APPLICATION OF AERIAL IMAGERY TO ANALYSE ON-FARM TRIALS

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Abstract

Aerial imagery, using a standard four-band multi-spectral video, was taken of an on-farm wheat variety strip-trial in southern Queensland in 2001. The image was explored to highlight within-strip and within-field variability in crop biomass and performance. A good correlation was found between NDVI at flowering and final grain yield ($r^2 = 0.77$; $n = 10$), suggesting that the image could provide a surrogate measure of yield variability. Transects taken through the centre of each variety strip provided a useful indicator of within-row variability, although spatial correlation was high. Coefficients of variation ranged between 12 and 20% for the variety strips, which suggested that much of the observed variation was due to random effects. Yield differences at harvest between varieties were modest, but pseudo-replication analysis could provide a useful means of determining what might have been an optimal strip length.

Introduction

Aerial imagery is increasingly becoming a critical spatial data acquisition tool for farm managers and agronomists to identify within-field variation, and to improve the spatial management of this variability. Key advantages over satellite-derived imagery include a higher resolution, a rapid turn-around from image acquisition to image interpretation, and the opportunity to obtain data on demand. Products derived from these images can provide multiple spatial and temporal indicators of growth. These include NDVI (normalised differential vegetation index), greenness, biomass estimates, yield estimates, and stress indices.

An added use of aerial imagery is in the site location and design of on-farm experiments. Typically, these experiments are sited to minimise variation within treatments, and blocks remove any confounding due to within-field variability. Opportunity is provided through aerial imagery to more effectively site on-farm experiments. On-farm experimentation, in concert with precision agriculture technologies, is increasingly recognised as a useful way to identify local responses (Bramley *et al*. 1999). However, the biggest disqualifier of on-farm experiments is ensuring localised site effects are not confounding the effects of treatments.

Site placement, based on variability, could be improved through the use of aerial imagery. Our goal was to explore aerial imagery as a surrogate indicator of field variability in order to improve the siting of on-farm experiments.

Materials and Methods

Site location and sowing

The trial location was located just north of Yelarbon, southern Queensland (150.74°E, 28.39°S), on a grey vertosol (Isbell 1996). A wheat-on-wheat rotation ensured that a full profile of moisture was present at sowing on 5th June 2001. Urea (46% nitrogen) was applied prior to sowing at 50 kg/ha, while an additional 40 kg/ha of zinc-coated ammonium phosphate (Starter-Z) (380/16/2/1 w/w equivalent of nitrogen, phosphorus, sulfur and zinc respectively) was applied with the seed. Seven wheat cultivars were sown at 50 kg/ha in parallel strips. An additional 3 replicate strips were sown with cv. Kennedy evenly distributed among the others varieties.

Crop growth and harvest

The site received 175 mm of in-crop rainfall. Aerial imagery was taken by SpecTerra Systems on 10th October 2001 using a digital multi-spectral video at a spatial resolution of 1-m. Four spectral channels – blue, green, red and near-infrared – were obtained at 450, 550, 660, and 750 nm respectively (Fig. 1). Crops were estimated to be 1-2 weeks after anthesis. Strips were then harvested on 6th November 2001 using a plot harvester with a 10 m width cutter bar. Strip length was 250 m. Data was analysed using ENVI (Research Systems Ltd) to assess within-row and between-row variability, and spatial correlations.

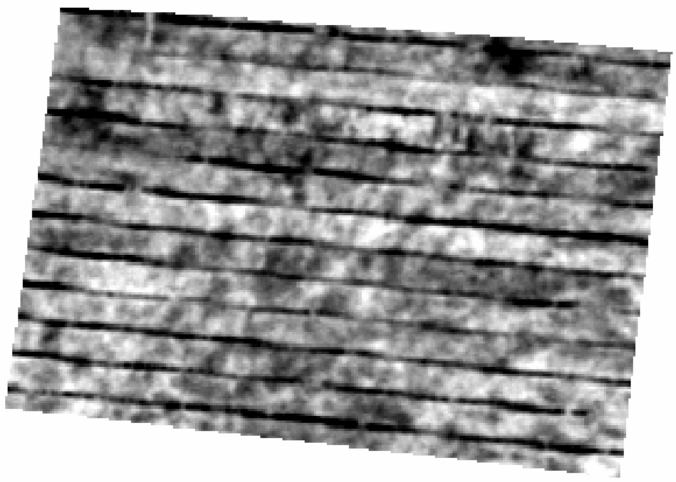


Figure 1. NDVI image taken of the McKechnie variety trial in October 2001.

