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

FY 2016 Annual Project Technical Progress Report
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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

Researcher-led field experiments are successfully completed in Uganda, with a third season of community-based field trials underway to enable farmers to learn about and test improved management practices and technologies, then evaluate, discuss and decide together. Two multistakeholder bean Innovation Platforms in Masaka and Rakai continue developing in membership size, diversity, enthusiasm and capability, with 10+ value chain member organizations and 400+ farmers. Field experiments in Mozambique will be completed by mid-2017. The project team (led by IIAM), is collaborating with the SEMEAR project (led by IITA) and with CLUSA for community-based field trials. Fifteen project team members presented papers/posters at the Joint 2016 PanAfrican Grain Legume and World Cowpea Conference. Three M.S. students graduated from ISU, with M.S. students at collaborating institutions on track to graduate. Research results are being prepared for publication in peer-reviewed journals and dissemination in regional/national practitioner and policy outlets in Africa. Effective and efficient methods and media (animated video, etc.) for information dissemination to intermediate and end users have been developed and assessed in a participatory manner, and are being refined. 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, and enhanced capabilities among farmers to diagnose and find 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 for researchers to 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 will enhance understanding and sustainable implementation of recommended cropping system improvements.

Following availability of field experiment results, community-based field trials and demonstration sites facilitate engagement of 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 in 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 radio, video animations delivered via smartphones, and print materials delivered through networks of partner organizations supplemented by field demonstrations and other participatory activities. These will engage farmers with diverse backgrounds, characteristics, and other key stakeholders in widespread dissemination and adoption of appropriate diagnostic and decision support aids.

III. Technical Research Progress

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

In Gurúè, smallholder farmers produce their crops on a number of small plots of approximately the same size in different locations as a way to maximize their overall yield as well as assess soil fertility status. Their method involves planting the same crop and seed in two or more locations and comparing yield. Typically, they compare summit land farmed during the rainy season and bottom land farmed, usually flood plain, during dry season.

They have actively participated in project field experiments which have served as the basis for farmer field days to stimulate widespread interest through direct observation and comparison of site-specific management practices and technologies (MPT). Farmers have clearly indicated interest in trying new MPT that can improve their crop yields. Most farmers involved in project activities are willing to buy improved seeds, plant in rows and apply fertilizer to their fields; most are already familiar with urea fertilizer. They cited constraints of access to extension services and capital, and labor if they increase the area devoted to bean production. Farmers are reluctant to make significant changes in their production system unless it results in reliable yield

increases and they have access to reliable markets so that they can increase net revenues and improve their livelihoods.

Objective 2: Develop and Refine Models about Smallholder Bean Farmers' Decision Making

Smallholder farmers - women and men - growing beans in Masaka and Rakai districts use their livelihood resources (natural, physical, human, social and financial) to increase productivity, income and natural resource integrity. Collective action and social learning are key elements. The two multistakeholder innovation platforms (IPs) established in Masaka and Rakai districts with project assistance have been very active in promoting improved bean production. Researchers from Makerere University and NARL continue to develop IP groups of farmers across the bean production value chain, including post-harvest handling, marketing, and farmer organization skills. IPs are comprised of farmers, extension, a quality bean seed producer, input sellers, microfinance, and bean buyers. Members share interests, concerns and strategies to address bean productivity and marketing constraints. IP farmer representatives pass on information to member farmers in their respective groups. Field trials and demonstrations, accompanied by hands-on trainings by resource persons have strengthened human and social capital through experimental/experiential learning and peer-to-peer learning based on field observations to increase bean productivity and improve soil fertility. For example, following community-based training and experimentation in 2015, some farmers have invested in triple bags and jerricans for storing their harvested beans. Open discussions are encouraged, joint planning and collaborations is achieved, and new networks and partnerships formed.

In season 2016A, IP members in Masaka and Rakai hosted 18 field trials to demonstrate improved management practices and technologies (MPTs) for bean production and assess the results. Having a full acre to demonstrate the various soil amendment field trials has proven very effective in attracting the interest of other farmers to raise questions and learn. Additional field trials are currently being conducted in Masaka and Rakai during the 2016B season. Competitions organized by the project highlight the most effectively managed field trial and demonstration, and the one that has attracted the most new learners to stimulate interest in improved management practices and technologies.

In 2016, 27 IP farmers received bean seeds under a contract farming arrangement for bean cultivation under CEDO (Community Enterprise Development Organization - a bean seed producing cooperative); this is a 50% increase from 2015. Due to unusually low rains and high temperatures during the first season of 2016, more farmers began contract farming. Many farmers (400+) opened accounts with IP partner MAMEDICOT (Masaka Microfinance and Development Cooperative Trust) to access loans to grow and market beans. Thus, a major benefit of the IP approach is that farmers gain access to information, quality seed, inputs and credit needed to produce beans. The partnership with CEDO has been especially important in making quality seed available to farmers in the area.

Several organizations have initiated activities with the IPs, and some have expressed interest in joining as IP members. These have included Kilimo Trust for marketing beans, African Forum for Agricultural Advisory Services (AFAAS) and Uganda Forum for Agricultural Advisory Services (UFAAS), m-Omulimisa - a mobile phone based extension service, Solar Now (SNV) - an environmental organization which plans to supply solar powered irrigation pumps to farmers to address drought challenges, and Nsanja Agro Dealer and Bukola Agro Chemicals which are

major suppliers. IP members have received training about the Kakasa (E-Verification) system designed to decrease the prevalence of counterfeit seeds and pesticides and increase agricultural yields. Supported by USAID's Feed the Future Uganda Agricultural Inputs Activity, Kakasa involves scratch code packaging labels containing a 14 or 16 digit verification number. Marketing agents explained their quantity and quality requirements. Major buyers include CEDO, Kasuja Produce Stores and Yash Commodities (from Kenya). The CIAT 'pre-cooked' bean project is also arranging a bean grain market for farmers, and will use radio to sensitize farmers about the program. The challenge is to fine tune the extension arrangements to support the farmers and the marketing strategies to efficiently reach the farmers with competitive price offers. Because all participants in the IPs have something to gain (farmers get more production, marketers get more quality beans to sell, dealers sell more inputs, CEDO contracts with farmers to get the quality seed it needs), the system is becoming self-sustaining.

