VERIFY THE EFFECTIVENESS OF UAS-MOUNTED SENSORS IN FIELD CROP AND LIVESTOCK PRODUCTION MANAGEMENT ISSUES

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Project Justification

There is interest by individuals and companies to use unmanned aircraft systems (UAS) as management tools in production agriculture, however there is little proof that sensors mounted on UAS can effectively identify crop development differences and anomalies.

This project is a “proof-of-concept” demonstrating specific UAS applications in production agriculture. Project personnel used UAS-mounted sensors to collect data of ongoing crop and livestock research projects during the 2014 crop season at the North Dakota State University Carrington Research Extension Center (CREC). Project personnel collaborated with NDSU research scientists conducting research at the CREC, and used UAS-mounted sensors to monitor research fields at specific times as identified by the individual researchers. **The primary goal of the project to demonstrate proof-of-concept of the usefulness and effectiveness of UAS in crop and livestock management in North Dakota.** Project personnel demonstrated UAS applications in crop and livestock management, and instances where UAS were not effective. Project personnel developed data processing methods and tools to convert image data to information that farmers, ranchers and consultants can use in their farming and consulting businesses.

UAS operations for this project began in May 2014, and are ongoing at the date of publication of this paper. All UAS remote sensing data is being correlated to data collected on the ground by the project investigators. All UAS applications for this project will be completed during 2014.

Project Objectives:

1. Evaluate the of use UAS with thermal and infrared sensors to monitor commercial sized crop fields and research plots at the Carrington Research Extension Center (CREC) to identify plant emergence, plant populations, nutrient deficiencies, disease symptoms, insect damage, weed infestations, weed management practices, plant vigor, moisture stress, expected yield, impacts of tillage and crop rotations, crop senescence, and the impact of soil salinity.
2. Evaluate UAS platforms and sensors to monitor livestock animal movements to detect diseased animals and breeding activity in beef cattle, measure feedlot surface temperatures for heat and cold effects of various bedding materials to mitigate environmental stress, identify and count animals, identify animals with extreme dispositions, and monitor the temperature of compost piles.

Project Description

Specific UAS Crop Objectives

Identify plant emergence and plant populations in corn, soybeans and sunflower. Plant emergence and plant population are important factors that affect the final crop yield. It is important for growers and crop consultants to know this information to tailor management decisions to suit the crop conditions in each field.

Collaborating researchers from CREC measured plant emergence and population 12 days after planting at multiple locations in the field. Multispectral image data acquired from UAS platform was mosaicked, and geo-referenced. The imagery was processed with MATLAB software to detect crop plants from the surroundings. The plant counts generated from the imagery were compared to the ground truth data to establish the accuracy and ability of the UAS sensing system to estimate plant population. The results showed imagery collected with UAS sensors can be effectively used count plants after emergence.

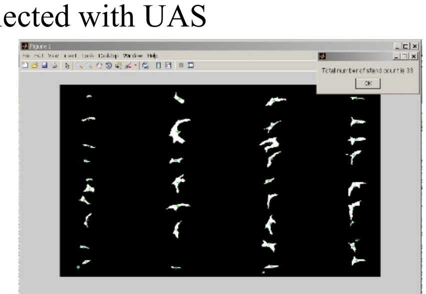


Figure 1 Plant Count in MATLAB

Figure 2 Image

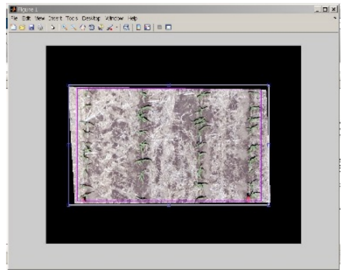
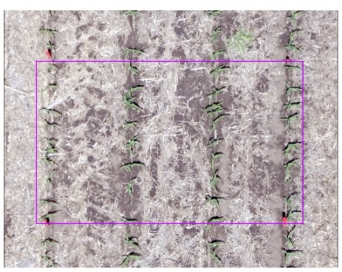


Figure 3 Image in MALAB

F_Stand	Pic_ID	MATLAB_Stand
25	DSC001	24
27	DSC002	27
26	DSC003	24
25	DSC009	24
18	DSC012	20
37	DSC017	38

Figure 4 Examples of Plant Counts

As of the date of publication, plant counts have only been completed on corn.



Identify nitrogen deficiencies in corn and wheat. Crop producers monitor nitrogen deficiencies to determine the needs, locations and amounts of in-season nitrogen applications to reach the projected yields. Wheat producers monitor nitrogen deficiencies to determine the needs, locations and amounts of in-season nitrogen applications to maximize the protein content of the grain.

