Feed the Future Innovation Lab for
Collaborative Research on Grain Legumes
(Legume Innovation Lab)

FY 2017 Annual Project Technical Progress Report
(October 1, 2016 – September 29, 2017)

Project Code and Title: SO2.1 - Farmer Decision Making Strategies for Improved Soil Fertility Management in Maize-Bean Production Systems

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I. Abstract of Research and Capacity Strengthening Achievements

Following completion of research experiments on common bean in Uganda, five rainy seasons of community-based field trials enabled farmers to learn about and evaluate improved management practices and technologies for adoption. A multistakeholder bean Innovation Platform continues to develop in membership size, diversity, enthusiasm and capability, with 10 value chain member organizations and 1000+ farmers. In Mozambique, field experiments were completed mid-2017 by IIAM. Two SAWBO video animations were released on research-based farmer-validated bean production recommendations in Uganda and Mozambique and one on jerry can storage for Mozambique. IIAM created and is field testing its first App, focused on bean production recommendations. Project team members presented 14 papers/posters at the Grain Legume Research Conference in Burkina Faso. One M.S. student graduated and two are near completion. One M.S. student and one Ph.D. student are progressing well. Research results are published in peer-reviewed journal articles and a book chapter, with others being prepared. Some will be disseminated in regional/national practitioner and policy outlets in Africa. Training methods and media are ready for dissemination to intermediate and end users. Capacity strengthening through applied research-based training has been successfully conducted.

II. Project Problem Statement and Justification

Sustainable intensification of smallholder cropping systems requires improved soil fertility management in which legumes play an integral role, with enhanced capabilities among farmers to diagnose and identify solutions to important soil and other production constraints. Project research activities focus on predominant soil types in key common bean production regions in Masaka and Rakai districts south-central Uganda and Gurúè district, northern Mozambique. To understand potentially limiting soil characteristics and nutrient deficiencies, relevant analyses include soil physical and chemical properties, nutrient omission studies, and researcher-managed field experiments. It is also valuable that researchers understand local/indigenous criteria and systems for characterizing soils, particularly those reflecting fertility vs. deficiencies and crops that are appropriate. The combination of scientific and local criteria can enhance understanding and sustainable implementation of recommended cropping system improvements.

Based on results of field experiments, community-based trials and demonstration sites engage farmers in understanding key management practices and technologies (MPT) recommended by researchers. Farmer field days stimulate interest through direct observation, participation, and comparison of site-specific MPT. These activities engage producers and other stakeholders in social learning, stimulate interest in the demonstrations and trials, and foster widespread use of MPT that are proven successful under local conditions. The MPT include field preparation and measurement, seed selection, plant spacing, application of organic and inorganic fertilizers, weeding, post-harvest handling, and farm business economic analysis.

An innovative communication and dissemination strategy integrates the use of multimedia, including radio, video animations delivered via smartphones, and print materials delivered through networks of partner organizations supplemented by field demonstrations and other participatory activities. These engage farmers with diverse backgrounds and characteristics and other key stakeholders in widespread dissemination and adoption of improved management practices and technologies to improve soil fertility and increase bean productivity.

III. Technical Research Progress

Objective 1: Characterize Smallholder Farmers' Motivations, Knowledge and Practices

Smallholder farmers continued their learning through initiating on-farm trials (12 one-acre sites in Masaka and 10 one-acre sides in Rakai) and leading farmer field days associated with those field trials. During the pre-season period, learning was fostered through discussions and decision making pertaining to location of on-farm trials and types and levels of treatments and inputs to be used. Farmers generally meet monthly for co-learning. Experiential learning during implementation of on-farm trials occurred when applying treatments, hands-on husbandry practices, observation of bean performance, and peer-to-peer communication. Smallholder farmers also learned through assessment of the results of on-farm trials at community level during informal field visits by both group members and passersby and organized field days that systematically explain the management practices and technologies involved, the costs incurred, and yields obtained. Local social networks have also been a channel for social learning and encouraging non-member farmers to learn. Finally, learning takes place during Innovation Platform meetings when they plan for the subsequent season's activities. Six joint IP meetings have been held from October 2016 to September 2017, with an average of 50 participants each.

<u>Objective 2</u>: Develop and Refine Models of Smallholder Bean Farmers' Decision Making

<u>Farmers' Learning and Adoption</u>

After identifying the resources and actions required for increasing bean crop productivity and marketing, and improving soil fertility, it was important to document farmers' actions to invest in and adopt (or intentions to do so) new management practices and technologies. Understanding the significance of these actions involved interviews with farmers and leaders of the multi-stakeholder innovation platform regarding the latter's efforts and successes. Information gained during these interviews provided the basis for formulation of recommendations for training and support to increase bean crop productivity and marketing, and to improve soil fertility.

Project farmers who have been part of the Innovation Platform in Masaka and Rakai Districts, have hosted field trails, demonstration gardens and field days. Through these activities, they have learned to mobilize and manage key resources: money to buy improved bean seed, including drought resistant varieties; mineral fertilizers (diammonium phosphate - DAP and urea), organic chicken manure, and biochar; pesticides; and labor hired for weeding, harvesting, etc. Some have purchased surfactants that reduce moisture loss and allow the crop to withstand drought, and some have invested in irrigation.

Focus Group Discussions were conducted with farmers in Masaka and Rakai during May 2017 by Rob Mazur and Naboth Bwambale. They met with farmers who are members of the Bean Innovation Platform to explore three topics: (1) growing beans, (2) soil fertility, and (3) being part of the bean innovation platform. Focus groups consisted of 4-8 participants, women and men, and lasted approximately two hours. For each topic, *four* questions guided the discussion:

- What are the *most important* things that you've *learned*? from whom?
- What *changes* have you made in relation to that *after learning in this project*?
- What *additional things* would you *like to learn*?
- What would be the *best way* to *help you learn*?

Key findings and insights from the focus group discussions are highlighted in this and other sections of this report. Of particular importance here is that farmers deeply appreciate the full range of benefits associated with recommended bean crop MPT. They described those MPT in detail regarding the MPT and procedures to use them: soil testing; early field preparation; timely planting in rows with proper spacing; trying new seed varieties and using new, quality seed at least every other season; applying manure and/or fertilizer according to soil type in a banded manner; monocropping beans when focusing on food security and marketing; and hermetic post-harvest storage of bean seed.

