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

Feed the Future Innovation Lab for Legume Systems Research

Final Project Report

Evaluating spatial resolution of remote sensing imagery to monitor crop growth in legume-based cropping systems: how much information is lost due to coarse spatial resolution?

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Executive Summary

This final report summarizes key activities and accomplishments of the quick project in 2019-2020. This project is funded by the U.S. Agency for International Development (USAID) under the terms of Cooperative Agreement No. 7200AA18LE00003. The objectives were to compare the impact of satellite images and their spatial resolutions on monitoring plant growth and productivity at selected small holder farmer in Ghana and Honduras.

Highlights of accomplishments during the course of the project include:

- Processed and analyzed more than 800 km^2 satellite images at three different scales (30m, 20m and 3m) for legume crops (pigeonpea included) in Ghana at both field and regional scales, and for bean growing areas in Honduras
- Quantified the impact of spectral and resolutions of satellite images on monitoring both legume crops in smallholder fields (in Ghana and Honduras) and staple-food crops in large commercial fields (in US)

Key activities toward achieving the project objective include:

- Determining satellite platforms with different spatial resolutions that were freely accessible for research purposes, and vegetation indices that would be used for monitoring plant status and growth
- Identifying of legume-based systems in Ghana, and critical legume cultivation areas in Honduras
- Processing satellite images and analyzing of the impact of spatial resolution on monitoring legume growth in the study areas in Ghana and Honduras
- Comparing the impact of spatial resolution on crop growth monitoring between smallholder fields (in Ghana and Honduras) versus large commercial fields (in US)

During this project, we developed partnership with the Council for Scientific and Industrial Research-Crops Research Institution (CSIR-CRI) in Ghana. Outcomes from this project has been presented at agricultural-technology panel discussions, research conference, and peer-reviewed journal articles. We expect to publish more peer-reviewed articles stemmed from this project. In spite of challenges in collecting ground-truthing field data, we were able to collaborate with the CSIR-CRI in Ghana and leverage publicly available data to identify legume-based systems in Ghana and Honduras. Satellite images and products, particularly high-resolution images, provide continuous legume growth and status information.

Project Partners

During the course of this project, we developed partnership with the Council for Scientific and Industrial Research-Crops Research Institution (CSIR-CRI) in Ghana. With this partnership, we collaborated on a project identifying the benefits of pigeonpea to yam yield and soil organic carbon.

Project Goals and Objectives

The overarching goal of this quick project was to assess the potentials of using satellite images to evaluate of the role of legumes in improving food security in smallholder fields. We aimed at identifying the optimal spatial resolution able to capture plant growth variation and productivity. The objectives were to compare the impact of satellite images and their spatial resolutions on monitoring plant growth and productivity at selected small holder farmer in Ghana and Honduras.

Overview of Activities

Our activities focused on four areas:

1. Determining satellite platforms with different spatial resolutions that were freely accessible for research purposes, and vegetation indices that would be used for monitoring plant status and growth
2. Identifying of legume-based systems in Ghana, and critical legume cultivation areas in Honduras
3. Processing satellite images and analyzing of the impact of spatial resolution on monitoring legume growth in the study areas in Ghana and Honduras.
4. Comparing the impact of spatial resolution on crop growth monitoring between smallholder fields (in Ghana and Honduras) versus large commercial fields (in US)

We listed specific activities for each of the four focal areas.

Activity 1. Determining satellite platforms with different spatial resolutions that were freely accessible for research purposes, and vegetation indices that would be used for monitoring plant status and growth

We obtained an educational license with the PlantLab to access their 3m-resolution PlantScope images. Including the publicly available Landsat and Sentinel2 images, we were able to compare the impact of spatial resolution on legume monitoring across three spatial details: 30m (Landsat, moderate resolution), 10m (Sentinel2, high resolution) and 3m (PlantScope, very high resolution).

Four vegetation indices were considered for this project: Normalized Difference Vegetation Index (NDVI), Green Chlorophyll Vegetation Index (GCVI), Enhanced Vegetation Index (EVI) and Wide Dynamic Range Vegetation Index (WDRVI).

Activity 2. Identifying of legume-based systems in Ghana, and critical legume cultivation areas in Honduras.

