DGFSC

Digital and Geospatial Farming Systems Consortium

Project title: Digital Geospatial Tools Consortium – building a new era of Predictive Agricultural Innovation to improve farming systems and the livelihood of smallholder farmers

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Executive summary

The new restructured consortium will focus on developing develop foundational information to support the development of digital support tools that can guide decision-makers and producers to take action towards improving food security, human nutrition, and risk management and resiliency of smallholder farming systems today and in the future. Ultimately, this project will provide new information that enhances long-term strategic and short-term adaptive management of smallholder farming systems and to increase capacity for Extension practitioners and government officials to utilize the outcomes obtained on this project to improve resiliency at the farming system scale. This consortium will integrate system models to quantify the impacts of innovations, building a new era on Predictive Agriculture, across five domains (productivity, economics, environment, social, and human condition) of the Sustainable Intensification Assessment Framework (SIAF). We strongly believe that the development of new data products can positively impact smallholders and help them to better adapt to emerging environmental and market pressures.

The consortium will target the main innovations and technologies identified in Phase 1 of the SIIL project, considering the most relevant farming systems in West Africa with the dual-purpose millet crop and in Asia with the rice-based systems as the main focus of the team efforts. The emphasis will be on leveraging cutting-edge digital tools and datasets (e.g., remote sensing, crop modeling, livestock modeling) and resilience-relevant innovative technologies to support decision making by farmers, researchers, and policymakers. The consortium members will cover the following topics: data-driven agricultural development, quantify and measure resiliency, sustainability, and productivity of agricultural systems, and integration of system models (both crop and livestock) to quantify impacts of innovations across five domains (productivity, economics, environment, social, and human condition) of the Sustainable Intensification Assessment Framework (SIAF). The main target audience will be focused on Extension practitioners, and stakeholders on assisting smallholder farmers with the aim of improving their livelihood.

In addition, the consortium will focus on strengthening collaboration with private industry partners. The main founding members from an industry standpoint will be Corteva Agriscience, Microsoft, Descartes Labs, and aWhere. These partners will provide in-kind data and cash support to translate our scientific innovations to make impact on youth by (1) supporting a Sustainable Intensification Symposia series (e.g., Corteva) in the relevant resilience zones and the Feed the Future Zones of Influence, (2) providing in-kind support as time commitment and for executing a Data Science Symposium (e.g., Microsoft), (3) providing access to their analytics platform for a data science professional (e.g., Descartes Labs), and (4) collaborating on carrying out data analysis workshops and providing access to weather data to the consortium partners (e.g., aWhere). This consortium will function as an integrated team where all the US universities participating in the team will collaborate with other consortiums such as SOILS, Policy and Mechanization with the goal of improving smallholder farming systems through the application of geospatial tools to support resilient farming systems. Lastly, the consortium will seek opportunities for training undergraduate and graduate students in the targeted countries in the main skillset related to data science. This can accomplish via establishing more integration between this consortium and the primary projects already in place on the targeted countries participating in the SIIL.

The long-term goal of the project team is to **improve the resilience of smallholder livelihoods through the application of digital geospatial tools for managing and enhancing productivity, economics, environment, and social aspects of human wellbeing.**

Technical Narrative Description

Team members

Ignacio Ciampitti
Kansas State University

Project Leader: Dr. Ciampitti will served as a director for the Consortium, in charge of the overall management and coordination. In addition, he will be leading the crop modeling section, and assist on the integration of data products with remote sensing and examine innovations and integration of data products (Objectives 1, 2, 4, and 5). For the overall project, implementation of the work plan will be achieved in close collaboration with the all project co-leads. Primary contact for administrative matters and reporting to the funding agency.

Amirpouyan Nejadhashemi
Michigan State University

Project Co-Principle Investigator: Dr. Nejadhashemi will be in charge of the task of modeling animal production considering environmental sustainability and stressors and lead the integration of crop and animal modeling framework (Objective 1). In addition, he will collaborate and assist on examine innovations and integration of data products across project outputs (Objectives 4 and 5).

Paul West, James S. Gerber, and Zhenong Jin
University of Minnesota

Project Co-Principle Investigators: Drs. West, Gerber, and Jin will provide expertise and lead the development of a set of remote sensing products (high resolution crop specific and intercropped map, maps of climate-risks and suitability) to assess current trends, and potential future conditions in target countries (Objective 2). In addition, they will all collaborate and assist on examine innovations and integration of data products across project outputs (Objectives 4 and 5).