In Gurúè, IIAM (on behalf of the project team), has established a collaborative relationship with the SEMEAR program (Improved Seeds for Better Agriculture, 2015-2019), led by IITA (with CIAT, ICRISAT and IIAM). SEMEAR uses a public-private partnership approach to disseminate improved legume seeds and complementary crop management practices already developed in Mozambique through the PARTI (Platform for Agriculture Research and Technology Innovation). The goals are to: (1) increase the production and supply of breeder, pre-basic, basic, and certified seeds; (2) increase adoption of improved technologies, income, and food security of 100,000+ smallholder farm households in Zambézia, Nampula, Manica and Tete provinces; and (3) enhance national policy dialog on seed and fertilizer supply. The collaboration involves coordination of field trial and demonstration activities and communication materials and activities.

Mapping indigenous soil classification with the scientific process has been initiated, and included farmers and extension worker field based classifications. Soil typologies are being documented and matched with scientific classification and commensurate management practices for bean production. The three predominant soils on the Buganda catena have differences and similarities in physical, chemical, and biological properties. However, sometimes apparently conflicting properties are cited within a given soil or horizon. This dichotomy can occur due to management induced soil changes that increased or decreased erosion or deposition or mining of soil nutrients (Table 1). Additional verification of properties will occur in 2016-2017.

♦ *Table 1. Soils and Prevalent Properties given Cropping Histories, Buganda Catena near Masaka, Uganda.*

Soil fertility improvement is a function of soil fertility status, crop nutrient requirements and available resources. Smallholder farmers and extension workers have had limited capacity to determine which nutrients to apply when and where based on indigenous soil types and existing soil maps. Under the project, two approaches have been taken to improve farmer decision making in choice of nutrient amendments: (1) refining farmers' indigenous soil classification system and (2) refining existing scientific soil maps. The farmers' indigenous soil classification system has been improved by making it hierarchical and more elaborate. Results from the field experimentation can be more precisely applied to these soils. Regarding refining of scientific soil maps, we are in advanced stages of deriving a Digital Elevation Model based on catenary sequencing of hierarchical indigenous soil types to refine the scientific soil maps. This will reduce cost, time and resources in determining appropriate soil amendments by using results from field trials and tests of soils on a few farmers' fields using soil test kits.

To promote adoption and use of recommendations, field trials/demonstrations are set up in strategic locations and farmer field days are organized in Uganda and Mozambique. Field days are important methods of sensitization and demonstration of management practices and technologies, attracting new farmers to try out project recommendations for improved bean production and soil productivity. Training materials on management practices and technologies are being developed for various stakeholders, including extension services.

Farmer's decisions to adopt or adapt new management practices and technologies is influenced by awareness, availability, access and affordability, and by their perceptions of key attributes. Significant attributes include: relative advantage of a practice (locally available materials, multifunctionality of the practice and relatively low cost of investment), ability to observe success of the practice before adoption (from fellow smallholders or through experimentation), and compatibility with existing farm operations and less complexity (less labor intensiveness and smaller package sizes). The influence of these attributes varies among farmers due to heterogeneity in household wealth, land tenure, social networks, access to input-produce markets and extension services. Extension agents and farmer-to-farmer interactions are the most trusted information sources for improved soil fertility management.

More broadly, farmers' decisions are shaped by opportunities and incentives, and moderated by the level of resource ownership and access, labor hiring practices, market sales, and social and economic networks. Our analyses concerning land revealed many significant differences related to the manner by which households acquired their fields. Households with a larger number of adult laborers are significantly more likely to have purchased land which, in turn, is associated with application of manure. Those with livestock have more fields and are more likely to use fertilizer (inorganic). Further analysis found that most households have so few livestock of any type that it's difficult or impossible for them to have a meaningful impact from application of manure only from their livestock. Availability of manure seems rather limited, so farmers default to purchasing fertilizer.

Households that hire labor are significantly more likely to use manure, fertilizer, as well as pesticides and herbicides. They have more resources for a full range of inputs to intensify their efforts and achieve higher yields. Examination of economic variables showed that those who purchase inorganic fertilizers have income from non-agricultural sources, have savings, can get credit when needed, and have borrowed in the preceding year. Those who can readily access credit also apply (generally purchased) manure, pesticides and herbicides. Households with savings also are more likely to apply manure and pesticides. Households that expressed concern over security of land ownership or use rights for bean and other crop production – approximately one-fourth in study communities in each country - were more likely to apply herbicides, reflecting a strategy to ensure a good harvest for the current season.

