

Recent Application of Scanning Technologies to Agricultural Systems



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Key Findings

In crops & pastures

1. Active optical sensors (AOS) are an effective photosynthetically-active biomass (PAB) assessment tool (cereal crops: emergence – head fill; pastures: 0 - ~3000 kg DM/Ha).
2. Users are unlikely to get an absolute calibration applicable for all times and all crops but AOS are good for day-by-day calibration and/or extending a few point measures to extensive surveys.
3. AOS as point-sensors can be used to calibrate remotely-sensed imagery allowing users to convert and NDVI (or PCD- simple ratio) image to a map of PAB.
4. AOS can be used with dGPS/dataloggers to conduct field surveys of PAB in crops and pastures.
5. Pasture PAB maps can be augmented using 3rd-party quality indicators- eg livestock tracking- bulk versus digestibility windows.

In vineyards

6. Data from AOS can provide maps of vine vigour. However utilizing single-band (as opposed to band ratios) data from AOS allows you to extend measurements to surface detection- eg- this is a useful tool for on-the-go characterization of grapevine architecture.

Introduction/Background

Airborne and satellite images offer a synoptic view of agricultural fields and can be readily converted into maps depicting indices (eg NDVI or PCD/simple ratio) that are related to PAB. However acquisition of satellite and airborne imagery is limited by cloud cover and/or availability of platform when suitable operational windows (eg crop stage, availability of ground staff to coordinate calibration, plant cuts etc) occur. Moreover, the data are un-calibrated, and application of imagery to change detection is limited to qualitative assessment. AOS can, by their definition, be operated irrespective of illumination conditions (including day/night). They can be used as hand-held optical sensors for PAB assessment or collection of calibration data for remotely-sensed imagery, or can be integrated with other on-ground sensors (eg EM38) configured with GPS/dataloggers to measure and map PAB in their own right. Furthermore, in VSP-trellised vineyards, where overhead remotely-sensed images struggle to delineate the relatively thin vine profile from a large inter-row space (even worse if the inter-row is actively growing), then on-ground AOS and passive imaging sensors can be used to measure and map descriptors related to vine canopy architecture.

This presentation summarizes a number of applications of AOS, as well as other passive optical scanning sensors currently being investigated by the Precision Agriculture Research Group at UNE.

Overview

General - AOS

- AOS are 'active' because they emit their own light and use detectors to sense the reflected radiation from this light
- AOS generally use pulsed light sources and 'synchronous detection' to allow them to select out the reflected light from their integrated source against the background light. This enables them to be used under any (including varying) light conditions
- The AOS' radiation reflecting back off a plant will vary with distance to plant (inverse square law) hence the AOS rely on band ratios (eg NDVI) which (over a fixed range) will be invariant. However, accessing the raw, single-band reflectance data provides a neat opportunity to employ AOS as a proximity, as well as PAB sensor.

Application to Pastures

- The overall objective of this activity is to validate CSIRO's Pastures From Space (PFS) pasture growth rate (PGR) algorithms for perennial pasture systems on the Northern Tablelands of New South Wales.
- Much of the validation work for PFS has to date been undertaken in southern Australia where grazing rotations are longer and paddock sizes larger. In these areas visual assessments combined with validating cuts in pasture cages have proven an effective means of validating PGR. Our fieldsites have significantly shorter grazing rotation intervals, relatively diverse terrain and smaller paddocks which preclude the use of standard PGR validation strategies.
- An AOS (a CropCircle unit- Holland Scientific USA) was tested on sown perennial fescue (*Festuca arundinacea*) at on the Northern tablelands of New South Wales.
- The CropCircle sensor was operated in two configurations; (i) manually for calibration with biomass cuts and (ii) mounted on an ATV (quad bike) and connected to a differential global positioning system (DGPS) and data-logger (Trimble Sunnyvale CA USA) for on-the-go sensing (Figure 1).