Molly Brown and Kathryn Grace
University of Maryland and University of Minnesota

Project Co-Principle Investigators: Drs. Brown and Grace will be in charge of modeling the relationship between health outcomes (child malnutrition) and agricultural intensification using remotely sensed, cropped area landscape data in combination with publicly available household survey data (Objective 3). In addition, they will collaborate and assist in the development on remote sensing products (Objective 2), examine innovations and integration of data products across project outputs (Objectives 4 and 5).

Jason Neff
University of Colorado Boulder

Project Co-Principle Investigator: Dr. Neff will be in charge of developing maps for land capability classification and examining the potential implications of agricultural innovations for local level social and biophysical risk and resilience (Objectives 1 and 4). In addition, Jason and his team will collaborate and assist in the integration of data products across project outputs (Objective 5).

Introduction

Overall goal, specific objectives, and expected outcomes

The overall goal of this consortium is to develop foundational data products to support the development of digital support tools that can guide decision-makers and producers to take action towards improving food security, human nutrition, risk management and resiliency of smallholder farming systems today and in the future. Ultimately, this project will provide new information that enhances long-term strategic and short-term adaptive management of smallholder farming systems and to increase capacity for Extension practitioners and government officials to utilize the outcomes of this project to improve resiliency at the farming system scale.

The new and restructured Geospatial Farming Systems Consortium will focus on providing high-resolution soil, climate, crop, livestock, nutrition, and socioeconomic data. These datasets can help in quantifying past conditions and inform future changes in the adoption of different management practices to improve the overall resiliency and sustainability of agricultural systems in the targeted regions (e.g., West Africa and Asia) and in the Feed the Future Zones of Influence.

The consortium will target the main innovations and technologies identified in Phase 1 of the SIIL project, considering the most relevant farming systems in West Africa with the dual-purpose millet crop and in Asia with the rice-based systems and introduction of short duration crops as the main focus of the team efforts. The main goal is to move from the description of the Genotype × Environment × Management (G×E×M) interactions to level of prediction of (G×M) ×E, Predictive Agriculture, improving our ability to react, adapt, and manage complexities of farming systems (Messina et al., 2020[1]). The utilization of this concept will enhance our capacity to allocate crops/livestock production systems considering all five domains (productivity, economics, environment, social, and human condition) of the Sustainable Intensification Assessment Framework (SIAF) to minimize the risk of farmers when making decisions. In addition, the consortium will focus on several sustainable intensification sub-types (Pretty et al., 2018) from conservation agriculture in Cambodia, integrated crop and biodiversity in Africa, and crop intensification and diversification in Bangladesh.

We plan to achieve the overall objective by pursuing the following integrated research aims:

1. Refine a set of modeling tools to examine mixed crop-livestock farming systems' suitability and land capability for agriculture productions in targeted regions.

2. Develop a set of remote sensing products that can be used to assess current conditions, trends, and potential future conditions in target countries.

3. Connecting agricultural productive capacity and child malnutrition using livestock ownership, field size, use of improved seeds and fertilizer, and climate variability.

4. Examine the potential implications of agricultural innovations on social and biophysical risk and resilience at local test sites in targeted regions.

5. Develop geospatial products that integrate across project outputs to map biophysical and social risk analysis for the targeted regions and the potential of specific agricultural innovations to increase resilience in the face of climate change.

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[1] Messina, C.D., M. Cooper, M. Reynolds, and G.L. Hammer. 2020. Crop science: A foundation for advancing predictive agriculture. Crop Sci

The consortium will focus on the development of resilience-relevant geospatial data products to create new opportunities to support the development of existing or new digital support tools and improve the livelihood of smallholder farmers and other relevant stakeholders (Figure 1).

Specifically, the consortium will focus on

1. Producing new datasets that can be used in the development of digital tools to improve smallholders' decisions considering risk management and resiliency of farming systems.
2. Building regional models and fine-tune the results with local-data to guide the development of in-season crop forecasting models to inform management decisions.
3. Providing decision resilience-relevant support tools to empower stakeholders (e.g., Extension practitioners) to better understand the benefits and pitfalls of using new management strategies and technologies for improving food and nutritional security
4. Creating new educational opportunities to train the next generation of farming systems managers and researchers (capacity building).

The team will be integrated and work together in each of the challenging regions (West Africa and Asia) – all objectives - following the proposed framework (Figure 1).

