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15th Precision Agriculture Symposium in Australasia

Wednesday 5th and Thursday 6th September 2012

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Increasing the Adoption of Precision Agriculture in Australia

15th Symposium on Precision Agriculture in Australasia

Welcome!

This Symposium series, one of the longest running Precision Agriculture (PA) gatherings in the world, continues to uniquely showcase the breadth of PA work that is undertaken in support of the agricultural industries of the region.

It has been an auspicious year for the organisers of this event, with the ACPA evolving into the University of Sydney's Precision Agriculture Laboratory and SPAA celebrating 10 years promoting the development and adoption of PA and releasing 'PA in Practice Vol 2'. With these milestones in mind it is worth reflecting a little on the state of PA.

Across the region, it is obvious that the use of Precision Agriculture (PA) technologies and techniques continues to expand. Obviously, research and application developments are fundamental to any increase in uptake in broadacre, viticulture, horticulture and pastoral production systems. However, gaining a definitive handle on the actual uptake figures for these industries remains difficult and may well be masking the true success of the efforts of all the researchers, advisors, agencies and companies that strive to improve cropping management through PA.

In the grains industry there have been a number of surveys reported over the past few years and what is clear is that exposure to PA through workshops/conferences/field days/consultants has meant that most farmers now have an appreciation of matching management to variation in within-field production potential. A synthesis of the results in these surveys can be used to provide some 'estimates' of the current state of PA adoption by farms in that leading industry. Here goes:

- 90% would have some form of navigation assistance, 80% of these now with autosteer;
- 75% use soil sampling and analysis to diagnose causes of lower yielding areas (however they are identified);
- 60% have yield mapping capability, 30% would use yield maps in some fashion;
- 30% are using VR equipment within field, a further 20% managing nutrient changes manually; and
- 25% would have used soil conductivity/gamma mapping to some degree.

These estimates are significantly higher than those of 10 years ago and increases are expected to continue in yield mapping and VR as the financial/environmental benefits continue to be better documented, prices of inputs go up, costs of PA equipment go down and services to help design infield experiments and use PA data increase in Australia.

The presentations in this year's PA Symposium will also provide convincing testament to the fact that the development of PA as a mainstream management option is strong across many industries. Sensors, application technologies, software and management techniques will be on show.

As organisers we encourage you to participate in the discussions and networking opportunities that this unique event presents. This engagement between industry participants is what will ensure that PA is seen as a crucial, cohesive component in the process of sustainably (commercially and environmentally) managing all inputs, natural retentions and emissions across agricultural operations.

The PA Lab and SPAA teams

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Presentation program

WEDNESDAY 5th SEPTEMBER 2012

12.00pm	***Arrival & Lunch***
12.55pm	***Welcome***
1.00pm	**Soil moisture mapping**. *Jeff Walker (Monash University)*
1.20pm	**The development of precision weed sensing and spraying technologies.** *Cheryl McCarthy (NCEA)*
1.40pm	**Comparative performance of VIS/NIR sensors.** *Pip McVeagh (NZCPA, Massey University)*
2.00pm	**Applying statistics to agronomy.** *Peter Johnston (Geosys).*
2.20pm	**Industry news – Landmark**
2.30pm	***Afternoon Tea***
3.10pm	**PA in Practice Book Launch** Rohan Rainbow and Randall Wilksch *(GRDC and SPAA)*
3.20pm	**Using sensor networks to study the social behaviour of cattle.** *David Swain (CQU)*
3.40pm	**EM38 to measure soil moisture content in Vertosols: are we any closer?** *John Stanley (UNE PARG)*
4.00pm	**Mixed fortunes in crop quality sensing.** *Rob Bramley (CSIRO)*
4.20pm	**Industry news – Incitec Pivot.**
4.30pm	**Precision Ag pays – a journey of learning.** *Robert Blair (Idaho farmer and leading PA practitioner)*
5.15pm	***Close***
5.20pm	***SPAA Annual General Meeting***
6.30pm	***Drinks and Dinner: Mildura Grand Hotel, Seventh St., Mildura***