Interviews were conducted with 104 farmers in Masaka and Rakai districts of Uganda by a team led by Eric Abbott. The interviews were intended to assess farmers' learning when shown either a video animation produced by SAWBO containing the project's research-developed and farmer-tested bean recommendations or a similar color print version using still images from the video animation plus text. Both were in Luganda, the local language. Following seeing and hearing - or reading - the recommendations, farmers were tested on what they remembered, what practices they already follow, and what practices they plan to follow in the next harvest season. Many of these farmers were members of the Innovation Platform or the Community Enterprise

Development Organisation (CEDO) seed production NGO and already knew about some of the practices, but none had seen the video or print materials before. Results of this learning are discussed below in the section for Objective 4.

Taking together those who indicated that they are either already doing it or say that they will do it, it is clear that most farmers will be following these guidelines in the next season. Examples of those who will not include 14% who won't plant in lines, generally because they consider that it involves too much work. Between 15-21% say they won't use at least one type of fertilizer, usually because they don't have access to it or don't have the money. Overall, however, the great majority of those who don't currently do it say they will do it in the next season.

- *TABLE 1* -

Table 1: shows farmers' adoption, plans and perspectives on management practices and technologies, Masaka and Rakai, Uganda in May 2017

Value of Innovation Platform Participation

During the focus group discussions, many farmers conveyed their understanding, gained through project activities, that fertility of any type of soil can and should be improved ("we must feed the soil"), since their soils are 'exhausted' and current conditions and improvement are associated with their management practices. Farmers recognize that "we can transform poor soils into productive ones." Applying fertilizer and manure according to soil type is viewed as beneficial not only to beans but also will carry over to the subsequent crop on that field. Several are now utilizing soil and water conservation measures.

On-site soil testing that provides quick results and is accompanied by guidelines which specify the quantities of fertilizer to add is of great interest to farmers, as conveyed clearly during the focus group discussions. Farmer group members are prepared to buy soil test kits on credit and share soil test results with group members and neighbors.

During focus group discussions, farmers expressed their appreciation for the increased access to knowledge, services and inputs derived from interacting with an array of value chain stakeholders who form the multistakeholder bean innovation platform, as well as knowledge from fellow bean farmers' experiences and suggestions. They have experienced a 'mindset shift' which reflects planning for the full crop cycle, developed a business orientation ("my garden is my office"), searched for new information and "all ways of learning", educated/trained others in improved bean crop management practices, and conveyed pride in their transformative achievements: "I am proud to be well informed and knowledgeable, no longer dependent on others to decide." "I have advanced from being a grain and seed buyer to now being a grain and seed seller." "I have seen the light – I will never stop growing beans!"

Farmers described how active participation and interaction in the innovation platform facilitates experiential collective learning and core knowledge development of all members. Members develop horizontal and vertical social linkages and networks which help them to identify 'true' partners needed to increase production and to 'know the market' and coordinate joint decision making and action.

Farmers have already experienced improved household food security, mobilized collectively for loans to increase productivity and production, increased savings, opened bank accounts, purchased durable goods, and used profits from coffee to invest in more intensive and expanded bean production.

Production Economics and Marketing

During the focus group discussions, it became clear that improved systems of record keeping are of great interest for farmers who want to calculate their costs and assess profitability in relation to market prices. They also want to better understand the range of market prices and details of contract farming, and thereby negotiate more favorable terms.

Beans are often intercropped – primarily with maize, but also with a variety of other crops. Researcher data and farmer generated information from our study allowed farmers to understand the production costs associated with various cropping systems so that they are able to make informed decisions. Analysis of primary data collected in Rakai and Masaka from 2014-2017 (during both growing seasons each year) on input and labor costs, and on bean sale prices, revealed the unreliability of data from a single source. Results of our profitability analyses varied significantly by sources of cost and price information. It was also evident that some farmers may have intrinsic motives for providing less-than-accurate information to researchers (cultural norms, privacy concerns, inflated rental price charged for research plots, etc.). This guided the development of an instrument that allows farmers to play a central role in data collection.

Our research documented that farmers selling beans are not only price takers, but also sell most of their beans individually at the farm gate. Nearly all farmers sold their beans individually – 90% in Uganda and 98% in Mozambique. It was evident that the average farmer is not well equipped to determine a profitable or even breakeven price when selling beans. Traders have played a major role as sources of information for farm inputs and production costs, as well as bean prices. This type of information asymmetry negatively impacted farmer profits. To enable farmers to better understand bean marketing practices, our research focused on methods of price discovery and determination that involve farmers documenting their production costs. Increased access to knowledge on accurate documentation of market bean prices, costs of land, inputs and labor, as well as yield data are not only key to planning for future seasons, but also help determine an individual breakeven price for that season, and ultimately use it as a benchmark for an asking sell price for their beans.

We undertook three iterations to aid farmers in keeping track of their production costs so that they are able to use the information generated to determine a breakeven price for their beans.

- Iteration #1: We designed a simple one page form for farmers to keep track of the most basic production costs (land preparation, seed, fertilizer, planting, weeding, harvesting, etc.) to spur interest in the decision making process.
- Iteration #2: Included all items in itineration #1 plus additional farmer profile information in a ringed bound booklet.
- Iteration #3: Included iterations #1 and #2, plus using a mobile phone App among members of farmers' networks.

Iterations #1 and #2 have been successfully implemented with promising results, while #3 is still in progress. It is designed to provide farmers with more advanced tools and a platform

through which they are able to participate in discovering and sharing not only bean price data but also pest outbreaks and other farm related challenges and opportunities.

Results from community-based field trials revealed that it is profitable for farmers to invest in fertilizer (organic, inorganic, and combinations) to increase bean yields. Having relevant and accurate data on market prices and input costs is vital for smallholder farmers to realize profitability from bean production. As Bluetooth-capable mobile phones and smartphones become increasingly prevalent, farmers will be able to more easily capture information about their soils, climatic conditions, weeds, and pests, in addition to the cost and price data. Using the basic mobile phone App that we are developing, farmers will be part of a comprehensive network that can gather and share relevant farming data and information for improved soil fertility and increased bean productivity.

