ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1, 2019 – December 31, 2019

PROJECT TITLE: Evaluating the potential for aerial imagery in detecting weedy rice in California rice fields

PROJECT LEADER AND PRINCIPAL INVESTIGATORS:

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LEVEL OF 2019 FUNDING: $ 10,526

OBJECTIVES OF PROPOSED RESEARCH:
1. To determine if weedy rice can be distinguished from cultivated rice using an Analytical Spectral Devices (ASD) spectrometer (hyperspectral energy sensor) in the greenhouse
2. To determine if weedy rice can be distinguished from cultivated rice using multispectral and/or hyperspectral sensors in the field, attached to an unmanned aerial vehicle (drone)

BACKGROUND:
In July 2018, the PIs conducted a preliminary study (not funded by the Rice Research Board) to determine if it was possible to identify weedy rice in the field using red-green-blue (RGB) and multispectral (blue-green-red-red edge, and near infrared) cameras attached to a multi-rotor drone. Plants were groundtruthed in the field using a handheld GPS device. The data was analyzed to determine if there were any differences between the rice variety and weedy rice. Unfortunately, after analysis, the data collected in the field in 2018 did not reveal any detectable differences. There is still great need for the ability to map weedy rice plants in the field, since there is a concurrent effort to develop a spray drone capable of targeting and spraying individual weedy rice plants in the field. Without a map, the spray drone will be less useful.

In 2018, the camera angle utilized was straight downward, so the PIs speculated that in 2019, shifting the angle to look at the plants from the side might result in better contrast. Furthermore, to determine if there were any spectral differences between the weedy rice and rice, the PIs proposed to use a hyperspectral sensor, which is more finely divided up across the electromagnetic spectrum than a multispectral or RGB camera, in the greenhouse under more controlled conditions. This would enable us to determine if using a hyperspectral camera on a drone in the field would allow for detection of weedy rice, and if so, what the spectral detection range for the hyperspectral camera would need to be.

OBJECTIVES AND EXPERIMENTS CONDUCTED, BY LOCATION, TO ACCOMPLISH OBJECTIVES:

Objective: To determine if weedy rice can be distinguished from cultivated rice using an Analytical Spectral Devices (ASD) spectrometer (hyperspectral energy sensor) in the greenhouse

1.1 **Greenhouse**

Methods

In 2019, 10 sample sets of rice and invasive weeds were cultivated in the UC Davis greenhouse facilities, including barnyardgrass (*Echinochloa crus-galli*), early watergrass (*Echinochloa oryzicola*), late watergrass (*Echinochloa phyllopogon)*, the medium grain rice variety M-206, and sprangletop (*Leptochloa* spp. *fascicularis*), as well as the five different weedy rice types identified in 2016 at different stages of growth. On August 19th, 2019 these samples were transported a short distance to the UC Davis Center of Spatial Technology and Remote Sensing (CSTARS) lab, where we used an Analytical Spectral Devices (ASD) hyperspectral electrospectrometer to collect spectral signatures from all of the plants. Each of these plant samples were scanned 3 times, from both a vertical (nadir) and horizontal perspective, against the gray backdrop of a spectralon panel, under controlled lighting. Calibrated reflectance spectral signatures of these samples were then plotted for the ASD's spectral range of 400 nanometers (ultraviolet/blue) to 2500 nanometers (shortwave infrared) using the ViewSpec Pro software application, and averaged for each plant to create a spectral library of the samples using the ENVI remote sensing software package (acronym for "Environment for Visualizing Images").

Results

We unfortunately found that even with the hyperspectral lab data, there was very little difference in shape the samples' spectra; with some minor exceptions in shape between 950 nanometers and 1400 nanometers of spectral wavelengths. The spectral library plot of averaged plant spectra from the vertical perspective (Figure 1) revealed a slightly higher contrast than spectra from the horizontal perspective, but differences were still minimal. The T5 weedy rice was most different spectrally from the M-206, but it was similar to the early watergrass and barnyardgrass. T4 was almost indistinguishable from M-206, and T1 and T2 are similar to one another.