Objective 3: Develop and Validate Diagnostic and Decision Support Aids

Soils in nearly all common bean fields in Masaka and Rakai are nutrient deficient. Field experiments conducted by Lance Goettsch (ISU M.S. student) documented that comparatively small additions of fertilizer P, K, Ca, Mg, and Zn resulted in more than doubling common bean yield on black soil. Utilizing small amounts of N and P fertilizer with chicken manure, Stewart Kyebologa (Makerere M.S. masters student) documented similar increases in common bean yield. Although data are lacking on elemental and nutrient composition of Ugandan chicken manure, it is well documented in other countries that chicken manure typically has good

concentrations of P, K, Ca, Mg, and micronutrients when properly stored before use as a source of plant nutrients. Through field research, preliminary fertilizer recommendations were developed for beans on different soils in Masaka and Rakai as follows: 7.5 kg N ha^{-1} + 7.5 kg P ha^{-1} + 2.5 t ha^{-1} chicken manure for black soil (*Cambic Luvic Phaeozem*), 15 kg N ha^{-1} + 15 kg P ha^{-1} + 2.5 t ha^{-1} chicken manure for red soil (*Eutric Sideralic Cambisol*) and 7.5 kg N ha^{-1} + 15 kg P ha^{-1} + 2.5 t ha^{-1} chicken manure for gravelley soil (*Skeletic Lixic Mollic Umbrisol*).

As farmers begin to consider adopting some of the fertilizer recommendations from field research, it is equally important that they gain an understanding of the economics of bean production. Project research has revealed that most smallholder farmers rarely keep accurate written records of inputs and other costs associated with their farming enterprises or track costs for use of family land and labor Further, farmers are not getting the best possible market prices for their beans, yet bean price is a key factor that influences their net economic return. Comparison of data from our household survey, graduate student research, District Production Officers, and other sources linked to our research (e.g., CEDO), will guide efforts to understand price dynamics in order to educate farmers on the importance of tracking price and using that information to decide when and where to sell their beans.

Farmers have identified the three major activities associated with bean production to be *labor costs* (for land preparation, ploughing, planting, weeding, input application and spraying), *input costs* (seed, fertilizer/manure, pesticides and herbicides) and *post-harvest handling* (threshing, winnowing, drying, bagging and storage). Input costs, especially directs costs, are the easiest to ascertain whereas labor and land are only accounted for if hired or rented.

Triangulation of cost data from scientist-led field experiments, community-based field trials, and individual farmers' plots, combined with the household survey, will be used to obtain a more accurate estimate of costs. In Uganda, farmers planted up to 10 different varieties of beans yet the price received doesn't seem to vary much by variety. In Mozambique, fewer varieties are planted (approximately 4), with price/kg for only one variety slightly higher than the other varieties. The market data collected for Uganda thus far one bean type commanding a much higher price, most likely due to high demand and low supply.

A model budget has been developed summarizing costs associated with one acre of bean production. Since the majority of farmers in our study intercrop, and beans are not necessarily the highest value crop, we have accounted for the value of other crops. We are working on a similar study for Mozambique. Preliminary results suggest farmers in some cases are realizing negative returns if all costs, including land and labor, are included. In 2017, three other data sets from a Makerere graduate student, District Production Officers, and other sources linked to our research (e.g., CEDO), will be used to refine the budget model.

Following completion of researcher-managed field experiments in Uganda, community-based field trials were initiated in early 2016 in Masaka and Rakai. Treatments included: a control, organic only (chicken manure), inorganic only (DAP+Urea) and a combination of organic with inorganic fertilizer. These were applied on the black, red, and gravelly soils following the recommendation for each type of soil. Results from 2016A (first) season showed that mean bean grain yields for the three soils were not significantly different. Fertilizer application significantly increased bean yield over the control (i.e., 1136, 1818, 1681 and 1733 kg ha^{-1} for the control, organic, inorganic and combination, respectively; $p<0.05$, $LSD_{0.05}=370$). Mean grain yields for the organic, inorganic or combination were not significantly different.

Considering that 2016A was a moisture stressed season, these results show that manure application on the three soils was as good as the inorganic, or a combination. Under such conditions, farmers can apply chicken manure (which is more readily available in their locality compared to inorganic fertilizers) at the recommended rate to improve bean yields. Field trials and demonstrations during the 2016B (August to December) season are further testing these recommendations, as well as examining band vs. broadcast application of fertilizer.

Planting common beans in rows, as done by Goettsch in Masaka, impressed cooperating and other nearby farmers leading them to immediately adopt the practice in their own bean fields. These farmers have continued to plant all of their common beans in rows. Studies done by Kyebogola had all common bean plots planted in rows; cooperating and other nearby farmers also have adopted this practice. All common bean field trial plots planted in collaboration with the Bean Innovation Platforms in Masaka and Rakai have been planted in rows. Farmers noted that although planting in rows required more time than their traditional 'scatter' planting method, the time, effort, and efficacy of weeding, pest and disease monitoring and control, and harvest made their farming bean much more efficient overall. Common bean stand density typically was about 10 plants m^{-2} in traditional scatter planting systems. Research by Goettsch documented that stand densities approaching 20 plants m^{-2} also improved yield. Planting in rows and at a higher density adoption has occurred on both black and red soils, an important improvement for farmers. However, many farmers have adopted even greater seeding rates that, when combined with high quality seed, are less efficient for seed cost and resource use. The research team has noted that many farmers don't have an accurate understanding of the size of their fields, which can make calculation and application of the recommended amount of manure and fertilizer problematic. Researchers and collaborators are exploring methods to effectively address this situation.

Soil acidity is a major factor limiting bean production in the highly weathered red soils of Mepuagíua, Gurúè district. Soil tested by our project and CLUSA revealed potential soil acidity problems, with significant variation of soil pH among communities and within sites (4.4-5.7 with median 5.0) measured in 1:2.5 soil KCl ratio. Our lime incubation study, carried out at the IMAPEG chemistry lab in Gurúè with four rates of fine calcite liming material (0, 0.5, 1.0, 3, 5), generated an estimate of 3-3.5 Mg/ha of limestone needed to ameliorate the pH level for beans.

