Flying Low and Slow: High Resolution Imagery for Agricultural Field Research

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Keywords: Unmanned Aircraft Systems (UAS), remote sensing, agricultural research

Abstract:
Remote sensing for agricultural research can offer challenges that differ from commercial agricultural applications. Spatial resolution is one issue, despite the availability of satellite imagery at 5m or greater resolution. The small size of research plots and/or the need to separate the crop canopy from the background soil or non-crop vegetation may require pixels at <5cm spatial resolution. Previous research evaluated 2-5m commercial satellite imagery for estimating canopy nitrogen in commercial apple and pear orchards, and determined the resolution wasn't sufficient to remove background effects (Perry et al. 2016). Another issue is the need to measure reflectance for specific narrow wavebands, thermal infrared imagery, or LIDAR not available from spaceborne platforms. Frequency of acquisitions, overpass time, and the challenge of cloud cover add additional challenges. Unmanned Aircraft Systems (UAS) provide a platform for research instruments, such as multispectral, hyperspectral, and thermal infrared imagers, and LIDAR. Multi-rotor platforms, in particular, offer the ability to fly close to the canopy, and remain stationary to acquire multiple images where necessary.

Examples of our current research utilising UAS are listed in Table 1. The UAS-based imaging is one part of a suite of proximal and remote sensing tools to characterise the crop canopies. In general, our research develops libraries of reflectance spectra, fluorescence, canopy temperature, and fractional green cover along with corresponding canopy measurements such as biomass, yield, disease assessment, traits, or other characteristics. The imaging utilises a six band multispectral camera (Tetracam Micro-MCA Chatsworth CA, USA) and a thermal infrared camera (FLIR Tau2, Wilsonville OR, USA). The two cameras are positioned together on a fixed mount, with an on-board computer controlling remote triggering and time/date stamps for the imagery. The multispectral camera is configured with six 10 nm wide spectral bands at 550, 660, 710, 720, 730 and 810 nm.

Our use of UAS systems for agricultural research is continuously evolving, in part, due to on-going challenges. We have learned that hardware failures to record GPS, as well as the limitations in accuracy, require the use of positional markers that are visible within the

image in order to identify plots. As the research requires absolute reflectance and temperature data, we have developed methods for direct calibration using distributed in-scene panels (Figure 1, upper left panel). The multispectral camera is generally configured to use an integration time that is determined (and adjusted) by the camera (based on pixel intensity), and calibration panels in each image allows for direct corrections to reflectance. Band to band registration is a challenge with the multispectral imagery, because of the hardware configuration (multiple optics), close distance to targets (e.g., flying at 25 – 30 m above ground level), and the varying distance to target within an image as is the case with trees. Rather than use spectra or indices computed on a pixel basis, we often extract regions of interest representing each plot, and use plot means to generate spectra and indices. In our continued development of UAS-based remote sensing platforms, we are evaluating hyperspectral imagers, and the use of LIDAR for estimating biomass.

Table 1. Examples of research using UAS

Research Project	Outcomes	Use of remote sensing
Early detection of frost in wheat	Detect and spatially map frost damage in wheat near flowering, so that growers can objectively decide whether to cut all or portions of the crop for hay.	Acquire and analyse libraries of reflectance spectra, fluorescence, canopy temperature, and yield.
Canopy N status for pears	Provide estimates of canopy N in pears, so that growers can refine fertiliser applications to maximise fruit quality.	Acquire and analyse datasets of reflectance measurements at leaf and canopy scales. Evaluate CCCI (Fitzgerald et al. 2010) and other vegetation indices relative to leaf N concentration.
Effects of Elevated CO_2 on grains	Improve our understanding of elevated CO_2 and extreme heat events on grain production and quality.	Acquire and analyse a suite of ground-based remote sensing and proximal measurements. Use to characterise crop traits such as water use efficiency and N use efficiency.