Results and Discussion

Variation in grain production, varieties and NDVI

Grain varieties produced between 2.15 and 2.48 t/ha per strip with Baxter marginally outperforming the other varieties (Table 1). There was a slightly positive relationship

Table 1. Plant population, grain protein, harvested weight and gross margin at McKechnie's, southern Queensland

Cultivar	Plant population	Grain protein	Grain yield	Gross margin
	plants/ha	%	t/ha	A$
Kennedy (rep 1)	1,240,000	10.6	2277	469
Sunvale	1,391,111	11.1	2467	526
Strzelecki	1,266,666	10.4	2403	487
Kennedy (rep 2)	na	10.6	2188	455
Hartog	1,240,000	10.3	2470	505
Baxter	1,284,444	11.6	2485	547
Kennedy (rep 3)	na	10.7	2151	447
Giles	1,311,111	10.5	2374	492
Leichhardt	1,297,777	10.4	2470	510
Kennedy (rep 4)	1,306,666	11.1	2448	522

between plant population and grain yield (r=0.38; n = 8), but all strips had an average plant population greater than the recommended population of 1 x 10^6 plants/ha. Grain protein varied between strips from 10.3% for Hartog to 11.6% for Baxter; grain protein values indicated that all varieties were yield-limited by N supplies.

The correlation between NDVI and grain yield was positive (Fig. 2), suggesting that the biomass present when the image was taken was related to final grain yield (r^2 = 0.77; n = 10). Given that plant population was not confounding the final yields, NDVI was a reasonable surrogate measure of grain yield.

There was little evidence that suggested the imagery could detect differences in reflection due to wheat varieties alone. Within-strip variability was larger, to some extent, than between-strip variability. Variation between the average spectral performance for the 4 replicates of cv. Kennedy was similar, for the 4 spectral bands, as that between other varieties (Fig. 3,4).

Strip variation

Analysis of the NDVI data within each strip was used as a surrogate measure of spatial variation. Duplicate transects were taken through the centre of each strip to provide a two-dimensional picture of within-strip variation (Fig. 5). However, each row had a high degree of spatial correlation that suggested that a moving average of the pixels might provide a more useful measure of spatial variability. The highest yielding variety,

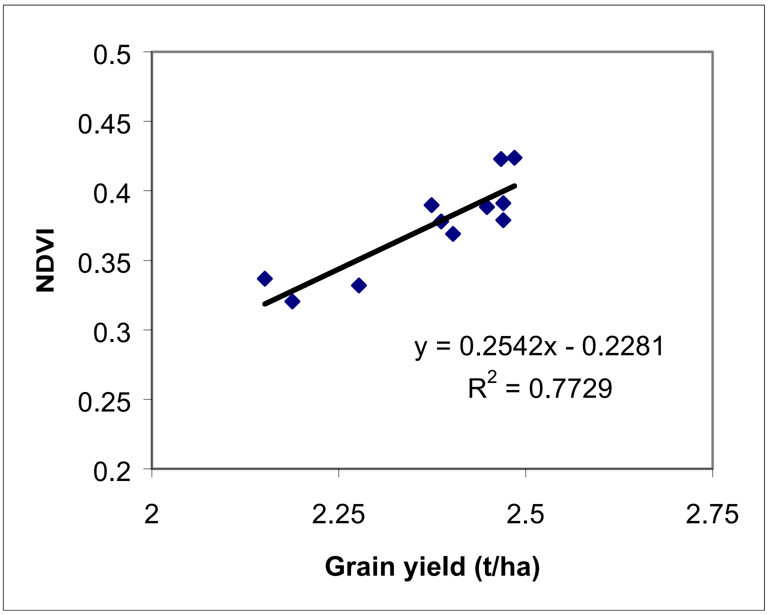


Figure 2. Relationship between NDVI and final grain yield for 7 wheat cultivars at McKechnie's in 2001.

