BIOAg Project Report

Report Type:
Final

Title:
Integrating drones into weed management on the Palouse

Principal Investigator(s) and Cooperator(s)
Principal Investigator: Alexander Fremier

Co-PIs: Ian Burke, Daniel Auerbach

Cooperator(s): Clark Family Farm

Abstract
Palouse farmers are increasingly spending more resources to manage weeds. Weed management, in part, requires fine-scale knowledge of weed populations. Mapping weeds with drones is promising but requires knowledge of environmental variation and weed phenology. Application of drones in weed management is growing globally but local applications on the Palouse are limited. We will develop drone and multispectral image analysis protocols for mapping common weeds and work with multiple farms to understand the best timing of flights to create weed maps across fields with different crops and solar aspects. We hypothesize that a multispectral imagery and field scouting approach will improve weed mapping efficiency in large extent, rain-fed cropping systems such as the Palouse. Consistent mapping of weeds will open more opportunities for targeted application of biologically intensive approaches to weed management and improved management outcome assessments.

Project Description
The current challenge for mapping weeds is not just the ability to discriminate between weeds and crops, but to integrate mapping of multiple weeds into on-farm weed management practices. This includes mapping very large areas at a high resolution, managing the data storage and analysis challenges, controlling environmental variability (soil color, light conditions, etc.), and aligning flight times with the ability to control weeds. Integration requires an understanding of the inherent on-farm environmental variability, and realistic assessments of the likelihood of implementing weed management. We can map weeds at a small scale, but to apply the resulting knowledge of weed spatial distribution, we need to consider the ability to quickly map weeds and the timing of mapping in relation to when farmers can implement management actions. To begin to understand how to do integrate weed mapping into weed management we proposed the following study objectives.

1) Develop multispectral image classification procedures for common weed species across a range of weed-crop combinations, growth stages, and topographic complexities using drone-based multispectral imaging
2) Field test the procedure on a single large contiguous area to begin to understand how to rapidly integrate spatial data into on-farm weed control measures

3) Prepare peer-reviewed manuscript(s), online training videos and presentations for farmers, and begin developing a multi-year proposal to USDA for development and assessment of drone-based weed mapping and on-farm weed management procedures in Palouse cropping systems

Output

Overview of Work Completed and in Progress

We completed all drone and field surveys in the Spring and Summer of 2023. Data analysis and coordination with the Clark Family Farm has occurred since Fall of 2023. Data analysis for the peer-reviewed manuscript and technical report are on-going. One related proposal was accepted, and another is in review. These proposals are drone-related but not focused on agriculture.

Methods, Results, and Discussion

Objective 1

From spring to summer of 2023, we conducted a field study on the six fields of the Clark Family Farms near Pullman (Figure 1). We flew two fields of each crop – wheat, barley and garbanzo beans (Table 1). We selected the site based on weed infestations covering a range of aspects and slopes. At each site, we field-mapped weeds, crops, and bare ground using survey grade RTK GPS (Figure 2). We collected multispectral, lidar, thermal, and RGB imagery using drones at each site but not each day. All sensors with the exception of the multispectral were flow on the Matrice 300 RTK. This drone is a quadcopter (four propellers) with a 55-minute flight time under ideal conditions. The multispectral sensor is equipped on a DJI Mavic 3 quadcopter. This sensor is fixed to the drone, meaning it cannot be swapped with other sensors. Each sensor was flown at a different altitude based on ground sampling distance (GSD)—the distance between the centers of two adjacent pixels as measured on the ground—but altitudes did not vary between sites. To collect RGB imagery we used the DJI P1 sensor flown at an altitude of 60 m resulting in a 0.75 cm/px GSD. Thermal imagery was also collected at 60 m using the DJI H20T sensor with a GSD of 5.33 cm/px. We flew the multispectral sensor at 45 m with a resulting GSD of 1 cm/px. To collect LiDAR, we used the DJI L1 sensor flown at 100 m and collected ~290 points per square meter. We created a classifier using the Randon Forest method to discriminate between crops, weeds, and bare ground across fields and flight conditions using the spectral reflectance values taken from the drone images. Figure 3 shows a comparison of weed and crop for four wavelengths (green, red, red edge, and near infrared) to illustrate the potential to discriminate between plants and bare ground. We are using multiple wavelengths, plant height, and common remote sensing indices (e.g., NDVI) to develop the best method. We tested the classifier against the field collected data using a separate validation dataset. The classifier testing is still in progress. Initial results show that separating wheat from Italian ryegrass is very difficult given similarities in color and structure. Discrimination is similarly difficult in barley. Garbanzo fields are much easier given the spectral differences among soil, weed and garbanzo in addition to less crop density.

