Application of remote sensing technologies to improve yield and water-use efficiency in irrigated peanuts

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Abstract

Remote sensing imagery of irrigated peanut crops using simple airborne digital video camera systems offers growers and consultants a cost effective technique for the assessment of 'spatial' variability in crop performance. Images of near infra-red reflectance taken from irrigated peanut crops (pivots) in southern Queensland showed major variability arising from crop stress, which was most likely a result of poor irrigation distribution and/or poor water infiltration. Near infra-red reflectance from peanut crops taken at approximately 4 to 6 weeks prior to harvest was also shown to be highly correlated with final pod yield, and offers a potential yield forecasting technique for growers and industry. The close association also allows an assessment of the magnitude of the yield deficit resulting from spatial variability (or 'yield gap').This provides growers and consultants with a useful method to calculate the economic impact of reducing the 'yield gap' in their own fields and has potential to be utilised as a strategic tool for identifying problems and improving various aspects of crop management.

Media summary

A low cost aerial remote sensing technique allows identification of spatial variability in peanut crops arising from water stress, disease and other constraints and provides a useful detection tool to improve in-season management of crops.

Key Words

Near infra-red, reflectance, aerial, imagery, spatial, variability

Introduction

Remote sensing (RS) of crops involves the acquisition and analysis of information without physical contact, via a range of sensors such as digital cameras, radar, multi-spectral scanners, mounted on aircraft, satellites or ground. Low cost airborne remote sensing is becoming more widely used in Australian agriculture, predominantly for its ability to provide a synoptic view of spatial variability in the vigour of crop plants, and thereby indicate spatial variations in productivity (Lamb, 2000). There are promising applications for this technology for the assessment and potential management of variability in irrigated peanut crops for the Australian industry. Recent research by QDPI&F personnel at Kingaroy in S.E. Queensland has developed a low-cost near infra-red (NIR), photographic technique using a digital video camera mounted in the door of a light aircraft to assess crop heterogeneity in peanut crops. This paper reports some of these findings and outlines how this technology might be used for future in-season crop management of irrigated peanuts via the identification and reduction of crop variability, and associated benefits in pod yield and water-use efficiency.

Methods

Airborne remote sensing platform

Variations in crop vigour can be remotely sensed via differential reflectance of infra-red light (around 720 nm) from areas of large actively growing biomass canopies versus areas with smaller less vigorous crops which may be affected by stress resulting from constraints such as water deficit, disease incidence, poor plant stand, etc… . A simple airborne digital camera system has been developed (G.C. Wright, unpublished data), which allows the capture of colour indexed aerial images of peanut fields/pivots. The system uses a 3CCD digital video camera (model DSR-PD100P), which is sensitive to infra-red light derived from an infra-red filter (Hoya 58mm, R72) placed over the camera lens. The camera was mounted within the modified door of a Cessna 185 aircraft, on a specially constructed frame to allow vertical shots of the ground. During the 2001/2 season a series of aerial photos were captured from a number of peanut fields/irrigation pivots in the Burnett and southern Queensland region (Coalstoun Lakes, Talwood, Texas, Inglewood). The data were acquired at a flying height of approximately 1500m producing an image resolution of approximately 1.5m per pixel. This elevation was used to ensure the entire field/pivot was captured in a single image. The imagery was captured on 15/2/2002 at which time crops were at full canopy and well into the pod-filling phase and approximately 4-5 weeks prior to harvest. Pseudo-colour images were produced by colour enhancing using an image processing software package (Adobe Photoshop), so that regions of high canopy NIR reflectance (high biomass/vigorous growth) show dark red - red colouration, and regions of lower canopy NIR reflectance (low biomass/poor growth) show yellow - green - blue colouration. The software package 'SmartClassify', distributed by Mapping and Beyond, was used to conduct supervised classification on the NIR imagery.

