PRECISION SENSING FOR IMPROVED WHEAT PRODUCTION

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ABSTRACT

Improving nitrogen (N) use efficiency (NUE) from current 35-40% is important for growers' sustainability and environmental quality. Unmanned Aerial Vehicles (UAVs) are proposed as an alternative to traditional field scouting for making crop management decisions. Precision sensors and cameras mounted on the UAVs provide high quality images which can be used to make fertilizer recommendations in-season based on crop nutrient status. A study was conducted at 5 locations in Southern Idaho in 2016 to access the feasibility of using UAV-based crop reflectance data for developing fertilizer N recommendations. Another objective was to compare the UAV-based data with that collected using ground-based hand-held optical sensor. Our study has shown that there was strong correlation between mid-season Normalized Difference Vegetative Index (NDVI) (both ground-based and UAV-derived) and spring wheat grain yield was observed for all 5 locations. Strong linear relationship between ground-based and aerial UAV-derived NDVI was noted. To develop a robust sensor-based N fertilizer algorithm for Idaho wheat producers, more data is required to verify the relationship between UAV-based NDVI and grain yield and quality.

INTRODUCTION

Wheat is one of the Idaho's most important crops and one of the main cereals grown in 42 of 44 Idaho counties. Idaho is 5^{th} in the nation in wheat production, with 780,000 acres of winter and 480,000 acres of spring wheat planted this year (Idaho Wheat Commission, 2014). The project is aiming to improve wheat production in Idaho by 1) developing sensor-based N rate calculator, 2) enhancing the variety testing program by utilizing precision agriculture methodologies.

Nitrogen use efficiency is only about 35-40% in most wheat production systems due to temporal and spatial variability (Gupta and Khosla, 2012). Failure to accurately evaluate a crop's fertilizer requirement, ignoring the impact of spatial and temporal variability, and difficulty in identifying the most appropriate timing for fertilizer application result in inefficient fertilizer management (Walsh et al., 2012).

Crop sensors can be successfully utilized for crop monitoring and prescribing N fertilizer rates (Walsh, 2015; Walsh & Belmont, 2015). The sensor-based approach to N fertilization has been shown to deliver over $10 per acre in savings. Precision agriculture – is one of the most substantial markets for the UAVs, aircrafts that can fly without a human operator on-board. 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. The major challenge in the adoption of UAVs for agriculture is the lack of proof of concept and sound methodologies for incorporating the UAV-based data into crop management decisions.

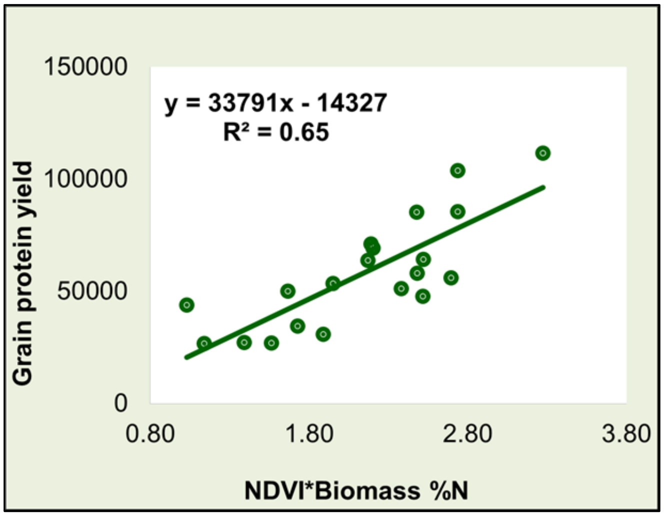
The economic impact of UAV systems in Idaho is estimated at $29 million during the 2 years from 2015 to 2017, and $174 million during the 10 years from 2015 to 2025, with a national impact of $82 billion (Association for Unmanned Vehicle Systems International, 2013). Development of sensor-based calculator for making N rate recommendations would help Idaho wheat growers to improve NUE by recommending N based on yield potential. The calculator could be used in-season for 1) “blanket” fertilization - one rate applied to the whole field (works best for smaller fields), or 2) variable-rate fertilization using on-the-go sense and spray units (for larger operations).