THURSDAY 6th SEPTEMBER 2012

8.50am	***Welcome***
8.55am	**Precision Agriculture New Zealand.** *(PANZ president)*
9.05am	**Industry news – John Deere**
9.15am	**Large-scale trials - using PA for research.** *Tim McNee (NSW DPI)*
9.35am	**Monitoring and managing landscape variability in grazing systems.** *Mark Trotter (UNE PARG)*
9.55am	**Crop yield simulation across space.** *Konrad Muller (USYD PA Lab)*
10.15am	**Research progress of intelligent variable equipments for precision agriculture.** *Zhang XiaoChao (Chinese Academy of Agricultural Mechanisation Sciences (CAAMS))*
10.35am	**Industry news – AgLeader**
10.45am	***Morning tea***
11.20am	**Industry News – New Holland**
11.30pm	**Applying Precision Agriculture to pastoral systems.** *Ian Yule (NZCPA, Massey University)*
11.50am	**Precision irrigation - a uniquely Australian perspective.** *Rod Smith (USQ/NCEA)*
12.10pm	**ProductionWise; online crop management.** *Michael Pengilley (Graingrowers)*
12.30am	**A big 18 months with PA and agronomy.** *Chris Hunt (local farmer and PA practitioner)*
12.50am	**UNE Student Awards.** *Mark Trotter (UNE)*
1.00 pm	***Close and Lunch***

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Soil moisture mapping.

Jeffrey Walker[1], Gift Dumedah[1], Ying Gao[1], Alessandra Monerris[1], Rocco Panciera[2], Chris Rüdiger[1] and Xiaoling Wu[1]

Civil Engineering, Monash University, Australia[1]
Infrastructure Engineering, University of Melbourne, Australia[2]

Contact: Jeff.walker@monash.edu

Summary

Accurate knowledge of current and future spatial variation in surface and root zone soil moisture at high resolution is critical for achieving sustainable land and water management. In agriculture, such information is essential for:

(i) grain growers to make informed decisions on what to plant and when based on likely germination rates, crop yield and trafficability, and
(ii) graziers to be proactive in their management of stocking rates based on likely pasture growth.

While soil moisture may be estimated from computer models, the predictions are often poor due to inadequate model physics, poor parameter estimates and erroneous atmospheric forcing data. An alternative is ground measurements but these are limited by spatial extent, or remote sensing but this only gives a soil moisture estimate for the top few centimetres. Consequently, a system that integrates remotely sensed near-surface soil moisture observations with model predictions, and validated with ground measurements, is required. This paper presents some examples of high resolution soil moisture mapping from ground measurements, remote sensing, and assimilation into a computer model.

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The development of precision weed sensing and spraying technologies.

Cheryl McCarthy, Steven Rees and Craig Baillie

National Centre for Engineering in Agriculture, Faculty of Engineering and Surveying, University of Southern Queensland, Toowoomba, Queensland, Australia

Contact: cheryl.mccarthy@usq.edu.au

Summary

NCEA is developing proof-of-concept machine vision-based technologies for automated weed identification and spot-spraying in the sugar, cotton, grains and pyrethrum industries. Current weed control options for minimum- and no-till farming systems involve indiscriminate application of herbicide to a whole field and manual spot spraying, which is a labour intensive and imprecise operation. Overuse of herbicides leads to environmentally-damaging runoff and the onset of weed herbicide resistance, such as glyphosate resistance in the cotton and grains industries. NCEA's proof-of-concept technology has potential use for weed mapping and selective spraying of particular weed species, thus offering a vast improvement over commercial systems for automated weed spot spraying which do not discriminate between crop and weed species.

The machine vision system uses image analysis algorithms that combine shape, colour, texture and depth (i.e. plant and/or leaf height) information to discriminate weeds from crop. NCEA's work has focussed on the discrimination of Guinea Grass from sugarcane, grasses from broadleaves for the cotton and grains industries and clover and hemlock from pyrethrum. NCEA's proof-of-concept systems consist of cameras mounted on the back of a tractor, or some other vehicle, which collect images on-the-go in the field. Images are analysed in real-time by automatic algorithms and positive identification of a weed results in the triggering of solenoid-controlled spray nozzles.