Photograph of the CropCircle (red) unit showing pulsing LED's located in the top of the detector head (note, only red radiation emitted by the LEDs is visible) and dual photodetectors below.



Manual deployment of a CropCircle unit.



ATV-mounted CropCircle (with GPS and datalogger) for on-the-go surveying.

Figure 1.

- To examine the correlation of the CropCircle sensor response to pasture biomass, the CropCircle operator pivoted the downward-directed sensor 360° around a central point (on a horizontal plane). Four 0.25 metre square (square quadrants 50cm x 50cm) square cuts were then taken inside this circle at the four compass points.
- The CropCircle was then mounted to the quad bike and transects of the selected paddock undertaken.

- The relationship between pasture biomass in kilograms of dry matter per hectare and CropCircle generated NDVI for an October (2007) sampling is shown in Figure 2. The NDVI points between 0.10 and 0.20 are predominantly bare soil. The NDVI 'saturates' for values greater than ~0.45, corresponding to dry matter values in excess of 3000 kg/ha. The measured dry matter explained 95% of the variance observed in the CropCircle response.

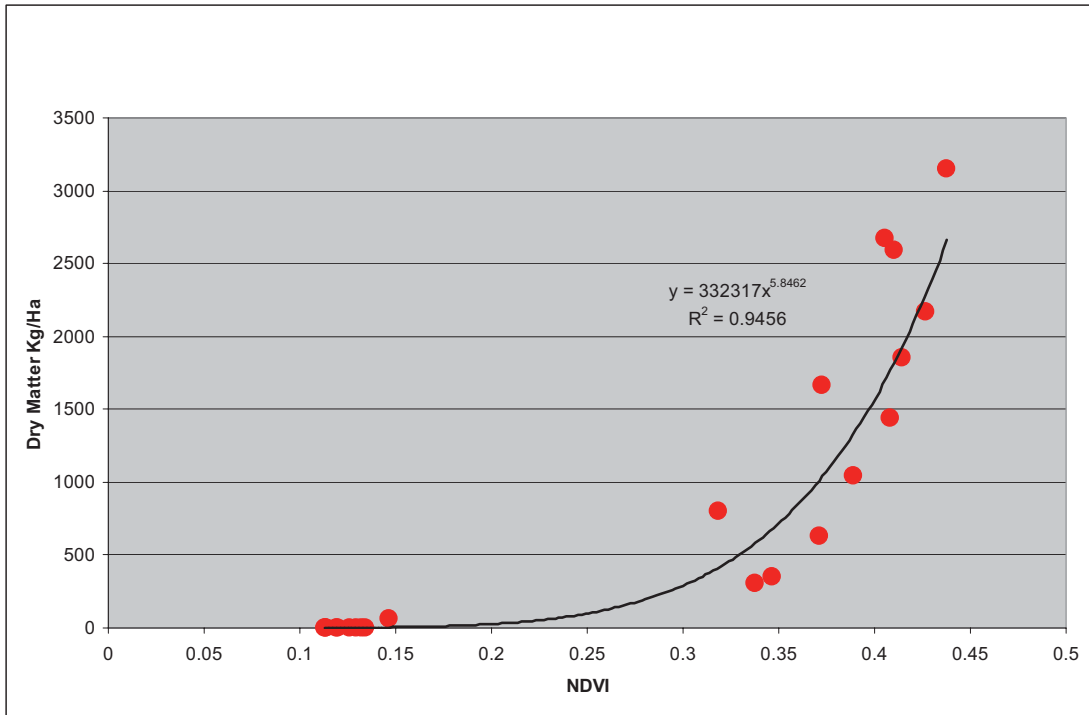
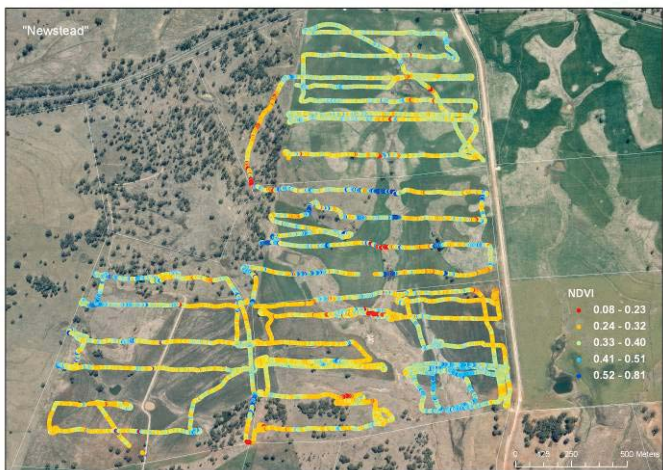
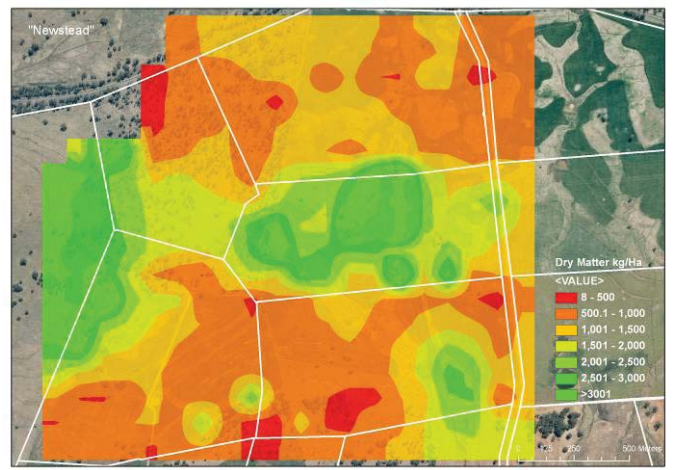