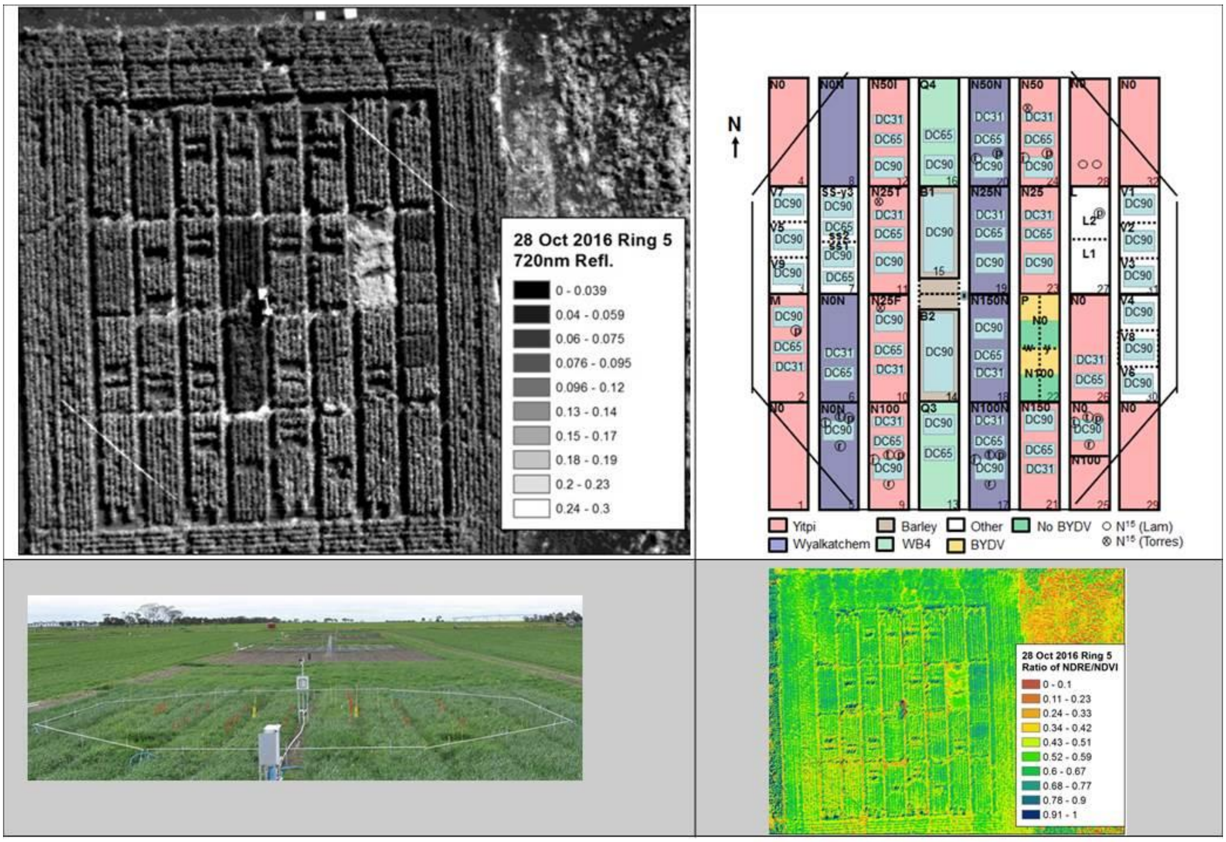

Figure 1. The AgFACE experiments (Mollah et al. 2011) are an example of research utilising UAS as a platform for research grade cameras. Carbon dioxide is injected over the canopy (lower left) in rings that contain a number of experimental plots (upper right). High spatial resolution (<5cm pixels) multispectral imagery is flown to generate reflectance images for 550, 660, 710, 720 (upper left), 730, and 810m. The 660, 720 and 810 nm reflectance images are used to generate vegetation indices related to canopy N (lower right).

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