BIOAg Project Progress Report

Title:
High-throughput screening of forage crops for environmentally sustainable crop production.

Principal Investigator(s) and Cooperator(s):
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Abstract:
Improving the sustainability of agriculture requires a wide range of research from the basic to the applied, from molecular to whole organism, and from field to system level. In-field studies are irreplaceable for gaining knowledge of best practices, varieties, rotations, crop mixtures, and other factors that will make real differences in agricultural productivity and environmental impacts. However, field studies are also very labor intensive and expensive to run, which often reduces the potential alternatives that can be researched. The proposed research would increase the economic efficiency and research capacity in sustainable agriculture. The project focuses on high-throughput screening of field studies needed for sustainable intensification of forage and cover crop production. A major challenge in crop improvement programs is the high-throughput screening of dozens to hundreds of crop types/varieties that produce quality forage with high biomass. Another limitation in large-scale field research is the assessment of plant biomass fairly across a heterogeneous landscape. The proposed project will use and validate non-destructive assessment of plant biomass by unmanned aerial systems integrated with multispectral data. Three very different field studies on sustainable forage production will be assessed. Study A screens varieties and new lines of forage and cover crop winter peas, Study B assesses effects of grazing density and soil fertility treatments, and Study C compares seven, autumn-sown species as components of mixed cover crops. This research will thereby leverage materials and methods developed by the USDA-ARS Legume Breeding program, Organic and Alternative Agriculture program, and the Plant Materials Center.

Project Description:
The goal is to evaluate the potential for using unmanned aerial systems integrated with red-green-blue (RGB) and near infrared (NIR) camera as a non-destructive sensing tool to quantify crop biomass to assist in forage and cover crop management research and decision making (selection of crop variety, fertility treatment, grazing, etc.) for sustainable production practices. To achieve this goal, the following specific objectives will be pursued:

Obj. 1: Optimize non-destructive sensing protocol and development of image processing pipeline to extract features associated with biomass quantity and quality using remote sensing data.

Obj. 2: Develop and validate robust crop-independent models using machine learning approaches for estimation of biomass yield and quality.

Obj. 3: Identify of specific spectral bands associated with forage quality traits using hand-held sensor.

Outputs

Overview of Work in Progress:

<u>Data collection:</u>

There were three studies proposed in this work. Study A on USDA-ARS Legume Breeding program (Pullman, WA), Study B on Soil Health and Pasture Productivity under Mob Grazing and Fertility Management (Cheney, WA) and Study C on USDA NRCS Plant Materials Center (PMC, Pullman, WA). In regard to Study C, due to failed emergence, no plant material was available to image in 2019. Similarly, in 2020, due to COVID-19, the plant materials were not harvested as well. Nevertheless, a mixed cover crop trial was leveraged.

Study A:

Experiment field	Traditional measurement		UAV measurement*	
	Wet harvest	Dry harvest	@10 m AGL	@20 m AGL
Genesee	June 19, 2019	July 31, 2019	June 18, 2019	June 18, 2019
Garfield	June 25, 2019	July 31, 2019	June 24, 2019	June 24, 2019
Pullman	June 10, 2020	July 27, 2020	June 10, 2020	July 27, 2020

Available ground-truth data:

Crop height, wet and dry biomass for quantitative analysis; biochemical traits include Ca, P, K, Mg, crude protein, ash, fat, lignin, acid detergent fiber, neutral detergent fiber, non-fibrous carbohydrates, digestible neutral detergent fiber, neutral detergent fiber digestibility, metabolizable energy, rumen undegraded protein, etc., associated with forage crop digestibility.

Study B:

UAV data acquisition: 28 May 2019

Satellite data was acquired from previous years to study the temporal changes in this study.

Satellite data availability: 5 June 2017, 8 June 2018, 29 May 2019.

Available ground-truth data:

Biomass quantity (sub-sample of the plot), crop diversity in terms of number of species.

Study C:

UAV data acquisition on mixed cover crop trial (pulse-chase experiment): 20 July 2020

Available ground-truth data:

Soil carbon and nitrogen sequestration data (details to be acquired)

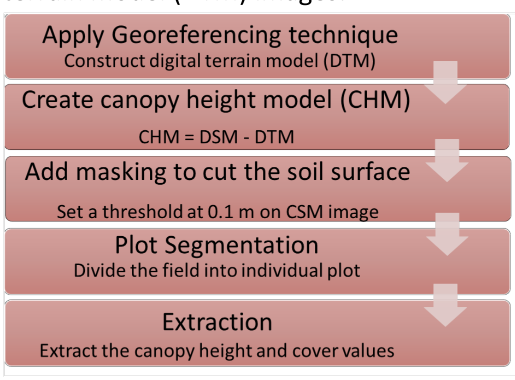
Methods and Results:

