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MISSISSIPPI SOYBEAN PROMOTION BOARD
PROJECT NO. 49-2018 (YEAR 1)
2018 FINAL REPORT

Title: Maturity state estimation with unmanned aerial systems (USA)

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BACKGROUND AND OBJECTIVES

The drone marketplace offers a variety of affordable, easy-to-obtain, easy-to-pilot options with high quality optics. At the same time, FAA has lowered the hurdles to use of unmanned aerial systems (UAS) in production agriculture through the introduction of the remote pilot certificate. On the engineering side, battery life (notorious for limiting potential) is improving. These improvements have made UAS more accessible, but we are still lagging behind on meaningful applications of the technology.

Many agronomic decisions in soybean production systems revolve around crop maturity. Therefore, it seems reasonable to assume rapid, objective detection of crop maturity on a field-scale basis is desirable for decision making. Our rationale is that UAS are a tool with the capability of filling this need. However, research has not yet verified this assertion. Moreover, we have not determined which aspects of soybean production can benefit from application of this tool, and to what economic end.

From observation, most producers and consultants enjoy the novelty of drones, but do not have the time to devote to becoming remote sensing experts. The products offered by UAS service providers are visually appealing, but generally do not offer more than confirmation of what a producer already understands about his or her fields. This being the case, the economic proposition for UAS is not clear. Our supposition is the immediately available potential for UAS lies in (1) the ability to quickly cover more acreage, with less effort, than a field scout on foot, and (2) the objectivity inherent in computing systems (in contrast to human observer subjectivity).

An understanding of the role unmanned aerial systems (UAS) can play in identifying critical maturity stages will allow producers to determine the appropriateness of UAS as a tool for tasks that rely on key maturity stages. The primary objective of this research is to evaluate the ability of UAS to determine when soybean have reached maturity stages (R6/R6.5) sufficient for harvest aid application. The secondary objective of this research is to evaluate the ability of UAS to determine when soybean have reached other agronomically-important growth stages such as R1/R2 and R3/R4.

REPORT OF PROGRESS

Two production soybean fields were selected for the study, one with irrigation capacity and one without. The fields were adjacent to each other to minimize variability due to weather and soil differences. The irrigated field was also being used to conduct variety trials funded by the MSPB,; therefore, it offered an opportunity for leveraging of data and effort. The fields were managed by the individual producers, both of whom are well respected and considered to be progressive farmers.

Fields were flown regularly with a DJI Phantom 4 Pro. This is a low-cost UAS that is popular with hobbyists and producers for its ease of use. Depending on the configuration, the current price ranges from $1,000 to $1,500. The integrated RGB camera provides high resolution imagery (~0.3 in/pixel at 100 ft AGL, increasing linearly with altitude) and 1080 HD video capture.

Because many crop health changes are reflected outside the visible range, a multi-spectral sensor was also utilized on many UAS missions. The Micasense RedEdge is a five-band sensor with individual cameras for blue, green, red, near infrared, and red edge portions of the electromagnetic spectrum. Using a third-party after-market mount, the RedEdge was mounted to the Phantom, and data were collected simultaneously with that of the integrated RGB camera. The resolution of the RedEdge is somewhat lower than the Phantom camera (~0.75 in/pixel at 100 ft AGL), but still quite high compared to what was available only a few years ago from aerial platforms.

Objective 1. Detection of maturity stage R6/R6.5

Flags were placed within the field, and a GPS unit was used to geotag the location of each flag so that the same area could be repeatedly visited for maturity staging and imagery could be georectified to align correctly with in-field sample locations. A total of 97 flags were placed within the field, divided into four rows, two rows per field (**Fig. 1**).

Once soybean began moving toward R5, flights were conducted with the RedEdge sensor as frequently as weather permitted. At the same time, field scouting for maturity was conducted at each of the 97 points. Rating was consistently performed by an individual student funded on this project to minimize variability between observers. On the two occasions when the student was not available, all samples were bagged, documented, and preserved so the student could rate the maturity the following day. Missions were also conducted on the MSU Foil Research Farm near campus on plots managed by Dr. Irby with his student providing the maturity ratings to coincide with flights.

Image data were processed to apply radiometric calibration per the sensor manufacturer's protocols. Geometric correction was performed to align all flight images to each other to ensure that field sample locations were accurately aligned with where they occurred within the image. Following data preparation, reflectance values in the five bands were extracted at each sample location. The extracted data were used in various combinations of the available bands to calculate 23 common indices. These index values, in addition to the absolute reflectance values for the five bands, were used in Spearman correlation analyses with maturity stage.

