop.com/engaging-the-world-oakland-university-archaeology-on-four-continents/event/CO4Lv9rIfW/ - presentation

(c) Frake, A., Namaona, W., Walker, E., & Messina, J. (2018). Estimating spatio-temporal distributions of mosquito breeding pools in irrigated agricultural schemes: A case study at the Bwanje Valley Irrigation Scheme. Malaria

(d) Snapp, S. (2018). Farmers and scientists learning to adapt to climate change. Workshop at Tropentag, a meeting held in Ghent Belgium, Ghent, Belgium. - Presentation

(e) Messina, J. & Peter, B. (2019). Errors in time-series remote sensing and an open access application for detecting and visualizing spatial data outliers using Google Earth Engine (pp.1165-1174). IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 12(4), IEEE, online.

(f) Peter, B., Messina, J., Carroll, J. W., Lin, S., Chikowo, R. (2019). Effective Spatial Resolutions for Monitoring Crop Health on Smallholder Farms. Monitoring Agricultural Productivity and Mosquito Breeding Potential via Remote Sensing and sUAS, Lilongwe University of Agriculture and Natural Resources. - Presentation

(g) Peter, B., Messina, J., Carroll, J. W., Zhi, J., Chimonyo, V., Lin, S., & Snapp, S. (2019). Multi-spatial resolution satellite and sUAS imagery for precision agriculture on smallholder farms in Malawi. PE&RS

(h) Messina, J., Peter, B., Frake, A., & Lin, Z. (2018). Web-based GIS for geovisualizing environmental niche: Cropping systems and disease transmitting vectors. Presentation at Environmental Science & Policy Program—Balancing Act: Food, Water, Energy, Climate, Michigan State University. - Presentation

(i) Peter, B., Messina, J., Snapp, S., & Carroll, J. W. (2019). Remote sensing for precision agriculture: A multi-scale view of farm productivity. Presentation at From the Ground Up: Improving Soil Health in Africa through Partnership, Michigan State University - presentation

(j) Peter, B., Messina, J., & Carroll, J. W. (2019). Multispectral drone imagery of a trial farm in Ntubwi, Malawi. doi:10.7910/DVN/OAWDZC.

C. Research Output Dissemination Study *(Project Completed)*

A. Name: Research Output Dissemination Study (PI: Nancy Allen, University of California, Davis)

B. Locations: Global – Due to the nature of the research study

C. Program Description: The objective of RODS was to gain a better understanding of the dissemination, use, and adoption of research outputs from USAID-funded Feed the Future Innovation Labs (ILs) and its predecessor program, Collaborative Research Support Projects (CRSPs). RODS was designed to explore partnership dynamics at the critical juncture at which ILs transfer an innovation to a dissemination entity. The study focused on research outputs after they were transferred to the entities facilitating their dissemination. Dissemination is defined in this study as "active and planned efforts to encourage target groups to adopt an innovation."

D. Collaborators: *United States* - Feed the Future Innovation Labs

E. Key Achievements:

(a) Completed and submitted the "Research Output Dissemination Study: Examination of Dissemination Pathways in the Use, Adoption, and Scaling of Research Outputs of Feed the Future Innovation Labs" final report of the findings from the field evaluations.

(b) Eight cases included in the study have generated innovations that confer both private economic benefits and public environmental benefits, some with good prospects for continued scaling and impact. The selected innovations included in the study were: Conservation Agricultural Practices to Reduce Global Land Degradation (Kenya and Nepal); Breeding Cowpea Varieties for Improved Insect Resistance (Senegal); Drying Beads for Post-Harvest Drying and Storage (Bangladesh); Index-Based Livestock Insurance (Kenya); High-Efficiency Multi-Purpose Solar Dryer to Decrease Post-Harvest Loss and Increase Crop Quality (Senegal); Low-Cost Hermetic Storage Bags for Long-Term Grain Storage (Bangladesh); Tomato Grafting for Resistance to Soil Borne Diseases (Bangladesh); and Trichoderma as Biocontrol for Soil Borne Pathogens (Nepal).

F. Capacity Building:

Nothing to report in FY 2019

G. Lessons Learned:

(a) Partnerships were largely driven by historical relationships and personal connections, rather than strategic choices about collaborating for dissemination or scaling purposes. IL scientists engage primarily with initial research partners regardless of anticipated delivery pathway. These relationships proved robust for onward technology transfer in most cases but were found to be less productive where an innovation was expected to diffuse or scale along a commercial pathway.

