

Remote sensing for crop variability in peanuts

On ground differences in peanut biomass between highest yielding zones – above – and the lowest yielding areas – right- matched the zones identified by the vegetation index generated from the high resolution satellite images. The pink dots represent ground sampling points.

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Satellite imagery is proving a useful tool for predicting crop vigour, maturation and yield in peanuts.

Growers, generally have a good understanding of where consistently poor performing regions of a crop occur. However, multispectral satellite imagery and field sampling guided by global positioning systems (GPS) has been shown to be an effective technology for predicting the spatial variability of crop vigour, maturation and yield within individual peanut crops. Determining the yield deficit produced by a limiting growth factor, combined with the area of crop affected, allows accurate predictions on total economic losses to be made.

Up to 60% of infrared (IR) radiation in sunlight is reflected upward (reflected energy) or downwards (transmitted energy) by the growing leaves of non-stressed vegetation. Any limitation on plant health reduces this percentage to a degree that can be measured by a number of remote sensing technologies, including high resolution multi-spectral satellite and aerial infrared (IR) imagery.

The spatial variability of plant vigour across individual peanut crops has been identified with satellite imagery, which in turn has been accurately correlated to pod yield and maturity in both dryland and irrigated crops. This information has enabled growers to formulate better harvest regimes in order to maximise quality and yield, whilst minimising the risk of aflatoxin (a toxin produced by soil-borne fungi under drought conditions at the end of the season).

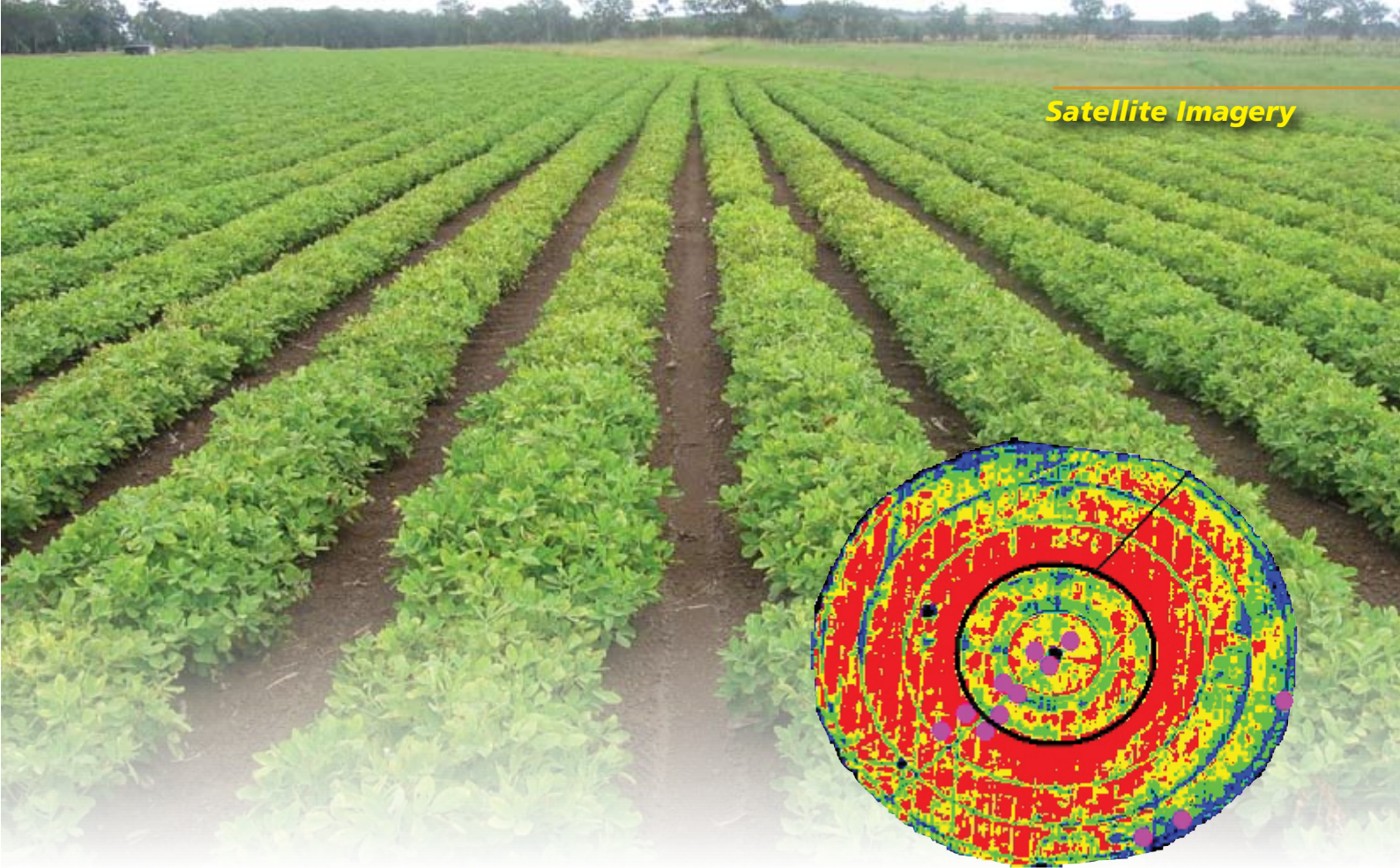
Acquisition and analysis of satellite and aerial imagery