Ground-truthing

Pod yield samples from large areas (>150m^2) were harvested from a peanut field in the Coalstoun Lakes area of the north Burnett region, using a commercial harvester. The locations of the sample sites themselves were pre-determined using the NIR imagery from the field, such that samples were taken from representative regions characterised as "healthy" (highest local value of NIR) and "stressed" (lowest local value of NIR). After each plot was harvested, pods were placed into a mobile peanut weigh bin and weighed to determine yield per ha, using techniques described by Krosch et al. (2002).

Results and discussion

Irrigation problems associated with extremes of soil variability

NIR imagery from two peanut pivots in the Texas (Figure 1) and (Inglewood Figure 2) regions of southern Queensland provided good examples of how soil problems associated with unstable/fragile soils can cause extreme crop variability. Figure 1 shows how although the central region of the pivot was growing well and uniformly, the outer sections were extremely variable, most likely as a result of poor infiltration in the hard setting soil and uneven water distribution. The red 'veins' of the image show how the regions of active crop growth occurred in gullies where water accumulated (and presumably infiltrated) from nearby runoff from surrounding areas, which had poorly structured soil (and hence low infiltration). There was also substantial evidence that water application rates in the outer 4 pivot towers was inadequate for optimal crop growth. Based on the information contained in this image, the peanut grower has subsequently substantially modified and upgraded his pivot and reassessed the soil management for production of peanuts and other crops.

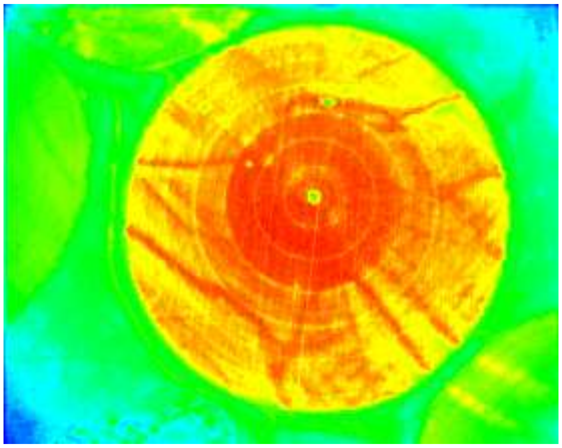


Figure 1. Peanut pivot in the Texas Qld region showing extreme crop variability associated with poor soil infiltration and distribution in the outer pivot.

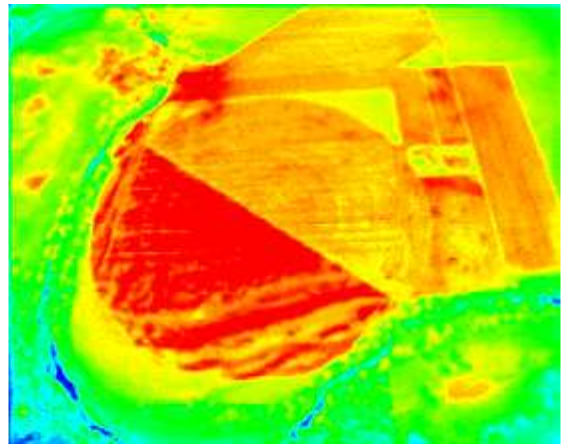
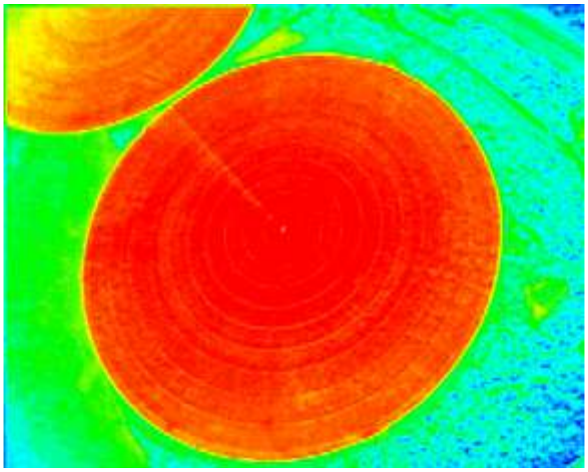


Figure 2. Peanut pivot (left half) in the Inglewood region showing crop variability associated with soil infiltration problems.