Soil pH in some paddy-rice production systems of Mepuagíua precludes good growth and yield of common bean. To assess bean response to limestone and fertilizer on paddy rice soil, we conducted an experiment with four treatments: (1) control (no limestone or fertilizer added), (2) limestone at 3 ton ha^{-1}, (3) fertilizer (20 kg N ha^{-1}, 35 kg P_2O_5 ha^{-1}, 12 kg K_2O ha^{-1}, 10 kg S ha^{-1} and 0.5 B + 2.5 Zn kg ha^{-1}) and (4) fertilizer as per (3) and limestone as per (2). Use of limestone alone significantly increased bean grain yield from 1420 kg ha^{-1} (control) to 2160 kg ha^{-1} with lime. The combination of limestone and fertilizer NPKSZnB provided mean bean yield above 2700 kg ha^{-1}, nearly double the yield of the control. Bean yield response was greater for limestone alone than for the fertilizer treatment alone.

♦ ***Figure 1*** *- Bean (Phaseolus vulgaris, L.) Yields influence by Limestone and Fertilizer*

During the 2016 rainy season in Mozambique, we conducted an experiment on soils of the upper topographic position in Mepuagíua to (1) improve soil phosphorus availability with locally available rock phosphate and nitrogen availability through the use of pigeonpea (*Cajanus cajan*, L.) before planting bean, and (2) expand the bean growing area by increasing productivity on

soils previously not considered suitable for bean. Available P levels are exceptionally low in soils of Mepuagíua. The use of pigeonpea in the season before planting bean rotation provided an opportunity to test the recently characterized Evate rock phosphate of Nampula province while also providing increased N availability for the subsequent bean crop. Triple super phosphate (TSP) was included as a comparison with the Evate rock phosphate.

Results confirm the need for phosphate inputs for pigeonpea and indicate that the phosphate needs were substantial (Figure 3), requiring approximately 20 kg P ha^{-1} as TSP to reach maximum yield. Figure 2 also indicates that the Evate rock phosphate, in this specific crop – soil combination was surprisingly effective providing a maximum yield of approximately 1000 kg pigeonpea grain ha^{-1}, with an application of 80 kg ha^{-1} of total P added as Evate rock phosphate. The maximum yield with the addition of soluble phosphate was about 1200 kg pigeonpea grain ha^{-1}. Given the low NAC (neutral ammonium citrate) solubility of the Evate rock phosphate, this effectiveness of the rock phosphate was much higher than expected. This may be due to several factors, including low soil pH and the 6-8 month pigeonpea growing cycle. Common bean will be planted on these plots in January 2017.

♦ ***Figure 2*** *- Response of Pigeonpea Grain Yield to Evate Rock Phosphate and Soluble Fertilizer Phosphate (TSP)*

There was a clear grain yield increase with increased soil pH (Figure 3). Increased soil pH resulted from previous burning of residue and the consequent liming effect of plant biomass ash (soil pH ranged from 4.6 to 6.0), so improved calcium and magnesium availability may also have improved yields. The yields of 1200 kg ha^{-1} of pigeonpea during this unusually dry year document an excellent potential for pigeonpea to provide grain and a crop for future study.

♦ ***Figure 3*** *- Increase in Pigeonpea Grain Yield where Soil pH Increased, Mepuagíua 2016*

Consistent with AGRA's suggested protocol for identifying nutrient response, an 8-treatment experiment (randomized complete block with three replications) was conducted to identify critical nutrients for varieties recently released by IIAM's breeding program (NUA 45 and VTTT). These red clay (*Ekotxokwa*) and black with high clay content *(Intxokwa*) soils proved responsive to N, P, K and S fertilizers. Mean yield for NUA 45 was 180-940 kg ha^{-1} (median 570). For VTTT, average yield was significantly lower ($p<0.05$); mean yield was 140-1120 kg ha^{-1} (median 370). The highest yield for NUA 45 had N, P, K, S and Zn added, and for VTTT it was for NPKS (no Zn). Lack of rain in the dry season significantly impacted nutrient uptake and bean yield.

Soils in Gurúè vary over space and time. Good soil management strategies for maintaining soil productivity require understanding physical, chemical and biological properties, soil clustering (classification) criteria and key farmer's indicators of soil quality. An intensive training workshop was conducted to strengthen skills of Mozambican research and extension personnel in Gurúè in spatial data collection, conducting interviews to determine farmer knowledge of soils, soil classification and management, soil sampling and soil profile description. The workshop included use of spatial tools (GPS, GIS and remote sensing). Farmers from Invacula, Hulane and Mepuagíua-Sede villages discussed soil classification. After discussion, a transect walk along catenae was taken to assess soil and other physical features and infrastructure.

Soils were sampled along a toposequence by individual farmers for focus group discussions about their properties, suitability for crops, and risk management strategies. Three soil profiles 150 cm along the toposequence were described and soil samples from different horizons were

collected for laboratory analyses and soil classification. Farmers' perceptions revealed three different observable transition models along toposequence in Mepuagia: (1) Ekotxokwa, Epupo, Intxokwa; (2) Epupo, Ehava, Intxokwa and (3) Epupo, Epupo, Intxokwa (Figure 4).

- ***Table 2*** *- Soil Types, Char. & Predom. Crops, & Approx. Planting Times along Catenae at Mepuagíua*
- ***Figure 4*** *- Dominant Soil along a Toposequence in Mepuagíua*
- ***Photo 1*** *- Focus Group Discussion about Major Soil Types in Mepuagíua*
- ***Photo 2*** *- Soil Map Developed by the Community in Mepuagíua*

Farmers in Gurúè distinguish different soil types (color, texture, stoniness) and their relationship with the toposequence (Figures 5 and 6). Their experiential knowledge enables them to match crops with soils, taking into account fertility and water demands of crops. In *Intxokwa* soil (black with relatively high clay content), major crops are rice, beans, maize, vegetables, and sugarcane. In the top slope, the dominant soil is *Ekotxokwa* (red with clay) for which major crops are sorghum, pigeonpea, cowpea, bambara nut, cassava, sweet potato, sesame, soybean and maize. Farmers share knowledge about variety, adaptability and soil suitability for a given crop.