Objective 3: Develop and Validate Diagnostic and Decision Support Aids

Solutions to Soil Fertility and Related Bean Production Constraints

The project research team determined solutions to soil fertility and other bean production constraints. For the research region in Uganda, these are listed here:

- Seeding for a density of 20 plants m^{-2} improves common bean yield over the standard farmer practice of planting bean for a stand density of 10 plants m^{-2}.
- Planting common bean in rows on 50-cm centers improves yield over the standard farmer practice of scatter planting through improved water use efficiency.
- Planting common bean in rows improves efficiency of weeding, allowing farmers to more completely remove weeds with far less labor utilized.
- For red soil, apply per acre: DAP 30 kg, urea 1.2 kg, 1000 kg of chicken manure
- For gravelly soil, apply per acre: DAP 30 kg, urea 1.5 kg, 1000 kg of chicken manure
- For black soil, apply per acre: DAP 15kg/acre, urea 0.75 kg, 1000 kg of chicken manure
- Utilization of 100-200 kg ha^{-1} of agricultural limestone on black soil can provide Ca and Mg for common bean, two nutrients often inadequate on the better soils in the region.
- Utilization of agricultural limestone at 1 to 2 Mt ha^{-1} for Ca and Mg and alleviation of aluminum toxicity, potash for K, and planting in 50-cm rows with 10-cm between seed of improved bean varieties, can increase yield of common bean 200% on red Oxisol (Ferralsol) soil. However, due to the high price of agricultural limestone, these systems are not currently profitable for smallholder farmers.
- Intensive input systems of common bean production can be profitable on black Mollisol (Phaeozem) soils. These intensive systems include utilization of 100 to 200 kg ha^{-1} agricultural limestone to supply Ca and Mg, potash for K, and planting in 50-cm rows with 10-cm between seed of improved bean varieties, can double yield of common bean and be economically profitable for smallholder farmers.
- Weeding common bean at two weeks after emergence, weeding a second time two to three weeks later, and removal of weeds above the bean canopy an additional two weeks later can improve bean yield. When beans are planted in rows, this weed management system requires substantially less time and labor than when beans are scatter-planted.

- Planting varieties of common bean with improved resistance to multiple diseases is essential regardless of management system used. Use of older varieties of beans results in less yield whenever and wherever stress occurs from limited or excess soil water. Older varieties have limited or no resistance to common disease-causing pathogens and should not be planted because the National Crops Resources Research Institute has released numerous varieties with improved resistance and suitable cooking times and taste.
- Nutrients/inputs (lime, P) for which the prices are currently prohibitive for the smallholder farmers can be incrementally added per season with beneficial effect.

During the past two years, two related field experiments were conducted in Gurúè, Mozambique using locally available Evate rock phosphate (ERP), limestone, common bean, and pigeon pea (*Cajanus cajan* L.). Research sites included the acidic reddish-brown soils at summit and backslope topographic positions in Mepuagíua. The goal of the first experiment was to improve soil conditions through incorporation of limestone to ameliorate low pH and aluminum toxicity. For common bean, soil pH was adjusted upward using lime produced in nearby Nampula Province at rates of 0, 1.0, 3.0, and 6.0 Mg ha^{-1}. In this study, seedling emergence and early growth of common bean was extremely poor in the absence of lime application. Maximum growth occurred with the modest application of 1.0 Mg ha^{-1} of lime. Additional studies are needed to determine the number of growing seasons that the 1.0 Mg ha^{-1} of lime will continue to support improved common bean growth. The second experiment utilized pigeon pea, which is better suited than common bean for the local soil conditions, particularly the low pH. This experiment compared two sources of phosphorus, the local ERP (40.7% P_2O_5) and triple super phosphate (TSP) (45% P_2O_5), each at four P application rates. The ERP was applied at rates of 20, 40, 80 and 160 kg P ha^{-1} while the TSP was applied at 0, 10, 20 and 40 kg P ha^{-1}. Grain yield of pigeon pea attained 1000 kg grain ha^{-1} following the application of 80 kg P ha^{-1} from ERP. By comparison, 20 kg P ha^{-1} as TSP was needed to reach the maximum yield of pigeon pea grain. This ratio suggests that Evate rock phosphate was 25% as effective as TSP on a total P basis. This research suggests that ERP can be an effective amendment for increased food grain productivity on the acid, relatively infertile upland soils of central Mozambique.

Using Improved Maps of Local Soil Types in Uganda to Guide Soil Fertility Decision Making

Objectives for this portion of the project were to (a) learn the local soil names while building trust with the farmers, (b) understand the soil-landscape relationships of those soils, (c) measure the properties of those soils, and (d) produce a set of visual aids. To be successful, the visual aids need to bridge local knowledge with the results of fieldwork and expertise in soil fertility. After the research was completed, officials provided and discussed soil reports consisting of (a) maps on aerial imagery that use local soil names, (b) block diagrams showing local landscape-soil relationships, (c) tables of suitabilities and recommended practices for each local soil, and (d) tables with fertilizer and lime recommendations for the important crops based upon locally measured soil properties.

Methods

1. *Initial Engagement of Local Farmers (6 hours at village)* - in the creation of an indigenous soil map for their village. It facilitates trust, interest, and commitment by all participants (research scientists, extension specialists, farmers, etc.). It provides the scientific community with knowledge about local needs and wants. It provides the scientific

community with the appropriate soil names that insure subsequent soil maps and recommendations resonate with the farmers. It sensitizes all participants to the local soil and field conditions. This engagement can be quite short – e.g., 1 day of meetings and collective mapping of the village.

2. *Inclusion of Soil Sampling (6 hours).* We found that simple, quick analyses such as slope steepness, color-book color, and litmus paper pH were especially valuable. Doing these has three impacts. First, it allows the scientists to have some semi-quantitative data that permit comparisons with the literature and other villages as well as providing a basis for final recommendations. Second, the soil measurements – especially pH - helps the farmers. Third, it furthers trust and interest in the project by all participants. Refinement will be needed to determine if the soil sampling impact is greatest if it occurs during the original indigenous map creation or if it is done subsequently. The key is to get the data back to the farmers quickly and to put it in terms of their soil names.
3. *Soil Mapping, Leveraging Modern Geospatial Tools (8 hours).* These maps blend catenic/hillslope principles with the original indigenous soil map. The two most important features of this map are (a) overlaying the soil map units on detailed satellite imagery so local farmers can orient themselves using local features such as roads, homesteads and such, and (b) use of local soil names. (8 hours - best if there is access to GIS).
4. *Creation of a Block Diagram* illustrating soil-landscape relationships (2 hours drawing).
5. *Summarizing the properties* of each of the local soils (as measured) as well as soil properties from comparable locations in well-organized tables (6 hours data analysis and writing).
6. *Creation of Management Guides* (4 hours writing) including tables with:
   a. *suitabilities* for various cropping systems
   b. *risks* of soil erosion, soil organic matter loss, etc.
   c. *fertilizer and lime recommendations*.
7. *Synthesis of a Final Report* with all of the above, followed by printing same (6 hours).
8. *Follow-Up Village Meeting* to present and discuss the preceding with farmers (6 hours).