Collaborating researchers from CREC used optical sensors to establish the NDVI (Normalized Difference Vegetative Index) when the corn is in the V5 and V8 growth stages at multiple locations in the field. Infrared image data acquired from UAS platform on the same days was mosaicked, and geo-referenced, calibrated and processed to detect nitrogen deficiencies. The NDVI values generated from the image were compared to the ground truth data to establish the accuracy and ability of the UAS sensing system to identify NDVI values that can be used to apply in-season variable rate nitrogen. The NDVI processing was accomplished with Fiji Image J software with a photo monitoring plugin made by Ned Harding. (http://flightriot.com/post-processing-software/fiji-imagej/)

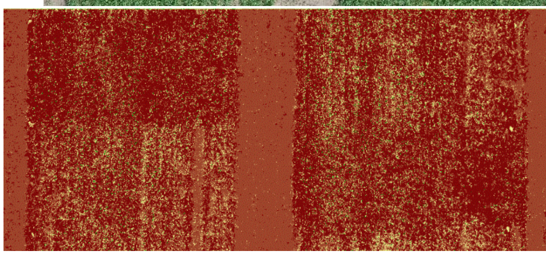


Figure 5 UAS-captured RGB Image Figure 6 NDVI Processed from RGB Image

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<u>All Other applications described in the following sections of this paper are on-going, and will be summarized in the project final report.</u>

Weed infestations. Crop producers need to monitor crop for weed infestations to determine the needs, locations and amounts of in-season herbicide applications.

Early Plant Health Assessments. Crop producers make numerous crop management decisions during the early phases of crop development based on the crops general health, vigor, stand, color and other related visual determinations. These visual determinations provide the producer with an assessment of the crops potential or challenges ahead. The producer may engage input strategies to correct a deficiency or choose to invest further with inputs to capitalize upon a crop that presents a high yield potential. Research collaborators are utilizing the broad diversity of spring wheat, soybean and corn studies at the CREC to identify plots with a range of early season yield potential, nutritional levels, plant vigor, and stand. Multispectral images are being acquired within the same timeline that researchers will collect ground based data related the same parameters measured on the ground.

Disease symptoms. Crop losses due to plant diseases are a frequent occurrence among the crop diversity of this region. A part of a systems approach toward disease management is having knowledge of disease incidence and severity within a field so that the producer can better manage that crop or field in subsequent seasons. CREC collaborators identify a range of disease severities within research trials. Multispectral image data acquired from a UAS platform are being used to collect the same days from these areas to be correlated with ground truth data. Initial crops and diseases being investigated are sclerotinia (white mold) in both soybean and dry edible beans.

Moisture stress on irrigated crops. Irrigating crop producers need to monitor crop moisture stress to manage irrigation scheduling. UAS images will be collected from crops as conditions develop during the growing season that result in crop moisture stress. To date, moisture stress has not been present.

Corn senescence for specific hybrids. Crop producers need to monitor the dry down times of individual corn hybrids to determine when to harvest corn, and to assist in variety selection in future years. Multispectral imagery will be collected of maturing field corn and correlated to hand-harvested samples. Researchers will use the moisture from the hand-harvested samples to correlate imagery to measure corn grain moisture in standing corn.

Specific UAS Livestock Objectives

Determine breeding activity for herd sires and beef females. . Breeding success is critical to profitable beef production. Real time monitoring of breeding activity and movement for bulls and cows will inform producers of mobility problems or normal breeding behavior.

Detecting diseased beef animals in pastures.

Beef producers need to identify diseased animals as soon as possible to treat the animals, and/or isolate the sick animals from the rest of the herd.

Counting animals in pastures Producers need to monitor animal numbers to know if all animals are present in pastures.

Multispectral and thermal image data is being acquired from UAS platform is being used to monitor animal herd numbers.

Determine the temperature of animals and the feedlot surface temperatures of various bedding materials. Feedlot managers need monitor heat load on feedlot surface temperatures and relate to actual animal body temperatures to mitigate stress in animals. Animal stress can be particularly detrimental to animal welfare when the outdoor temperatures either very cold or very warm. Monitoring pens and cattle in winter will also permit mitigation of cold with bedding as insulation.

Collaborating CREC center researchers measure the surface temperature of the various bedding materials using ground-based thermometers. Thermal image data is being acquired from UAS platform at the same times and corrected, calibrated and processed, to detect the surface temperature of the feedlot surface. The thermal image data is being compared to the ground truth data to establish the accuracy and ability of the UAS sensing system to monitor feedlot surface temperatures.

Expected Results

The *expected outcomes* of this project are to: 1) validate specific uses of UAS in crop and livestock production management decisions; 2) identify significant UAS services for the Private Sector Partners; 3) develop methodologies that the private sector can use to implement agricultural applications of the UAS; and 4) promote the commercialization of unmanned aircraft systems using sensors to manage specific crop and livestock management decisions.

The results of using UAS and sensors on the various crop and livestock projects listed in this research proposal will help UAS-related businesses develop business models with greater likelihood of success.

The NDSU Extension education objectives of this proposal will help ND crop and livestock producers identify UAS applications on their farms. Since many agricultural producers currently higher consulting services, particularly to monitor their crops, research, demonstrations and educational presentations on various UAS topics will provide necessary information to select UAS services.