Figure 2. CropCircle-derived NDVI as a function of dry matter (kg/ha) for October 2007 cuts.

- Figure 3 depicts the Crop Circle NDVI data (October) as recorded in survey mode, the subsequently converted biomass data (using Figure 2) and a map is interpolated by applying an inverse-distance weighting surface interpolation to the point data.



(a) Predicted dry matter (kg/ha) map of 4 paddocks derived from calibrated NDVI survey data



(b) Interpolated surface of predicted biomass (kg/ha) created using inverse-distance weighting of survey data points

Figure 3.

- Work is now in progress to mount the AOS on a low-flying fixed-wing aircraft and an unmanned autonomous vehicle (UAV).
- We are also augmenting the basic AOS PAB data using the diurnal grazing behavior extracted from GPS cattle tracking collars to see if we can infer indicators of pasture quality.

Application to crops

- Work is underway to calibrate AOS data (CropCircle) for use in crop evaluations; specifically PAB and crop height up to head-fill stage, and to apply the AOS response versus PAB or crop height to calibrate airborne/satellite imagery.
- An example of crop height calibration data for Triticale at late-tillering and grain-fill is given in Figure 4.
- The AOS response varies with phenological stage (especially during senescence) however at any given time, the underlying plant height explains >80% of the variance observed in the AOS response.