(b) ILs make vital contributions to the dissemination of innovation in multiple ways which is most evident in capacity building of national research partners to adapt and develop technology for local conditions and sustain necessary adaptations over time.

(c) Many well-recognized dimensions of agricultural technology transfer and adoption already documented in decades of technology transfer literature.

H. Presentations and Publications:

(a) Nothing to report in FY 2019

D. Gender Integration Highlights:

During the FY 2019 reporting period, SIIL requested the Consortia and subwardees to provide additional information on how their projects were integrating gender into their research. All of them are actively integrated gender into their programs. Below are some selected highlights in some projects:

The gender equity and women empowerment analysis is based on IFPRI surveys and preliminary results suggest that women in Ethiopia did better in terms of their input in decisions about irrigated cash crop farming after interventions than before the intervention. Also in this study, a comparison of the number of hours allocated by women to different agricultural activities before and after the introduction of small-scale irrigation technologies shows an increase in number of hours worked after the interventions.

The WAgN project saw one student defend her M.S. thesis this fall at Penn State University, and will enter Penn State's Ph.D. program spring semester 2020. Three other female graduate students have either completed their degrees or are nearing completion. Additionally, the SI assessment framework has been used to analyze gender aspects of the projects Wild Gardens research.

The ASMC presented at the ECHO Annual Conference in Fort Myers Florida November 13, 2019. Two hour Conference workshop on 'Assessing Technologies for Gender Sensitivity' attended by 22 participants. Additionally, the workshop acted as a springboard to test a revised framework for the training module. They also presented at the Gender in Innovation Lab Meeting, June 6, 2019, Washington D.C. on 'Gender Transformative Approaches: Lessons from ASMC'.

The ASMC-Ethiopia team conducted Gender Technology Assessment of Maji pump in Alefa and Dangista kebeles. Women farmer network formed by ASMC-Cambodia team to address the needs specific to female farmers.

Forty one women participated in ASMC-Bangladesh field days in Wazirpur, Barishal, and Dumuria, and Khulna. Women participated in field days and training in the seedling raising process and the women engaged in tray/mat preparation and intercultural operations like irrigation and pest management. A gender training session took place in 2018 and the project stakeholders were trained for technology assessment. Dr. Salimata SONDE/POUSGA was selected as the responsible for this process on ripping-planting-weeding system.

A joint gender issue report was produced from the collaboration of Senegal and Burkina Faso teams for the ASMC-Burkina Faso project.

E. Nutrition Integration Highlights:

During the FY 2019 reporting period, SIIL also requested the Consortia and subwardees to provide additional information on how their projects were addressing nutrition as a cross-cutting theme into their research activities. Below are the highlights from few selected projects:

For the Bangladesh polder project, nineteen training events were organized involving 67 male and 281 female teachers and mothers of kindergarten, primary and high school children during the reporting period. The main reason for involving the school teachers is to teach them about the nutritional aspects of zinc bio-fortified rice, sunflower oil, and nutrition from pulses and maize that SIIL-Polder project has introduced in polder 30 so that they can teach their students on those nutritious crops. In addition, 434 household members (37% women) of the farm families of ten LHs were also provided nutritional awareness training. In these trainings, the importance of micronutrients and protein on the overall nutrition on children, pregnant, and lactating mothers were discussed. We have also made them aware that the nutrients are available in higher amounts in the crops introduced by the SIIL-Polder project.

For the ASMC-Burkina Faso subaward, 492 farmers was trained on animal nutrition with 115 women from six locations in the Hauts-Bassins Region.

The main reason of food insecurity in Burkina Faso is the low yield of crops and drudgery of labor. By using the planter, farmers – especially female – save time and will be able to use it for other activities to benefit family nutrition. The theory of improvement of ASMC is: how the extra-time opened up by the farmer due to mechanization can be used to produce vegetables for family consumption. The project developed a small drip irrigation system affordable by small holder farmers and especially women to produce vegetables.

Nutrition data collected from the eight study sites in Burkina Faso will allow the project to evaluate the distribution of access to food not only among surveyed households but among the separate eating groups within households (often shaped by gender).

In Ethiopia, the SIPSIN project found that the use of irrigation during the dry season to expand cropping produced additional food and generated income. The increased income as a result of irrigated crops sales, especially fodder and tomatoes, allows the household to purchase additional food items such as animal products (milk, eggs, beef, and chicken) from the markets to complement their nutrition. Production and sale of fodder increased the availability of animal feeds at the market.