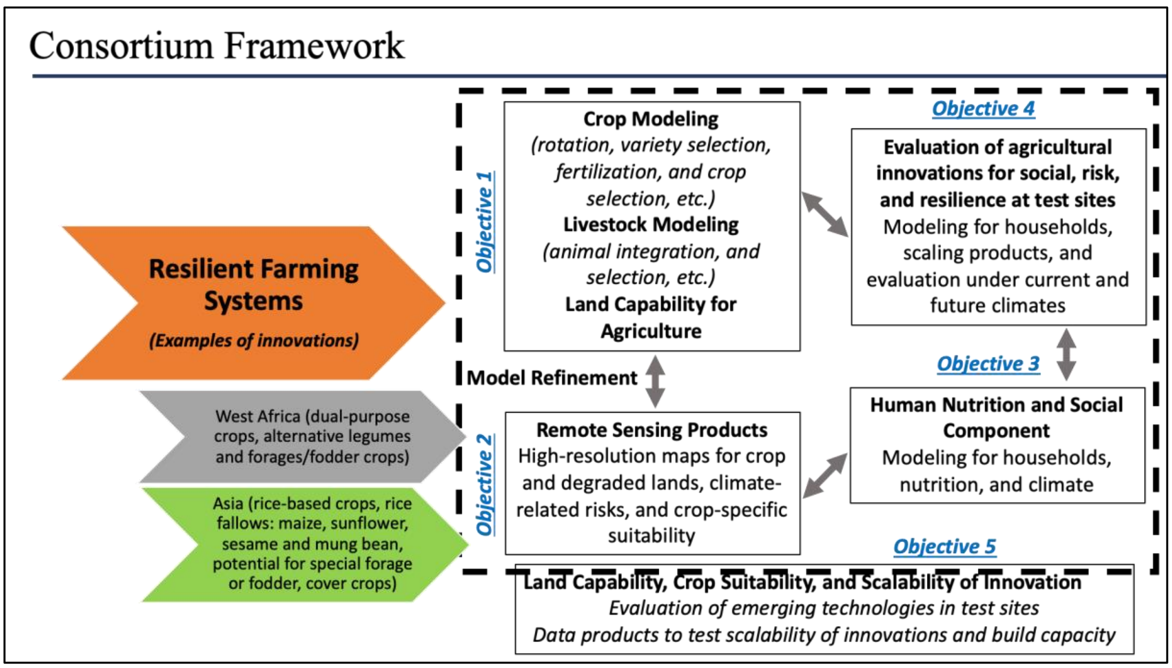

Figure 1. A conceptual framework for data collection and processing to build regional and local models and finish with data products to improve environmental resilience for smallholders.

Geographical focus

The geographic focus of the proposed project will be West Africa and Asia regions with the goal of targeting farming systems. We will primarily focus on 1) the performance of millet as dual purpose in Senegal and Niger (Agro-Pastoral and Cereal-Root Crop Mixed Farming Systems for West Africa); 2) the introduction of short duration crops such as maize and sunflower, fodder, or cover crops in fallow in rice-based farming systems in Bangladesh (Asia); and 3) focus more on conservation agriculture such as cover crops and soil health in Cambodia (Asia).

Research needs, opportunities for scaling technologies, and pathway entry points

This consortium will be focused on assisting the implementation of technologies in African (livestock and cereal-based) and Asian (livestock and rice-based) farming systems to support practitioners and the farming community to enhance resilience outcomes. Currently, there is observation that a large amount of geospatial data is difficult to access, poorly suited to on-the-ground needs, and often of poor or unknown accuracy. Building local capacity in this area will be critical for the success of future initiatives in this arena. Emerging technologies will follow the principles for digital development (https://digitalprinciples.org/principles/) that should: be data-driven, design with the user in mind, help with understanding the ecosystem, build for sustainability, design for scale, reuse, address privacy and security, and be collaborative.

Relevance of technologies for the region(s)

As sustainable farming systems aim to increase crop diversity, it is even more essential to match the right farming system with the suitable environments (Garrity et al., 2012[2]). These objectives hold meaning for agricultural systems worldwide, regardless of geography or level of prosperity, and this broad relevance also aligns well with the Sustainable Development Goals established by the United Nations General Assembly in 2015 (United Nations Sustainable Development Programme, 2016). We will integrate livestock and crop models, remote sensing data, with current and future climate scenarios and nutrition outcomes of crop diversification and improved productivity.