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Comparative performance of VIS/NIR sensors.

Philippa McVeagh[1], Ian Yule[1] and Jemma Mackenzie[2]

New Zealand Centre for Precision Agriculture, Massey University, Palmerston North, New Zealand.[1] Agri-Opitcs NZ Ltd, Ashburton 7776, Canterbury, New Zealand.[2]

Contact: P.J.McVeagh@massey.ac.nz

Introduction and objectives

Three VIS/NIR sensors were tested and compared over approximately 280 hectares of mixed cropping. The three commercially available sensors used – Greenseeker™ from Trimble, Crop Circle ACS-470™ from Holland Scientific and CropSpec™ from Topcon – differ in terms of their design, operation and setup although they share common management purposes.

VIS/NIR sensors are designed to measure crop canopy reflectance to map in-field variability. There is growing interest amongst arable cropping farmers regarding the potential of VIS/NIR sensors to inform their nitrogen fertiliser strategies, particularly the ability for informed on-the-go variable rate nitrogen fertiliser application to various arable crops.

VIS/NIR sensor measure light absorbed and reflected by the crops canopy. Crop canopy sensors generally use two bands, one in the visible red region and one in the near infra-red region. These values are used to generate vegetation indices. This gives the farmer an indication of the state of the crop in that particular location, in terms of the crops condition and biomass.

Data gathered by the sensors was compared. Firstly the consistency of the information (in the form of an NDVI value) between the sensors and how this would affect decisions made regarding variable rate nitrogen fertiliser application. Consistency of the sensors was compared at various growth stages of the crops. The differences between sensors was analysed to assess if differences were random or if there was a spatial component to these discrepancies.

Although the sensors are different in terms of their sensing footprint (size and position), wavelengths used and indices produced from their data, they share a common management purpose. It is noted that the sensors footprints were not overlapping; however the aim of this trial was to replicate commercial conditions so the sensors were mounted as recommended by the manufacturer.

Methods

This trial included three sensor systems set up on a tractor and 24m trailed sprayer including: four Greenseeker™ sensors mounted on the sprayer boom, two Crop Circle ACS-470™ sensors mounted on the sprayer boom and two CropSpec™ sensors mounted on the roof of the tractor cab (Figure 1).

Figure 1: Sensors mounted on a tractor and trailed sprayer (McVeagh et al. 2012).

Approximately 280 hectares including winter wheat, winter barley, ryegrass for seed production and maize were sensed on five commercial farms over two seasons in New Zealand. Crops were sensed over a number of different stages, with the target stages for the cereal crops being Zadocks growth stages 13 (3 leaf stage), 32 (during stem elongation), 39 (flag leaf just visible), 50 (head emergence) and 65 (mid flowering). NDVI values were used to determine in-paddocks sites (high, medium and low) where cut sample were taken to estimate plant biomass.

The smallest unit of management considered was a 24m by 24m grid cell. Figure 2 shows the base grid created oriented parallel to the swaths driven, the sensor point values and the raster grid generated from the average point values within each raster grid square used for comparative purposes.

(a) (b) (c)

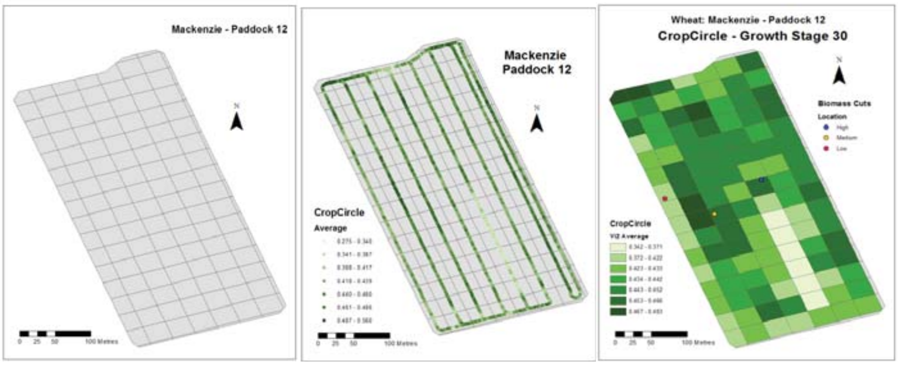

Figure 2: (a) Base grid, (b) point data collected by the sensor (NDVI), (c) calculated average sensor values in grid format (McVeagh et al. 2012).