- *TABLE 2* -

Table 2: shows selected soil properties for the surface horizon (0 to 15 cm) at releve sites on 16 model farms in Masaka and Rakai Districts, Uganda, 2014

- *TABLE 3* -

Table 3: shows suitability recommendations for bean production in Masaka and Rakai, Uganda

Results

A village-specific map, showing local soil variation, overlaid on satellite imagery with local landmarks combined with a block diagram helps farmers connect to the information and understand the spatial relationships of the soil landscape in which they live. That information has implications for:

- *Soil and Water Conservation* - Maps of local soil types coupled with a block diagram introducing the aspects of slope steepness and location on the landscape can be powerful tools for communicating how soil loss occurs and promoting adoption of soil and water conservation measures.
- *Fertility Management Decisions* - Maps of local soil types can be used by farmers to improve their farm level decisions on soil fertility management. Farmers are already making amendments on their soils but use of the maps helps in refining their decisions.
- *Soil Testing* - The process of soil testing for farmers is strengthened and the utility multiplied by availability of local soil maps.
- *Community Cooperation* - A village map of local soils helps in building collective action for soil conservation and fertility management.

- *FIGURE 1* –

Figure 1. Elevation data from the Shuttle Radar Topography Mission (SRTM) was re-interpolated to produce a high resolution base map of slope gradient. There was insufficient data available to create a statistical model, but fieldwork provided the basis for a mental model relating soil type with slope gradient and relative slope position. Guided by both the slope gradient map and the soil observations, a detailed map of soil units based on soil-landscape relationships was produced.

- *FIGURE 2* -

Figure 2. This map was presented to the farmers, showing the partnership between the contributing institutions. The soil map was draped over satellite imagery to help the farmers orient themselves on the map with landscape features with which they were already familiar. Many farmers were surprised by the extent of red soils in their village.

- *FIGURE 3* -

Figure 3. To assist in the communication of the soil-landscape relationship concepts, this block diagram was developed. It demonstrated the expected repeating pattern of soils in the area, known as a catena. The pattern of red and black soils illustrated why certain areas have black soils. Understanding how the black soil is lost and accumulated in different parts of the hillslope motivated the farmers to improve soil conservation practices that can improve their soil fertility.

Implementation of Soil Mapping in Masaka

- Fieldwork and spatial analysis to provide the framework for soil map development at two locations
- Grid sampling of villages to identify soil-landscape relationships
- Soil description by local farmers for producing a map legend suitable for local understanding.

Presentation and Utilization of Soil Maps by Farmers in Masaka

- Maps communicating how soil loss occurs and promoting adoption of soil and water conservation measures
- Process of soil testing for farmers strengthened and the utility multiplied by availability of local soil maps
- A village map of local soils helps in building collective action for soil conservation and fertility management
- Soil survey interpretations on nutrient management
- Farmers have refined their soil conservation practices to include water diversions consistent with the soil map and landscape
- Farmers have soil fertility-soil liming-soil maps recommendations.

Farmers' participation in diagnosing their soil-related problems using maps (which combine indigenous knowledge with scientific knowledge) and predict local soil types, as well as block diagrams, helped them understand and appreciate new dimensions of the problem as never before, changing their mind-sets and attitudes. In addition, when we first inquired about indigenous knowledge regarding soils, it was largely tacit. However, after working with farmers and extension workers we were able to improve the local soil classification system and make it hierarchical.

Farmers were then able to put in practice the soil erosion control measures that they had never previously implemented. Moreover, discussions with extension workers revealed that they were only somewhat aware of farmers' indigenous knowledge about their soils, but did not really appreciate its value. Upon learning the findings of the research project, they have now been empowered to support farmers both with and without access to soil testing services using the improved maps of local soil types in conjunction with guidelines indicating the amendments for each local soil type. Both extension workers and farmers used the maps and indicated that they were useful, and even provided suggestions for scaling up the knowledge gained in combining indigenous knowledge with scientific knowledge beyond our study site.

Way Forward

The experience of this soil mapping project in the villages of Kiwanyizi and Kaganda, Uganda demonstrated that this process builds on existing local knowledge and provides farmers with the tools to expand their thinking about the functioning of their soil landscape. Improved soil maps can be produced remotely, but are much more accurate when supported by local soil data. Further, the key to the soil map having maximum impact is the involvement of the farmers. The 8-step process implemented in this soil mapping project is scalable and has the capability of

building upon each preceding village's soil map by increasing the data support for map unit descriptions and refining soil-landscape concepts. There is a tremendous opportunity to see the results from this project replicated across the region.

Objective 4: Develop and Assess Effectiveness of Innovative Approaches for Dissemination

The lack of effective channels for delivering quality information about legume production to farmers and for gathering feedback for researchers and policymakers constitutes a serious constraint to enhancing bean production and improving soil quality in both Uganda and Mozambique. Researchers are identifying and testing innovative methods for making farmers aware of project-based recommendations to improve their soils and increase bean productivity, and ways that farmers can actively become involved in the process so that their knowledge and insights are integrated into project-based recommendations. Highlights of progress made during the 2016-2017 period include:

Development, Pre-Testing and Release of Research-Based, Farmer-Validated Bean Production Recommendations Using a Variety of Channels and Methods

Uganda:

- Use of an Innovation Platform and its associated groups and NGOs to prioritize needs, participate in research design, and conduct farmer-managed field trials to validate key recommendations for improving bean production, including: use of improved seed; specific fertilizer recommendations for black, stony and red soils using chicken manure, DAP and urea; banding fertilizer application; planting in rows and according to spacing recommendations; and conducting three weedings.
- Conducting a radio 'launch event' to bring together local officials, extension, IP representatives, input providers and farmers to demonstrate effectiveness of bean recommendations, show soil testing techniques and improved seed varieties. This consisted of a one-hour live radio program using the local station most-listened to for agricultural information in Masaka and Rakai districts plus an additional two hours of demonstrations and testimonials concerning bean production. The radio station has thousands of farmer listeners in the local area. The special program was a new initiative to create interest in bean production and 'spread the word' well beyond the IPs. Government agency officials and extension agents publically supported the research, and invited those interested to contact them for further information.
- Creation, pre-testing, and final release of a 7-minute video animation produced by Sustainable Animations Without Borders (SAWBO) that shows the four major bean recommendations in the local language (Luganda). Farmers were invited to view a draft version and made suggestions, which were then included in the final version released in October 2017 by SAWBO. It is available via the SAWBO App or website as a free download. It also is being distributed via Bluetooth by extension agents and from farmer to farmer, which requires no internet access after the initial download. Another channel is NGO partners such as CEDO, which already has shown it to more than 400 farmers to whom it provides training and seeds.

