New methodology to measure small plot research trials using drone imagery.

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Key messages

- When crop responses to treatments are highly variable, drone imagery can be an efficient method for measuring crop growth.
- Crop ground cover measurements on individual plots using drone images provide superior information compared to manual plant counts.
- Drone imagery can provide data that would previously require destructive measurement techniques.

Introduction

The use of drone imagery to monitor crop growth and performance has become more common in recent years. However, the potential of this technology for gathering data in small plot research has not been widely adopted. The use of drone imagery on soil water repellence (SWR) research trials during the 2017 season was investigated to determine whether the drone imagery can be used to collect data for plot responses that are difficult to achieve by conventional techniques.

Water repellent soils are common throughout the higher rainfall areas of south-west Western Australia. Soil water repellence (SWR) can cause significant reductions in plant establishment and crop vigour leading to reduced yield. A common symptom of SWR is delayed or patchy establishment of crops. This variability in crop establishment, even after SWR amelioration techniques have been implemented, causes high levels of within plot variability which can significantly reduce the reliability of field measurements such as plant numbers, plant vigour, tiller numbers and crop phenology. It is not unusual for seedlings to emerge over an eight week period or longer within the same plot.

Regular collection of high resolution drone images can be used to monitor crop growth over time. This paper summarises what has been learnt during these investigations during the 2017 season.

Method

Three trial sites at North Kojonup, South Kojonup, and Corrigin were selected as focus sites for drone imagery. The North Kojonup has been looked at in more detail and will be the focus of this paper. It is a replicated site that was established in 2015 to investigate and compare the various agronomic options to address SWR including deep tillage, wetting agents, and on-row sowing (Table 1). The soil type is a gravelly sandy duplex and was sown to Scepter⍦ wheat on the 9th May 2017.

Table 1. Treatments for North Kojonup trial site.

Treatment	Description
Control – off-row seeding	No wetter applied, seeding row between previous seasons rows
On-row seeding	No wetter applied, seeding row on previous seasons rows
Banded wetter – off-row	Wetter banded on furrow following press wheel, seeding row between previous seasons rows
Banded wetter – on-row	Wetter banded on furrow following press wheel, seeding row on previous seasons rows
Banded wetter with seed	Wetter banded on furrow following press wheel, seeding row on previous seasons rows
Blanket wetter – 2015, 2017	Full coverage blanket wetter post sowing every second year
MBP – no pre-emergent	Mouldboard plough (2015), no pre-emergent herbicide applied post seeding
MBP – pre-emergent	Mouldboard plough (2015), pre-emergent herbicide applied post seeding to suit crop rotation at label rates
OWP – no pre-emergent	One-way plough (2015), no pre-emergent herbicide applied post seeding

OWP – pre-emergent	One-way plough (2015), pre-emergent herbicide applied post seeding to suit crop rotation at label rates

Immediately after sowing permanent Ground Control Points (GCP's) were established in each corner of the three trials using a differential GPS (DGPS) system to enable accurate site monitoring over time (Figures1a-d). At this time the first set of drone images were obtained to provide a background image for the site and topographical data. Regular drone images were collected at about three week intervals at an altitude of 20 m which provided images with a 2-3 cm Ground Sample Distance (GSD). The high resolution images were captured using the RGB camera on the DJI Inspire® drone (www.dji.com) plus a MicaSense RedEdge® multispectral camera (www.micasense.com) also fitted to the drone. The RedEdge® camera provides accurate multi-band data for agricultural remote sensing applications. It uses 5 discreet bands (Blue, green, red, red edge, near-infrared) when capturing images. Images were captured at an 80% overlap to provide sufficient tie points for processing of images. Prior to each flight a Calibrated Reflectance Panel (CRP) image is taken. The calibration data is provided as an absolute reflectance (a value between 0.0 and 1.0) in the range of 400 nm to 850 nm (in increments of 1 nm).

Figure 1. Examples of procedures used to capture drone images. a) Ground Control Point, b) differential GPS point creation, c) DJI Inspire-1 fitted with RedEdge camera, d) example of Calibrated Reflectance Panel for NIR.

Results

At the time of sowing it was thought that a range of information could be gleaned from the drone imagery, such as plant counts, ground cover accumulation, crop volume and crop height. However, it was quickly determined that the pixel size was too large to accurately measure plant number and that the collection of good ground cover data was more useful due to the variability in plant emergence.