The highest significant correlations were detected for red edge and green reflectance, and accordingly indices which were strongly influenced by one of these values in the calculation showed higher correlation that others (**Table 1**). Correlations with in-field data were moderate (0.40 – 0.55). Based on results from this single field, the likely explanation is that a single point in time is not enough to estimate maturity reliably and repeatedly, and dynamic solutions provided by algorithms are required. In other words, rather than saying, "when the index value is x, the maturity is y" the answer would be similar to "when the index value changes by x% over y days, the projection of maturity is z." Thus, in phase 2, analyses were conducted on time series of data to examine trends.

Trend analyses indicated that all 23 indices showed stable patterns of behavior, with minor fluctuations due to noise, across the study period. The rate of change accelerated once soybean reached R6. Poor weather conditions limited frequency of image collection towards the later stages, however, and it is not clear if the significant change in rate is due to physiological change or the larger timing between samples. As presented, it seems that vegetation indices perform well in later R stages at predicting maturity; however, confidence is lacking until more data can be collected to validate this finding. Using other project funds, weather permitting, these data will be collected in 2019.

Objective 2. Determination of other growth stages

The prevailing practice when conducting UAS missions is to cover the entire field in a series of overlapping flight lines to produce a whole-field mosaic image. A more efficient approach to data capture could be to target sentinel sites within the field, perform non-linear flight from point-to-point, and collect single high-resolution still images of the sentinel sites for analysis. Since the inception of this project, at least one company has built a platform for agriculture based on this principle. The benefit of this method is that clouds, which have perpetually hindered remote sensing operations in Mississippi, have less potential to interfere with quality data collection because the chances for changes in lighting and uneven lighting conditions are reduced. The aircraft could alternatively be utilized to quickly cover acreage, and soybean viewed using the video stream to quickly scout fields.

Over the 2018 summer, "video scouting" was employed frequently to collect information about crop maturity. Using ultra-low flight to scout crops, the UAS was able to detect signs of maturity up to R7. Additionally, other issues such as herbicide burn, insect damage, and weeds were easily identified. The aircraft is an asset in this effort in that the propellers create sufficient air movement to separate the crop canopy for under-canopy views. A curated sample of video clips showing this work is available on-line; links are provided in the End Products section.

Given the reliability and ease of this approach, it is now our recommendation for beginning users to consider video feed assessment as an alternative to current procedures which use "lawnmower flight" practices that cover the entire field. The advantages of this system are that it (1) can be easily understood by viewers, (2) uses a low-cost, off-the-shelf, easy to fly aircraft, (3) reduces risks associated with entering fields which are wet and muddy, following pesticide applications, and also in periods of high heat stress when robust physical exertion could be dangerous, and (4) creates an archive of field conditions than can be referred to at a later date, or shared with producers or consultants instantly through text messaging of stills, or later through transfer of video data. If a substantial number of issues are seen, then the time can be invested in obtaining whole-field coverage using more traditional methods.

There are issues with use of this approach related to current methods of triggering insecticide applications based on sweep counts. Application triggering methods would have to be adapted for video scouting. It was observed that the aircraft flushed many insects from the canopy, so it is possible methods could be devised to conduct visual counts in this manner in the future. Other options are being investigated for traps carried on an aircraft. Neither effort is mature and ready for use at this time, however.

IMPACTS AND BENEFITS TO MISSISSIPPI SOYBEAN PRODUCERS

The goal of this research and extension program is to conduct investigations necessary for Mississippi soybean producers to understand and take advantage of this new technology to the extent that it makes sense for their farming operation. When used effectively, UAS can reduce the time required to view crop status across a large field as the aircraft moves much more quickly than a human on foot slogging through a muddy field with chest-high beans in July.

Identifying the opportunities for UAS in soybean production will take some time, but at the moment, there are day-to-day tasks that can be done more quickly or with less risk by using the UAS as a tool. Real examples from this research study where the UAS provided value to the research team included the benefits previously mentioned. We were able to continue to scout fields despite recent rains that muddied up fields and following immediately behind pesticide application because we did not have to physically enter the field. This reduced chances for adverse human health impacts, as well as wear and tear on planting beds from foot traffic during wet periods. To this last point, particularly in no-till systems, preserving planting beds can be challenging; thus, this could be useful for producers moving towards those systems.