Flight mission planning is part of the testing process to account for battery times and environmental influences, such as solar shading and atmospheric conditions. The technical specifications documentation is also still in progress. We plan to submit a peer-reviewed publication and host the technical document on our website in the summer of 2025.

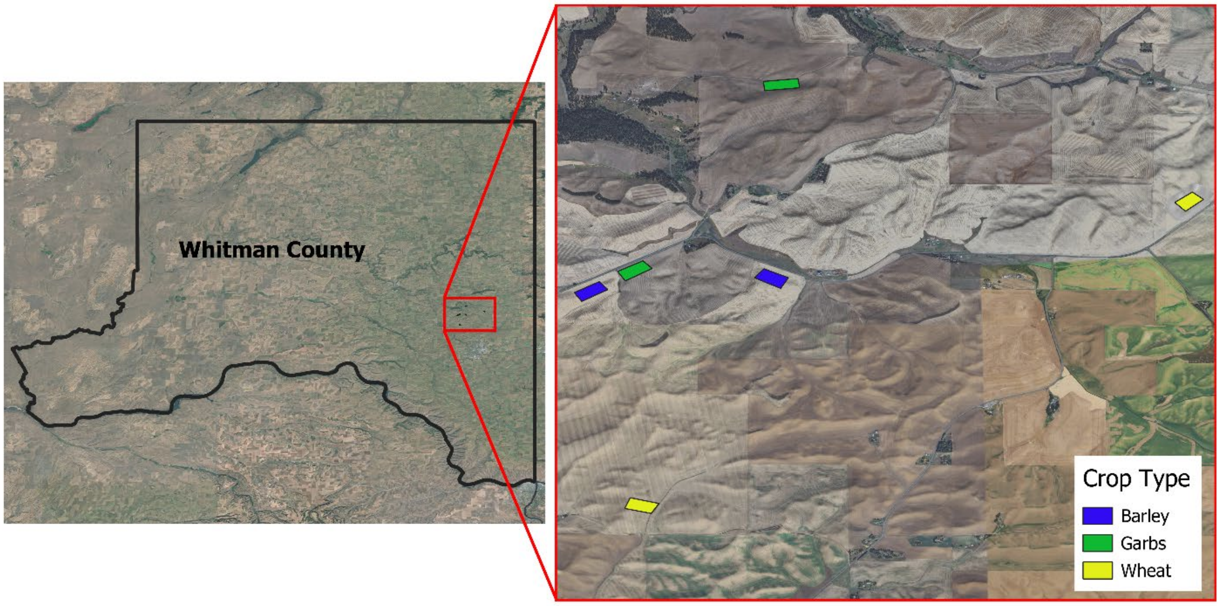

Figure 1: Field site locations and crop types for flights on the Clark Family Farms in 2023.

Table 1: Summary of flights on the Clark Family Farm. All sites include the following sensors: RGB, lidar, thermal, and multispectral.