Due to differences in the sensors, comparisons were completed using standardized values from the population of measurements taken. Figure 3 shows the comparison between two sensors using standardised values.

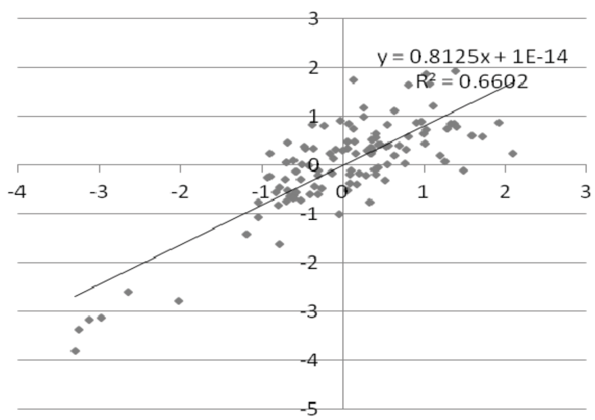

Figure 3: Example of a scatter plot comparing two sensors (CropSpec (x) and CropCircle (y) axis) at growth stage 30 (McVeagh et al. 2012).

The difference between the sensors was also mapped, calculated by subtracting the standardised NDVI value of one sensor was from another. Therefore a value closer to zero indicates greater agreement in the values. The darker the colour of the grid square, the greater the discrepancy between sensor values. The colour of the grid square (CropCircle – blue, CropSpec – orange in Figure 4 indicates the sensor giving the higher value.

(a) (b) (c)

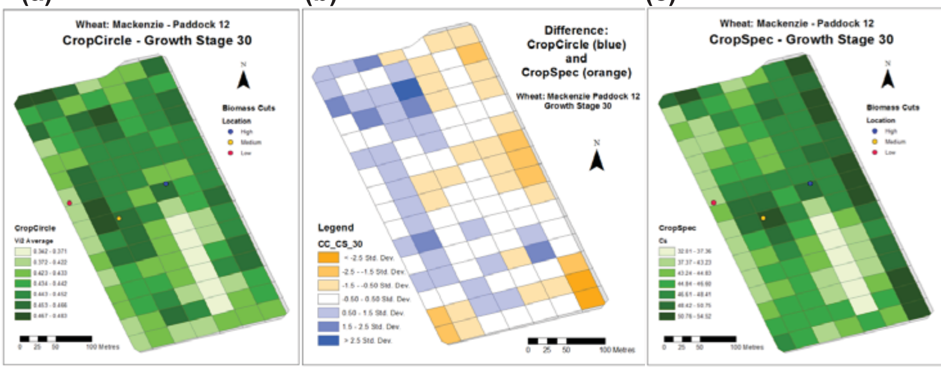

Figure 4: Example of difference between two sensors CropCircle (left) and CropSpec (right) at growth stage 30 (McVeagh et al. 2012).

Results and Conclusions

The Greenseeker™ and Crop Circle ACS-470™ were generally more strongly correlated during the earlier growth stages. Sensor readings taken at head emergence and mid flowering were poorly correlated between all three sensors. Sudduth *et al*. (2011) carried out a similar trial but using a different CropCircle sensor model that uses different wavebands. Their findings however, are similar to the results of this trial as Sudduth *et al*. found stronger correlations, between Greenseeker™ and CropCircle ACS-210™ sensors than the CropSpec™ sensors with either of the other two sensors.

There is evidence from this study to suggest that there are non-random differences in how the sensors respond, however trials under more carefully controlled circumstances are required to gain a better understanding of the differences. It is realised that these sensors are different in terms of their technology and set up but their primary objective is the same and that is to inform nitrogen based fertilisation strategies. Differences in sensor readings will lead to different levels of N fertiliser being applied if similar algorithms are used, so far these differences have not been tested to see if there is a real and measurable effect resulting from the choice of sensor.