Rationale and significance

A sustainable farming system considers crop management strategies that address the goals of protecting the environment while maintaining overall productivity. Sustainable farming systems are vital components for attaining the overarching challenge of global food security, which was defined at the 1996 World Food Summit to exist "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (FAO, 1996). Improving our knowledge and understanding of the ability of the global food system to adapt and respond to shocks and trends in agricultural productivity, herein termed as resilience, is critical for long-term sustainability. The biophysical capacity to ensure the production of the adequate food supply is a crucial step towards the goal of alleviating poverty and achieving better health and nutrition.
The leading pillars for this project are the integration of geospatial technologies for guiding resilient farming systems to make data-driven decisions, building resiliency, and to improve our understanding of the direct impacts of management and climate on smallholders providing a real possibility to react and adapt.

Mission: This consortium will focus on developing resilience-relevant data. This datasets can be used in digital platforms to inform USAID and local policymakers to better strategies in helping vulnerable populations by building resilience to environmental stressors such as climate change. Ultimately, these activities enhance current efforts towards achieving the Sustainable Development Goal target of ending malnutrition by 2030. Working collaboratively with

[2] Garrity, D., Dixon, J. & Boffa, J. 2012. Understanding African Farming Systems. Australian Centre for International Agricultural Research 55p.
United Nations Sustainable Development Programme. 2016. Sustainable Development Goals. http://www.undp.org/content/undp/en/home/sustainable-development-goals.html Accessed 14 January 2020.
FAO. 1996. Food, Agriculture and Food Security: Developments since the World Food Conference and Prospects, Technical Background Document No 1 for the World Food Summit, Rome.

institutions across the US and the globe, this consortium will support the mission of the SIIL lab by providing a geospatial integration framework of the five domains of the SIAF.

Vision: This consortium will build upon the five domains of the sustainable intensification process, developing an interdisciplinary and solution-oriented geospatial framework, integrating remote sensing, farming systems modeling, and geospatial data layers to provide innovative data products to take actions towards more resilient farming systems, benefiting families and communities.

The long-term goal of the project team is to **improve the resilience of smallholder livelihoods systems through the application of digital geospatial datasets/tools for managing productivity, economics, environment, social, and improving the human condition.**

Approach

To achieve the goals of this project, we will develop and integrate a series of models and remote sensing data products for the agro-pastoral and cereal-root crop mixed farming systems in Senegal and rice-based and fodder-crop farming systems in Cambodia and Bangladesh and deliver these to the SIIL Geospatial Consortium actors in the field.

The consortium project will utilize high-resolution geospatial resources that can be used across a range of tools and by the consortium partners. We will work with the consortium partners to explore a simplified interface for access to data generated from consortium activities. Each partner can access the information via GPS location via API, via the raw grids, customized grids for the users' own tools, or in an online portal where the data can be viewed and interacted with such as an ESRI webapp. As the consortium project progresses, we would test this initial data visualization activity with consortium partners in target countries, gather feedback, and refine the approach for subsequent work. This type of iterative development will let us deploy our data at low cost and then build access points with user input throughout this project.

We will first describe the models and the deliverables, and show how data and information will flow through the system, and provide outputs to support SIIL projects in each country.

A summary of the capacity building plan (short- and long-term) is provided in the below table:

Training topic	**Methods**			**Target groups**		
	Hands-on	Webinar	Mentoring	Ext	USAID	SMH
Short-term						
Modeling workshop	X	X	X	X	X	X
Utilization of satellite data	X	X	X	X	X	X
Use of LandPKS		X		X	X	X
Utilization of support decision tools		X		X	X	X
Human nutrition and social data		X		X	X	X
Long-term						
Mentoring and training of young professionals			X			

- Ext = Extension practitioners (GO, NGO, BG), and in-country universities - USAID = SIIL consortia, government officials, USAID stakeholders, and agency partners - SMH = Farming community, youth, women and community leaders

Industry partners

The four primary industry partners supporting our efforts will be Corteva Agriscience, Microsoft, Descartes Labs, and aWhere. Corteva Agriscience will support our efforts to translate our scientific innovations via supporting the Sustainable Intensification Symposia series in targeted countries, and providing in-kind support to our research partners. Microsoft education will provide in-kind support as time commitment for personal working in the Predictive Ag Research team, support for executing Symposia series, and collaborate on carrying out data science workshops. Descartes

Labs will provide access to their data science platform, support for utilizing and obtaining analytics facilitating the use of satellite data from a variety of sensors, quickly scaling models, and visualizing results. aWhere will partner providing access to near real time history and forecast weather data, virtual training to students, collaborate in workshops, and providing expertise (Dr. Bergvison) in scaling up technologies partnering with industry and policy makers (Africa/Asia).