END PRODUCTS – COMPLETED OR FORTHCOMING

As an Extension function, Louis Wasson has worked with consultants and producers to introduce them to the use of the UAS for video scouting. Extension personnel at other universities have shown interest in the approach and an effort is being made to develop a multi-state core Extension product for UAS, to include video scouting.

Herbicide burn http://bit.ly/herbburn Growth stages http://bit.ly/2Pwj0EV

The initial soybean maturity estimation effort was presented at the International Conference on Precision Agriculture in June. Although the focus of the poster was primarily on the initial effort, credit was given to MSPB for funding the field-based research, which at the time was just beginning. The poster is available on-line at http://bit.ly/2C2ebAW. This poster was also presented at the NE Miss. Producers Advisory Council meeting.

Based on current results, more data are likely needed before true peer-reviewed publications will be possible. Weather has been a perennial problem for collecting the imagery necessary for estimation of later growth stages. Using other funds, more data will be collected in the 2019 growing season to refine estimation of R6/6.5 stages, and confirm initial findings.

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Graphs and Tables

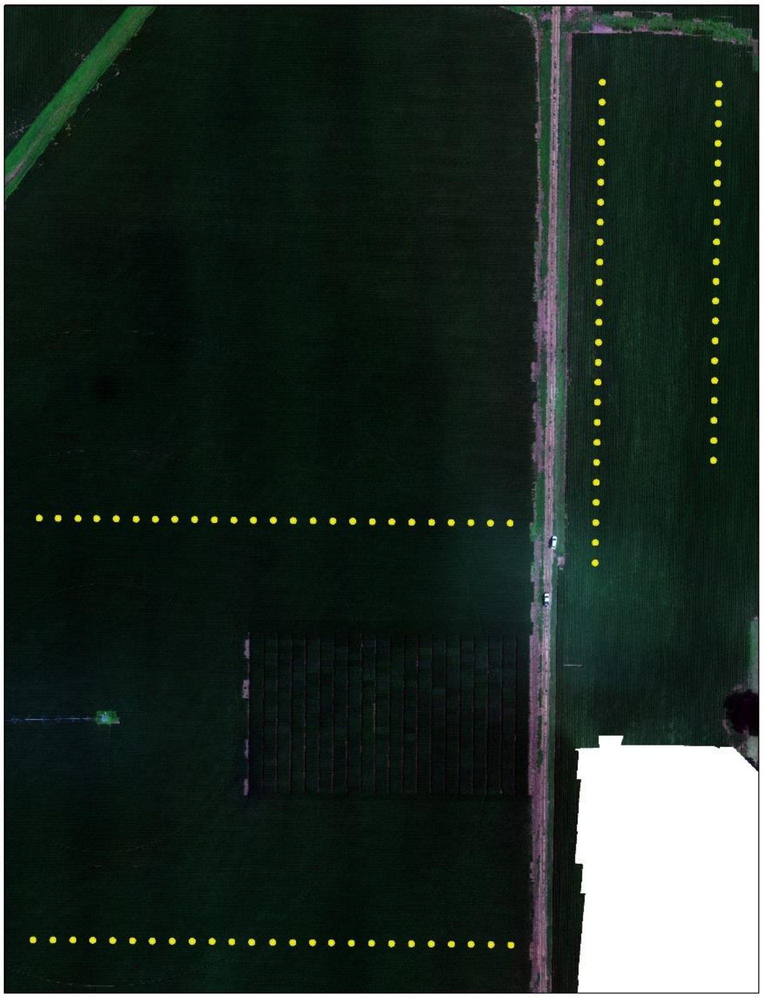

Figure 1. Location of sample points (shown yellow) for repeated field sampling of soybean maturity. Four rows were used, with two rows per field. The field on the left had irrigation capacity, while the field on the right did not.

Table 1. Spearman correlation coefficients for maturity stage and selected spectral reflectance and calculated indices. All values shown are significant at the α = 0.05 level.

	GS	RE	G	GRVI	RGRVI
GS	1	0.54	0.52	-0.41	-0.44
RE	0.54	1	0.95	-0.73	-0.67
G	0.52	0.95	1	-0.88	-0.85
GRVI	-0.41	-0.73	-0.88	1	0.87
REGRVI	-0.44	-0.67	-0.85	0.87	1

Abbreviations: GS = Growth stage, RE = Red Edge, G = Green, GRVI = Green ratio vegetation index, RGRVI = Red edge substituted green ratio vegetation index
Equations: $GRVI = Near\ infrared/Green$, $RGRVI = Red\ Edge/Green$