- FIGURE 4 -

Figure 4: shows video animations of recommended practices for improved bean production in Uganda developed by SAWBO

- Creation, pre-testing and final release of a printed guide including the four major bean production recommendations. It was pre-tested in the same way as the video animation before final release. The printed guide uses still images from the video animation, printed on A4 paper in color. NARL has printed 500 copies of this guide in Luganda and another 500 in English for distribution in the area.
- Comparative testing of the video animation and the printed version was conducted with 104 farmers (men and women in both Masaka and Rakai). Results show that both communicate the recommended steps effectively and are available, depending on the distribution channel.

- TABLE 4 -

Table 4: shows farmers' knowledge gained from video animation or printed version about bean production recommendations, Masaka and Rakai, Uganda in May 2017

Mozambique:

A special version of the video animation for bean production was also created for Gurúè, Mozambique (in Lomwé language). This version is similar to the Uganda version except that the fertilizer recommendations have been adjusted for soil fertility conditions in Gurúè and other bean-production areas of the country. This version has been released by SAWBO, and is available through the SAWBO app or website. It also is being passed to farmers and extension agents by Bluetooth.

- FIGURE 5 -

Figure 5: shows selected soil properties for the surface horizon (0 to 15 cm) at releve sites on 16 model farms in Masaka and Rakai Districts, Uganda, 2014

Post-Harvest Jerry Can Bean Storage

Building on project research in 2015-2016 in Gurúè District, Mozambique, which showed that a SAWBO-produced video animation was effective in teaching farmers how to store their beans safely after harvest using jerry-can storage, researchers returned to the same two sub-districts that were used for the 2015 study to assess how many of those who watched and listened to the original video (or extension training alternative) were actually using the jerry can storage technique two years later. Approximately two-thirds of a subset of farmers who participated in the video or extension training in 2015 in two different districts were re-interviewed in July 2017. Strikingly, of 100 farmers interviewed, 91.3% had tried the jerry can storage method, and 89.4% had used it more than once, indicating that adoption was pervasive. Further, they had explained and demonstrated the method to an average of 8.5 other farmers. In addition, the evaluation found that they accurately remembered an average of 7.7 of the 8 steps involved in the process.

Both the video animation and the extension demonstration/lecture methods were effective, indicating that video animation can be used to supplement the current extension agent dissemination system. The jerry can storage experiment was especially successful because farmers had experienced severe post-harvest losses due to weevils, and they needed to safely store their seed for planting. Most already had jerry cans, so there was only minimal expense associated with adoption.

Development and Testing of Bean-Guide App for Smartphones by IIAM in Mozambique

Because most extension agents now have a smartphone or a Bluetooth-capable phone, and because more farmers are now acquiring smartphones, a supplemental grant was used to create and field test an App for Android smartphones that provides IIAM research-based recommendations for bean production in Mozambique. The App is in Portuguese, since IIAM research recommendations are in that language, and since extension agents and many farmers speak Portuguese. Version 1 of the App was created, and an early pre-test was conducted among bean extension agents and some farmers in Gurúè District, the project's focal bean growing region in Mozambique. Recommendations and suggestions resulted in revisions, and an updated version was created. In early September 2017, the App was placed on the smartphones of 10 key extension agents and 4 farmers in the area, all of whom received training in how to use it and how to share the App with others using Bluetooth. In June 2018, IIAM will conduct an evaluation of the App's use to see how extension agents and farmers have used it, and whether or not they have passed it along to others. In addition to activities in Mozambique, IIAM's communication specialist Sostino Mocumbe traveled to Uganda to demonstrate the App to agricultural scientists and extension communication staff of NARO, and to 50 computer science and more than 100 agricultural students at Makerere University.

IV. Major Achievements

- Based on results from our researcher-led field experiments in Uganda, we guided the fourth and fifth seasons of community-based field trials that have enabled farmers to learn about and test improved management practices and technologies, discuss together, and decide which practices and technologies to incorporate in their bean crop production systems. The number of farmers who have adopted some or all of the project's recommendations are 800+ in Masaka and 350+ in Rakai.
- A mapping strategy was developed using a hybrid of local knowledge and GIS; used as a basis for interpretations. One block diagram and two proof of concept soil maps were produced. These communication aides are currently being used by farmers to understand where their field resides in the context of the landscape, how that affects their crop production, and the value of various types of management practices and technologies that they might consider adopting.
- Built capacity of Innovation Platform member organizations and extension workers in sustainable soil fertility management using diagnostic and decision support aids - with and without soil testing.
- Our multistakeholder bean Innovation Platform for the Greater Masaka Region has developed in membership size, diversity, enthusiasm and capability. It is now registered as a

formal cooperative organization – the Buddu Bean Farmers Primary Cooperative, comprised of 10 value chain member organizations and more than 1000 farmers. At least 25 organizations have been involved to date in supporting the IP's development. Ready markets for the beans that farmers are yet to satisfy exist including a produce trader who is also the chairperson of the IP, CEDO (buys seed), and other domestic and international buyers.

- A comparative study of innovative communication approaches for dissemination of information about legumes compared the effectiveness of four methods in increasing the knowledge that farmers have about legumes and their willingness to adopt new techniques: (1) traditional extension lecture/demonstrations; (2) video animations; (3) actual video; and (4) a printed guide (in color) using video still images and text. Results, presented at the 2017 Grain Legume Research Conference in Burkina Faso, indicate that all four of these methods were very effective. In the experiments, all four approaches had these commonalities: (1) used a participatory initial approach that identified key problems that the farmers faced; (2) were pre-tested with farmers to ensure that the messages worked; and (3) used the local language of farmers. Local languages were least effective in the *printed* version because many farmers, especially women, had difficulty reading the local language. Video animations can be especially useful when the same message is relevant and the knowledge can be applied in several countries or many language-speaking areas.
- Project researchers presented 14 papers and posters at the Feed the Future Legume Innovation Lab Grain Legume Research Conference in Burkina Faso, August 13-18, 2017.
- At Makerere University, one M.S. student graduated, one M.S. student is near completion, and one M.S. student is progressing in his research.
- At the University of Hawai`i, one M.S. student will graduate in December 2017.
- At Iowa State University, one Ph.D. student is progressing well in program of study coursework and research activities, and is on track to graduate in May 2019.
- Three journal articles have been published based on project research results, and many others are being prepared for publication in peer-reviewed journals and dissemination in regional/national practitioner and policy outlets in Africa.
- Recommended management practices and technologies are described in print materials and animated videos for dissemination to intermediate and end users have been developed and assessed in a participatory manner, and are being disseminated.
- Capacity strengthening through applied research-based training has been achieved.