<u>Objective 4</u>: 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 creates 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 production, and ways that farmers can actively become involved in the process so that their knowledge and insights are integrated into project-based recommendations.

One innovative method tested used animated video messages delivered by smartphones to farmers. In July 2015, Sostino Mocumbe, (ISU M.S. student) carried out a field experiment in project areas of Mozambique that evaluated the effectiveness of delivery of animated video educational messages via smartphones to small groups of farmers. The topic was post-harvest storage of beans using sealed airtight jerry cans, to address a problem of insect damage reported by many farmers during earlier interviews. Results show that farmers learned more from the animated video, or a combination of animated video and traditional extension lecture/demonstration, than they did from the traditional extension lecture/demonstration alone. Farmers viewed the animated video in small groups, and were permitted to view it multiple times. Women learned at least as much as men from viewing the video. The animated video was produced by SAWBO and was presented in the local language. Results of Mocumbe's research have been presented to IIAM in Mozambique as well as two international conferences. Animated video messages were also shown to groups of farmers in both Masaka and Rakai in Uganda, and were evaluated positively by farmers. In Mozambique, at the time of training, farmers were asked about each step of the recommended process – would they do it? Do they think it would work? Are insect pests a post-harvest problem for them? A follow-up event six months after the training again gathered those who participated to ask if they had actually begun using the jerry can storage method.

In addition to development and testing of the use of animated videos, a second innovative method has been the use of Innovation Platform (IP) groups to both provide information and actual inputs/support. Innovation Platforms developed and supported by Makerere University

and NARL in Masaka and Rakai in Uganda have been utilized extensively to assess farmer reactions to messages about bean production. More important, the IP farmers themselves, with guidance from project staff, have conducted their own farmer-managed field trials in multiple locations. Based upon these results, the IP farmers themselves have reached decisions about which new methods of bean production are appropriate and most valuable for them.

For 2017, an animated video message is being developed by SAWBO as a result of project activities focuses on research-based recommendations for growing beans. Principal recommendations include: (1) soil testing for acidic soils; (2) use of quality seed; (3) increased density of planting; (4) use of a single seed per hole if seed is quality assured or certified; (5) row planting; (6) three weedings; and (7) use of chicken manure as fertilizer. This animation will also be in the local languages of farmers in both Uganda and Mozambique.

In both Uganda and Mozambique, NGO partners have been recruited to help evaluate the effectiveness of this SAWBO animated video. In Uganda, CEDO has agreed to help the project evaluate the video by showing it through CEDO's network of farmer-trainers. This will reach thousands of farmers in the area, and the CEDO training system gathers evaluation feedback using mobile devices. In Mozambique, CLUSA has agreed to show the SAWBO animated videos to its bean producing farmers in a similar way to gather their reactions and input. Additional participatory sharing and feedback is being developed with IITA and other projects in the area.

Soil analysis indicates that acid soils are a major limiting factor for bean production in both Uganda and Mozambique. Makerere University has developed a soil testing kit that can quickly assess soil acidity and a number of other soil factors limiting bean production. Through the IPs, farmers will gain access to soil testing kits, and printed materials/guides/posters explaining how and why to test soils will be produced. Printed decision guides and other materials will be produced based upon research-based findings and farmer participation in field demonstrations. Photos from the project's archive will be used to document key decision steps.

Because research has indicated the importance of support and 'buy-ins' from the entire value chain and information network, a launch event will be scheduled in 2017 in Uganda featuring a key radio station one-hour public event, the official launch of the smartphone animated videos, and testimonials by key local leaders/vendors/marketers/farmers/extension. While the IPs in Masaka and Rakai have played a major role in strengthening the entire value chain for bean production, this public event will alert many other farmers about the possibilities for bean production and collaboration with the IP.

IV. Major Achievements

- Our researcher-led field experiments in Uganda have been successfully completed, and we are guiding the third season of community-based field trials (n=27) that enable farmers to learn about and test improved management practices and technologies, and discuss together.
- Our two multistakeholder bean Innovation Platforms in Masaka and Rakai continue to develop in membership size, diversity, enthusiasm and capability and as formal organizations, with a growing list of value chain member organizations (10+) and farmers (400+).

- Our researcher-led field experiments in Mozambique are progressing well, and will be completed by mid-2017. The project team (led by IIAM), has established a working relationship with the SEMEAR project (led by IITA) and CLUSA to collaborate in community-based field trials that will enable farmers to learn about and test improved management practices and technologies, and discuss together.
- Fifteen project team members presented papers and posters at the Joint 2016 PanAfrican Grain Legume and World Cowpea Conference, Livingstone, Zambia, 28th Feb. to 4th Mar.
- Three M.S. students have graduated from ISU, with M.S. students at other research institutions on track to complete their programs of study and research, and graduate on schedule.
- Research results are being prepared for publication in peer-reviewed journals and dissemination in regional/national practitioner and policy outlets in Africa
- Our analyses of weekly market prices and patterns, along with detailed costs of inputs, is contributing to refined development of decision support aids and training.
- Effective and efficient methods and media for information dissemination to intermediate and end users have been developed and assessed in a participatory manner, and are being refined.
- Capacity strengthening through applied research-based training has been successfully conducted.