In all three locations (Cheney, WA; Genesee, ID and Garfield, WA), aerial data were acquired using two unmanned aerial systems (UAVs), namely AgBot (ATI Inc., USA) mounted with Sentera Double 4K (Sentera Inc., USA) and Phantom 4 Pro (DJI Inc., USA) with its original digital camera. In addition, the visible-near infrared spectra or hyperspectral data were acquired the plant materials from Study A (Genesee, ID) using a portable spectroradiometer (SVC HR-1024; 350-2500 nm) using a leaf clip. In 2020, 10-band multispectral sensor was utilized instead of 5-band multispectral sensor. All the aerial data from these locations (Study A, B) were pre-processed using the 3D maps template in Pix4D (image stitching). From the DJI-RGB sensor, a crop surface model (in m above ground level), were developed, using the triangulated irregular networks method in Quantum GIS. Currently, the data is being processing to extract image features.

Currently data analysis pipelines are being developed in Python integrated QGIS and Matlab software to extract relevant information. In addition, review of literature was performed to learn and develop useful data processing pipelines for rapid feature extraction and analysis.

Methods and Preliminary Results: No progress made thus far with *Study C* data.

Study A:
Method of analysis following generation of orthomosaic, digital surface model (DSM), and digital terrain model (DTM) images:



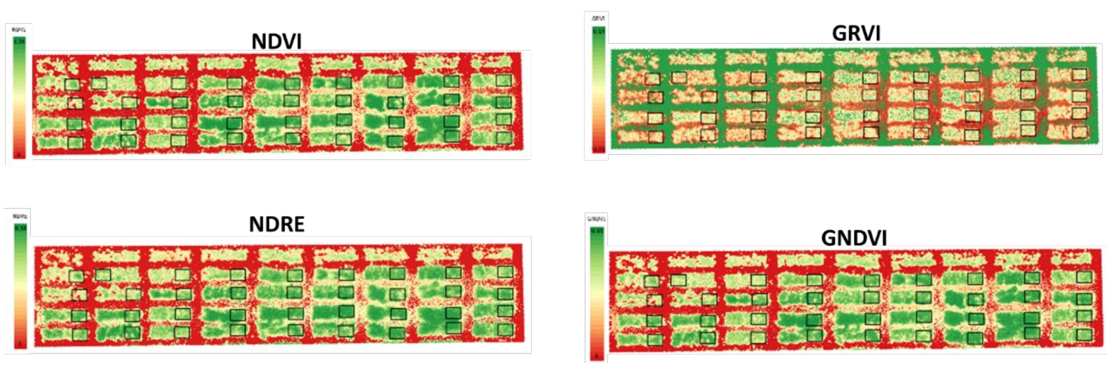


Fig. 1. Generation of vegetation index images such as normalized difference vegetation index/NDVI, green-red vegetation index (GRVI), normalized difference red edge index (NDRE), and green normalized vegetation index (GNDVI) from UAV data (2019, Garfield).

The results indicated that the UAV data acquired at 20 m flight altitude showed high correlation up to 0.85 with canopy height, total weight, and above ground biomass, and NDRE showed high correlation up to 0.89 with total weight and above ground biomass.

Study B:

Method of analysis following radiometric corrections and development of vegetation indices (e.g. NDVI, GNDVI, soil-adjusted vegetation index/SAVI) image development (QGIS integrated Python code):

	UAV	**Satellite**	Pan sharpened images
Semi-Automatic **Georeferencing**	Use **QGIS:** Georeferencer *GCPs from Sentara image as a reference		GCP: 30 GCPs (Challenge) **Transformation type: Thin Plate Spline* **Resampling Method: Nearest neighbor*
↓			
Automatic **VI Creation**		Use **Python:** GDAL package	Created: GNDVI, NDVI, and SAVI **More Vis will be created to find the best suitable digital trait to estimate biomass*
↓			
Semi-Automatic **Masking**	Use **QGIS** and **Python:** Find the threshold on SAVI image		Next plan: Machine learning approach
↓			
Manual **Plot Segmentation**	Use **QGIS:** Advanced Digitizing		Specified width and length **Subplots were created*
↓			
Automatic **Extraction**	Use **QGIS** and **Python:** Zonal Statistic		Calculated: Mean, Median, Summary, and Standard deviation