Site	# of Flights	Crop	First Date	Last Date	Sensors
LandingStrip	27	Wheat	19 Apr 23	8 Jun 23	All
LonePine	23	Wheat	26 Apr 23	29 Jun 23	All
Rose	16	Garbanzo	1 Jun 23	30 Jun 23	All
IanG	16	Garbanzo	1 Jun 23	30 Jun 23	All
IanB	24	Barley	31 May 23	1 Jul 23	All
Silos	24	Barley	31 May 23	1 Jul 23	All
Total	**130**				All

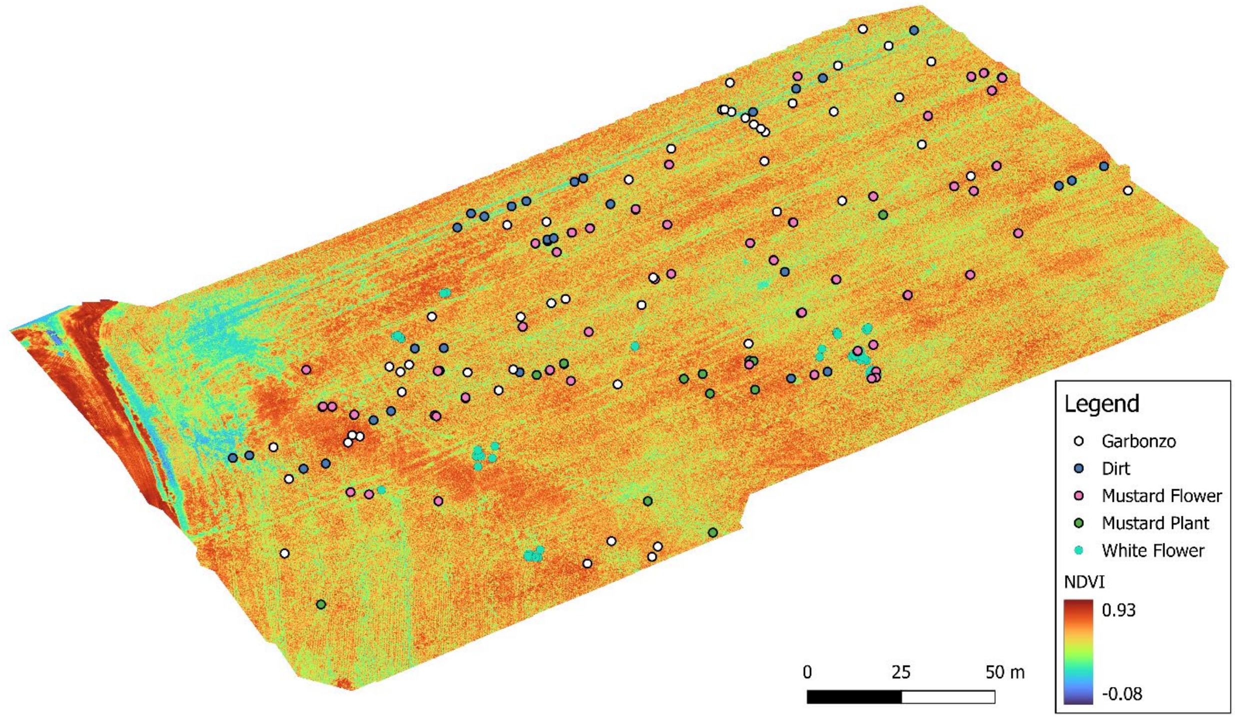

Figure 2: IanG field site illustrates the normalized difference vegetation index (NDVI) and field collected points of weeds, garbanzo and bare soil.