Figure 2 shows another half pivot of peanuts (lower left-hand side) with major crop heterogeneity associated with problems in water infiltration on the fragile soils which typify this region. Ground truthing at this site confirmed that hard setting soil had severely reduced infiltration of irrigation water and limited or totally halted crop growth in a number of regions of the pivot (yellow regions). Although the crop was still growing in these regions, plants were severely stunted and their yield potential substantially reduced due to these infiltration problems. Adjacent areas of severe waterlogging and greatly reduced crop growth in the same field were similarly noted when the crop was ground-truthed. The RS image shown here clearly allows a detailed assessment of the extent and position of these soil related problems, which a grower may be able to better manage for the benefit of future crops.

The pivot from the Talwood region (Figure 3) shows a peanut crop with a uniformly active growing canopy, in stark comparison to the pivots in Figures 1 and 2. There is still however evidence that the outer sections of the pivot had crop that was suffering significant stress, which presumably was associated with inadequate water supply in the outer sections of the pivot. It is known that the design capacity of some of the pivots being used to irrigate peanuts in this region is below that required to meet evaporative demand (eg in the Talwood crop, transpiration in excess of 12mm per day, or ca. 84 mm per week can occur). The use of end guns severely exacerbates this problem. The image highlights this potential deficiency and clearly indicates yield losses in the outer sections of the pivot may have occurred.



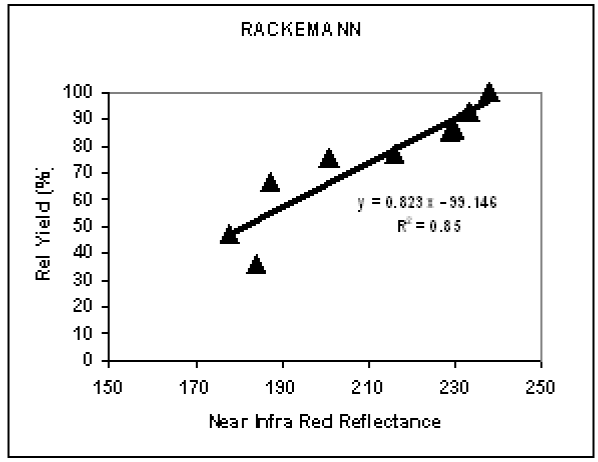


Figure 3. Peanut pivot in the Talwood region of S. Queensland showing good crop uniformity. Note the crop in the outer sections of the pivot which appears to be suffering substantial water stress (yellow patches), associated with under-watering in the outer pivot.

Figure 4. The relationship between relative pod yield and NIR measured in the crop at Coalstoun Lakes.

Quantifying the yield gap

The use of NIR imagery can assist growers and consultants in assessing the yield gap, or lost production from a paddock/pivot of peanuts. Preliminary research has shown that there is a very close correlation between the crop NIR reflectance measured 4 to 6 weeks from maturity and final pod yield (G.C. Wright, unpublished data). An example of this correlation was observed in a peanut crop from the Coalstoun Lakes area of SE Queensland, where large pod yield samples were taken in areas that differed in infra-red reflectance, based on a colour-indexed remote sensing image. A plot of relative yield (actual yield divided by the highest yield in the 'reddest' region of the image) versus NIR reflectance showed a very close correlation (r^2 = 0.85, Figure 4) and clearly shows the potential for predicting (or forecasting) pod yield based on NIR images. The same correlation has since been observed for numerous peanut crops under both irrigated and rain-fed conditions (data not shown). This relationship was also used to estimate the actual 'yield gap' arising from crop heterogeneity present in peanut fields/pivots, which is clearly highlighted from the above NIR images. An analysis of the magnitude of the yield gap in the peanut crop shown in Figure 1 was made using the empirical relationship observed in Figure 4. Initially, the NIR image was classified into 4 regions, which were based on 'training areas' specified in NIR regions as corresponding to yield areas of 100%, 80%, 60% and 40% of the potential yield, according to the relationship presented in Figure 4.