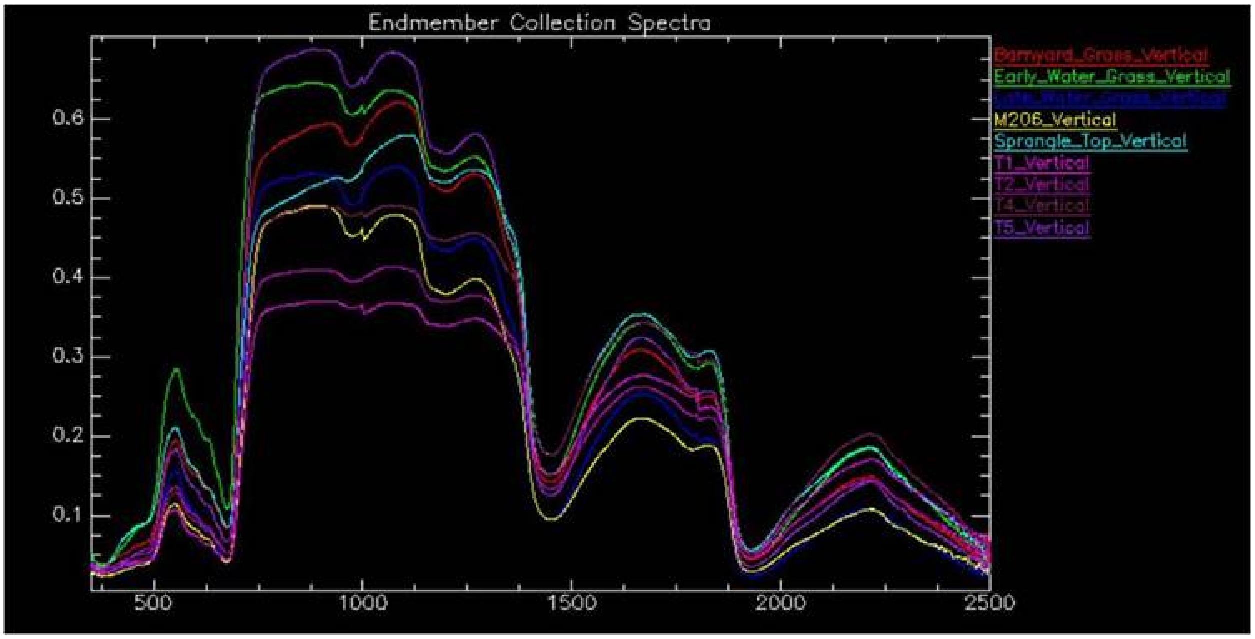

Figure 1. *Spectral library plot of averaged plant spectra, from the vertical perspective, which revealed a slightly higher contrast than spectra from the horizontal perspective. Weedy rice types (1, 2, 4, and 5) are in shades of purple, barnyardgrass is in red, early watergrass is in green, late watergrass is in dark blue, M-206 is in yellow, and sprangletop is in light blue.*

Unfortunately, the slight differences in relative energy reflectance or absorption between 950 and 1400 nanometers were outside of the range of the drone's Micasense Camera (Figure 2). Thus, with the current camera, the ability to detect differences with a drone in the field are unlikely, as the drone camera cannot "see" the range where the slight differences in spectra are found.