V. Research Capacity Strengthening

The breadth of our team spans soil and crop sciences, sociology, economics, extension and communications, contributing significantly to conceptualizing our research objectives, methods, data collection, analysis, interpretation and action. Members from various institutions and disciplines contribute significantly to mentoring and guiding the research of graduate students:

- Naboth Bwambale, Ph.D. student in Sustainable Agriculture and Sociology at Iowa State University, is conducting research on "Inclusive Innovation Space? Motivation and participation in a multi-stakeholder bean research innovation platform in central Uganda."

- Lance Goettsch (M.S. 2016, ISU) was assisted by project researchers to publish two papers from his project thesis research on improved production systems for common bean in south-central Uganda on Phaeozem and Ferrasol soils in the *African Journal of Agricultural Research* in 2016 and 2017.
- Prossy Kyomuhendo, M.Sc. student in Soil Science at Makerere University, defended her thesis research on limiting nutrients and lime requirements for bean production in Leptosols and Luvisols, graduated in January 2017, and is preparing a paper for publication in *African Crop Science Journal*.
- Stewart Kyebogola, M.Sc. student in Soil Science at Makerere University, completed research on the effect of integrating organic with inorganic fertilizers on bean yield on three contrasting soils. He submitted his thesis for examination and is preparing a paper for publication.
- Sostino Mocumbe (M.S. 2016, ISU), is preparing a paper for publication in *Information Technologies & International Development* based on his thesis "Use of Animated Videos through Mobile Phones to Enhance Agricultural Knowledge and Adoption among Bean Farmers in Gurúè District, Mozambique."
- António José Rocha, M.S. student in Soil Science at the University of Hawaii, conducted research on alternative management practices for improving bean production in Gurúè, defended his thesis, was assisted by project researchers to publish one paper from his project thesis research on improving grain legume yields using local Evate rock phosphate in the *African Journal of Agricultural Research* in 2017.
- Jafali Matege, M.Sc. student in Extension Education at Makerere University, is conducting research on gender dimensions of bean farmers' decision making for soil fertility management.
- Abbas Isabirye, Ph.D. student in Agricultural and Rural Innovations at Makerere University, is examining the efficacy of the bean innovation platform in Masaka and Rakai.

Short-Term Training of Technical Staff

Two scientists from Uganda, Moses Tenywa and Onesmus Semalulu, were trained on all the latest strategies of soil mapping utilized in the USA in January 2017. This occurred in two phases: (a) professional discussions with USDA NRCS National Leaders about traditional nationwide mapping at the USDA NRCS National Soil Survey Center, and (b) through hands-on rigorous use and geospatial analysis of soils data at Iowa State University with Bradley Miller and Lee Burras. These activities resulted in their primary strategy being the soil-landscape paradigm. It enables efficient, detailed soil mapping. Then geospatial technologies were introduced because of their value for improving efficiency and consistency in that type of soil mapping. The skills acquired enabled the scientists to develop GIS-based local soil maps which were overlaid onto corresponding Google maps. Farmers were then able to interpret the improved map in terms of easily identifiable features within their locality. These maps were used as learning aids for farmers to appreciate the variation in soil types and characteristics along a landscape. Block diagrams were then drawn to represent in three dimensions the variation in soil types and their characteristics across the landscape. With this knowledge, management recommendations were jointly developed and discussed by researchers and farmers.

The project team benefitted from an Institutional Capacity Strengthening grant which involved close collaboration among the Institute of Agriculture Research of Mozambique, Uganda's National Agricultural Research Organisation (NARO), Makerere University, and Iowa State University. IIAM communication specialist Sostino Mocumbe and ISU professor of communication Eric Abbott traveled to Kampala to demonstrate and discuss the App with agricultural scientists and extension communication staff of NARO, and to 50 computer science and more than 100 agricultural students at Makerere University. NARO's extension communication staff are now in the process of developing one or more Apps. Abbott and Mocumbe discussed overall strategies and costs for App development and maintenance with more than 40 specialists and supervisors who have been charged with App creation. At Makerere University, Abbott and Mocumbe first made presentations to students and faculty demonstrating the IIAM App and discussing the role of Apps in future agricultural communication activities. Following each meeting, the team met with faculty members from the College of Computing and Information Sciences and then with faculty members from the College of Agricultural and Environmental Sciences to initiate a collaborative process that will be used to link computer scientists and agricultural specialists in the creation of future Apps.

VI. Human Resource and Institution Capacity Development

A. Short-Term Training

1. ***Training on development and use of soil-landscape maps***
   a. Purpose of Training – development and use of soil-landscape maps
   b. Type of Training – hands-on guided experience with GIS programs
   c. Country Benefiting – Uganda
   d. Estimated USAID funding for activity
      1) US$ for Instruction = $750
      2) US$ for Participants = $2,500
      3) US$ for Travel = $4,250
   e. Location and dates of training – Ames, Iowa Jan. 8-18, 2017
   a. Number receiving training (by gender) – 2 men
   f. Home institution(s) – Makerere University, National Agricultural Research Labs
   g. Institution providing training – Iowa State University
2. ***Training on development and use of mobile phone app***
   a. Purpose of Training – development and use of mobile phone app
   b. Type of Training – demonstration and discussion
   c. Country Benefiting – Mozambique and Uganda
   d. Estimated USAID funding for activity
      1) US$ for Instruction = $500
      2) US$ for Participants = $1,835
      3) US$ for Travel = $2,810
   e. Location and dates of training – Kampala

f. Number receiving training (by gender) – 75 men, 75 women
g. Home institution(s) – Makerere University, National Agricultural Research Labs
h. Institution providing training – Institute of Agricultural Research of Mozambique, Iowa State University

B. Degree Training

Trainee #1

1. Name: Naboth Bwambale
2. Citizenship: Uganda
3. Gender: Male
4. Host Country Institution Benefitting from Training: Makerere University
5. Training Institution: Iowa State University
6. Supervising Legume Innovation Lab PI: Robert Mazur
7. Degree Program: Ph.D.
8. Field or Discipline: Graduate Program in Sustainable Agriculture *and* Sociology
9. Research Project Title: Inclusive Innovation Space? Motivation and Participation in a Multi-Stakeholder Bean Research Innovation Platform in Central Uganda
10. Estimated USAID funding for activity if not conducted in US
    a. US$ for Instruction = n/a
    b. US$ for Participants = $5,000
    c. US$ for Travel = $2,000
11. Estimated funding from other sources for activity if not conducted in US
    a. Provider of Funds = n/a
    b. US$ for Instruction = n/a
    c. US$ for Participants = n/a
    d. US$ for Travel = n/a
12. Start Date: August 2016 (following M.S. program Jan. 2014 – Dec. 2015)
13. Projected/Actual Completion Date: May 2019
14. Is trainee a USAID Participant Trainee and registered on TraiNet? Yes
15. Training status: (active, completed, pending, discontinued or delayed): Active