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, M.S. student in Sustainable Agriculture and Sociology at Iowa State University, defended his thesis and graduated in December 2015. Thesis title: "Farmers' Knowledge, Perceptions, and Socioeconomic Factors Influencing Decision Making for Integrated Soil Fertility Management Practices in Masaka and Rakai Districts, Central Uganda." He is preparing on a paper for publication.
- Naboth Bwambale, Ph.D. student in Sustainable Agriculture and Sociology at Iowa State University, is planning his research. Dissertation title: "Influence of Social Structure and Power on social Learning and Adoption of Soil Fertility Management Practices."
- Lance Goettsch completed requirements and graduated with an M.S. in Crop Production & Physiology, Iowa State University, in May 2016. Thesis title: "Improved Production Systems for Common Bean in South-Central Uganda. I. Liddugavu soil II. Limyufumyufu soil."
- A manuscript was accepted for publication in *African Journal of Agricultural Research*, "Improved production systems for common bean on Phaeozem soil in south-central Uganda", authored by L.H. Goettsch, A.W. Lenssen, R.S. Yost, E.S. Luvaga, O. Semalulu, M. Tenywa, and R.E. Mazur.

- Prossy Kyomuhendo, M.Sc. student in Soil Science at Makerere U., completed research in limiting nutrients and lime requirements for bean production in Leptosols and Luvisols. She defended her thesis, is preparing a paper for publication, and will graduate in January 2017.
- Stewart Kyebogola, M.Sc. student in Soil Science at Makerere U., completed research on the effect of integrating organic with inorganic fertilizers on bean yield on three contrasting soils in Masaka district. He submitted his thesis for examination and is preparing a paper for publication.
- Sostino Mocumbe, M.S. student in Communications at ISU, completed research, defended his thesis and graduated in August 2016. Thesis title: "Use of Animated Videos through Mobile Phones to Enhance Agricultural Knowledge and Adoption among Bean Farmers in Gúruè District, Mozambique." He is preparing on a paper for publication.
- António José Rocha, M.S. student in Soil Science at U. of Hawaii, is conducting research on alternative management practices for improving bean production in Gurúè.
- Jafali Matege, M.Sc. student in Extension Education at Makerere U., is conducting research on gender dimensions of bean farmers' decision making for soil fertility management.
- Chrysostom Muyanja, B.Sc. Agriculture student at Makerere University, completed a survey on the use of foliar fertilizers.
- Abbas Isabirye, Ph.D. student in Agricultural and Rural Innovations at Makerere University, is examining the efficacy of the bean innovation platforms in Masaka and Rakai.

Short-Term Training of Technical Staff - The project team benefitted from Institutional Capacity Strengthening grants which involved close collaboration among Makerere University, Uganda's National Agricultural Research Laboratories, the University of Hawaii, Iowa State University, and the Institute of Agriculture Research of Mozambique. They focused on combining indigenous and scientific knowledge of soils and recording, analyzing and interpreting GIS associated data with biophysical, economic, and social data. They also involved training scientists, technicians, students and district staff in GIS and geo-spatial skills for distinguishing toposequencing, chronosequencing and lithosequencing of soil catena. Through this field and lab-based activities, trainees acquired practical skills and detailed understanding of soil variability along selected landscapes of the catena using characteristics identified locally by farmers and related it to modern scientific approaches (GIS, geo-statistics and the FAO World Reference systems). Trainees also developed practical skills to enhance farmer decision making for soil fertility management through combined use of indigenous and modern scientific soil classification. This activity assists in understanding and documenting the importance of geomorphology and topography of soils and their importance in farmers' classification of soils in project villages. Some relevant details are shown in Tables 1 and 2, and the discussion there. In August 2016, António Rocha (M.S. student at University of Hawaii) traveled from Mozambique to Uganda to discuss project research experiences with Ugandan project colleagues, to learn about differences in project implementation, results, and implications. He participated in interviews with innovative farmers to understand their knowledge of soils and crop management practices and outcomes. He is compare these findings with the Mozambique experience.

VI. Human Resource and Institution Capacity Development

1. Short-Term Training

A. *Innovation Platform*

ii. Purposes of Training – IP strengthening, agronomic practices, marketing

iii. Type of Training – Soil classification; Planting of beans; Disseminate soil characterization and beans research findings; formation of primary cooperatives; Results from economic analysis of triple bagging; experiences from farmers hosting the 2015B bean trials; Review IP constitution; results from the bean trials & contract farmers 2015; plan activities for 2016; Harvesting of beans; Organize bean farmers for contract farming with CEDO for 2016A season; introduce crop insurance; Introduction to biogas use; Pesticide use training; External evaluation of the beans project & the IP process; introduce the pre-cooked beans project; agro-chemical handling; Seed selection and processing, pest and disease identification; Strategic planning meeting between Yash commodities Ltd and farmer business organizations over finding market for the beans produced by farmers; Post-harvest handling and beans marketing; Harvesting of beans; Preparation of farmers for planting of beans for the 2016B season trials.

iv. Country Benefiting - Uganda

v. Location and dates of training – 37 events in Masaka and Rakai, 10/2015–09/2106

vi. Number receiving training (by gender) – 1,088 females, 863 males

vii. Home institution(s) – Makerere University and National Agric. Research Lab.

viii. Institution providing training – MAK, NARL, CEDO, MAMEDICOT, Agro-dealers, ISU, U. Illinois, MSU, UC-Davis, Kilimo Trust