References

McVeagh, P., Yule, I. and Mackenzie, J. (2012). *A comparison of the performance of VIS/NIR sensors used to inform nitrogen fertilization strategies*. Paper Number: 121340830. Presented at the 2012 ASABE Annual International Meeting: Dallas, Texas.

Sudduth, K. A., Kitchen, N. R. and Drummond, S. T. (2011). *Nadir and Oblique Canopy Reflectance Sensing for N Application in Corn*. Paper Number: 1111261. Presented at the 2011 ASABE Annual International Meeting: Louisville, Kentucky.

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Peter Johnston

GEOSYS

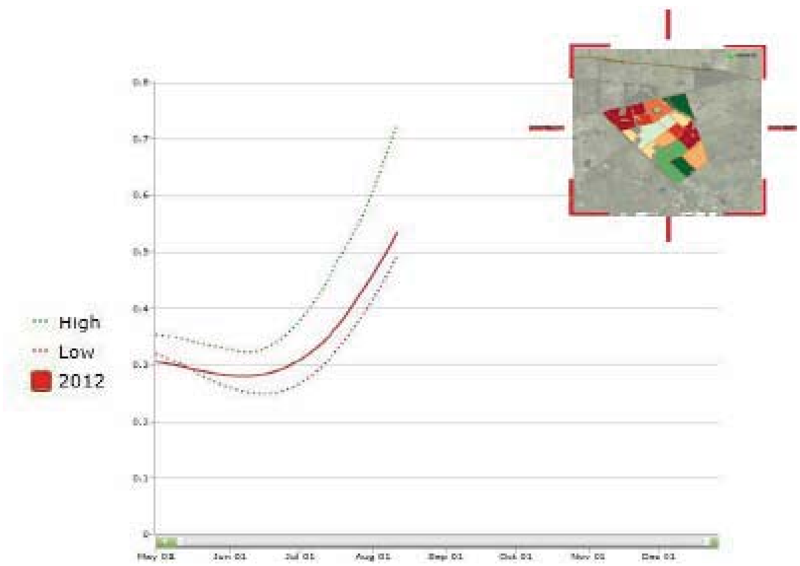
Contact: *peter.johnston@geosys.com*

Summary

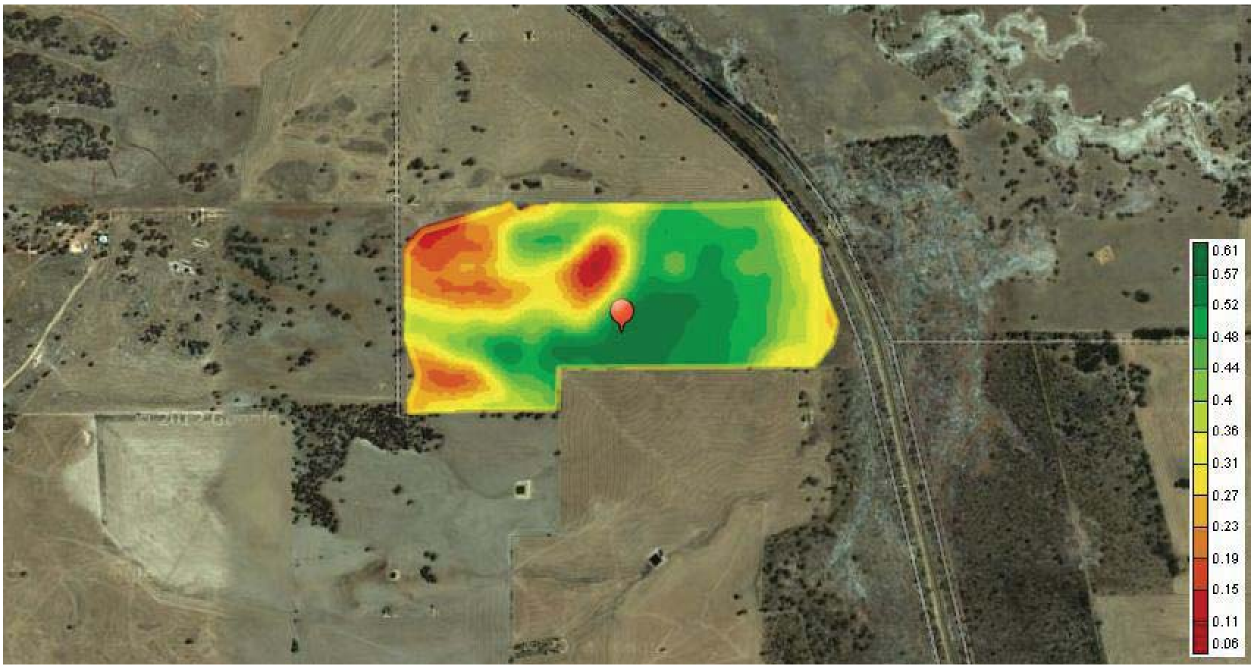
For the Past 25 Years, GEOSYS has been reviewing and developing the statistical relationships between plant growth evolution through measurement of NDVI, environmental influences (including but not limited to Rainfall, Soil type, Sunlight) and subsequent crop yield. NDVI does a good job at estimating the first components of yield that are plant population, number of tillers and biomass that will fill-up the grain, which are the most important components in the Australian context.

