UAV-Based Crop Scouting for Precision Nutrient Management

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Abstract. Precision agriculture – is one of the most substantial markets for the Unmanned Aerial Vehicles (UAVs). Mounted on the UAVs, sensors and cameras enable rapid screening of large numbers of experimental plots to identify crop growth habits that contribute to final yield and quality in a variety of environments. Wheat is one of the Idaho's most important cereal crops grown in 42 of 44 Idaho counties. We are working on establishing a UAV-based methodology for in-season prediction of wheat yield potential – and prescribing nitrogen (N) fertilizer rates. Development of sensor-based calculator for making N rate recommendations would help Idaho wheat growers to improve N use efficiency by recommending N based on yield potential. Idaho wheat producers rely on timely, comprehensive, scientifically sound information on wheat yield potential, quality, and tolerance to stress. The research component of this project aims to enhance the technical knowledge on application of UAV systems in wheat production by developing a system for remote wheat crop assessment. At seeding, wheat was fertilized with five N rates: 0, 75, 150, 225, and 300 lb N/a. The wheat plots were scanned utilizing 3D Robotics 8X+ (quad-copter) UAV twice in the growing season – early tillering (Feekes 2-3) and late tillering (Feekes 5-6). The tandem Canon SX260 (one with near infrared image collection capabilities and another with natural light) were used to collect the wheat reflectance measurements – Normalized Difference Vegetative Index (NDVI). The same day, the experimental plots were scanned with the ground-based handheld GreenSeeker sensor (Trimble Navigation Ltd., Sunnyvale, CA) to calibrate and correlate the UAV-based readings with the ground-based readings. Plant height has proved to be a useful yield potential prediction component. Plant height was measured on each day the sensor data is collected and at harvest. Previous work indicated that SPAD readings can be useful for yield potential prediction in wheat. Wheat chlorophyll content was estimated using SPAD meter. The relationship between NDVI values and harvested grain yield (determined with regression analysis, SAS v9.4 (SAS Institute, Inc., Cary, N.C.)) will be used to develop wheat yield potential prediction model and the N rate calculator.

Keywords. UAV, UAS, drone, wheat, nitrogen, crop sensors, precision sensing; NDVI, mapping, yield potential

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Study was conducted at 4 experimental locations in Eastern ID, irrigated - Aberdeen, Ashton, Rupert, and dryland - Soda Springs. At seeding, spring wheat was fertilized with 5 N (granular urea (46-0-0) rates: 0, 75, 150, 225, and 300 lb N/a. The plots were scanned utilizing 3D Robotics 8X+ (quad-copter) UAV equipped with natural color cameras (Canon S100 and SX260), a near-infrared camera (converted Canon SX260) and a Forward Looking Infrared thermal camera (TAU 2) to collect wheat reflectance measurements - Normalized Difference Vegetative Index (NDVI). Approximately 90 UAV flights were conducted June - September of 2015. The goal of these flights was to test image quality, detection resolutions, altitudes, the effects from wind and heat variances, field of view and flight line overlap characteristics and flight support operations.

The plots were scanned with the ground-based handheld GreenSeeker sensor (Trimble Navigation Ltd., Sunnyvale, CA) to develop wheat yield potential prediction model. The mean yield (averaged across treatments, for 4 sites) achieved in this study was 70 bu/a. According to UI recommendations, the optimum N rate should have been 215 lb N/a. Relationship between N rate and grain yield suggested that 75 lb N/a rate is close to optimum for Eastern ID. Study results underline the importance of updating N fertilizer guidelines.

Strong linear relationship between plant height and grain yield, GreenSeeker NDVI and grain yield indicated potential great potential for developing sensor-based N recommendations. GreenSeeker NDVI explained 68% of variation in yield; combining NDVI and plant height increased accuracy of yield prediction to 73%. This shows great potential of NDVI-based crop sensors for accurate wheat yield potential prediction and sensor-based N fertilizer management.

The relationships between NDVI and yield was similar for irrigated and dryland sites. If this trend is confirmed, this will significantly streamline sensor-based recommendations and will enable us to develop one strong algorithm for both dryland and irrigated wheat cropping systems. With such a great accuracy of yield prediction obtained with just one growing season-worth of data, we are confident in development of robust sensor-based N fertilizer algorithm for Idaho wheat producers.

We have made great strides in understanding of UAV's application in Precision Agriculture and identified several key steps to development of UAV-based methodologies: *Airframes:* 1) The copter airframes have proven to be stable platforms suitable for smaller areas of image capturing assignments (10 acres and less) with a condensed level of flight times (45 minutes or less). 2) To improve flexibility of image acquisition, we plan to include a flying-wing aircraft. *Cameras/Sensors:* We plan to utilize a UAV equipped with a multi-spectral camera consisting of three filters allowing for energy to enter the sensor array in bands of green, red and near-infrared radiation equivalent to Landsat Thematic Mapper bands. This will enable us to utilize obtained images as excellent early warning signals for plant stress. *Software / Image Processing*: 1) Continue to utilize GIS software (for geospatial processing), structure from motion (SfM) software (for creating three-dimensional surface models); 2) To incorporate software for computing mapping area and pixel value statistics of remotely sensed images and for analyzing multi-band formatted images for determining vegetative indexes ratios.

Conclusions

Upon collecting a robust multiple site-year data set, and verifying the yield potential equation, the sensor-based N rate calculator will be developed. Further analysis of data is required to determine whether the same algorithm can be used for irrigated and dryland wheat. Detailed analysis of GPS-tied data points is required to calibrate UAV vs handheld collected data.

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