Anticipated Outputs and Expected Impacts

At the end of the project, we expect to provide a set of diverse data products (outputs) to enhance resilience outcomes for improving food security, human nutrition, and livelihoods of smallholder farmers (tasks, outputs, and indicators for each objective; Table 1).

Table 1: Target output and indicators of the projects

OBJECTIVES	TASKS	OUTPUTS	INDICATORS
1.0. Refine a set of modeling tools to examine mixed crop-livestock farming systems' suitability and land capability for agriculture productions in targeted regions	1.1 Crop modeling for identifying suitable farming systems and examine risk and resiliency	Scenarios of best production systems for reducing risk and improving resiliency offer as outputs for the regions of study	At least one publications and one extension will be produced for each of the targeted country
	1.2 Modeling animal production considering environmental sustainability and external stressors	Assess animal nutritional requirements and outputs for the regions of study	At least one extension bulletin will be produced for each of the targeted country
	1.3 Integrated crop and animal modeling framework	An integrated framework for crop and animal modeling	Framework can be used at local level to examine different farming scenarios
	1.4 Land capability	Spatial maps of land capability classification for target countries	Tested/validated maps submitted for online distribution in vector and raster format. One peer reviewed publication.
2.0. Develop a set of remote sensing products that can be used to assess current conditions, trends, and potential future conditions in target countries	2.1 Develop high resolution maps of degraded lands.	Mapped indicators of degraded lands.	Incorporate data and feedback from in-country partners, Share interim and final products with in-country partners, Publish the data sets and related methods/analysis in peer-reviewed journals. and Provide access and archive the data through USAID's data hub
	2.2 Develop maps of climate-related risks to agricultural production.	Climate-related risk maps (both recent changes and IPCC projections)	
	2.3 Develop crop-specific suitability maps across the farming systems in the three target countries.	Crop-specific suitability maps (current potential and future climate conditions).	
3.0. Connecting agricultural productive capacity and child malnutrition using livestock ownership, field size, use of improved seeds and fertilizer, and climate variability	3.1 Obtain and connect relevant datasets on socio-environmental factors from DHS and LSMS regarding human health outcomes and household characteristics to SIIL Data	Provide linked datasets to GeoCenter and in country partners	At least one report per year on climate anomalies in each country and potential food security linkages
	3.2 Conduct modeling to estimate the relationship between households, nutrition and climatic conditions	Training modules on climate-nutrition relationships	At least 3 feature articles explaining connections between climate, agriculture and food security
	3.3 Provide interpreted modeling outcomes that allow for translation of climate shocks to nutrition outcomes depending on the context	Documentation of relationship between climate and nutrition outcomes by country	At least 3 agencies in each government informed about climate-nutrition relationships and relevant interventions
4.0 Examine the potential implications of agricultural innovations for local level social and biophysical risk and resilience at specific test sites in Cambodia, Bangladesh and Senegal	4.1 Evaluation of current and future climates	Spatial maps and as associated documentation	Tested/validated maps submitted for online distribution in vector and raster format.
	4.2 Establish target locations within each country for detailed review of products and develop integrated biophysical and social drought risk assessments from geospatial products.	Integration risk assessment products built from product data products evaluated by country teams.	At least two peer reviewed publications implementing the risk assessment product and completed trainings for SIL partners.
	4.3 Establish target locations within each country in collaboration with SIIL regional partner organizations in order to evaluate geospatial products in target locations.	In-person or virtual workshops on site selection for each target country. Documentation of selection criteria	Methodological report for evaluation strategy for each target country.
	4.4 Scaling up of products	Presentations at regional meetings and/or webinars with targeted follow up in possible expansion countries or via private partners	Presentation in at least 6 meetings and participation in follow up meetings
5.0. Develop geospatial products that integrate across project outputs to map biophysical and social risk for the two target countries and the potential of specific agricultural innovations to increase resilience in the face of climate change	5.1 Technology transformations	New emerging technologies are evaluated, and feedback received by partners, refining the data products	Effective evaluation and feedback methods established in collaboration with partners
	5.2 Assemble existing base data for in-country partners	Data products delivered to partners and via DATAVERSE (open access)	More than two data products per objective (1-4) are delivered to stakeholders
	5.3 Scalability of the innovations	Data products are shared with other partners and Consortia to extend impact	At least 5 data products from all our team efforts are used by other consortia
	5.4 Capacity building	Knowledge sharing sessions either webinar, workshops, meetings	At least more than 10 sessions will be executed during the entire duration of the project

Microsoft

CORTEVA agriscience

Descartes Labs

aWhere