Precision Integrated Pest Management (IPM) for smallholder cowpea farmers in West Africa

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes,
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Technical Description

I. Charitable Purpose

We will develop a prototype precision Integrated Pest Management (IPM) platform for the control of major cowpea pests in West Africa that will lay the foundation for the doubling of cowpea yields by smallholder farmers.

II. Executive Summary

The primary output of this 36-month grant is a prototype 'precision Integrated Pest Management (IPM)' platform for small-holder farmers and extension personnel which focuses on a single critical pest (podborer Maruca vitrata) in Benin for the proof-of-concept phase. This platform will be designed for scaling up to include other major cowpeas pests and to achieve long-term, large-scale, and sustainable impact on cowpea productivity for smallholder farmers throughout West Africa.

There are more than the 10 million resource poor cowpea farmers in five West African countries (Benin, Burkina Faso, Ghana, Niger and Nigeria). This project will provide the initial basis for a long term sustainable effort to address insect pest attacks that currently reduce cowpea grain yields by over 50%. The long term vision of this project is a precision integrated pest management platform that leverages digital systems, and incorporates traditional and novel approaches including biological controls, local biopesticides, new cowpea varieties, and other management practices to addresses farmers' needs for safe, sustainable and cost-effective management of cowpea pests.

This proposal seeks funding to develop the initial foundation for a highly scalable precision Integrated Pest Management (IPM) platform, applying digital tools to IPM approaches. The work funded under this proposal will be focused on three main pillars:

1) Development of a prototype Expert System (ES) for modeling pest attack combined with a Farmer Interface Application (FIA) that has the potential for both receiving data and delivering pest control recommendations
2) Experimental releases of biological control agents and assessment of their effectiveness
3) Completion of ex ante economic and financial analyses to estimate the potential impact of biologicals with complementary financial analysis of community biopesticide production

The activities under these pillars will focus on the control of podborer *Maruca vitrata* in Benin. This podborer is one of the major insect pests that reduces cowpea productivity in West Africa. Benin is an ideal location for the validation of this IPM approach because it is representative of the major cowpea production agroecologies and smallholder demographics of West Africa. Benin is also home of the Biocontrol Unit of the International Institute for Tropical Agriculture (IITA), increasing the cost-effectiveness of this project.

Major Activities

The prototype ES will be assembled from new and existing models, datasets and digital platforms on pest and natural enemies, farmer economics, ecology and dynamics, population genetics, and long term climatic data relevant to the cowpea podborer in West Africa. Much of the existing data is derived from multi-year collaborative projects led by the University of Illinois at Urbana-Champaign (UIUC) and IITA. This prototype ES will allow us to identify pest problems and propose local solutions for control of podborers in Benin based upon the data available for this initial work. The FIA will be a simple farmer-friendly interface so that farmers and others (e.g. extension agents) can easily input data into the ES and retrieve pest control recommendations in local languages.

The prototype FIA will be designed for both data collection and solution delivery capability. First we will identify the necessary components of the data collection interface and the minimum dataset required for diagnosis. Then we develop (or adapt) an internet –based prototype interface to be used by farmers and others in the field for collecting data on pest occurrences. We will validate this methodology of data collection by comparing farmer collected data to those collected by extension agents and field researchers. If validated, these podborer data from Benin will be integrated into the prototype ES to generate preliminary sets of recommendations to be evaluated by researchers and extension agents.

As a key component to the ES and its ability to provide solutions, this project will conduct field evaluations in Benin of biocontrol agents through experimental releases of novel parasitoids, targeting the podborer *Maruca vitrata*, coupled with a regulatory dossier for their prospective large scale releases. These evaluations provide the critical information for the prototype ES and for developing the implementation strategy for safe and effective large scale release of biological controls. These releases will be based on the ongoing rigorous confined lab and screenhouse testing, satisfying the Food and Agriculture Organization (FAO) code of conduct for the importation and release of biocontrol agents (http://www.fao.org/docrep/x5585e/x5585e0i.htm). The FIA data collection indicated above could potentially provide a mechanism for tracking the impact of these agents, introducing a dynamic element to ES, resulting in appropriate recommendations.