Through taking daily imagery of all crop production regions, there is adequate data to generate improved NDVI: Vegetation Vigour Index. This indicator is the result of what affects production of crops biomass: soil type, fertility, moisture availability, weather… hence it is the best indicator for a quick assessment of the variability of yield potential. We can assess intra relationships with a high degree of certainty of crop outputs. In cereal crops, we typically achieve R^2 values of 0.82 or higher.

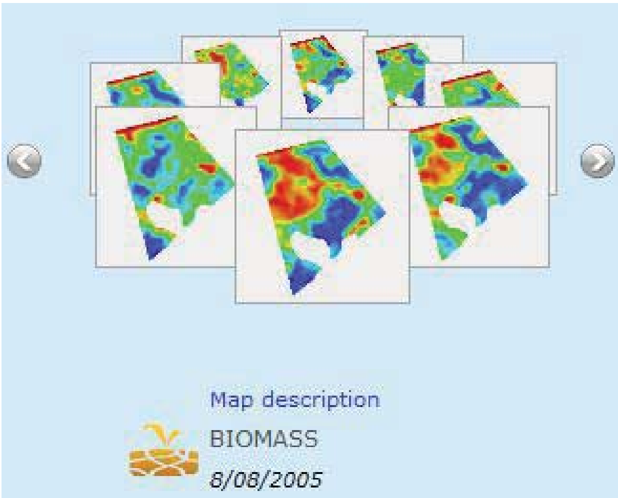
Understanding the typical evolution of Vegetation Vigour Index throughout the crops growth allows us to “Filter” out crop v non crop, so that pixels within the image can themselves be classified into what we call Agricultural Monitoring units (AMU). By grading and filtering the raw information in this way, we can provide a statistically robust process for comparing regions to regions, farms to farms, and now paddock to paddock. Monitoring growing conditions through this indicator at the AMU level is a usual tool for Grain-handlers to forecast production and plan logistics. It is also a robust tool for producers to assess production potential of paddocks compared to previous seasons or to neighbouring paddocks. This is used for management purpose to qualify growing conditions in each paddock and decide where to make top-dressing of fertilizer or how to apply any given crop input.



Complementary high resolution satellite imagery is also used to identify within-paddock variability and adjust fertilizer application by zone depending on the relative potential of each zone.



Decision making process is backed up by historical data on the impact of preceding environmental conditions and images that are statistically relevant for developing Management Zones maps that can then be converted into fertiliser or seed prescription files.



Utilising the services of over 30 separate remote sensing companies, GEOSYS has developed an enviable archive of low, medium and high resolution data. This raw data is continually validated against the crop models and AMU's to ensure that information generated is statistically robust, irrespective of source. In doing this, GEOSYS can "mosaic" information from multiple suppliers, to generate a seamless image, which is critical for regions where cloud cover during the growing season can be an issue and the only way to deliver robust multi-scale services as described here.