Figure 5 presents the results of this supervised classification, which can effectively be considered a peanut 'yield map' derived from the aerial remote sensing image in Figure 1. High yielding areas (near 100% yield potential) are coloured in green, while poorer yielding areas (near 40% yield potential) are coloured in red. It is clear that the central part of the pivot had high yield performance compared to the outer parts where soil/crop heterogeneity severely constrained the crop yield potential. The yield map derived from this type of imagery can also allow a simple economic analysis of the value of the yield gap observed in peanut fields/pivots arising from crop heterogeneity. The actual commercial yield harvested and gross returns from the 38ha crop shown in Figure 1 are presented in Table 1. By scaling the crops according to the yield map information, it was possible to calculate that the potential yield in the high yielding regions (green) was of the order of 6.0 t/ha (Table 1), with the potential yield gap on the 38ha pivot being of the order of 1.3 t/ha, or 49.3 t, which is equivalent to a potential loss of $40,229, based on a average grade-out price of $816/t.

The NIR images in conjunction with the above yield and economic analysis have provided a novel method to allow growers to assess and quantify the opportunity cost of crop variability. The imagery is extremely useful for identifying low performing regions of a field or pivot, and hence targeting crop inspection by growers and/or consultants to allow diagnosis of potential constraints (e.g. poor infiltration, nutrition, disease etc…). The technology also allows for the potential identification of inadequately designed and operated irrigation systems and hence could lead to significant improvements in water-use efficiency. Certainly in this case just showing the grower the NIR image and associated analysis made it a very easy decision to invest in substantial alterations. Other applications of the NIR imagery have recently been reported, including the detection and management of high aflatoxin risk regions within peanut crops (Wright et al, 2002).

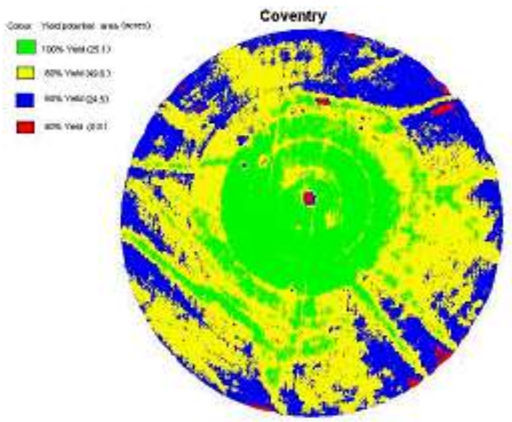


Figure 5. A peanut yield map derived from a NIR aerial image (from Figure 1) after conducting a supervised classification following the observed close relationship between NIR reflectance and pod yield (shown in Fig 4).

Table 1. Actual and potential pod yield and gross returns for a 38 ha peanut pivot as shown in Figures 1 and 5.

Actual Pod Yield on 38ha pivot (t)	178.7	Potential Pod Yield on 38ha pivot (t)	228.0
Actual Gross Returns on 38ha pivot ($)	145,819	Potential Gross Returns on 38ha pivot (t)	186,048
Actual Average Pod Yield (t/ha)	4.7	Potential Average Pod Yield (t/ha)	6.0
Yield Gap on 38ha Pivot (t)	49.3		
Yield Gap (t/ha)	1.3		
Gross Returns Gap ($)	40,229		

Conclusion

Remote sensing imagery offers irrigated peanut growers a useful tool for the assessment of spatial variability in peanut, and potentially other, crops. The research has shown that NIR images can provide growers with indicative yield maps and the likely ‘yield gap’ and resulting reduction in gross income prior to harvest. The imagery can direct crop inspection and hence the detection and early warning of water, disease, nutrient and other stresses for potential in-season management. The strong relationship between NIR and pod yield in peanut crops also suggests there is potential for using the technology as a yield forecasting tool for regional irrigated and rain-fed production with a significant potential role in other field crops.

References

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