Finally, this project will conduct financial and economic analyses to provide insights on the potential economic and financial sustainability of selected IPM interventions. A major effort will be the ex ante assessment of financial and economic impacts of biological controls on smallholder farmers and farming systems in Benin. In addition to surveys approaches, decision experiments with farmers will help to understanding how they might modify their investments in other forms of pest control if biological control effectively reduces pest pressure on cowpeas. A complementary analysis will look at financial aspects of cottage industry production of a podborer-specific virus by women's groups. Establishing the direct and spillover effects of biologicals as well as the financial viability of biopesticides contributes to IPM strategy development.

Vision
Our vision for cowpea pest control is deployment of locally tailored interventions built on an underlying infrastructure that is able to monitor pest pressure and respond in real time. Beyond the scope of this 36 month project, the ES will use farmer, extension, and researcher collected data from the FIA coupled with the linked datasets to produce tailored, precision IPM solutions that would feed back into the FIA to provide local recommendations to individual farmers. For the future delivery of farm level recommendations, we will explore the potential for linking with or adapting existing knowledge exchange platforms such as Open Data Kit (ODK; http://opendatakit.org/), and linking to appropriate training materials in Scientific Animations Without Borders (SAWBO; http://sawbo-illinois.org/main.htm) and elsewhere. Finally, the platform will be expanded to cover other cowpea producing countries in West Africa as well as additional pests.

III. Project Description

Cowpea, *Vigna unguiculata* Walpers (Papilionaceae), is the most important grain legume in West Africa. Recent FAO statistics indicate that total production in the region is just less than six million tons grown over an estimated area in excess of ten million hectares (ha) (FAOSTAT, 2010). The overall average grain yield is 586 kg/ha, which is just a fraction of the estimated potential yield of more than two tons/ha (Singh *et al.*, 1997)[1]. While the reasons for this yield gap are diverse (drought, poor soil fertility, arthropod pests, diseases, birds and rodents), insect pests are by far the single most important constraint to cowpea production In the Sudano-Sahelian region of West Africa. Four of them in particular, the cowpea aphid *Aphis craccivora* Koch (Homoptera, Ahoididae), the flower thrips *Megalurothrips sjostedti* Trybom (Thysanoptera, Thripidae), the podborer *Maruca vitrata* (Fabricius) (Lepidoptera, Crambidae), and the brown coreid bug *Clavigralla tomentosicollis* Stål (Heteroptera, Coreidae) can cause up to 100% grain yield loss.

Recent studies from Northern Nigeria (Kamara *et al*., 2007)[2] indicate average yield losses due to insect pests of 53% using improved varieties and 67% using local farmer varieties. Translated into monetary terms, with a conservatively estimated average production loss of 3.8 million tons of cowpea grain for the three major cowpea countries (Nigeria, Niger and Burkina Faso), the yearly economic loss is more than US$3 billion. Reducing the yield loss through the use of biological control products and agents on cowpea by 50% would provide U.S. **$1.5 billion** in additional farm household revenue just for the above three countries in one year. Throughout West Africa, women play a major role along the cowpea value chain and the prototype precision IPM platform proposed here will provide the foundations for reducing losses and potentially doubling cowpea productivity.

IPM has been designed to reduce pest damage by the application of compatible control measures, as first defined by Smith and Van den Bosch (1967)[3]. In practical terms, this involves a detailed understanding of pest systems for determining when and where they are a problem, defining ecologically and economically viable management strategies, and sustainable reduction of pest

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[1] Singh, B.B., D.R. Mohan Raj, K.E. Dashiell, and L.E.N. Jackai (eds). 1997. Advances in Cowpea Research. Copublication of IITA and Japan International Research Centre for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.
2 Kamara, A., Chikoye, D., Omoigui, L. and Dugje, I. 2007. Influence of insecticide spraying regimes and cultivar on insect pests and yield of cowpea in the dry savannas of north-eastern Nigeria. Journal of Food, Agriculture and Environment, 5(1): 154-158,
[3] Smith, R. F., & van den Bosch, R. (1967). Integrated control. In: W.W. Kilglore & R.L. Doutt (Eds.), *Pest control: biological, physical and selected chemical methods* (pp. 295-340). New York: Academic Press.

populations below an economic threshold level for increased yields. However, IPM remains a knowledge-intensive management strategy which in most cases has been difficult to understand and implement by resource-constrained and low literacy farmers in Africa. With the advent of modern digital communication, molecular, and mapping tools, we are now well-positioned to develop "Precision IPM" strategies. Precision IPM, like precision agriculture, leverages these modern tools to formulate recommendations for integrated pest control that are tailored to individual farmer's needs and resources; the recommendations must be easily understandable and implementable. The control options include insect-resistant cowpea varieties, mixed cropping systems, the judicious and safe use of synthetic pesticides, biological controls, and biopesticides.