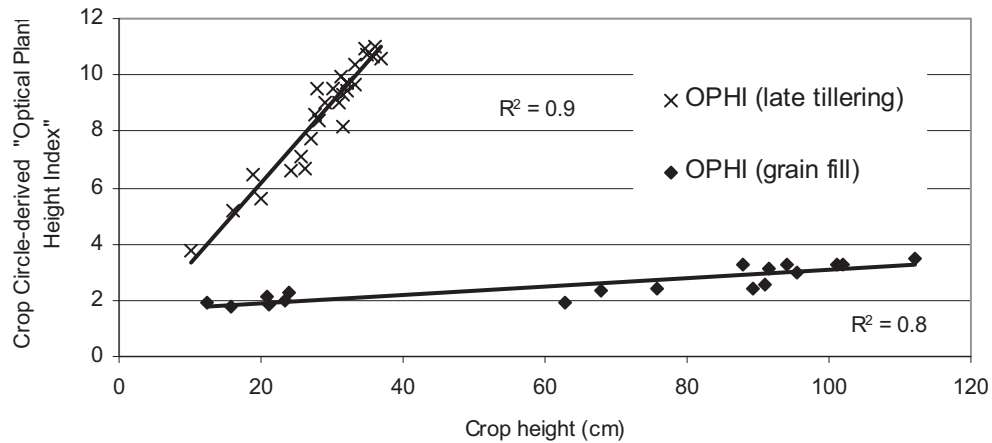


Figure 4. CropCircle-derived plant height for Triticale at 2 stages of development.

- This data was subsequently used to convert an airborne image (NDVI) into a plant-height map for a field trial site (Figure 5).

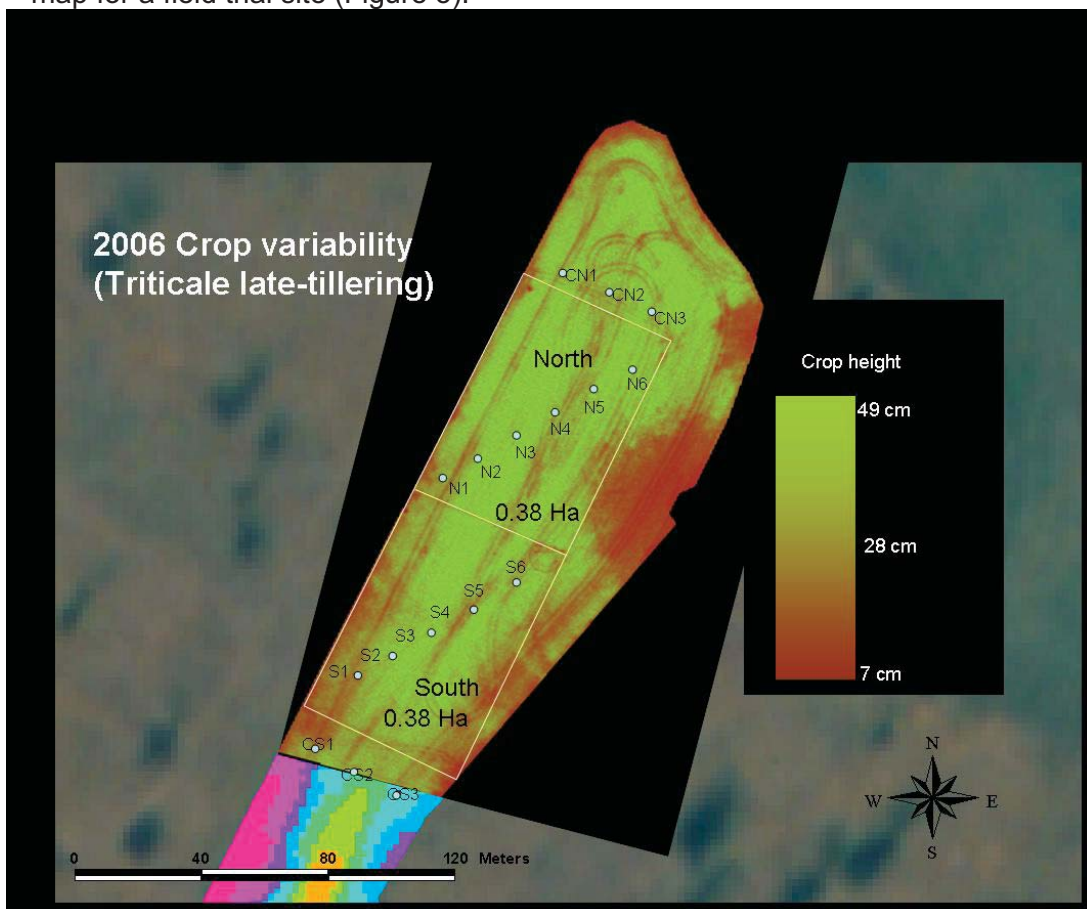


Figure 5. Crop variability (late-tillering Triticale) superimposed on EM38 and aerial photograph