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Using sensor networks to study the social behaviour of cattle.

David Swain

Central Queensland University, Centre for Environmental Management, Rockhampton, QLD 4701, Australia

Contact: d.swain@cqu.edu.au

Summary

The application of precision livestock management (PLM) in the rangelands has not kept pace with the uptake of precision technology in the cropping industry. The use of sensor technology for livestock applications is limited by practical constraints such as fitting devices to livestock and maintaining power for long periods of time. Precision livestock research has seen a general trend of increasingly complex technology developments. Sensors including high sample rate GPS, tilt switches, three way accelerometers and magnetometers have been used to derive behavioural information. The high power demands of multiple sensors constrain the monitoring of livestock movement and behaviour for a maximum period of several weeks and do not provide promise for practical PLM applications.

Understanding the simplest sensor that can monitor useful information to meet practical livestock applications is considered a research priority. A radio contact between two devices that are each fitted to an individual animal which records the ID, date, time and duration provides the most basic data that can be recorded. Proximity sensors not only provide a simple monitoring capability they can also be small and low powered addressing two of the major practical constraints for PLM in extensive livestock production system. This paper explores some of the information that can be derived from proximity sensors and demonstrates how the data can be used within social network analyses to provide information on cattle social associations.


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EM38 to measure soil moisture content in Vertosols: are we any closer?

John Stanley, Derek Schneider and David Lamb

Precision Agriculture Research Group, University of New England, Armidale NSW, 2351 (www.une.edu.au/parg) and Cooperative Research Centre for Spatial Information (CRCSI).

Contact: jstanle4@une.edu.au

Summary

For Australia, high resolution, spatial measurement of plant available water (PAW) remains the Holy Grail for crop management. If we knew the PAW for every 10 m2 unit of cropping area, we could go a long way towards matching sowing rates and nutrients (both possibly zero) to this fundamental driver of crop production. The only non-intrusive instruments capable of sensing soil moisture rapidly without resorting to a network of buried moisture sensors are those based on electromagnetic induction (EMI, eg. Geonics EM38TM or DualemTM) and numerous groups have explored this approach. But are we any closer to achieving this in an operational sense?

Currently the correlation between ECa and soil moisture is put to use in a somewhat indirect way. For suitable soil types; where soil salinity, metallic content or soil depth are not overwhelmingly disruptive; higher ECa zones are commonly indicative of higher moisture content, and therefore greater yield potential. RTK elevation and yield maps contribute to this prescription map for crop potential, and both have functional links to plant water availability. Greater ECa also correlates to heavier clays and therefore greater water holding capacity, further holding the ECa to moisture assumption together. Many studies have reported correlations between ECa and soil moisture content of around 80% (R2). So EMI surveys have been interpreted as soil moisture maps as part of prescription mapping for seed and fertiliser placement.

Here, our group will report on recent efforts that produced 80 to 95% (R2) correlations between ECa (from an EM38) with average soil moisture content measured using a neutron probe in plastic access tubes. The relationship between neutron probe count and ECa was linear for the whole range from full to wilting point for these non-saline vertosols under cotton at Moree, NSW. From a practical perspective, regular EM surveys after rain could provide repeated measures of ECa full point and likewise after-cropping, provide repeated measures of ECa wilting point. Over time these would inform growers of the upper and lower PAW limits for every unit of their farm. Such a self-calibrating series of EMI surveys offers a way to directly map soil moisture at high resolutions.

EMI appears to offer the only technology capable of rapid, non-intrusive, on-the-go measurement of soil moisture but the currently available sensors are prohibitively expensive as fixed sensors on irrigation machines or for regular use on tractor-booms. The technology is safe and requires very low energy. Therefore, progress in generating high resolution maps of soil moisture appear to be hindered only by the lack of inexpensive EMI sensor units.

Mixed fortunes in crop quality sensing.