In Senegal, the dual-purpose millet project initiated the study of infant flours prepared from the target varieties shows that the variety SL169 followed by the variety SL243 would be more recommended for local cereal processors to produce flours in order to fight against protein-energy malnutrition in children, particularly. The basis of this recommendation could be reinforced by the results of organoleptic tests conducted with an internal ITA panel.

XIV. Issues

A. Government Shutdown and Delay of Federal Funding Allocation

The partial government shutdown, from December 2018 to January 2019, impacted some project-implementation activities and decision-making functions. In addition, the funding allocation delay from USAID caused slight disruptions within some research activities. Host-country institutions have had difficulties in conducting their activities without the timely distribution of funds. Corrective measures have been taken in discussion with our AOR and other administrative staff from USAID, so all consortia and projects are now fully functioning with the exception of the Congressional-restricted countries in our Innovation Lab, Cambodia and Ethiopia. Delays in funding impacted the end of the five-year time frame, requiring no-cost extensions from the subawardees through March 2020.

XV. Future Directions and Activities

A. Implementation of No-Cost Extensions for Subawards and Consortia

The SIIL will continue to support our existing subawards and consortia with no-cost extensions through March 2020. All subaward PIs will be required to develop a transition plan, outlining how they will ensure that their research will continue to be supported and integrated with other research programs in the country or region past the end date of the award. We will prompt project teams to clearly and systematically define the role of each collaborator engaged in their research or scaling efforts. Strategic engagement with the host country partners, NGOs, and private sector will be crucial for sustainability.

B. Extending Focus on Resilience and Capacity Building

The SIIL has extended an invitation to several subawards to submit a concept note informed and built on their previous research achievements, and designed to address the suitability, scalability, and sustainability of the technologies developed by their projects. Future project activities must focus on the resilience of smallholder farmers, and proposed for three years (April 2020 to March 2023), continuing after the current timeline of the project. Following the evaluation of the concept notes, full proposals will be requested with an anticipated due date of January 30, 2020. As part of the SIIL funding extension, future funded research projects will build on the achievements of the past four years while ensuring the continued relevance of the research, and aligning with the SIIL's renewed focus on supporting local responsibility and accountability. The SIIL will lean towards a regional approach to enhance coordination as well as scaling and adoption of appropriate technologies, and contributions to the U.S. Government's Global Food Security Research Strategy (GFSRS).

C. REACH Finalization and Implementation

The SIIL, CORAF, and USAID came together to create at concept note and strategic plan for the implementation of the West African Research, Extension, and Advisory Coordination Hub (REACH). The REACH strategic plan aims to (i) increase the use of appropriate technologies and innovations in the region; (ii) increase the uptake of strategic decision-making for policies, institutions, and markets; (iii) enhance institutional and human capacity in agricultural research for development; and (iv) meet the demands of agricultural knowledge for target clients. The proposed objectives and activities of REACH align well with CORAF's Priority Intervention Domains (PID) – agriculture, food, and nutritional security; policy, institution, markets and trade; and gender, youth and social equity, as well as the associated Activity Pillars – community of practice on scaling technologies and innovations for sustainable impact; Integrated regional capacity strengthening in agri-food research and innovation; and knowledge management and foresight. Continued collaboration with various partners will continue as REACH is put into place over the next years.

D. Evaluating System Productivity, Synergies and Tradeoffs

Last year, all of the projects used the SI Assessment Framework to evaluate their technologies and look at the synergies and tradeoffs. We will continue these efforts and encourage researcher and implementing partners to look into further details and quantify the overall systems productivity by putting all the components of the research or package of practices. In addition, they looked into the synergies and tradeoff at the farm or household scale rather than at individual plot levels with one innovations.

Appendix A – List of Awards Given to U.S. Universities

Title: Geospatial and Farming Systems Research Consortium
Awarded institution: University of California, Davis
Dates: September 16, 2014 - September 15, 2019
Current year funding: $852,085
Total funding: $4,185,524

Title: Appropriate Scale Mechanization Consortium
Awarded institution: University of Illinois at Urbana-Champaign
Dates: October 1, 2015 -September 15, 2019
Current year funding: $1,361,354
Total funding: $4,700,000

Title: Unlocking the Production Potential of "Polder Communities" in Coastal Bangladesh through Improved Resource Use Efficiency and Diversified Cropping Systems
Awarded institution: Kansas State University
Dates: October 1, 2015 -September 15, 2019
Current year funding: $170,246
Total funding: $999,508