Application to Vineyards

- "Grapesense" is a passive imaging unit developed by staff of Lincoln Ventures Ltd, Hamilton, New Zealand. It is an on-the-go imaging device that captures, approximately 5 times per second, side-looking images of vine canopies. The vine canopy is contrasted against a uniform background and on-board software immediately analyses each image by counting the relative numbers of vine pixels (ie non-background pixels) and the number of background pixels (Figure 6). With each image the computer calculates a value of vine porosity (the ratio of non-vine to vine pixels) and, when operated in conjunction with a differential global positioning system (DGPS) and data-logger, a map of vine porosity can be produced (Figure 7).



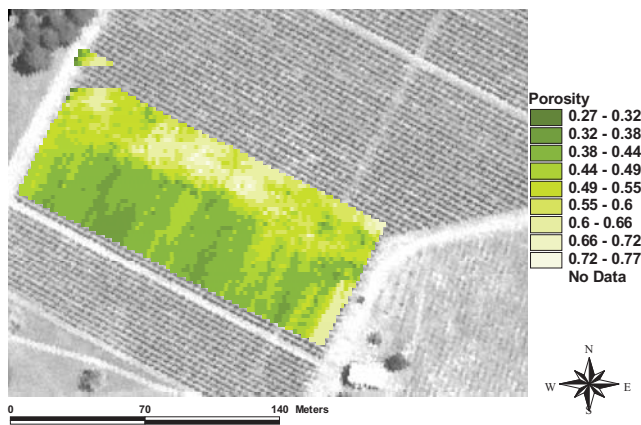
Side view of the assembled Grapesense unit.



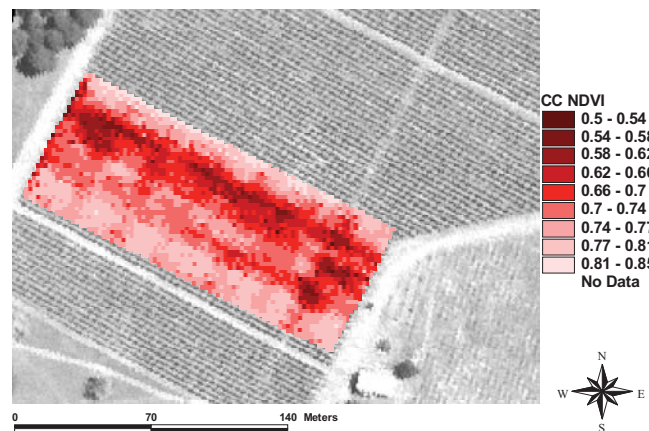
View of the vines as 'seen' by Grapesense. Vine leaves are clearly contrasted against the background and the computer classifies vine and non-vine pixels to calculate a value of porosity.

Figure 6.

- The project set out to compare the response of the Grapesense with a side-looking CropCircle unit.
- An example of Grapesense Porosity map and a CropCircle NDVI map is given in Figure 8. A comparison of these two maps indicates that where the vine porosity is relatively high the vine NDVI is relatively low. This is consistent given that a higher vine porosity is indicative of lower leaf density and thereby lower NDVI values.



A map of vine porosity of a block of c.v. merlot, at veraison 2005. The vines were trellised using a VSP configuration.



An NDVI map of the same block of c.v. merlot as, created using CropCircle. Measurements were acquired by sensing the North side of the vines. Note the vine row direction is approximately SE →NW.

Figure 7.

- Grapesense or CropCircle data can be used to augment vine performance measures. Figure 8 is a plot of measured Crop Circle NDVI and yield for 60 vines sampled within the mapped region of Figure 7. Interestingly, the data of Figure 8 do not form a curve but instead occupy a region bounded by a maximum observed yield envelope (marked as a dashed red line) between vine yield and Crop Circle NDVI.