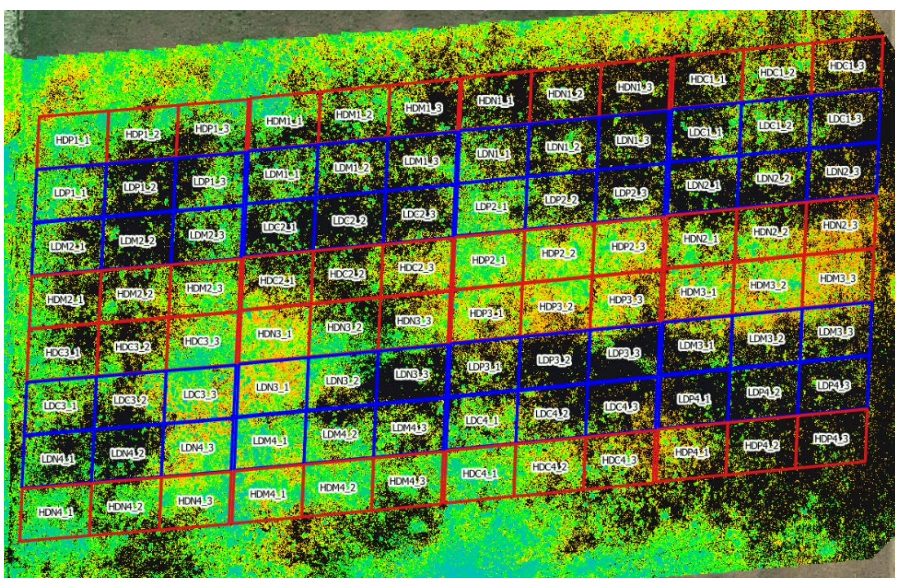


Fig. 1. UAV imagery of Study A. The HD and LD refer to high and low density grazing, respectively; while C, N, M, P refer to compost team, control, manure, and organic nutrient (P, S, also referred as mineral in Fig. 2) treatment.

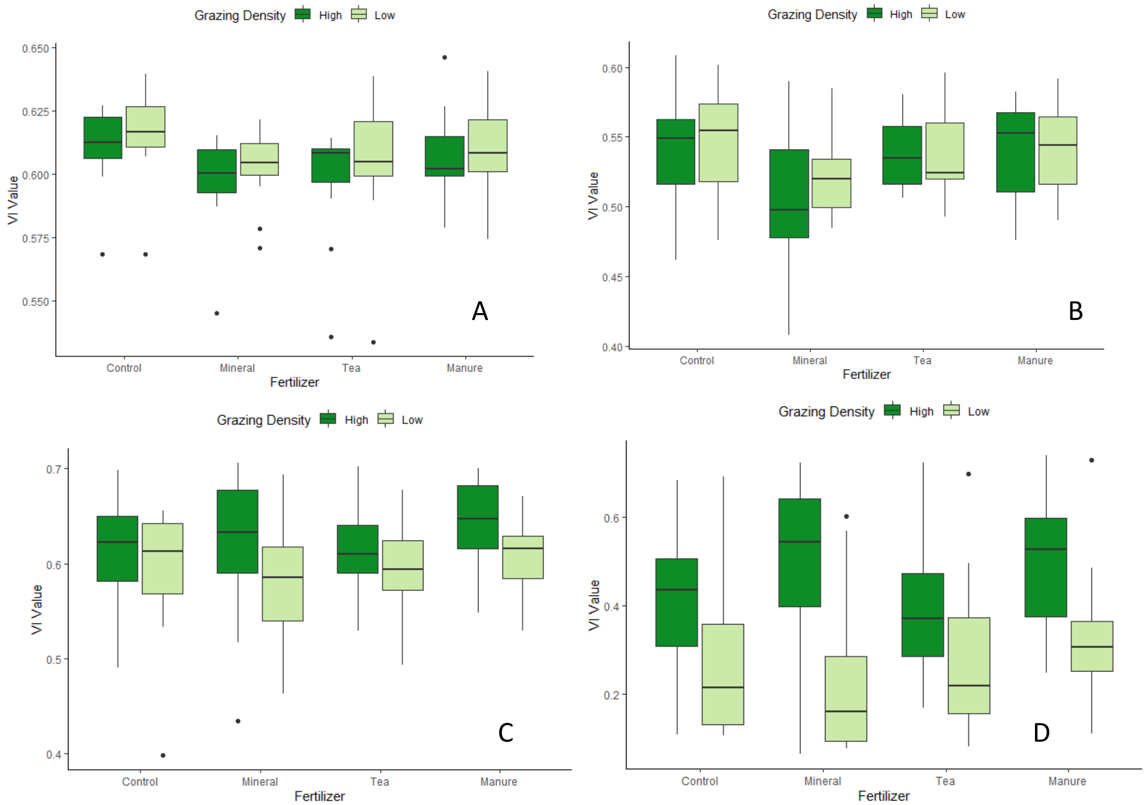


Fig. 2. The average vegetation index data (NDVI) is presented for satellite imagery acquired from (A) 2017, (B) 2018, and (C) 2019; and UAV imagery from (D) 2019. In 2019, both satellite and UAV data, showed significant different (P<0.05) grazing density treatment effects.