B. *Training on Agro-Technology of Bean Production and Post-Harvest Handling*

i. Purpose of Training – strengthen farmer's knowledge on best agronomic practices, including soil and pest management

ii. Type of Training – Extension demonstration, farmer discussion, PowerPoint and animated video presentation

iii. Country Benefiting – Mozambique

iv. Location and dates of training – Gurúè, Mozambique

v. Number receiving training (by gender) – men 57, women 21

vi. Home institution(s) – Institute of Agricultural Research of Mozambique

vii. Institution providing training – Institute of Agricultural Research of Mozambique in partnership with Center for Interdisciplinary Studies and Development (CEID)

C. *Promotion of Soil Fertility Management: Summary of Soil Health Research Findings*

i. Purpose of Training – Create awareness about soil fertility problems and build broader partnership among agricultural practitioners

ii. Type of Training – Class presentation of major research achievements, fertilizer use computation and communication strategy for farmers

iii. Country Benefiting – Mozambique

iv. Location and dates of training – Gurúè, Mozambique
v. Number receiving training (by gender) – men 47, women 23
vi. Home institution(s) – Institute of Agricultural Research of Mozambique
vii. Institution providing training – Institute of Agricultural Research of Mozambique in partnership with Center for Interdisciplinary Studies and Development (CEID)

D. ***Training on Soil Profile Description, Interview Technique for Capturing Soil Information, Soil Sampling Strategies and Coding***

i. Purpose of Training – Building skills among collaborating partners on soil data gathering and record keeping for soils description and classification
ii. Type of Training – Class presentation and field exercise
iii. Country Benefiting – Mozambique
iv. Location and dates of training – Gurúè, Mozambique
v. Number receiving training (by gender) – men 6, women 3
vi. Home institution(s) –
vii. Institution providing training – Institute of Agricultural Research of Mozambique

2. Degree Training

Trainee #1
Name: Naboth Bwambale
Citizenship: Uganda
Gender: Male
Training Institution: Iowa State University
Supervising Legume Innovation Lab PI: Robert Mazur
Degree Program for training: Ph.D.
Program Areas or Discipline: Graduate Program in Sustainable Agriculture *and* Sociology
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Host Country Institution Benefitting from Training: Makerere University
Thesis Title/Research Area: Farmers' Perceptions, Knowledge and Socioeconomic Factors Influencing Decision Making for Integrated Soil Fertility Management
Start Date: August 2016 (following M.S. program Jan. 2014 – Dec. 2015)
Projected Completion Date: May 2019
Training status: (active, completed, pending, discontinued or delayed): Active

Trainee #2
Name: Prossy Kyomuhendo
Citizenship: Uganda
Gender: Female
Training Institution: Makerere University
Supervising Legume Innovation Lab PI: Moses Tenywa
Degree Program for training: M.S.
Program Areas or Discipline: Soil Science and Crop Production
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Host Country Institution Benefitting from Training: Makerere University

Thesis Title/Research Area: Limiting Nutrients and Lime Requirements for Bean Production
Start Date: January 2014
Projected Completion Date: January 2017
Training status: (active, completed, pending, discontinued or delayed): Active

Trainee #3
Name: Stewart Kyebogola
Citizenship: Uganda
Gender: Male
Training institution: Makerere University
Supervising Legume Innovation Lab PI: Onesimus Semalulu
Degree Program for training: M.S.
Program Areas or Discipline: Soil Science and Crop Production
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Host Country Institution Benefitting from Training: National Agricultural Research Laboratories
Thesis Title/Research Area: Effect of integrating organic with inorganic fertilizers on bean yield on three contrasting soils of Masaka district
Start Date: July 2014
Projected Completion Date: January 2017
Training status: (active, completed, pending, discontinued or delayed): Active

Trainee #4
Name: Jafali Matege
Citizenship: Uganda
Gender: Male
University to provide training: Makerere University
Supervising Legume Innovation Lab PI: Richard Miiro
Degree Program for training: M.S.
Program Areas or Discipline: Agricultural Extension Education
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Host Country Institution Benefitting from Training: Makerere University
Thesis Title/Research Area: Gender Dimensions of Bean Farmers' Decision Making for Soil Fertility Management in Masaka and Rakai Districts, Uganda
Start Date: July 2014
Projected Completion Date: August 2017
Training status: (active, completed, pending, discontinued or delayed): Active

Trainee #5
Name: António José Rocha
Citizenship: Mozambique
Gender: Male
Training institution: University of Hawaii - Manoa
Supervising Legume Innovation Lab PI: Russell Yost
Degree Program for training: M.S.
Program Areas or Discipline: Agronomy and Tropical Soils
Is trainee a USAID Participant Trainee and registered on TraiNet? Yes

Host Country Institution Benefitting from Training: Institute of Agricultural Research of Mozambique (IIAM)
Thesis Title/Research Area: Alternative Management Practices for Improving Bean Production
Start Date: January 2015
Projected Completion Date: August 2017
Training status: (active, completed, pending, discontinued or delayed): Active

Trainee #6
Name: Lance Goettsch
Citizenship: United States
Gender: Male
Training institution: Iowa State University
Supervising Legume Innovation Lab PI: Andrew Lenssen
Degree Program for training: M.S.
Program Areas or Discipline: Agronomy
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Host Country Institution to Benefit from Training: Makerere University
Thesis Title/Research Area: Improved production systems for common bean in south-central Uganda. I. Liddugavu soil II. Limyufumyufu soil.
Start Date: August 2013
Projected Completion Date: May 2016
Training status: (active, completed, pending, discontinued or delayed): Completed

Trainee #7
Name: Sostino Mocumbe
Citizenship: Mozambique
Gender: Male
Training institution: Iowa State University
Supervising Legume Innovation Lab PI: Eric Abbott
Degree Program for training: M.S.
Program Areas or Discipline: Communications
Is trainee a USAID Participant Trainee and registered on TraiNet? Yes (was)
Host Country Institution to Benefit: Institute of Agricultural Research of Mozambique (IIAM)
Thesis Title/Research Area: Socio-technical Approaches for Dissemination of Information and Decision Support Aids
Start Date: July 2014
Projected Completion Date: August 2016
Training status: (active, completed, pending, discontinued or delayed): Completed

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, 1135 women and 973 men have benefited and one woman is benefitting from long-term training.