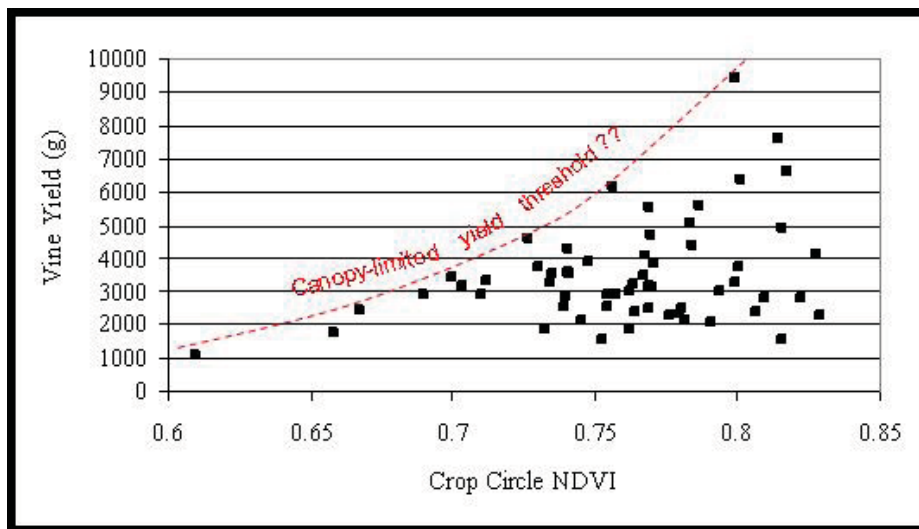


Figure 8. Plots of actual 2005 vine yield versus CropCircle NDVI (at harvest) as measured on the NE side of the vines. A curve specifying the envelope of maximum observed yield is given as the solid line.

- Current research, however, is focused on extracting accurate descriptors of canopy architecture using the single-band reflectance (inverse-square law) data generated by the CropCircle AOS (Figure 9).

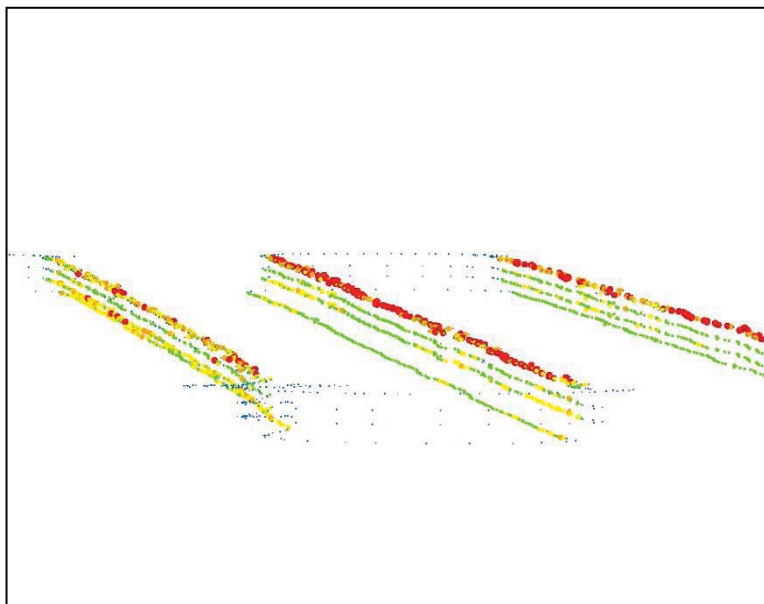


Figure 9. Vine canopy shape profiles for 3 adjacent rows of cv. Merlot as determined using a scanning array of three vertically-positioned (side-looking) and three horizontally-positioned (downward-looking) CropCircle sensors. Red indicates larger canopy volume, green indicates smaller canopy volume.

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John-Paul Praat
Kenji Irie

NOTE: use of commercial product trade names, for example GrapeSense and CropCircle does not constitute an endorsement of these specific products.

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