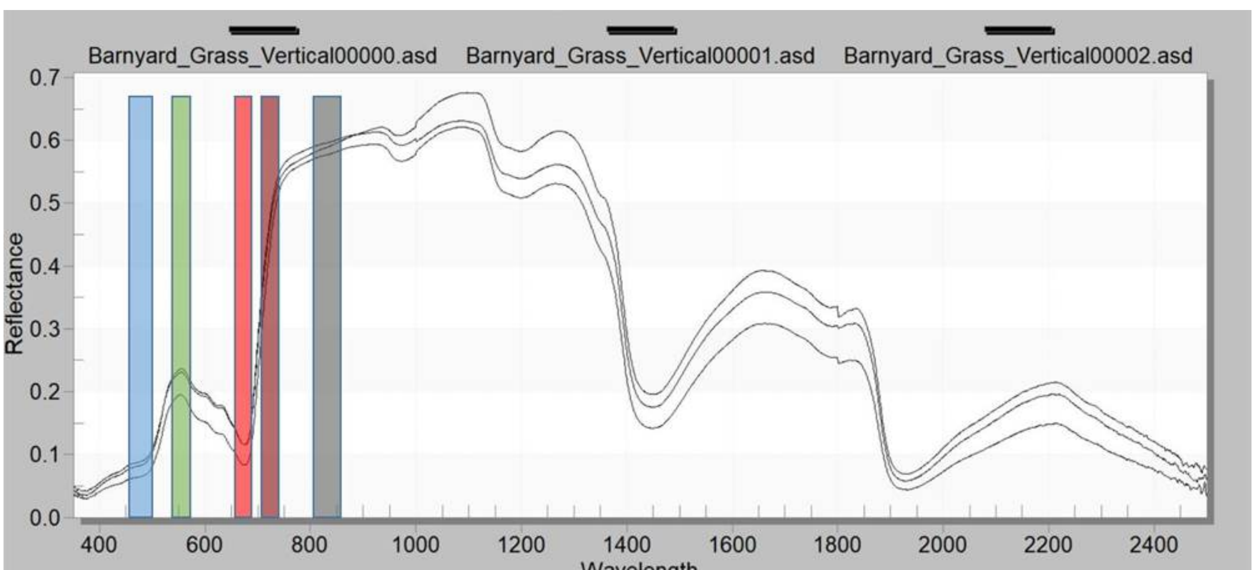

Figure 2. *Comparison of the drone's detection bandwidths versus the hyperspectral plots (from the barnyard grass data set). The bands indicate the Micasense RedEdge camera's five spectral wavelengths (blue, green, red, red-edge, and near infrared).*

Objective: To determine if weedy rice can be distinguished from cultivated rice using multispectral and/or hyperspectral sensors in the field, attached to an unmanned aerial vehicle (drone)

2.1 Field testing

Methods

On August 18, 2019 we flew a fixed-wing eBee drone, equipped with a 20mp red-green-blue (RGB) SODA 3D camera and a multispectral Micasense RedEdge (blue, green, red, red-edge, and near infrared) camera, over a 3.7 acre rice paddy plot, near East Nicolaus, CA. This was the same location we flew for our initial survey in 2018. Both cameras were flown in preplanned grid missions, with the RGB camera was flown at 70 meters above ground level, and the multispectral camera at 80 meters above ground level. Prior to the flights, 7 geopositional ground control target points (GCPs) were placed around the study site, and were recorded with a Trimble Geo 7X GPS; with a post-processed positional error of less than 5 cm. This site included a 0.25-acre concentrated study area, where 33 GPS records were collected for the locations of conventional rice (M-206), weedy rice Type 1, sprangletop, and watergrass (early or late watergrass).

On September 4, we then flew a DJI Matrice 100 quadcopter, equipped with a conventional DJI 12mp RGB camera and a similar Micasense RedEdge camera (noted above), over a 6.95-acre study site near Maxwell, CA. These flights were conducted at 50m above ground level in a grid pattern, like before. Four GCPs were placed and recorded with the Trimble GPS at the four corners of the plot, and 19 GPS sample positions were recorded for the above invasive weeds. This site contained weedy rice Type 3.

Once collected, the imagery from both mission dates were processed into orthomosaic images and digital surface models (DSM), using the Pix4D Mapper Pro software application. The spatial resolution of the image products were as follows:

East Nicolaus RGB data – 0.65 inches
East Nicolaus multispectral data – 3.56 inches
Maxwell RGB data – 1.48 inches
Maxwell multispectral data – 1.3 inches

The GPS elevation values of the GCPs were then artificially altered so that the point values along the southernmost side of the flight areas would be at a 90-degree downward slope from the northern most points. These new artificial coordinates were fed into the Pix4D processing to manually override it's photogrammetric processing, so that the view angle of the orthomosaic outputs would be at an oblique 90-degree angle, to more fully reveal the sides of the surface features rather than their tops, from an nadir view angle (Figure 3).