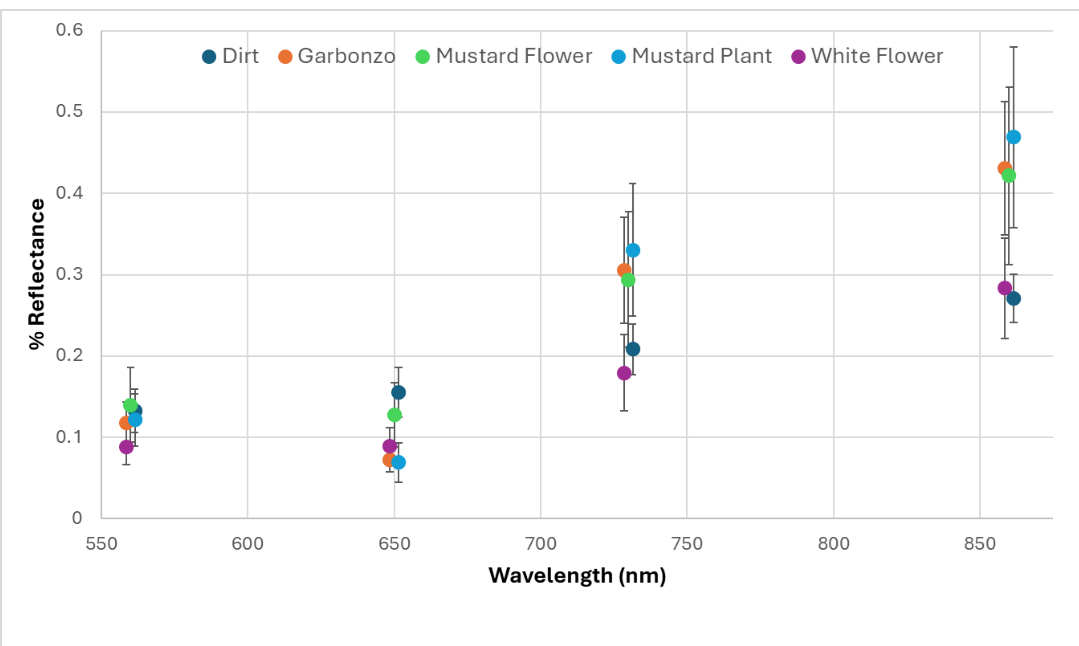

Figure 3: Figure showing differences in spectral signatures between crop, weed and bare ground for the IanG site. Points are the mean value with error bars of the standard deviation for mapped cells.

Objective 2
Developing the data protocols and discrimination functions for mapping weeds is only part of the procedure to increase on-farm weed management. Our preliminary findings suggest that for wheat and barley there is a two-week window around June to (1) best discriminate between crops and weeds and (2) allow for on-farm treatment of weed patches. Garbanzo weed applications are much simpler because the spectral differences are distinct, and growth primarily occurs in June. Over the last year we shared data and sat down with Ian Clark of the Clark Family Farms to develop a strategy for the use of drones to map weeds at the appropriate timing for treating weeds.

The scale of wheat farms on the Palouse presents a data collection challenge. Flying large areas at a resolution high enough to identify weeds is a technical challenge, balancing battery charging, data storage and analysis. To test ideas, we performed a test of a large field by flying two drones (quadcopter and fixed wing). The fixed wing drone is the best way to capture data at the scale of a typical wheat field on the Palouse. However, we will need to develop procedures from the high-resolution images to scale-down the mapping. That is, it is logistically very challenging to collect high resolution (sub centimeter data) for large fields. Coarser resolution might allow rapid mapping for immediate weed management actions. These observations were informed by multiple meetings with Ian Clark over the 2023 and 2024 field season to share data and discuss potential for implementation at scale. The technical report will include our initial conclusions for on-farm application of using drones to map weeds at scale.

Objective 3
We plan to submit one peer-reviewed paper publication on drone use in mapping weeds on agricultural fields in the Summer of 2025. We will prepare multi-media materials to introduce producers to weed mapping using drones and technical transfer once we have completed the data analysis. We have produced similar materials on our previous BioAg grant. We submitted two proposals related to drone use although they are not related to agricultural applications. The first funded proposal develops drone use for counting individual salmon (external agency $156,800). Auerbach is the PI and Fremier the Co-I. The BioAg project helped us secure this funding as it allowed us to learn about flying drones at large scale. Fremier is PI and Auerbach is Co-I on a Major Research Instrumentation proposal to NSF ($1.2 million). We submitted the proposal in November 2023 and requested funds for a drone-based bathymetric lidar sensor.