Trainee #2

1. Name: Prossy Kyomuhendo
2. Citizenship: Uganda
3. Gender: Female
4. Host Country Institution Benefitting from Training: Makerere University
5. Training Institution: Makerere University
6. Supervising Legume Innovation Lab PI: Moses Tenywa
7. Degree Program for training: M.S.
8. Field or Discipline: Soil Science and Crop Production
9. Research Project Title: Limiting Nutrients and Lime Requirements for Bean Production on Three Contrasting Soils of Lake Victoria Crescent Agroecological Zone
10. Estimated USAID funding for activity if not conducted in US
    a. US$ for Instruction = n/a
    b. US$ for Participants = n/a
    c. US$ for Travel = n/a
11. Estimated funding from other sources for activity if not conducted in US
    a. Provider of Funds = n/a
    b. US$ for Instruction = n/a
    c. US$ for Participants = n/a

    d. US$ for Travel = n/a
12. Start Date: January 2014
13. Projected/Actual Completion Date: January 2017
14. Is trainee a USAID Participant Trainee and registered on TraiNet? No
15. Training status: (active, completed, pending, discontinued or delayed): Completed

Trainee #3

1. Name: Stewart Kyebogola
2. Citizenship: Uganda
3. Gender: Male
4. Host Country Institution Benefitting from Training: National Agricultural Research Laboratories
5. Training institution: Makerere University
6. Supervising Legume Innovation Lab PI: Onesimus Semalulu
7. Degree Program for training: M.S.
8. Field or Discipline: Soil Science and Crop Production
9. Research Project Title: Effect of Organic with Inorganic Fertilizers on Bean Yield in Three Contrasting Soils
10. Estimated USAID funding for activity if not conducted in US
    a. US$ for Instruction = n/a
    b. US$ for Participants = $500
    c. US$ for Travel = $1,000
11. Estimated funding from other sources for activity if not conducted in US
    a. Provider of Funds = n/a
    b. US$ for Instruction = n/a
    c. US$ for Participants = n/a
    d. US$ for Travel = n/a
12. Start Date: July 2014
13. Projected Completion Date: March 2018
14. Is trainee a USAID Participant Trainee and registered on TraiNet? No
15. Training status: (active, completed, pending, discontinued or delayed): Active

Trainee #4

1. Name: Jafali Matege
2. Citizenship: Uganda
3. Gender: Male
4. Training institution: Makerere University
5. Host Country Institution Benefitting from Training: Makerere University
6. Supervising Legume Innovation Lab PI: Richard Miiro
7. Degree Program for training: M.S.
8. Field or Discipline: Agricultural Extension Education
9. Research Project Title: Gender Dimensions of Bean Farmers' Decision Making for Improved Soil Fertility Management in Masaka and Rakai Districts, Uganda
10. Estimated USAID funding for activity if not conducted in US
    a. US$ for Instruction = n/a
    b. US$ for Participants = $500
    c. US$ for Travel = $1,000

11. Estimated funding from other sources for activity if not conducted in US
    a. Provider of Funds = n/a
    b. US$ for Instruction = n/a
    c. US$ for Participants = n/a
    d. US$ for Travel = n/a
12. Start Date: July 2014
13. Projected Completion Date: August 2018
14. Is trainee a USAID Participant Trainee and registered on TraiNet? No
15. Training status: (active, completed, pending, discontinued or delayed): Active

Trainee #5

1. Name: António José Rocha
2. Citizenship: Mozambique
3. Gender: Male
4. Host Country Institution Benefitting from Training: Institute of Agricultural Research of Mozambique (IIAM)
5. Training institution: University of Hawaii - Manoa
6. Supervising Legume Innovation Lab PI: Russell Yost
7. Degree Program: M.S.
8. Field or Discipline: Agronomy and Tropical Soils
9. Research Project Title: Improving Food Security of Highly Weathered Soils of Gùrué District, Mozambique
10. Estimated USAID funding for activity if not conducted in US
    a. US$ for Instruction = $4,000
    b. US$ for Participants = $21,000
    c. US$ for Travel = $10,000
11. Estimated funding from other sources for activity if not conducted in US
    a. Provider of Funds = n/a
    b. US$ for Instruction = n/a
    c. US$ for Participants = n/a
    d. US$ for Travel = n/a
12. Start Date: January 2015
13. Projected Completion Date: December 2017
14. Is trainee a USAID Participant Trainee and registered on TraiNet? Yes
15. Training status: (active, completed, pending, discontinued or delayed): Active

VII. Achievement of Gender Equity Goals

The project team has actively promoted participation of women farmers during research activities and trainings in Uganda and Mozambique. In our short-term training, 409 women and 465 men have benefited and one woman has benefitted from long-term training.

VIII. Implementation of Data Management Plan

Quantitative and qualitative data will be archived in the USAID archive according to protocols established by the hosting agency. Data from each study will be made available in machine-

readable format that does not rely on proprietary software. Each data file will be accompanied by a separate file listing and describing each parameter and the units of measurement used. For quantitative and qualitative data, these files will not rely on proprietary software for access. Papers, abstracts, posters, and other materials published by this project will be listed in a single file in the USAID data archive in one scientifically acceptable format that does not use proprietary software. Additionally, where copyright allows, published journal articles, abstracts and posters from scientific meetings, and other published materials will be archived in the Iowa State University Digital Repository. All materials in the ISU-DR are publically available world-wide to anyone with access to the world-wide-web without any sign-in or purchase required, and are readily downloadable without proprietary software.