Although all of these control options are included as part of precision IPM, recent advances in the understanding of insect biology and vulnerabilities indicate that significant yield gains from biological control could be realized within a few short years through a rapid deployment strategy. The ability to change pest dynamics with limited behavioral changes required by farmers at the farm field level makes biological control the most cost effective and sustainable approach for pest management. IITA, through its station in Benin, has played a central role in continent-wide biological control of the cassava mealybug (*Phenacoccus manihoti*) and the cassava green mite (*Mononychellus tanajoa*). The Africa-wide cassava mealybug biocontrol project resulted in an estimated $8 to $20 billion U.S. gain in cassava production. The cost to benefit ratio on this project was an estimated 1:150 to 1:600, depending on the scenario (Zeddies *et al*., 2001)[4]. While the design and impacts of other pest controls in cowpea are well documented, it is critical for the development of the precision IPM platform here to gain additional insights into the dynamics of biological controls for cowpea pests.

Changes in temperature and humidity are perceived as the two most important climatic factors that affect insect development, reproduction, survival, and movement patterns. Climate change might lead to range expansion of a native pest into new areas, shorter development time and hence more generations per season, as well as increased damage potential from invasive alien species. There are also potential negative effects of increasing temperatures on the expression of host plant resistance, including the expression of transgenes. Increased efforts to understand the impacts of climate change on pest and natural enemy dynamics, so as to develop appropriate management and adaptation strategies are underway (Estay *et al*., 2009)[5]. Thus in light of climate change, there will be an increasing need for a systems understanding and pest population monitoring for the design and delivery of sustainable pest management solutions, which is an essential component of the proposed precision IPM platform.

The team from the UIUC and IITA has been working for the past eight years with national collaborators through the Dry Grain Pulses Collaborative Research Support Program (CRSP), now Legume Innovation Lab, both funded by United States Agency for International Development (USAID). This team has developed research approaches for facilitating the deployment of biological control agents and bio-pesticides against major cowpea pests. The main result from this effort has been the collection of data on insect population dynamics and genetics, and on the ecology of pests and associated natural enemies. Whereas this effort is still continuing within the next phase of the

[4] Zeddies, J., Schaab, R.P., Neuenschwander, P. and Herren, H.R. (2001), Economics of biological control of cassava mealybug in Africa. Agricultural Economics, 24: 209–219.

[5] Estay, S.A., Lima, M., Labra, F.A. (2009) Predicting insect pest status under climate change scenarios: combining experimental data and population dynamics modelling. J Applied Entom 133(7): 491–499.

Legume Innovation Lab, this precision IPM project will develop the prototype of a system for better targeting biological control and bio-pesticide interventions at the farm level.

Leveraging this long history of collaborative research for the benefit of smallholder farmers, this grant provides the foundation for a precision IPM platform, to be initially validated in Benin for the control of the podborer based on three main pillars:

1) Prototype Expert System (ES) for modeling pest attack (as influenced by host plant ecology and climate) combined with a Farmer Interface Application (FIA) that has the potential for both receiving data and delivering pest control recommendations
2) Experimental releases of biological control agents as a new element of precision IPM for cowpeas in the region and an assessment of their effectiveness
3) Feasibility assessment that includes economic and financial analyses providing empirical evaluations of the potential for high impact and financial viability of specific strategic interventions

Benin is an ideal location for this proof-of-concept phase because it reflects the major cowpea production agroecologies and smallholder demographics of West Africa. Benin is also home of the IITA Biocontrol Unit, increasing the cost-effectiveness of this project. ***This platform introduces a pioneering approach for applying digital tools to IPM approaches in an African context, going far beyond this initial work in Benin with cowpea podborers.***

Pillar 1

We will create a prototype ES to serve as the 'brain' of our precision IPM platform, starting with previously known data on pest locations and timing, genomics data on pest movement patterns, GIS information and other information. A substantial amount of data and knowledge have been generated over the past 20 years by the investigators on this grant, including identification and quantification of many of the key parameters needed for the modeling for incorporation into the ES. Pest population models will be constructed based on life history, temperature-dependence development, host plant ecology, known and predicted movement patterns based on molecular markers, and interactions with natural enemies, among other aspects. This prototype ES will allow us to assess pest problems and propose local solutions for control of podborers in Benin based upon the data available for the prototype platform. Lessons learned over the course of the project will contribute to improvements in the ES platform design and function. We will work with the National Center for Supercomputer Applications on the UIUC campus and consult economic entomologists regarding decision making tools and code that will be needed in the server that will stand behind ES.