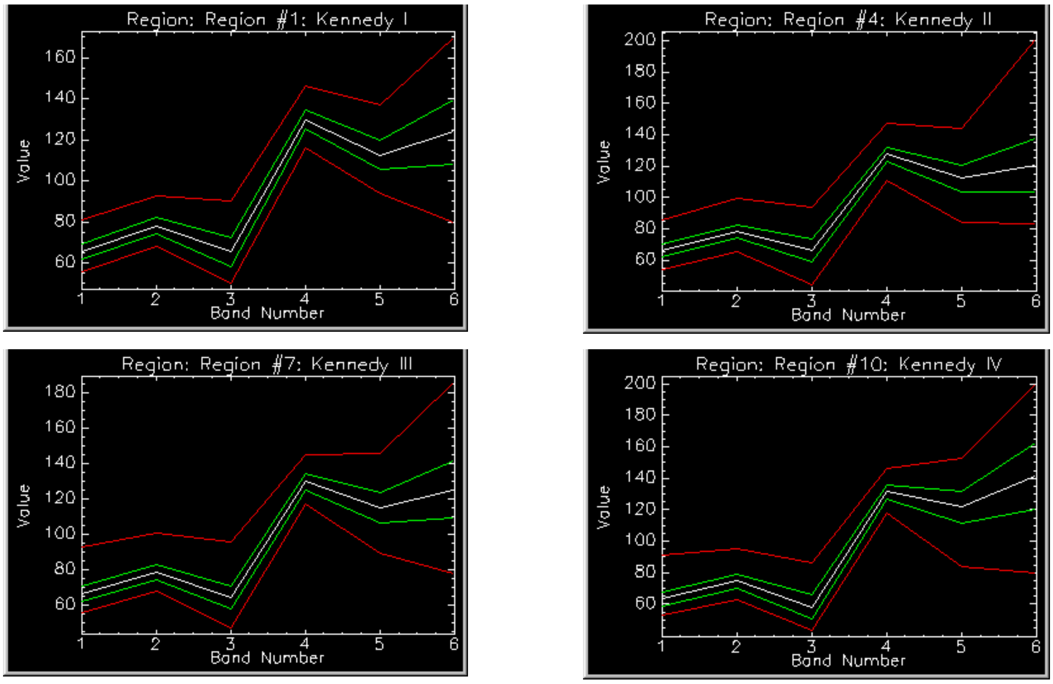
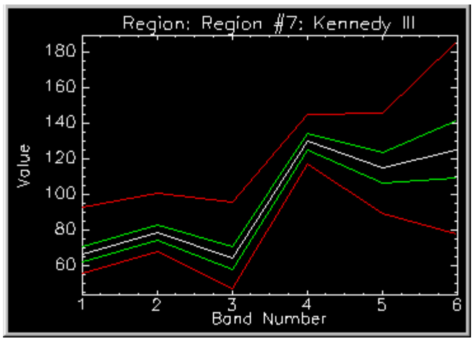


Figure 3. Statistics of reflectance values for each spectral band and the accompanying spectral signatures for the 4 replicates of cv. Kennedy.

Band	*Min*	*Max*	*Mean*	*Stdev*
1	56	93	66.42	4.11
2	68	101	78.61	4.12
3	47	96	64.46	6.46
4	117	145	129.7	4.35



Band	*Min*	*Max*	*Mean*	*Stdev*
1	51	98	60.26	4.65
2	63	106	72.89	4.85
3	39	95	54.29	6.57
4	119	163	133.8	5.21

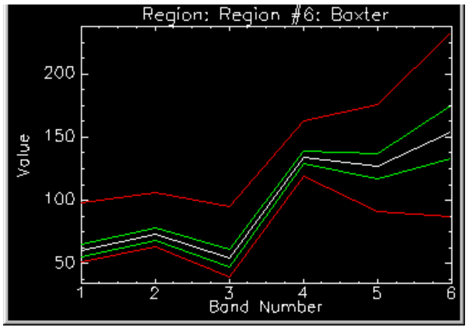


Figure 4. Statistics of reflectance values for each spectral band and the accompanying spectral signatures for the lowest (top, Kennedy replicate 3) and the highest performing wheat variety (bottom, Baxter) at McKechnie's in 2001.