For Ghana, we identified legume-based systems at both regional and field scales. At a regional scale, we identified two landscape in the northern Ghana where legume crops are grown. At a field scale, we identified two locations (Ejura and Fumesua) in the south and central Gaghana where pigeonpea was planted in research stations.

For Honduras, we identified legume crops at a regional scale (10km resolution) based on a global crop production dataset, Spatial Production Allocation Model (SPAM), which was prepared by the International Food Policy Research Institute. We considered the most popular legume crop of Honduras — beans — for this project. A total of 8 bean growing areas were included in this project.

Activity 3. Processing satellite images and analyzing of the impact of spatial resolution on monitoring legume growth in the study areas in Ghana and Honduras.

For the 3m-resolution Plantlab images, we first downloaded a total of about 3000 PlanetScope (visible and near infrared band) scenes for the 8 Bean Growing Areas (10x10 km per growing area) in Honduras in 2018, 2 legume landscapes in the northern Ghana in 2018, pigeonpea fields in central Ghana in 2017-2019. We then pre-processed the images by removing cloud pixels. Lastly, we computed the four vegetation indices, NDVI, GCVI, EVI and WDRVI for each of the study areas.

For the 30m-resolution Landsat and 10m-resolution Sentinel2 images, we processed the images and computed the vegetation indices using the Google Earth Engine.

With the computed time-series vegetation indices, we quantified the spectral and spatial resolution on monitoring legume crops. To quantify the impact of spectral resolution, we compared the average value of each of the four vegetation indices at each of the determined study areas. To quantify the impact of spatial resolution, we computed the standard deviation of each pixels in the high- and very-high-resolution images when a finer image was scaled up to a coarser image.

Activity 4. Comparing the impact of spatial resolution on crop growth monitoring between smallholder fields (in Ghana and Honduras) versus large commercial fields (in US)

In addition to analyzing the impact of different satellite images on crop monitoring in smallholder fields, we further quantified such effect using images taken by Unmanned Aerial Vehicle (about 0.2m) for 12 commercial corn, soybean and wheat fields in US in 2017-2019, alongside the PlantScope, Sentinel2 and PlantScope images.

Accomplishments

We accomplished our project objective. Below lists our specific accomplishments.

- Identified proper satellite imageries and vegetation indices for this project
- Downloaded about 3000 PlanetScope (3m resolution in visible and near infrared band) scenes and utilized the Google Earth Engine to process and analyze satellite images
- Processed and analyzed more than 800 km^2 satellite images at three different scales (30m, 20m and 3m) for legume crops in Ghana at both field and regional scales, and for bean growing areas in Honduras
- Quantified the impact of spectral and resolutions of satellite images on monitoring both legume crops in smallholder fields (in Ghana and Honduras) and staple-food crops in large commercial fields (in US)

Utilization of Research Outputs

The knowledge generated from this project was disseminated through panel discussion, conference presentation and peer-reviewed journal articles.

- 2019, Panel Discussion on “Improving Food Security in Africa: Pros and Cons of Tech Transfer”, Michigan State University, organized by Dr. Lin Liu, and panelists included Drs. Jeffery Andresen, Bruno Basso, Eric Owusu Danquah, Barry Pittendrigh and David

Tschirley.

- 2019, poster presentation at the Annual American Geophysical Union international meeting
- 2020, paper accepted in Field Crops Research, “Modeling Soil Organic Carbon and Yam Yield under Different Agronomic Management across Spatial Scales in Ghana” (authors: Lin Liu, Eric Owusu Danquah, Cholani Weebadde, Enoch Bessah, Bruno Basso)
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Further Challenges and Opportunities

We were not able to collect ground-truthing data in Honduras due to travel restrictions. When we consulted potential datasets on legume distribution, we did not find up-to-date pulses growing locations in Honduras. But the gridded crop production dataset that include crop production area and type, together with landcover classification, was proved to be adequate in determining pulses growing areas. When analyzing large spatial scale for extracting vegetation index for monitoring bean crop growth over growing seasons, monthly composite could be used to detect the growth cycle for large spatial areas (10kmx10km).

This project allowed us to initiate studies on linking vegetation indices extracted from high-resolution images with crop yield, and on detecting agricultural drought and the implications to legume cropping systems using satellite images and products for Honduras.

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