Linked to the ES, FIA will be created as a user-friendly interface accessible to farmers so that they and others (e.g., extension agents, private sector scouters) can input data into the ES and retrieve pest control recommendations in local languages. In the proof-of-concept phase for the FIA, a prototype for both data collection and solution delivery capability will be developed. First we will identify the necessary components of the data collection interface and the minimum dataset required for diagnosis. Then we will develop an internet-based prototype interface to be used by farmers and others in the field for collecting data on pest occurrences. The interface may also be adapted using existing systems based on open source software such as Open Data Kit.

During this proof-of-concept phase, we will explore an interface design for FIA including voice recognition (even in local languages) allowing low-literacy farmers to understand and to collect quantitative and diagnostic data on podborers in Benin. Data accuracy will be critical for providing quality pest management recommendations both in the short and long terms. Therefore, we will validate farmer collected data by comparison with those collected by extension agents and field researchers. If validated, these podborer data from Benin will be integrated into the prototype ES to generate preliminary sets of recommendations to be evaluated by researchers and extension agents.

Our longer term goal, beyond the scope of this 36 month project, is to develop a platform for producing tailored, precision IPM solutions that would provide local recommendations to individual farmers. This platform needs to be designed to adapt and evolve as new insect monitoring and communications instruments and decision tools become available. To this end, the team will be identifying and taking inventory of currently available IPM educational content and determining what new content needs to be created for use in the current project. Looking forward to the delivery of farm level recommendations, we will explore the potential for linking with or adapting existing knowledge exchange platforms such as Open Data Kit (ODK), M-Farm and Manobi. Solutions will draw upon appropriate training materials available in Scientific Animations Without Borders (SAWBO) and elsewhere.

Pillar 2

The second pillar of this project focuses on the innovative area of biological controls, a critical input into the prototype ES. The IITA team, in close collaboration with national plant protection and biological control specialists in Benin, will conduct experimental releases of hymenopteran parasitoids to determine and refine the most effective release strategies of these biocontrol agents for the control of podborer populations. Based on a spatial dispersion model, we will predict the effects of the biological controls as they disperse across space and time. Additionally, the environmental impact of the released beneficial organisms will be assessed by comparing pest populations on the target crop, cowpea, but also on the most important alternative host plants, both before and after the releases. These data will be fed into the spatial dispersion model incorporated within the prototype ES above. Also, environmental impact analyses on biocontrol agents are routinely performed by IITA and we will follow all standard sets of protocols on this issue.

In addition, the technical feasibility of cottage industry production of the podborer-specific virus MaviMNPV will be assessed in Benin, in collaboration with self-help enterprises involving women's groups. A regulatory package that contains all the necessary documentation for larger-scale release of biocontrol agents (including the virus and the parasitoids) will be created for Benin during the proof-of-concept phase, and expanded to include Niger, Nigeria, Ghana, and Burkina Faso in the long term. Standard regulatory procedures as described in the FAO code of conduct for the import and releases of biological control agents will be adhered to. Letters of authorization for importation of the target natural enemies has already been obtained from the National Plant Protection and Regulatory Services Authorities of Benin.

Pillar 3

The final pillar of this project is the economic and financial assessment of the pest control interventions, focusing on the biological control efforts. We will develop a spatial baseline estimate of the costs and benefits of cowpea pest damage and current pest management practices, including all of the application costs (time, cost of inputs and capital equipment, health costs) of current pesticide use. We propose to survey farmers in the region on their existing knowledge of cowpea pests and control, their estimated yield loss from pests over the past 3 years, and their past as well as current insect management practices. The estimates of potential benefits will be derived from the estimates of pest pressure and the effectiveness of different methods in reducing the pest pressure and damage.

We will collect information on demographics, farm and local market characteristics to estimate the value of biocontrol interventions based on the increased production and changes in management practices. We will use a choice experiment to estimate the effectiveness of the biological controls needed to induce farmers to switch from their current pest management practices (such as the use of chemical pesticides). This includes estimating a threshold for farmers to change pest control strategies. Information on farmers' social networks will be used to determine how farmers currently get information about agricultural and pest management technology. Further, we will construct a spatial network of farmers to be able to model the possible spatial dispersion of the knowledge on bio-pesticides and alternatives to current pesticide-based control methods. Having this baseline of pest pressure and economic information will allow us to better evaluate the ex-post economic impact of both biological controls and alternative approaches including the spillover effects of the technology. A complementary analysis will be conducted on the feasibility and competitiveness of local production of a podborer-specific virus by women's groups will contribute to the evaluation of options.