Aerial images of a disease-affected irrigated pivot where taken on 30 April 2003, using a Sony digital camcorder mounted in the door of a Cessna 185. Digital images were geo-referenced using ground control points collected with a handheld Global Positioning System (GPS) at strategic locations around the site. This camera system only outputs one digital reflectance data value for

each pixel, so is unable to be used for band ratios or specific vegetation indices. However, images can be classified into regions of differing IR reflectance.

For satellite imagery, the American owned QuickBird satellite was selected due to its high pixel resolution of 0.6m and its multi-spectral format (blue 450- 520nm, green 520- 600nm, red 630- 690nm and near infra-red (NIR) 760- 900nm).

Imagery of the centre pivot monitored for maturity timing was acquired on 17 March 2006 near the S.E. Queensland township of Wooroolin, while the pivot displaying inefficient irrigation was acquired on 20 February 2007 near the township of Texas, Queensland. Imagery was used to develop a Normalised Differential Vegetation Index (NDVI) to remove noise errors such as those associated with shading and crop geometry.



Both the aerial IR image and the NDVI transformed satellite images were segregated into five classes of IR reflectance. The classes were then colour coded with Red indicating a high reflectance value and therefore larger crop vigour, followed by Yellow, Green, Blue and then Black indicating low vigour or bare soil.

Field validation of aerial IR and QuickBird satellite images

From the classified images, pod sampling locations were selected to represent each colour class and were located on the ground with a non-differential GPS. To compensate for the GPS accuracy of 5m, each sample location was selected within a 20m² area of homogenous colour zone. Three replicate samples of intact peanut bushes and pods were collected from two adjacent 1m lengths of peanut row.

For the harvest timing trial the grower left test strip areas unharvested around the sample locations, so that hand samples could be collected after the commercial harvest. The samples were dried and threshed to

determine pod yields. A 200g pod sub-sample was shelled and the percentage of pods having a black (i.e. mature) pericarp was used as an index of crop maturity. The maturity and yield values from each sample location were then correlated against the corresponding IR and NDVI values.

Impacts of inefficient irrigation and soil type on peanut yield and economic gains

The true colour high resolution satellite image of the Texas pivot (cv. Holt) provided useful paddock information, such as the location of wheel tracks and contours etc. However, the addition of the infrared (IR) spectral band and subsequent vegetation index (NDVI) clearly identified the spatial variation in crop vigour. A clear separation in plant vigour was observed within the area of the second irrigator wheel track where smaller plants were located, compared to surrounding irrigator runs that produced predominantly high vigour plants. This was later identified to be the result of the incorrect installation of irrigator nozzles.

Replicated ground sampling of this peanut crop, within the classified zones, produced a highly significant correlation between yield and NDVI with higher IR reflectance or crop vigour (Red) zones producing a higher yield, in this case over 12t/ha compared to 4t/ha in the Blue zones (Table 1).