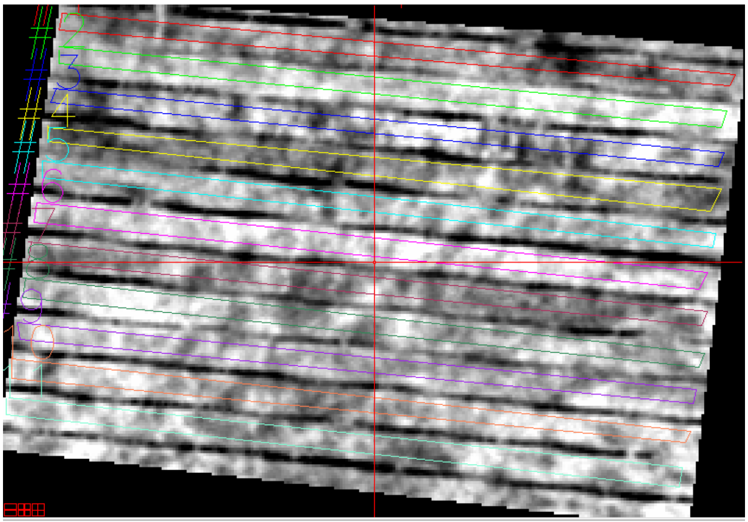
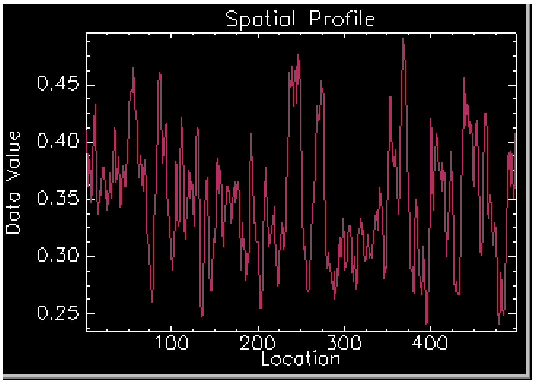


Figure 5. Duplicate transects, indicated by the twin lines within each strip, used for analysis of within-row variability for 7 wheat cultivars at McKechnie's in 2001.

Baxter, had a CV of 13% whereas the lowest yielding variety, Kennedy (rep 3), had a CV of 16% (Table 2). Mean spectral profiles for the highest and lowest performing varieties are shown in Figure 6.

Table 2. Statistics of NDVI values within each strip for 7 wheat cultivars at McKechnie's in 2001.

Variety	Min	Max	Mean	SD	CV (%)
Kennedy (rep 1)	0.13	0.47	0.33	0.06	17.2
Sunvale	0.27	0.55	0.42	0.05	11.2
Strzelecki	0.14	0.58	0.37	0.08	20.5
Kennedy (rep 2)	0.14	0.53	0.32	0.06	18.6
Hartog	0.08	0.51	0.38	0.05	13.9
Baxter	0.17	0.58	0.42	0.06	13.3
Kennedy (rep 3)	0.12	0.50	0.34	0.05	16.1
Giles	0.08	0.55	0.39	0.07	16.8
Leichhardt	0.22	0.53	0.39	0.05	12.10
Kennedy (rep 4)	0.20	0.53	0.39	0.06	16.21



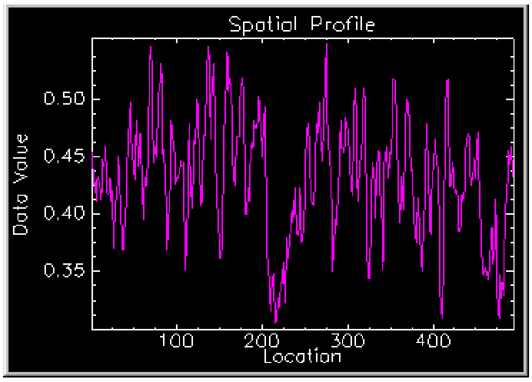


Figure 6. Mean spectral profiles determined from twin transects for the lowest (LHS, cv. Kennedy rep.3) and highest (RHS, cv. Baxter) performing wheat varieties at McKechnie's in 2001. The left side of each spectral profile corresponds with the west of the field.

Conclusions

Exploration of the on-farm trial suggests that the NDVI image can provide a useful indicator of within-field and within-strip variation. Consequently, these data can also provide a measure of spatial variability and spatial trends. Yield data gathered from a yield monitor confounds much of the spatial variation present in the field through convolution. Aerial imagery provides then a means of measuring this variation without needing to take the effects of convolution into consideration.

Although not undertaken in this study, pseudo-replication could allow one to determine the optimal length of strip required at this site. This technique splits the strips into sub-strip replicates, allowing for an analysis of variation between replicates. Further exploration of the data using this technique will assist with this determination.

References

Bramley, R., Cook, S., Adams, M., and Corner, R. 1999. *Designing your own on-farm experiments: How precision agriculture can help*. GRDC, Canberra. 28p.

Isbell, R.F. 1996. *The Australian Soil Classification.* CSIRO Publishing, Melbourne. 102p.