Leveraging legume research

This work leverages the research investments under the Consultative Group for International Agricultural Research (CGIAR) Research Program on Grain Legumes and the Feed the Future Innovation Lab for Collaborative Research on Grain Legumes (Legume Innovation Lab) and other innovation lab programs funded under USAID Feed the Future. Examples include the IPM, genomics and cowpea breeding research under the Legume Innovation Lab, research on resistance breeding under Tropical Legumes II, additional USAID research on climate resilient legumes, and IITA-led CGIAR research concerning insect smart cowpea systems, among others.

Breeding for low to moderate resistances in cowpea germplasm (landraces and breeding lines) for flower thrips and pod sucking insects is an ongoing effort in collaboration with the University of California–Riverside. Also, a transgenic cowpea expressing the Cry1Ab gene from *Bacillus thuringiensis* (*Bt*) is currently being field tested in a few West African countries against the podborer *M. vitrata*, and the preliminary results from the confined field trials (CFTs) are encouraging. *Bt*-cowpea—if, when, and where released—has the potential to play a role in IPM control programs and to increase grain yields of cowpea.

For the development of the ES and the FIA, a consultative process will be followed bringing in a multidisciplinary range of specialists from the CGIAR system, national agricultural research system (NARS) in the region, US universities, Bill and Melinda Gates Foundation (BMGF), and private technology firms to contribute to the identification of needs for the prototype ES, as well as the technological innovations for the FIA interface. The platform will need to be adaptable, given the dynamic nature of information and communication technologies (ICTs). In particular, dialogue with BMGF staff and digital design partners will be critical to this dynamic nature, as well as ensure interoperability with other initiatives of the Foundation.

Project Management and Implementation

Michigan State University (MSU) will assume administrative leadership for this grant. In this role, MSU will assume legal responsibility for contractual and financial management of the prime contract with the Bill and Melinda Gates Foundation and all subcontracts with partner institutions, such as the IITA and the UIUC. For purposes of coordination and technical management, as well as monitoring and evaluation of implementation activities, a doctoral level project manager with appropriate expertise in economics and IPM and international experience will be hired. The project manager, who will be based at MSU and supervised by Dr. Irvin Widders, will work closely with Drs. Manuele Tamò (IITA) and Barry Pittendrigh (UIUC) to provide technical leadership to the project. This person would also have responsibility for the *ex ante* economic impact analysis, in collaboration with a UIUC economist Dr. Kathy Baylis and MSU economist Dr. Cynthia Donovan.

A highly functional trilateral relationship of an MSU–UIUC–IITA team has been built over the past eight years under the Bean/Cowpea CRSP, Dry Grain Pulses CRSP and now the Legume Innovation Lab. The success of this relationship has been based on respect for distinct institutional capacities and roles, transparency in communication, a shared commitment to excellence and the achievement of development outcomes that benefit resource-poor smallholder farmers, and on collaboration with diverse partners so as to successfully achieve research and agriculture development goals. Over the course of the past eight years, the foundations for the precision IPM platform have been established. Key performance indicators include both important technical outputs and more than a dozen publications that provide the technical basis for the precision IPM platform. MSU economists have been collaborating with UIUC and IITA to assess potential impact of biological controls on farmer incomes. Moreover, both the IITA and UIUC teams have collaborated extensively with the Institut National de Recherche Agricole du Niger (INRAN) and Institut de l'Environnement et de Recherches Agricoles (INERA) of Burkina Faso for almost a decade, with IITA having worked with Institut National de Recherche Agronomique du Benin (INRAB) for more than 20 years, and with Bio-Phyto (Benin) since its inception four years ago. In addition, Dr. Tamò has been collaborating with several Nigerian universities and with the Crops Research Institute (CRI) and the Savanna Agricultural Research Institute (SARI) in Ghana for more than 15 years on cowpea IPM. This collective team currently has $2 million in Legume Innovation Lab funding for the next four years (2014–2017) to continue research on the development of IPM strategies and technologies. This research will be complementary to and not duplicative of the planned objectives and activities for the development and delivery of sustainable precision IPM strategies for cowpea in West Arica.