Data in Table 1 shows that only 39 per cent of the crop grew at an optimum level (Red zones). At an estimated yield of 12.68t/ha this zone would have produced 107.8 tonnes. This production nearly equalled the sum of the other three zones that encompassed 61 per cent of the pivot and produced 139.8 tonnes.

Had the entire crop achieved optimum growth (Red) then the predicted total pivot yield would have been 278 tonnes or 50 tonnes more than the total predicted yield based on the measured variation within each zone. In monetary terms, this represents a potential loss of \$50,000 (at \$1000 per tonne).

While impacts resulting from the irrigator are easily corrected, other

Satellite Imagery

Table 1. Average pod yield (t/ha) measured from the replicated hand samples, the area encompassed by each colour zone and the calculated yield (t/ha) produced by each colour zone.

	Red	Yellow	Green	Blue	Black	Total
Area (%) of pivot of each zone	38.3	31.5	20.5	7.8	0.3	100.0
Area (ha) encompassed by each zone	8.5	6.9	4.5	1.7	1.4	21.9
Yld (t/ha) (calculated from hand samples)	12.68	10.31	9.18	4.31	n/a	
Total yield (t) per zone (area of each zone* hand sample yield)	107.79	71.17	41.33	7.34	n/a	227.64

Note: Black zones were not sampled as these mainly represented irrigator wheel tracks.

poor performing regions were likely to be the result of a poorer soil type. By locating, sampling and identifying the soil deficiency with this technology, an agronomist could determine whether remedial action, such as earth works, liming etc., would be a cost effective management option based on the estimate of lost production within this area.

Impacts of harvest timing on peanut yield and lost economic production

The classified NDVI image of the Wooroolin pivot identified both a large region of low crop vigour, a result of a gravelly soil type, and a similar area of high vigour, which was attributed to a heavier soil. Replicated ground samples were collected within these regions on three separate occasions, the first corresponded with the actual crop harvest (20 April 06), the second 13 days later (3 May 06) and the last 22 days later (12 May 06).

A strong relationship between NDVI value and yield was again identified, with larger more vigorous plants producing a greater yield (3.75t/ha) than the low vigour areas (2.28t/ha). The yield measured from the high vigour zone increased from 3.75t/ha to 5.3t/ha and the low vigour from 2.28t/ha to 3.11t/ha over the 22 days following actual harvest time. This was attributed to pod maturity, with high crop vigour zones in particular demonstrating a 46 per cent increase in mature pods over that time period.

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The estimated yield gain of 20.05t between actual harvest timing to 22 days later, equates to \$20,000 (at \$1000/t) and could be further increased by an additional \$23,000 if the pivot achieved uniform optimum growth (Red zones) rather than cause the regions of reduced growth potential.

Impacts of foliar disease on peanut yield and lost economic production

The temporal imaging of a Wooroolin irrigated pivot identified that the spread of Net Blotch (*Didymosphaeria arachidicola*) spores over a 51 day period resulted in nearly the entire crop being exposed to some level of infection.

The IR imagery was able to distinguish the impacts of the foliar fungal disease, by reduced IR reflectance, in some cases when no visible effects could be seen by the grower.

Hand samples taken within varying crop vigour regions, caused by disease, produced a strong correlation between pod yield and IR reflectance or in this case brightness

values, with the worst effected plants yielding less than 4t/ha in comparison to up to 8t/ha produced in the optimum Red zones..

In monetary terms, the lost production resulting from this foliar disease could be estimated at nearly \$12,000. By using this technology to determine the potential yield loss, a grower could estimate whether the application of additional fungicide treatments at \$50/ ha or \$750 for the pivot, would be a cost effective option.

The results presented indicate a number of possible applications that remote sensing and subsequent image analysis offers to cropping industries, using peanut crops as an example. These include the accurate prediction of maturity and yield variability across individual crops, a cost analysis of possible lost production from under performing areas; the in-season identification of irrigation deficiencies and other limiting constraints such as foliar diseases.

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