Publications, Handouts, Other Text & Web Products:

[1] Quirós Vargas, J. J., Zhang, C., Smitchger, J. A., McGee, R. J., & Sankaran, S. (2019). Phenotyping of Plant Biomass and Performance Traits Using Remote Sensing Techniques in Pea (Pisum sativum, L.). Sensors, 19(9), 2031.

[2] Sangjan, W., and Sankaran, S. Phenotyping architecture traits of tree species using remote sensing techniques. Transactions of the ASABE, November 2020, submitted.

Outreach & Education Activities:

Technical and Outreach Talks:

Sankaran, S. 2020. Artificial intelligence-based selection of forage/cover crop varieties to promote environmental sustainability. AI for Earth Digital Summit, Microsoft's AI for Earth Program, 17-19 November, 2020. [Flask Talk, Virtual] [*Participants: 50*]

Sankaran, S. 2020. Sensing technologies guided phenotyping to support crop improvement programs. 2020 AgroBIT Evolution, 10 November, 2020. [Virtual] [*Participants: 3000*]

Sankaran, S. 2020. Phenomics tools to support crop improvement programs in the digital agriculture era. 2020 WSU Digital Agriculture Summit, 6-7 October 2020. [Virtual] [*Participants: 112*]

Sankaran, S. 2020. Use of proximal and remote sensing data in crop phenotyping to support breeding programs. Online International Training on Agriculture 4.0 Precision and Automated Ag Technologies, 1 October, 2020. [Virtual] [*Participants: 778*]

Sangjan, W., McGee, R., J., Zhang, C., and Sankaran, S. 2020. Biomass estimation using remote sensing techniques in forage and pasture crops. Paper No. 2000758, 2020 ASABE AIM (Virtual), 12-15 July 2020.

Sankaran, S. 2020. Artificial intelligence-based selection of forage/cover crop varieties to promote environmental sustainability. AI for Earth Digital Summit, Microsoft's AI for Earth Program, 25-26 June, 2020. [Flask Talk, Virtual] [*Participants: 78*]

Sankaran, S. 2020. Sensor applications in phenomics for impact in crop improvement programs. Online International Training on Present and Futuristic Trends in Agricultural Mechanization, Center of Excellence for Digital Farming Solutions for Enhancing Productivity by Robots, Drones and AGVs. Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, India, 23 June, 2020. [Webinar] [*Participants: 192*]

Zhang, C., Marzougui, A., McGee, R., Chen, W., Vandemark, G., and Sankaran, S. 2019. Applications of phenomics technologies in pulse breeding, Emerging Opportunities for Pulse Production: Genetics, Genomics, Phenomics, and Integrated Pest Management, Pullman, WA, 24-25 June 2019. [Participants: 50+]

Sankaran, S. 2019. Phenomics data management in Washington State. Tech Talk, Google X, Mountain View, CA, 14 March 2019. [Invited Talk] [Participants: 10]

Zhang, C., Marzougui, A., McGee, R., Chen, W., Vandemark, G., and Sankaran, S. 2019. Applications of phenomics technologies in pulse breeding. CPAAS Agricultural Technology Day - Automation in Specialty Crops, Prosser, WA, 22 August 2019 (Poster). [Participants: 75-90]

Zhang, C., Marzougui, A., McGee, R., Chen, W., Vandemark, G., and Sankaran, S. 2019. Applications of phenomics technologies in pulse breeding, Fairfield Field Day, Othello, WA, 28 June 2019. [Participants: 25]

Impacts

Short-Term: One graduate student is being trained.
Intermediate-Term: Currently, none to report.
Long-Term: Currently, none to report.

Additional funding applied for/secured:

Facebook Computer Vision for Global Challenges [*Satellite imagery for crop assessment: a step towards food security*] – Applied– Not funded

CGIAR Inspire [*Farm connectivity for data-driven agriculture*] – Applied– Not funded

Microsoft AI for Earth Grant [*Artificial intelligence-based selection of forage/cover crop varieties to promote environmental sustainability*] - $15,000 computational credits – Funded

Graduate students funded:

Worasit Sangjan
Pavithra Srinallapathur (left in Spring 2020 due to personal reasons)

Recommendations for future research:

Further progress in this project is needed for recommendations.