Ground Cover

The regular images enabled us to monitor the ground cover from sowing to flowering for every plot (Figure 2). Using this information we calculated the percent ground cover for the whole plot to show the effectiveness of the various SWR amelioration treatments at different times during the season. For example, the 4 tillage treatments had less growth than all other treatments except the Control for the first seven weeks after sowing (WAS). By the 28th June (8 WAS) the four tillage treatments had similar ground cover to the other treatments because they were able to continue growing during the dry period in June when other treatments did not (Table 2).

It is also possible to see the increased efficacy of pre-emergent herbicide on the ground cover of the mouldboard plough (MBP) and one way plough (OWP) tillage treatments. Where herbicide was applied to MBP and OWP both treatments had a reduction in ground cover compared to where no herbicide was applied indicating some detrimental effects. While not significant, this trend continued through until full canopy closure. Another example of using drone derived data in Table 2 is that the benefits of on-row seeding on crop emergence can be seen by 8th June, but this treatment did not recover after the dry June period as well as other treatments. This relationship between on-row seeding and soil moisture would not have been recognised without the drone imagery.

Table 2. Ground cover proportion (%) as calculated from drone imagery. Statistical difference to the Control shown as; LSD 1% = **, LSD 5% = *, LSD 10% = $^{\#}$.

	Drone flight					
Treatment	**8th Jun**	**28th June**	**18th July**	**6th Aug**	**28th Aug**	**2nd Oct**
Control – off-row seeding	13.3	11.1	35.3	34.5	54.1	85.3
On-row seeding	33.2**	27.4*	48.9*	63.8**	81.7**	94.7**
Banded wetter – off-row	26.8*	25.3*	62.5**	72.5**	90.6**	98.1**

Banded wetter – on-row	32.2**	26.6*	57.8**	71.1**	89.4**	96.5**
Banded wetter with seed	42.9**	40.3**	64.3**	82.8**	91.5**	97.5**
Blanket wetter – 2015, 2017	24.1*	22.2#	49.6*	62.6*	85.8**	96.3**
MBP – no pre-emergent	19.5	24.3*	62.4**	68.3**	89.7**	97.3**
MBP – pre-emergent	16.8	20.0	56.2**	64.6**	87.4**	96.7**
OWP – no pre-emergent	20.6	25.1*	59.3**	73.9**	93.7**	97.9**
One-way plough std pre-em	16.7	21.7	62.0**	67.1**	86.8**	96.9**
**LSD 1%	13.7	17.6	18.3	28.8	15.1	3.4
*LSD 5%	10.0	13.0	13.3	21.0	11.0	2.5
#LSD 10%	8.2	10.7	11.0	17.3	9.1	2.1