Title: Adoption of Sustainable Intensification in Dual-Purpose Millet - Leguminous Crops – Livestock Systems to Improve Food and Nutritional Security and Natural Resources Management for Rural Small Holder Famers in Senegal
Awarded institution: Kansas State University
Dates: October 1, 2015 -September 15, 2019
Current year funding: $243,246
Total funding: $996,360

Title: Raising Crop Response: Bidirectional Learning to Catalyze Sustainable Intensification at Multiple Scales
Awarded institution: Michigan State University
Dates: October 1, 2015 -September 15, 2019
Current year funding: $247,629
Total funding: $996,764

Title: Women in Agriculture Network (WAgN) Cambodia: Gender- and Ecologically – Sensitive Agriculture
Awarded institution: Pennsylvania State University
Dates: October 1, 2015 -September 15, 2019
Current year funding: $247,403
Total funding: $1,000,000

Title: Evaluation of the Relationship between Sustainably Intensified Production Systems and Nutritional Outcomes (SIPSIN)
Awarded institution: Texas A&M University
Dates: October 1, 2015 -September 15, 2019
Current year funding: $249,957
Total funding: $999,198

Title: Developing Indicators for Sustainable Intensification
Awarded institution: Columbia University
Dates: September 1, 2015- January 31, 2017
Current year funding: $0
Total funding: $237,454

Title: Developing Indicators for Sustainable Intensification
Awarded institution: University of Florida
Dates: February 1, 2017- November 30, 2017
Current year funding: $0
Total funding: $185,622

Title: Developing Indicators for Sustainable Intensification
Awarded institution: Michigan State University
Dates: July 1, 2015 – August 31, 2017
Current year funding: $0
Total funding: $374,548

Title: Precision Agriculture for Smallholder Systems in Africa
Awarded institution: Michigan State University
Dates: March 15, 2017 – August 31, 2018
Current year funding: $0
Total funding: $507,990

Title: Research Dissemination Output Study (RODS)
Awarded institution: University of California at Davis
Dates: February 1, 2018 – February 28, 2019
Current year funding: $0
Total funding: $499,409

Appendix B – Success Stories

Success Story #1: Emerging Evidence from Tanzania that Sustainable Intensification can Improve Child Nutrition

In many developing countries, including Tanzania, food insecurity and child malnutrition remain persistent problems. In 2017, globally, about 151 million children under age five are stunted, where 55% and 39% of these children live in Asia and Africa, respectively; but Africa has shown relatively slow progress in reducing stunting and it is the only region where the rate of stunting has risen since 2000. Malnutrition is a leading cause of child mortality, making children more vulnerable to severe diseases. Approximately 45% of global deaths of children under age five are linked to malnutrition, and the mortality rate of children in sub-Saharan Africa (SSA) is the highest in the world. Tanzania – a focal country in this study – is the third worst affected country in SSA based on the prevalence of stunting.

Agriculture and nutrition are closely linked because the majority of undernourished people still live in rural areas and many of them are smallholder farmers. This linkage suggests that agricultural intensification via farmers' adoption of improved inputs and management practices may improve the nutritional status of nutritionally vulnerable household members including young children. This can be done by enhancing the household's agricultural production, productivity, and/or income, as well as by providing better access to more diverse or nutritious foods. However, there is an emerging consensus that conventional agricultural intensification via high-yielding crop varieties and inorganic fertilizers may be insufficient to sustainably raise agricultural productivity and could have negative environmental consequences (Pingali, 2012). Moreover, in many parts of SSA, rapidly growing populations and a lack of new land to farm has led to continuous cultivation of plots and reduced fallowing, thereby degrading soils and adversely affecting crop yields and yield response to inorganic fertilizers. A major question then is, what is the impact of this declining natural resource base on family nutrition status, and should agricultural development just focus on intensification (via fertilizer subsidies), or pay equal attention to organic matter technologies and

agrobiodiversity for a sustainable approach to intensification?

In this context, agricultural sustainable intensification (SI) is, at its core, an approach that seeks to "produce more food from the same area of land while reducing the environmental impacts" (Godfray et al., 2010, p. 813). In our study, we focused on the effects of SI maize production on the child nutrition outcomes in maize-growing households in Tanzania. We focused on maize due to its importance as a staple food in Tanzania, and because it accounts for approximately 75% of the total cropped area in the country. To do this, we applied a multinomial endogenous treatment effects (METE) model, combined with the correlated random effects (CRE) approach, using three waves of nationally representative household panel survey data (the Tanzania National Panel Surveys of 2008/09, 2010/11, and 2012/13). These surveys were conducted by the TNBS in conjunction with the World Bank.