Techniques and Management Plan

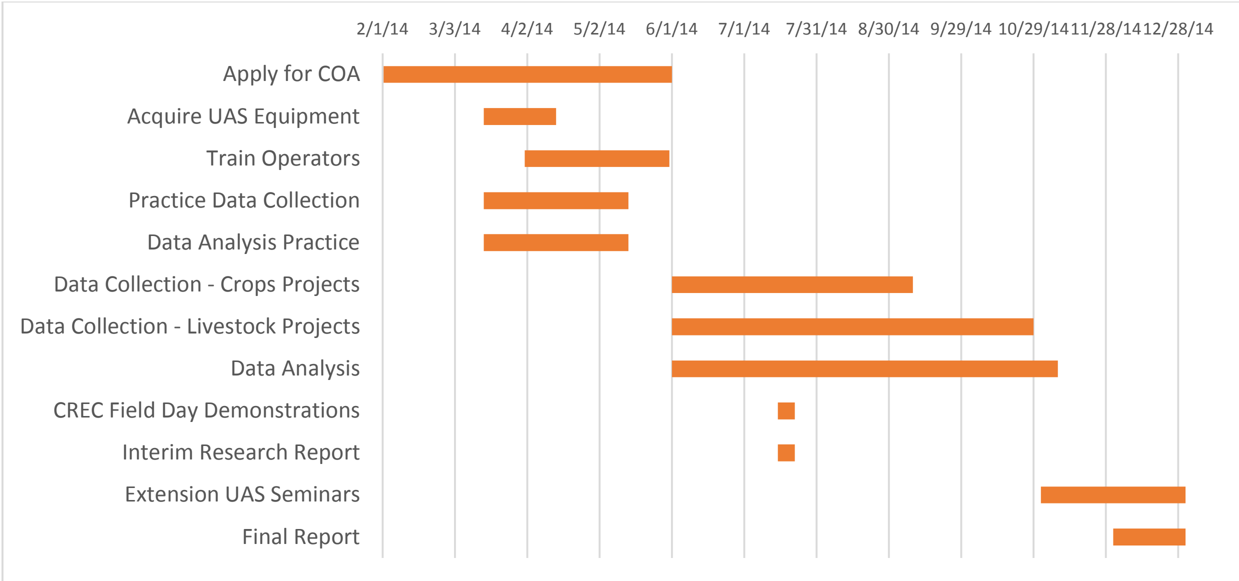
The NDSU Agricultural and Biosystems Engineering Department personnel are coordinating this project. Personnel from the University of North Dakota Unmanned Aircraft Systems Center are operating the UAS and collecting the imagery. The NDSU Agricultural and Biosystems Engineering Department personnel are processing and analyzing the imagery and correlating the data to the data collected on the ground. The correlated data will be used to validate specific uses of UAS in agricultural production management decisions.

The University of North Dakota Unmanned Aircraft Systems Center personnel prepared and submitted the requests to the Federal Aviation Administration for the required Certificates of Authorization.

The individual NDSU Carrington Research Extension Center researchers are collaborating with the principle investigators to select appropriate sensors and monitoring schedules for the research projects. These researchers are also collaborating with investigators to correlate the UAS-sensed data with the data collected on the ground for each project.

The principle investigator will conduct an educational program on UAS applications to crop and livestock production at the end of the project. Projects summaries will be published in the NDSU Agricultural and Biosystems Engineering Department Web site: http://www.ag.ndsu.edu/agmachinery.

Milestone Chart



Private Sector Partners

1. ND Corn Council
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    b. 1411 32nd Street S. Ste 2, Fargo, ND 58103. Phone 701-364-2250
    c. greg@ndcorn.org
2. Pulsar Operational Boundaries, Inc.
    a. William L. Harnisch, CEO, Pulsar Operational Boundaries, Inc.
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    c. wharnisch@pulsarobi.com

Technological & Economic Impact

The economic impact of UAS in North Dakota is estimated as $83 million during the 10 years from 2015 to 2025, with a national impact of $82 billion. Precision agriculture is considered as a major application of UAS. The major stumbling block in the adoption of UAS in agriculture is the lack of proof of concept and methodologies for adopting UAS data in crop and livestock management. With this project, we are expecting address this gap in information. Currently there are many producers, consulting companies and small precision agriculture industries in North Dakota interested in adopting UAS technology. This research will provide the information and tools necessary for these companies to successfully use UAS technology in agriculture. This research will also further the technical knowhow on how apply UAS in agriculture. We expect to develop decision support systems that can be adopted and further refined by UAS industries.

Summary and Conclusions

At the time of this paper submission most of the objectives had not been completed. Project personnel have demonstrated that UAS imagery can be effectively used to accurately calculate count emerged corn plants. All other objectives will be reported in the final report published in December, 2014.