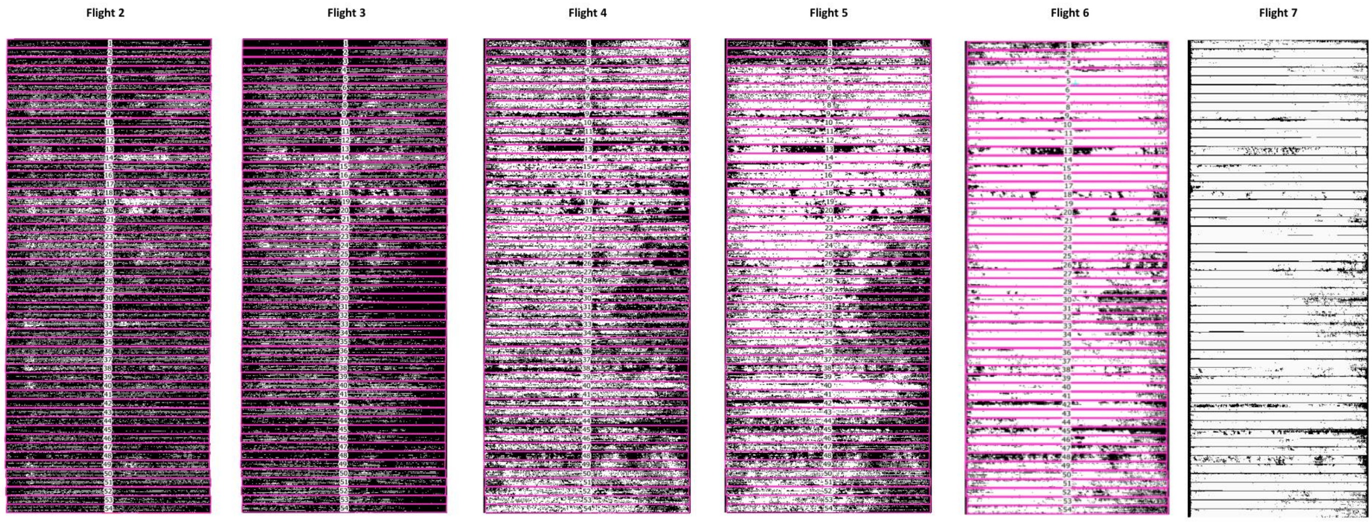

Figure 2. Sequence of images showing ground cover for each plot from 8th June until 2nd October 2017. Green leaf area is represented as white in the images, with black being the soil in the background.

NDVI

The NDVI data was less straightforward than the ground cover results and requires more careful interpretation. Similar to ground cover, NDVI of the tillage treatments started slowly but eventually caught up, on-row sowing was good during establishment but suffered when dry in June, and wetter banded with the seed enabled the crop to establish faster than the other treatments (Table 3). Ground cover accumulation seems to be a better measure of crop performance than NDVI, especially between crop emergence and flag emergence. The average NDVI data per plot shows less differentiation between treatments than ground cover. Once canopy closure is approached then the NDVI values are superior for monitoring crop health. For example, at the last image capture date the NDVI for the MPB and OWP treatments did not decline as much as the other treatments relative to the control. This indicates that these tillage treatments had a healthier crop and was accessing more soil water than other treatments.

Table 3. Plot NDVI as calculated from drone imagery. Statistical difference to the Control shown as; LSD 1% = **, LSD 5% = *, LSD 10% = #.

	Drone flight					
Treatment	**8th Jun**	**28th June**	**18th July**	**6th Aug**	**28th Aug**	**2nd Oct**
Control – off-row seeding	0.210	0.179	0.173	0.401	0.615	0.454
On-row seeding	0.246**	0.287*	0.252*	0.533*	0.722**	0.525*
Banded wetter – off-row	0.231*	0.270*	0.339**	0.564**	0.749**	0.523#
Banded wetter – on-row	0.243**	0.282*	0.310**	0.554**	0.742**	0.498
Banded wetter with seed	0.265**	0.349**	0.347**	0.622**	0.760**	0.539*
Blanket wetter – 2015, 2017	0.225	0.254#	0.263*	0.522*	0.732**	0.523#
MBP – no pre-emergent	0.206	0.247#	0.360**	0.551**	0.762**	0.573**

MBP – pre-emergent	0.202	0.226	0.311**	0.534*	0.756**	0.572**
OWP – no pre-emergent	0.213	0.260*	0.333**	0.569**	0.773**	0.551*
One-way plough std pre-em	0.203	0.238	0.351**	0.539**	0.744**	0.541*
**LSD 1%	0.027	0.110	0.107	0.137	0.082	0.099
*LSD 5%	0.020	0.080	0.078	0.100	0.060	0.072
#LSD 10%	0.016	0.066	0.064	0.082	0.049	0.059

Canopy volume

Once the initial site bare ground elevation and site topography has been determined after sowing, it is possible to extract vertical height data from the subsequent images. Using this digital elevation data a three dimensional surface model can be produced of the whole trial site. With the higher resolution drone imagery this can be sensitive enough to pick up differences in height of individual plants. A surface model has been produced by Precision Agronomics Australia for the North Kojonup site with a still image of the 3D model shown in Figure 3. Using this height data, it is possible to calculate the volume under the surface of the 3D model for any particular area with software such as Pix4Dmapper® (www.pix4d.com). For example, the off-row sown Control indicated by "A" in figure 3 has a plot canopy volume of 9.57 m^3 whereas the neighbouring plot with wetting agent sown with the seed ("B") has a canopy volume of 26.3 m^3. The corresponding grain yields for plots "A" and "B" are 2.95 t/ha and 3.86 t/ha respectively.