Publications, Handouts, Other Text & Web Products

To be completed this year.

- Blog post – Spring 2025
- Submission of peer-reviewed paper Summer 2025
- Post of technical procedures for mapping weeds with drones – Summer 2025

Outreach & Education Activities

- Multiple meetings with Ian Clark and others to field test ideas for drone applications in agriculture not just related to weed management. This involves a two-way communication between WSU and the producer - technical aspects of drones and on-farm application details.

- Trained two undergraduate students. Riley Curn-Clark (BS 2024, School of the Environment) and Lily Simmons (BS 2027 expected, School of the Environment) on data collection and analysis.

Impacts

- *Short-Term:* Development of mission protocols for flying drones for weed mapping.
- *Intermediate-Term*: Initial discrimination algorithm for separating weeds, crops and bare ground across environmental conditions.
- *Long-Term*: Development of a drone-based program at WSU to help pilot further drone studies in agriculture and aquatic environments.

Additional funding applied for/secured:

Pending

- Fremier, AK and DS Auerbach. National Science Foundation. Equipment: MRI Track 1: Acquisition of a state-of-the-art drone bathymetric LiDAR system to measure and understand sediment-water-ecosystem interactions. $1.2 million.

Funded

- Auerbach, DS and AK Fremier. Kuskokwim River Inter-Tribal Fish Commission. Drones in Fisheries and Community Monitoring. $156,800.

Graduate students funded

- Daniel Auerbach, PhD, School of the Environment

Recommendations for future research:

Our research confirms the potential to map common weeds with relatively high precision on the Palouse. After discussions, here are a few ideas for the next steps for future research:

- Developing a platform for farmers to decide if drone-based mapping is worth the investment and to learn how to fly drones.
- Developing an easy and rapid platform for uploading drone images to map weeds with minimal field data.
- Producers are already looking into the use of drones to spray pesticides. Is there a non-toxic application for the use of drones? Or a more biological intensive way to use drones to limit the use of pesticides?

Pilot and Flight Details.

<u>Remote pilot information</u>

FAA Part 107 Certified sUAS Remote Pilot: Daniel Scott Auerbach

Certificate number 4242317 issued 30 Mar 2019

ALC-677 Recurrent exam date: 18 May 2021, certificate number 1171440-20210518-00677

ALC-515 Recurrent exam date: 09 Mar 2021, certificate number 1171440-20210309-00515

Contact phone: 650-793-2531

Certificate of Achievement

This is to certify that

Daniel Auerbach

has successfully completed the

FAA Safety Team Aviation Learning Center Online Course

Part 107 Small Uas Recurrent

Course Number ALC-677

Presented by Online Courses

May 18, 2021

Federal Aviation Administration

Certificate Number 1171440-20210518-00677

Valerie G Palazzolo, National Manager, FAA Safety Team


Certificate of Achievement
This is to certify that
Daniel Auerbach
has successfully completed the
FAA Safety Team Aviation Learning Center Online Course
Part 107 Small Unmanned Aircraft Systems (Small Uas) Recurrent
Course Number ALC-515
Presented by Online Courses
March 9, 2021
Federal Aviation Administration
Certificate Number 1171440-20210309-00515
Valerie G Palazzolo, National Manager, FAA Safety Team

UAS information
Owner Name: Daniel Auerbach
Manufacturer: DJI
Model: Matrice 300 RTK
Serial Number: 1ZNBJB700C005G
Certificate Number: FA3FT9YY9P
Issued: 05/20/2022 Expires: 05/20/2025

UAV-based sensor information

1. Zenmuse P1 – red, blue, green spectral bands
2. Zenmuse L1 – Lidar and red, blue, green spectral bands