VIII. Explanation for Changes

We significantly exceeded the planned number of short-term training participants/beneficiaries in demand-driven activities.

IX. Self-Evaluation and Lessons-Learned

Our collegial multidisciplinary multi-country team is responsive in multi-way communications and collaborates well in planning and implementing all project activities in Uganda and Mozambique. Researchers from all institutions are actively involved in mentoring all of our graduate students in their research. This generates high quality scientific data, engages diverse teams in analysis and making critical decisions, and following through. We continue to build on our diverse experiences and expertise to make wise decisions with our resources and achieve meaningful outputs and impacts. We have adapted to weather-related challenges in our field experiments, and are supporting the important partnership opportunities provided by Bean Innovation Platforms in Uganda and SEMEAR project in Mozambique to advance our work and long term positive impacts.

X. Scholarly Accomplishments

Theses completed, publications prepared or submitted for peer review:

- Bwambale, Naboth. 2015. "Farmers' Knowledge, Perceptions, and Socioeconomic Factors Influencing Decision Making for Integrated Soil Fertility Management Practices in Uganda." (M.S. thesis, Iowa State University)
- Goettsch, Lance. 2016. "Improved Production Systems for Common Bean in South-Central Uganda. I. Liddugavu soil II. Limyufumyufu soil." (M.S. thesis, Iowa State University)
- Goettsch L.H., A.W. Lenssen, R.S. Yost, E.S. Luvaga, O. Semalulu, M. Tenywa, and R.E. Mazur. "Improved production systems for common bean on Phaeozem soil in south-central Uganda" (accepted for publication in *African Journal of Agricultural Research*)
- Sostino Mocumbe. 2016. "Use of Animated Videos through Mobile Phones to Enhance Agricultural Knowledge and Adoption among Bean Farmers in Gúruè District, Mozambique." (M.S. thesis, Iowa State University)

Scientific papers and posters also prepared and presented at the Joint 2016 PanAfrican Grain Legume and World Cowpea Conference, AVANI Victoria Falls Resort and Conference Center. Livingstone, Zambia, 28th February to 4th March 2016 (in alphabetical order by lead author):

- Bulyaba R & Lenssen A. "Nutritional Composition of Pulse Legume Crops and the Impact of Leaf Removal on Yield"
- Bwambale N, Mazur R, & Abbott E. "Adoption of Integrated Soil Fertility Management in Central Uganda: Influence of perceived practice characteristics and socioeconomic factors"
- Goettsch L, Lenssen A, Mazur R, Yost R, Semalulu O, & Tenywa M. "Improved Production Systems for Common Bean in South Central Uganda"
- Kyebogola S, Semalulu O, Tenywa M, Lenssen A & Mazur R. "Effect of integrating

organic with inorganic fertilizers on bean yield on three contrasting soils"

- Kyomuhendo P, Lenssen A, Tenywa M, Semalulu O & Mazur R. "Improving rapid assessment of production constraints for common bean: results from a biweekly survey in Masaka, Uganda"
- Kyomuhendo P, Tenywa M, Semalulu O, Lenssen A, Yost R and Mazur R. "Limiting nutrients for bean production on three contrasting soils in Uganda."
- Luvaga E, Mazur R, Semalulu O, Tenywa M, & Salegua V. "Determinants of Smallholder Participation in Common Bean Markets in Uganda and Mozambique"
- Maria R, Mazur R, Americano J, Yost R, Waite U, Salegua V. "Participatory Action Research to Improve Farmer Decision Making in Integrated Soil Fertility Management in Mozambique"
- Mazur R, Miiro R, Salegua V, Abbott E & Luvaga E. "Farmer Decision Making Strategies for Improved Soil Fertility Management in Uganda and Mozambique"
- Miiro R, Tenywa M, Mazur R, Semalulu O, Matege J, Kyebogola S, Kyomuwendo P, Kabango F, Kasujja M, Katabalwa C, Mugagga K, Luswata C & Kyambadde T, Lutaya Y, Nkonge J. "Private Sector Led Agricultural Innovation Platforms: Lessons in Formation and Operationalization"
- Mocumbe S, Abbott E, Mazur R, Bello Bravo J, & Pittendrigh B. "Animated Videos on Smartphones for Training Farmers to Improve Bean Storage Practices: A Field Experiment in Gurúè, Mozambique"
- Semalulu O, Tenywa M, Yost R, Mazur R, Luswata C, Kyebogola S, Kabango F & Smith C. "Comparison of the Indigenous Soil Classification System with the FAO and Soil Taxonomy Systems"
- Tenywa M, Kyomuhendo P, Semalulu O, Zebosi B, Lenssen A, Kyebogola S, Yost R & Mazur R. "Liming Requirements for Two Contrasting Soils in the Lake Victoria Crescent"

XI. Progress in Implementing Impact Pathway Action Plan

The project team has made excellent progress in implementing the impact pathway action plan: (1) project research activities have largely determined soil and crop system improvements to recommend, and refined appropriate models of farmer decision making strategies; (2) we have been compiling materials for development of diagnostic and decision support aids using observable characteristics that enable farmers to make site-specific management decisions; and (3) we have been assessing the appropriateness of existing methods and media for information dissemination to intermediate and end users.

ANNEXES

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

Annex 2. Literature Cited