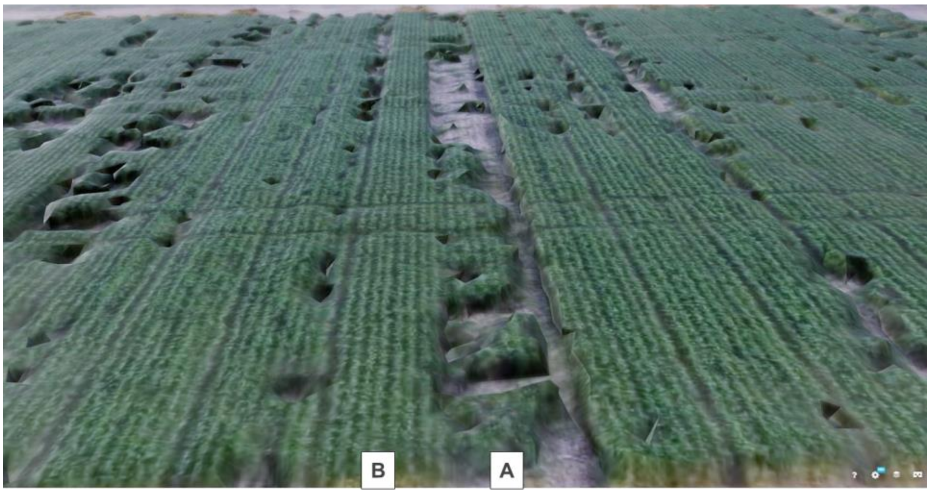

Figure 3. Partial view of three dimensional surface model of North Kojonup site. Plot "A" = Control - off-row sown; Plot "B" = Banded wetting agent with seed. The surface model created from digital elevation data using Pix4Dmapper software for this site can be viewed at sketchfab.com/models/8feb647dd7024a00aad4f54868957cfe

Spot sampling

The high resolution NDVI images with DGPS accuracy can be used to select specific locations with plots that either require further investigation or can be reference samples to calibrate or interpret the drone images, such as points where plant growth was unusually patchy or unusually good. For example, through the use of these images in 2017 it was discovered that patches of barley straw and chaff that were burnt following in the 2015 season, influenced plant emergence and vigour during the 2017 season. This effect would not have been identified without the use of the drone imagery and has resulted in a change of harvesting practice for these multi-year trial sites.

Using the NDVI images at North Kojonup four small areas with consistent crop performance per plot were located using the digital images and identified in the field with small plot markers after flowering. These four sampling areas cover a range of crop growth responses and were physically sampled and taken back to the lab for further analysis. At the time this paper was written, the processing of these samples was continuing. Using these georeferenced sampling points we can accurately return to the same position in the plot in following seasons and monitor treatments responses over multiple seasons.

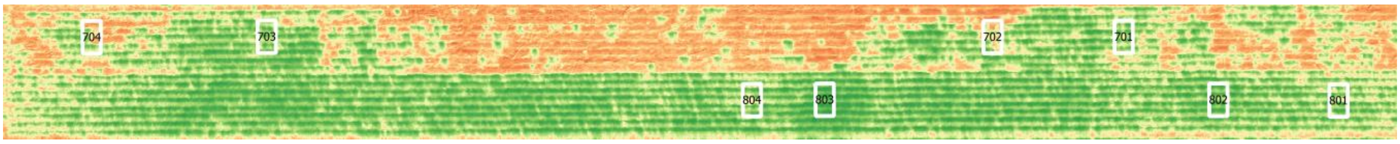

Figure 4. Partial view of NDVI image captured 6th August showing physical sampling locations for plots "A" and "B" as described in Canopy Volume section above.

Conclusion

The project is in the process of collecting physical field data for a range of observations which will be compared to the drone acquired data to determine the level of correlation between in-season measurements obtained by drone and grain yield, grain quality or harvest index.

The use of drone imagery to collect data and monitor crop performance at a plot or sub-plot level has advantages over traditional field sampling. The drone images can be used to identify targeted sampling locations within a plot, evaluate crop uniformity, or provide actual data of crop performance without needing to enter the plot area. These drone images have also been used to identify potential experimental problems with trial management, such as stubble management at harvest.

Our results showed that using RGB images from drones to monitor canopy cover during the vegetative phase of growth and NDVI images from canopy closure to crop senescence is a superior method to random sampling in the field for measurements such as seedling establishment and vigour. This is particularly important in the case of small plot trials where the responses to treatments are very variable, such in the case of SWR trials. For trial sites that are highly variable, such as SWR, other soil amelioration treatments or even crop disease treatments, using drone imagery to monitor treatment effects can provide a better understanding of treatment responses than random sampling.

Key words

Drone imagery, NDVI, ground cover, non-wetting soil, water repellence.

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