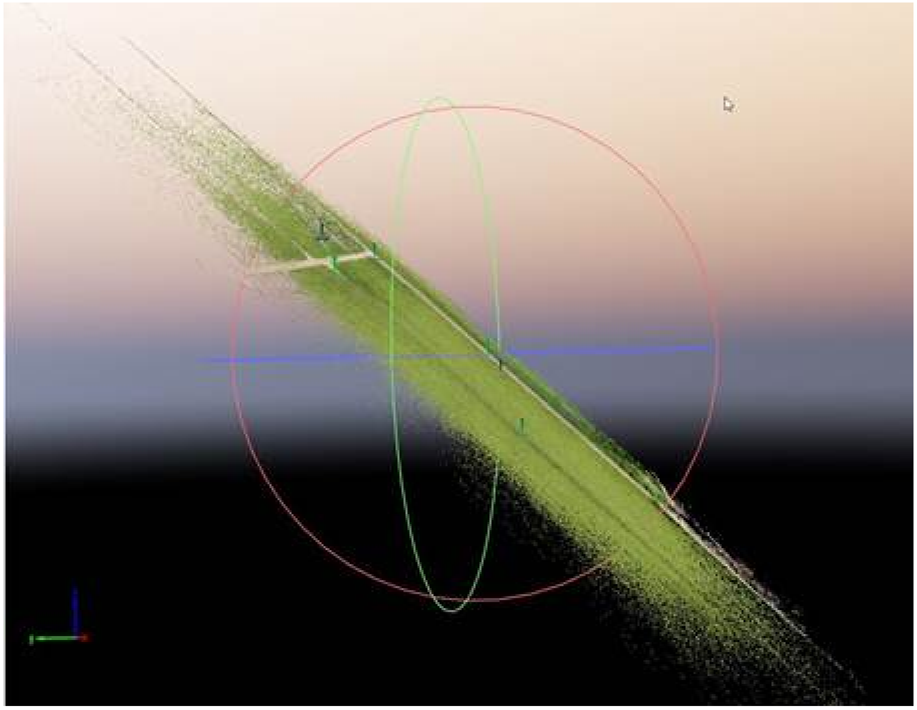

Figure 3. *90-degree 3D representation of the East Nicolaus red-green-blue (RGB) data. The blue line is the horizontal plane, green is east-west, and red is north-south. The 4 tiny anchor points are the adjusted ground control target (GCP) points.*

Results

Although the rendition of the drone imagery from an at-nadir (straight downward) perspective to a 90-degree oblique perspective increased contrast in the imagery, we were still not able to detect a significant difference between conventional rice and the invasive plants (weedy rice or the weeds: sprangletop, late or early watergrass). The RGB image comparison (Figure 4) from the East Nicolaus site illustrates the comparison (the truck is called out to highlight the oblique angle perspective comparison).

Figure 4. *A 20mp red-green-blue (RGB) SODA 3D camera comparison from the East Nicolaus site. The nadir (straight downward) perspective is on the left and the oblique 90-degree south leaning perspective is on the right. Note: the truck highlights the angle perspective comparison.*

We found that the multispectral imagery was distorted and blurry when processed at the 90-degree angle, however at a nadir (straight downward) angle it revealed interesting surface characteristics that we were unable to see with the naked-eye while in the field, such as a darker area at the east side of the plot (unrelated to plant types), previous tire tracks and footprints in the field. Unfortunately, when the imagery was analyzed using the ENVI software application, we found no discernable difference between the weedy sample points and conventional rice points (Figure 5). A false color infrared mosaic (red indicating near infrared) at the East Nicolaus site (Figure 6) likewise illustrates the lack of difference between the sample points.