IV. Alignment with Foundation Strategy

This initiative is in line with the BMGF's Agricultural Development Strategy to sustainably increase productivity for millions of poor farming families in sub-Saharan Africa that depend on cowpea, a BMGF target crop, as a major source of nutrition, income and to help rebuild the fertility of degraded soils. The platform is being piloted in Benin, but designed for easy scalability with all of the BMGF West African focus countries and beyond.

The platform will ultimately reduce the costs and use of chemical pesticides with an IPM technology that benefits all farmers in this region. It lays the groundwork for a precision IPM strategy strongly aligned the principles with the Foundation Strategy for Agricultural Development in Africa and Asia:
1) Listening to farmers and addressing their needs, especially women farmers - this is central feature of our precision IPM platform and the FIA in particular.
2) Increasing farm productivity – our precision IPM platform has this goal at its core.
3) Fostering sustainable practices – our precision IPM platform enables farmers to economically control pests with minimal environmental costs and lower health risks.
4) Achieving greater impact through partnerships – this initiative leverages USAID funding to the Legume Innovation Lab with the University of Illinois and donor funding to the Grain Legumes Program of the CGIAR.

BMGF prioritizes women farmers and in this proposed project, women will be both collaborators and beneficiaries in the development and use of the precision IPM platform. For women farmers, with generally lower asset levels and less access to information and inputs, biological control is particularly valuable, providing high grain yield and potential income with little investment by the farmer. This is because the biological control agents, once released and established, will continue to provide control without farmer intervention or need to spend scarce resources on pesticides. In the farmer assessments of pest incidence and damage, both men and women will be included in the test of the FIA data collection, and our hypothesis, based on previous experience, is that the women will be more precise observers. Communication materials under this Platform will be designed with women farmers in mind, taking into account lower literacy rates.

This grant will be implemented in collaboration with NARS scientists and extension specialists in Benin. In addition, the network of NARS cowpea scientists engaged in the Legume Innovation Lab will provide technical input into the development of the Platform, and particularly in the farmer/extension pest assessment within the FIA. This broader regional participation ensures that the Platform will be relevant across the region for future scaling up.

V. Sustainability and Scalability

This proof-of-concept phase in Benin with cowpea podborers will set the stage for a highly scalable system. We anticipate a follow up grant that will enable scaling up of precision IPM interventions to include other West African BMGF-focus countries and additional key cowpea pests. Our long term vision is a precision integrated platform addressing farmers' needs for pest management that leverages existing digital knowledge systems and incorporates traditional and novel approaches including biological controls, local biopesticides, resistant varieties, and other management practices, going far beyond this initial work in Benin with cowpea podborers. This system for tailoring recommendations will empower farmers to make informed decisions on their own pest control investments.

Prior to this scaling up, at the beginning of the follow up grant, additional work will be required to refine the ES and FIA. By design, the ES is dynamic and will evolve with technological advances and incorporate additional data. Continuous assessment of the ES recommendations will be required to ensure their applicability for farmers. For the FIA, work will focus on the design of farmer-friendly interfaces for the ES recommendations, using participatory methods geared to low literate farmers. We start with a relatively low cost structure, including the use of open source software. When the FIA is fully developed with extension messages and diagnosis, business expertise will be brought in to then work with the program. Private models, as well as public and civil society service models, would be explored and contribute to the sustainability of the platform as a whole.

Looking at environmental sustainability, the precision IPM includes releases of biocontrol agents that are expected to become established in the ecosystem and keep target pest populations below damage thresholds, requiring little-to-no farmer investment in the long term. Thus, these biologicals are scale neutral and benefit a diversity of cowpea farmers, independent of farm size. In addition, for women farmers, with generally lower asset levels and less access to information and inputs, biological control is particularly valuable, providing high grain yield and potential income. During this proof-of-concept grant, the ex ante economic and financial analyses will identify the costs and benefits that influence whether a technology will be adopted and sustainable, along with the spillovers that can either undermine or contribute to that sustainability.

Support for the follow up project, necessary to move the platform from prototype to full scale, could be from larger legume initiatives such as the Tropical Legumes Initiative, ensuring the integration of this platform into the broader investments under the CGIAR Research Program on Grain Legumes by USAID, BMGF, and other donors. Ultimately, this will provide the intellectual and technological basis for application of precision IPM in other cropping systems.