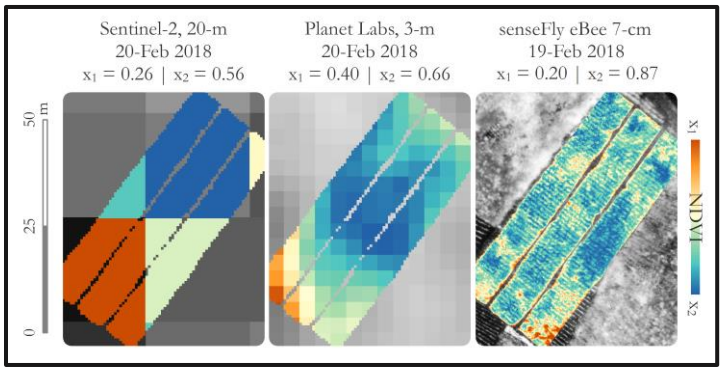
Some of our key findings included the results from our exploration the effects of different combinations of three soil-fertility management practices (inorganic fertilizer, organic fertilizer, and maize-legume intercropping) used by rural Tanzanian households on their maize plots on the nutritional outcomes of children aged 6-59 months within the household. The results suggested that joint use of inorganic fertilizer with maize-legume intercropping and/or organic fertilizer (which we refer to as the sustainable intensification or *SI* group of practices) is associated with increases in children's height-for-age z-score (HAZ) and weight-for-age z-score (WAZ), as compared to households that adopt none of these practices. The positive effects of the *SI* group are mainly among children aged 25-59 months who, as compared to younger children, are less likely to be breastfed and may be more directly affected by household diet changes associated with changes in agricultural practices. The joint use of maize-legume intercropping and inorganic fertilizer is a key driver of the positive *SI* effects, in the form of crop income and productivity pathways.

Success Story #2: Going to Space to Image a Farm: Drones and Satellites in Smallholder Precision Agriculture

For millennia, humans have had a deeply rooted bond with the land that they sow—knowing the soils, planting the seeds, protecting the plants, and helping them grow. Mechanization, crop breeding, and fertilization, all of which led to the Green Revolution, have increased how efficiently we are able to produce food, but these advancements are still linked to the ground. In 1959, approximately one century after the first aerial image by balloon, Explorer 6 captured the first satellite photo of Earth. In the early 1960s, the U.S. made a substantial push in investments to monitor our planet from above and one of the earliest large-scale initiatives by NASA to monitor agricultural health via aircraft was during the corn blight of 1971.

In the modern era, we have access to a plethora of data collected by Earth-monitoring satellites. Most notable are the Landsat missions by NASA/USGS, which have been ongoing since 1972. Commercial satellites, too, have entered the arena, and most recently, drones have begun rapidly occupying more and more of our airspace. Individual-use, small, unmanned aerial systems (sUAS) are at the frontier of aerial agricultural observation, offering high resolution information that cannot be seen by the naked eye. From drones to satellites, each of these systems cover a vast range of altitudes, but how high *should* we fly? Researchers affiliated with Michigan State University, Oakland University, and the University of Alabama sought to answer this question and more.

In collaboration with Africa RISING and the Lilongwe University of Agriculture and Natural Resources (LUANAR), a research team led by Dr. Joseph Messina of the University of Alabama visited central Malawi in March of 2018 to collect drone imagery over smallholder maize experimentation farms. A senseFly eBee fixed-wing drone flew at flight heights ranging between 80 and 300 meters to measure crop productivity at multiple scales. On-farm measurements of relative chlorophyll content were collected using a handheld sensor to relate crop health status to the imagery.



Along with these images, Dr. Brad Peter evaluated imagery collections from both commercial and governmental satellite systems, including SPOT 6/7, Pléiades, Planet Labs, Sentinel-2, Landsat, MODIS, and AVHRR. Each of these systems offer data at a different spatial resolution (i.e., the land area that each pixel in the image represents). For SPOT 6/7, each pixel represents a 6 meter by 6 meter area (i.e., 6-m spatial resolution), while Sentinel-2 is a coarser 20-m spatial resolution. At the finest resolution, the drone captured images at a spatial resolution of 7 centimeters. In the smallholder farming context, which is typically characterized as less than 2 hectares (or 4.9 acres) in Malawi, finer spatial resolution platforms can elucidate intra-farm variability. While whole farms may be evaluated with global satellite systems such as Landsat, a drone can evaluate individual maize plants.