MATERIALS AND METHODS

This was the second year of this study. The study was conducted at 4 irrigated locations – Parma, Aberdeen, Ashton, Rupert, and 1 dryland - Soda Springs. At seeding, spring wheat was fertilized with 5 N (granular urea (46-0-0) rates: 0, 75, 150, 225, and 320 lb ac^{-1}. Newer quad-copters with increased flight duration time of 20% and more stable camera platform which translated to the capturing of clearer and shaper imagery. Over 250 flights were conducted May - September of 2016 wheat reflectance measurements – NDVI- and other indices. Acquiring multi-spectral sensor with 5 separate cameras in a single payload unit has enabled collection of 5-bands of reflectance energy on a single flight. Acquisition of updated GIS software for conducting geospatial processing and cartographic product creation has enabled cloud-storage and in-depth data analysis capability. The plots were scanned with the ground-based handheld GreenSeeker sensor (Trimble Navigation Ltd., Sunnyvale, CA) to develop wheat yield potential prediction model. Nitrogen fertilizer application significantly increased grain protein content at all 5 sites. At all locations, except for Aberdeen, a complete data set was obtained at Feekes 5 and Feekes 10 growth stages. At Aberdeen, data was collected at Feekes 10 only.

RESULTS AND DISCUSSION

Strong correlation between mid-season NDVI (both ground-based and UAV-derived) and spring wheat grain yield was observed for all 5 locations. Sixty five percent of variation in grain protein yield (product of grain yield and grain protein content) was explained by biomass index (NDVI*biomass N content) (**Figure 1**). Strong linear relationship between ground-based GreenSeeker NDVI and aerial UAV-derived NDVI was determined (see example for Parma location, **Figure 2**). This indicated strong potential for successful application of UAVs for utilizing aerial imagery for crop monitoring. **Figures 3** and **4** show relationship between GreenSeeker NDVI and grain yield in 2015 and 2016, respectively. In 2016, a notable separation was observed between two groups of data – Soda Springs and Ashton sites had substantially lower yields spread out over a wide range of NDVI values. To develop a robust sensor-based N fertilizer algorithm for Idaho wheat producers, more data is required to verify the relationship between UAV-based NDVI and grain yield and quality. The study will continue at 5 locations in southern Idaho in 2017 growing season.



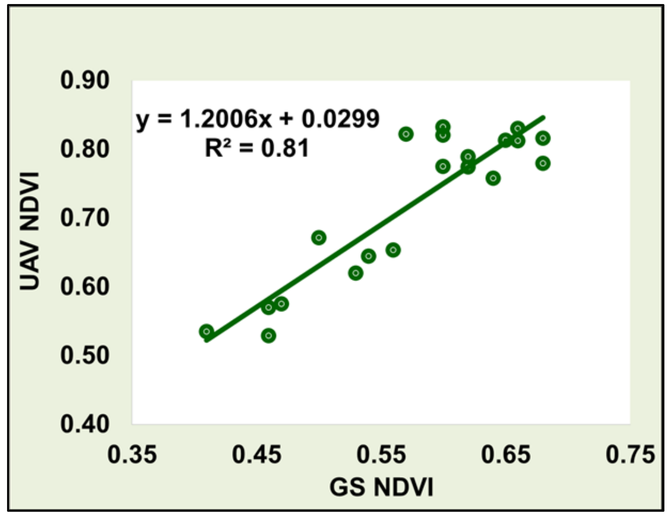


Figure 1. Mid-season NDVI, in combination with biomass total N content, explained 65% of wheat protein yield, 2016.

Figure 2. Strong linear relationship between hand-held GreenSeeker NDVI and aerial UAV-based NDVI, Parma, Idaho.