IX. Scholarly Accomplishments

Theses completed, publications prepared or submitted for peer review:

- Goettsch Lance H., Andrew W. Lenssen, Russell S. Yost, Ebby S. Luvaga, Onesmus Semalulu, Moses Tenywa, Richard Miiro and Robert E. Mazur. 2017. "Improved production systems for common bean on Ferralsol soil in south-central Uganda" *African Journal of Agricultural Research* 12(23):1959-1969. DOI: 10.5897/AJAR2017.12122.
- Goettsch Lance H., Andrew W. Lenssen, Russell S. Yost, Ebby S. Luvaga, Onesmus Semalulu, Moses Tenywa, and Robert E. Mazur. 2016. "Improved production systems for common bean on Phaeozem soil in south-central Uganda" *African Journal of Agricultural Research* 11(46):4796-4809. DOI: 10.5897/AJAR2016.11760.
- Rocha António, Ricardo Maria, Unasse S. Waite, Uatema A. Cassimo, Kim Falinski and Russell Yost. 2017. "Improving grain legume yields using local Evate rock phosphate in Gùrué District, Mozambique." *African Journal of Agricultural Research* 12(22):1889-1896. DOI: 10.5897/AJAR2017.12331.
- Bello Julia, Anne Namatsi Lutomia, Eric Abbott, Robert Mazur, Sostino Mocumbe, and Barry Pittendrigh. 2017. "Making Agricultural Learning Accessible: Examining Gender in the Use of Animations via Mobile Phones" (5:74-100) in M. Mills and D. Wake (eds.) *Empowering Learners with Mobile Open-Access Learning Initiatives*. Hershey PA: IGI Global. DOI: 10.4018/978-1-5225-2122-8.ch005.
- Kyomuhendo, Prossy. 2017. "Limiting Nutrients and Lime Requirements for Bean Production on Three Contrasting Soils of Lake Victoria Crescent Agroecological Zone." M.Sc. thesis, Makerere University.
- Rocha, António José. 2017. "Improving food security of highly weathered soils of Gùrué district, Mozambique." M.Sc. thesis, University of Hawai'i at Manoa.

Scientific paper presentations and posters were prepared and presented at the Feed the Future Legume Innovation Lab Grain Legume Research Conference, Ouagadougou, Burkina Faso - 13 to 18 August 2017 (listed below in alphabetical order by lead author):

- Abbott E, Miiro R, Mazur R, Mocumbe S, Pittendrigh B, Bello-Bravo J, & J Matege. "Comparative effectiveness of video animation delivered by smartphones versus printed

images in communicating bean-growing recommended practices to farmers in Uganda and Mozambique." (paper presentation)

- Bello-Bravo J, Dannon A, Zakari O, Laouali A, Baoua I, Tamò M & B Pittendrigh. "An assessment of localized animated educational videos (LAV) versus traditional extension presentations or LAV followed by extension agent discussions among farmers in Benin and Niger." (paper presentation)
- Bwambale N & R Mazur. "Inclusive innovation space: The bean value chain innovation platform in Masaka district, central Uganda." (paper presentation)
- Luvaga E, Mazur R, Miiro R, Kyebogola S, Kabango F, Matege J, Abbott E, Semalulu O & M Tenywa. "Utilizing imperfect and inconsistent data: Economic feasibility analysis of common bean production in Uganda and Mozambique." (paper presentation)
- Maria R. "Optimizing fertilizer application in common bean (Phaseolus vulgaris L.) in Gurúè, northern Mozambique." (paper presentation)
- Mazur R, Bwambale N, Miiro R, Tenywa M, Semalulu O & E Abbott. "Development and Lessons Learned from a Bean Innovation Platform in Uganda." (paper presentation)
- Mazur R, Miiro R, Abbott E, Tenywa M, Luvaga E & O Semalulu. "Social and economic factors in farmer decision making for improved soil fertility management and bean production in Uganda." (paper presentation)
- Miller B, Burras L, Semalulu O, Kizza C, Majaliwa J, Tenywa M & R Mazur. "Strengthening the indigenous soil classification system using GIS-based mapping of the Buganda catena, Uganda." (paper presentation)
- Mocumbe S, Abbott E, Mazur R & and R Maria. "Rapid Appraisal of a mobile app linking researchers with extension officers and bean farmers in Gurúè District, Mozambique." (paper presentation)
- Rocha A, Maria R, Cassimo U, Glazer C, Crow S, Rajan S & R Yost. "Evate rock phosphate: A potential regional source of a nutrient input for acid, impoverished soils of Gurúè district, Mozambique." (poster)
- Rocha A, Maria R, Waite U, Cassimo A & R Yost. "Improving pigeon pea and common bean yields in Gurúè district, Mozambique." (poster)
- Rocha A, Sandlin M, Yost R & R Maria. "Crop management strategies in the Mepuagíua community, Gurúè district. (poster)
- Semalulu O, Kyebogola S, Tenywa M, Miiro R, Lenssen A, Yost R, Abbott E & R Mazur. "Fine-tuning research findings to famer decision making in soil fertility management: From bean fertilizer recommendations to farm level action." (poster)
- Tenywa M, Semalulu O, Miiro R, Kyebogola S, Kyomuhendo P, Kiiza C, Majaliwa J, Nampijja J, Lenssen A & R Mazur. "Developing a methodology for mapping local soil types along the Buganda Catena, Uganda." (paper presentation)

Posters presented at the 18th Annual World Bank Conference on Land and Poverty: Responsible Land Governance - Towards an Evidence-Based Approach. Mar. 20-24, 2017. Washington, D.C.

- Mazur R, Bwambale N, Abbott E & M Tenywa. "Land Rights and Farmer Decision Making for Productivity and Soil Fertility Management in Uganda and Mozambique."
- Bwambale N, Mazur R & E Abbott. "Perceived Land Tenure Security and Investment in Integrated Soil Fertility Management Practices among Smallholders in Masaka District, Central Uganda."

X. Achievement of Impact Pathway Action Plan

The research team and in-country collaborating organizations have jointly achieved all Key Project Outputs as envisioned in the Impact Pathway Action Plan for improved soil fertility management and increased bean productivity, with details contained in the preceding sections:

- Process for identifying alternative strategies and management practices and technologies
- Effective and efficient methods and media for information dissemination to intermediate and end users developed and assessed – the principal end users are farmers, extension agents, farmers' associations, development organizations, and agriculture agency staff
- Capacity building through applied research-based training conducted
- Results of research produced in various formats for an array of stakeholders – these are being shared with farmers, extension agents, farmers' associations, development organizations, agriculture ministry staff, and research scientists.

The project team's Vision of Success has been realized:

- Increased effectiveness & efficiency in determining constraints & solutions for sustainably implementing investments in bean productivity and soil fertility in Uganda & Mozambique
- Widespread use by farmers of diagnostic and decision support aids to solve problems - in Uganda and Mozambique, and available for use elsewhere.

ANNEXES

Annex 1. Tables, Figures, and Photos Cited in the Report