The drone that was flown was equipped with a Parrot Sequoia multispectral camera that not only collects data within the visible spectrum, but also wavelengths of light in the near infra-red inaccessible to the human eye.

Indices produced using these metrics, such as the normalized difference vegetation index (NDVI), have proven success in monitoring vegetation health. Despite the utility of NDVI as the status quo, there is a broad range of indices that can outperform it depending on the crop, farm structure, and measurement of interest (e.g., chlorophyll content).

What was found is not what one might expect. The 'highest' quality images (flight height of 80 meters/7-cm spatial resolution) were not the most effective for relating imagery to on-farm measurements of crop health. Conversely, the most effective spatial resolutions were closer to the dimensions of a maize plant (14- and 27-cm spatial resolution). As for the satellite sensors, they were not nearly as effective for intra-farm assessments, attributed in part to problems associated with cloud cover and infrequent revisit rates. Furthermore, evidence from this study suggests that spectral indices produced using the green wavelength are critical for evaluating crop chlorophyll content, which has a strong correlation with yields.
The results of this study demonstrate that drone imagery is needed to address intra-farm crop variability in the smallholder context and that spatial resolutions of imagery acquired should be designed to consider the size of the plants being evaluated, as well as the cropping density of the farm.

So, are drones the answer?

Drones have immense potential to transform how we do agriculture, but given their current costs and labor requirements, "scaling these technologies requires institutional investments," says Dr. Jon Carroll, drone pilot and anthropological archaeologist of Oakland University. Dr. Peter's view of the future includes continual advancements in sUAS technologies, but he also asserts that finer spatial resolution satellite systems with frequent revisit rates, particularly radar-based systems that are able to penetrate the cloud layer, are a promising way forward.

Outcomes of this research will improve the way we approach precision agriculture; through interdisciplinary collaborations, increased yields, and improved food security on smallholder farms can be achieved. If we produce map products that are accurate representations of where crops are stressed and why, farmers can intervene in a timely manner and ensure a more successful harvest.

Success Story #3: Tomato Grafting for Improved Rainy Season Nutrition and Income

Tomatoes are difficult to grow during Cambodia's monsoonal rainy season. Flooding, waterlogged soils, diseases, and high temperatures can kill young tomato transplants or significantly reduce yields.
The vast majority of tomatoes found in the marketplace and used by restaurants and hotels during the May-October rainy season are imported from neighboring countries, commanding a premium price.
Grafting tomato scions onto selected rootstocks of eggplant can minimize problems caused by flooding and soil-borne diseases. Sometimes the use of grafted tomato plants can be the difference between harvesting a good crop and harvesting no crop at all.

The research team first evaluated and determined the best rootstock selections that offered the highest degree of resistance to flooding, fusarium wilt, bacterial wilt, and root knot nematodes – the most serious tomato pests present during the rainy season.

Prior to this project, tomato grafting was untested and relatively unknown to farmers and agricultural development workers in Cambodia. The team implemented a series of 'hands-on' training workshops spanning over two years, and strategically targeted women farmers, entrepreneurs, and NGO staff. Outreach activities, demonstrations, and promotion to key stakeholders was critical for creating a strong and broad foundation for scaling up this important sustainable intensification technology.

Small farm diversification is critical to creating resilient food systems, particularly in countries like Cambodia, that are highly susceptible to the ills associated with climate change. Vegetable grafting technology is a powerful tool to improve food production at one of the most challenging times of the year. Additionally, home vegetable production and marketing remains a feminine enterprise in Cambodia. Development of a 'rainy season vegetable production toolkit', including tomato grafting,

promotes women empowerment via increased market access and participation.

Grafted tomato production provides an entry point into local lucrative produce markets for smallholder women during the rainy season, and has the potential to improve both nutritional and economic outcomes. Added household income from increased market participation also holds the potential to directly benefit children by improving access to education, health care, and nutritious food.
This project represents longstanding collaboration between researchers at Penn State University and key Cambodian collaborators.

Three disease-resistant eggplant rootstocks were tested and identified from the World Vegetable Center's germplasm resources, along with a local eggplant landrace. The University of Battambang engaged graduate students in both grafting research and assisting with crucial outreach and training activities. CE SAIN (Center of Excellence on Sustainable Agricultural Intensification and Nutrition) has established tomato grafting demonstration plots at several of its technology parks. Tomato grafting is now a proven SI technology to aid Cambodia's effort to improve food security. Rural women farmers have adopted the technology and locally-grown tomatoes are now present in the marketplace – even during the rainy season.