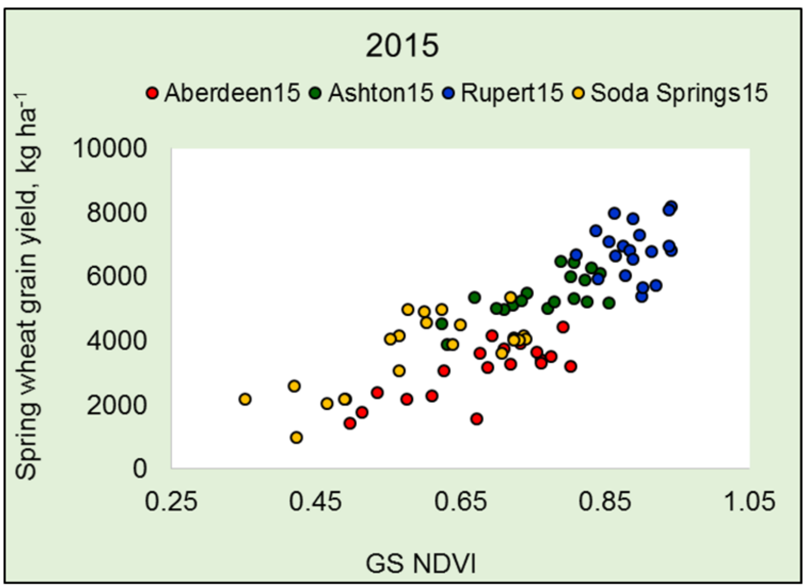


Figure 3. Relationship between GreenSeeker NDVI and grain yield, 4 locations in Idaho, 2015.

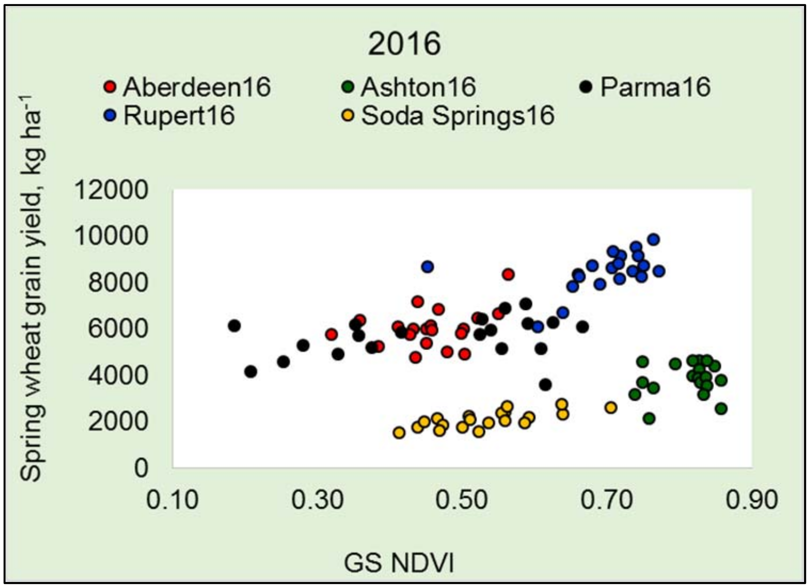


Figure 4. Relationship between GreenSeeker NDVI and grain yield, 5 locations in Idaho, 2016.

SUMMARY

The first year of study has shown that we are able to successfully predict wheat grain yield potential mid-season with the use of NDVI-based crop sensors in Idaho for both dryland and irrigated conditions. This suggests that, with one or two seasons of data, we will be able to generate a strong yield prediction equation and develop sensor-based N fertilization guidelines. Our 2016 data collected in SE and SW Idaho indicated that current University of Idaho N fertilizer recommendations may need to be adjusted (decreased) without impacting wheat grain yield or quality. Decreasing N fertilizer inputs without yield/quality penalties would translate into substantial economic, agronomic and environmental benefits to Idaho growers and agricultural communities.

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