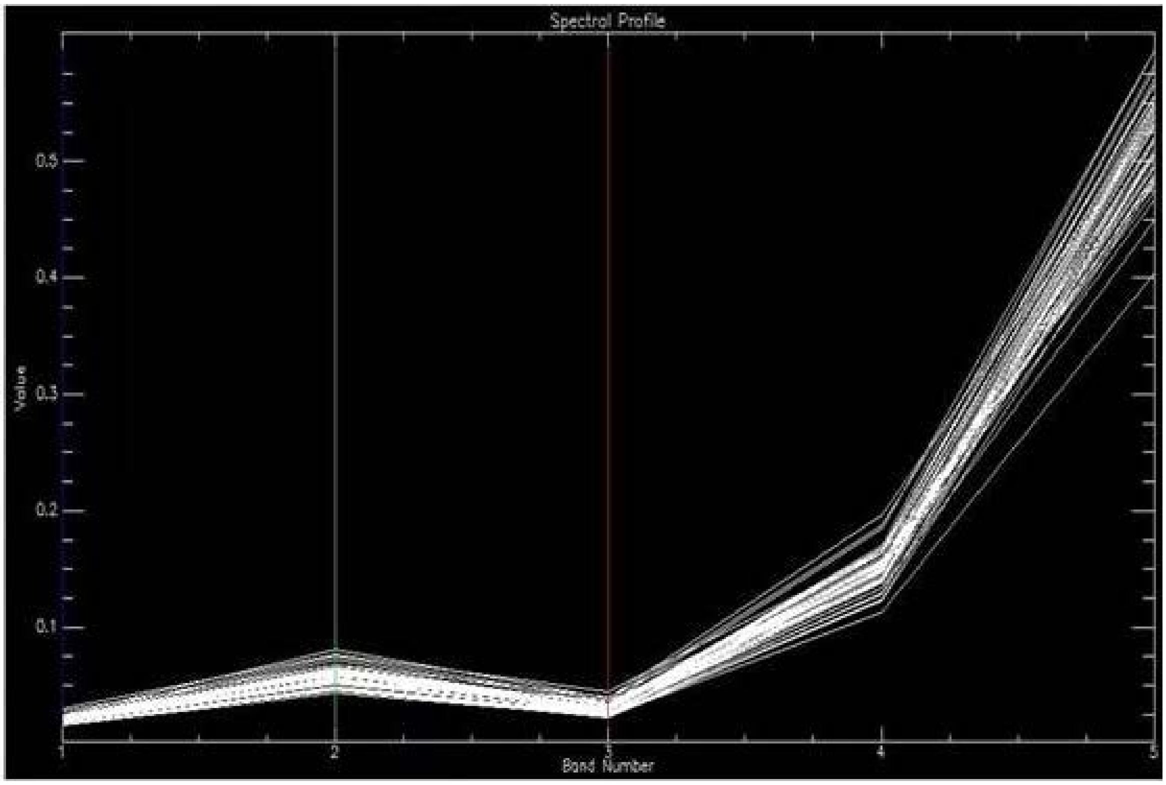

Figure 5. *Spectral signatures of the 33 sample locations at the East Nicolaus site, plotted for the Micasense RedEdge's five wavelengths. No significant differences were found between the weedy rice, weeds (sprangletop, late and early watergrass), and M-206 rice variety.*

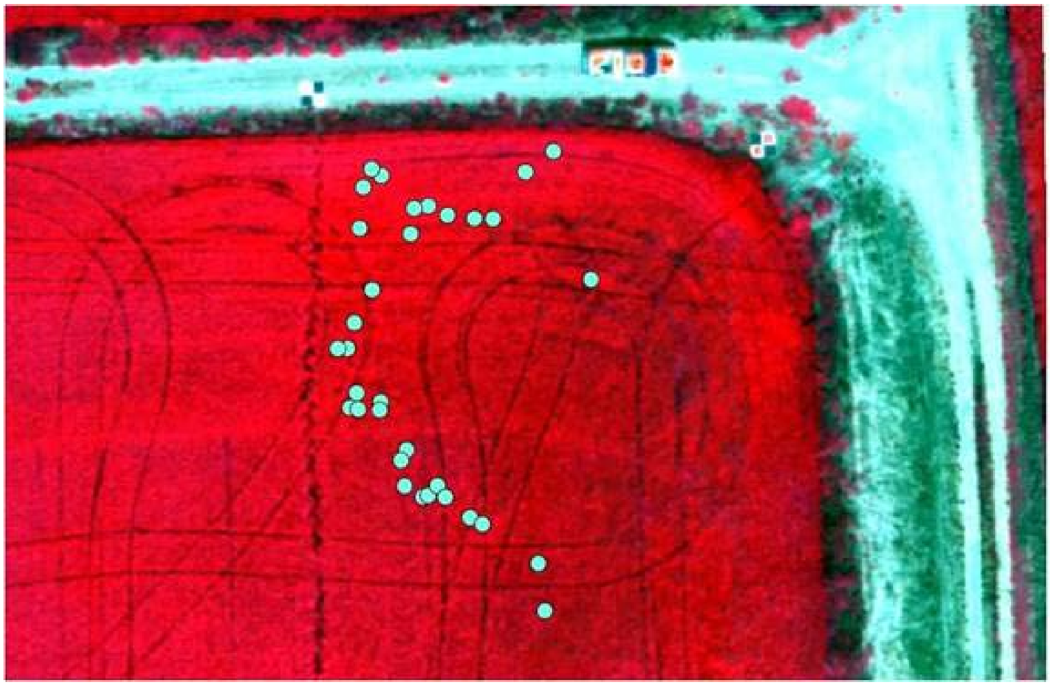

Figure 6. *A false color infrared mosaic (red indicating near infrared) at the East Nicolaus site. The 33 GPS locations are indicated in green.*

GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

Even under ideal lighting conditions, such as those found in the CSTARS remote sensing lab, most of the plant species could not be distinguished from one another based solely upon their spectra. Given these lab results, it is not surprising that the multispectral imagery collected in the field was also nearly identical between sample locations. That said, tilting the RGB imagery seemed to bring out more contrast in the imagery, and maybe with different view angles relative to the sun, the weedy rice might stand out. Given our current technology, we suspect that only architectural differences (e.g. high variability relative to the sun and sensor angle), or seasonally dependent differences in senescence, might reveal a distinction between the plants. Further testing of this theory can be conducted using the data set we have already collected.