Rob Bramley

CSIRO, Waite Campus, Glen Osmond, SA 5064

Contact: Rob.Bramley@csiro.su

A significant benefit of a group such as SPAA is the opportunity it provides for the cross-industry sharing of ideas and practices. This paper relies on an identical line of thinking.

It is now well understood that whereas a major focus of Precision Agriculture (PA) in broadacre cereal production has been on the variable rate application of *inputs* such as fertilizers, in the wine sector, interest has been much more focussed on selective harvesting; that is, the targeted management of *outputs*. Selective harvesting is defined as the split picking of fruit at harvest according to different yield / quality criteria, in order to exploit the observed variation. Early work in the Australian wine industry has demonstrated that very significant increases in the value of production can be achieved through this strategy, with benefits accruing to both grapegrowers and especially winemakers, whether production is geared towards 'boutique' high-value wines, or high-volume, lower-priced table wines.

In the absence of a fruit quality sensor, early adoption of selective harvesting has been based on the idea of segregating a vineyard block into two or three zones using a range of spatial data (typically remotely sensed vine vigour, EM38 soil survey and sometimes a yield map), and then harvesting these zones into separate product streams using two or three chaser bins during a single harvest event.

At the last Australasian PA symposium held in Albury during September 2010 (http://sydney.edu.au/agriculture/pal/documents/Symposium_2010.pdf), the question of incorporating an understanding of crop phenology into this process was discussed, with a view to considering variability in crop maturity as a part of the selective harvesting decision, notwithstanding that it was still reliant on the assumption that fruit quality and vine vigour zones are the same (Trought and Bramley, 2011). Clearly, a grape quality sensor would be valuable!

The performance of a hand-held grape sensor (the Multiplex™, Force-A, France), was discussed at the 2009 Australasian PA Symposium held during September in Armidale (http://sydney.edu.au/agriculture/pal/documents/Symposium_2009.pdf). In brief, this UV fluorescence-based sensor appeared, at that time, to be inappropriate to Australian conditions due to our typically larger canopy sizes and higher levels of ambient UV experienced here compared to those in Europe. Further, the sensor was considered somewhat cumbersome, and collection of sufficient data for mapping was deemed too time-consuming to be practical or commercially viable. However, in subsequent work, a modified sensor (to accommodate the UV issues) deployed on-the-go on a grape harvester discharge chute during commercial harvest showed real promise for the sensing of grape anthocyanins (i.e. colour), an important quality attribute in red winegrapes (Bramley et al., 2011; Figure 1). Clustering of the on-the-go anthocyanin map with maps derived either from the conventional 'wet chemistry' lab analysis of anthocyanins on 268 berry samples, or a lab-based analysis of the same samples using the modified Multiplex in hand-held mode (Figure 2), supported the view that this was a crop quality sensing success story.

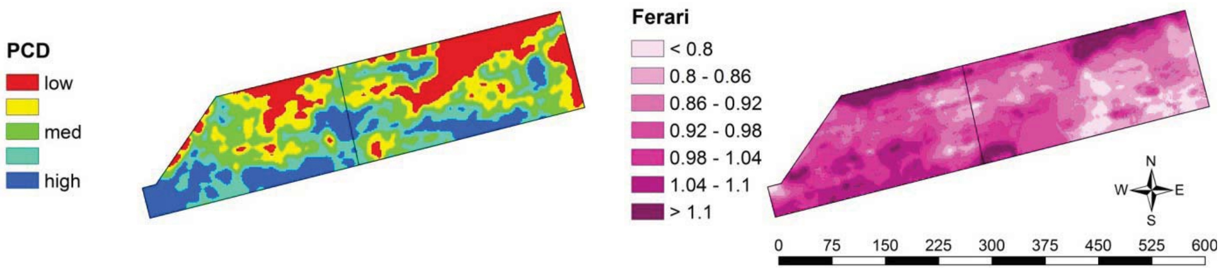

Figure 1: Remotely sensed vine vigour (PCD) and grape anthocyanin content as measured using the FERARI index sensed on-the-go during harvest. The line running through the middle of the block delimits the area to the east in which target vines were sampled for lab analysis (Figure 2). Data of Bramley et al. (2011).

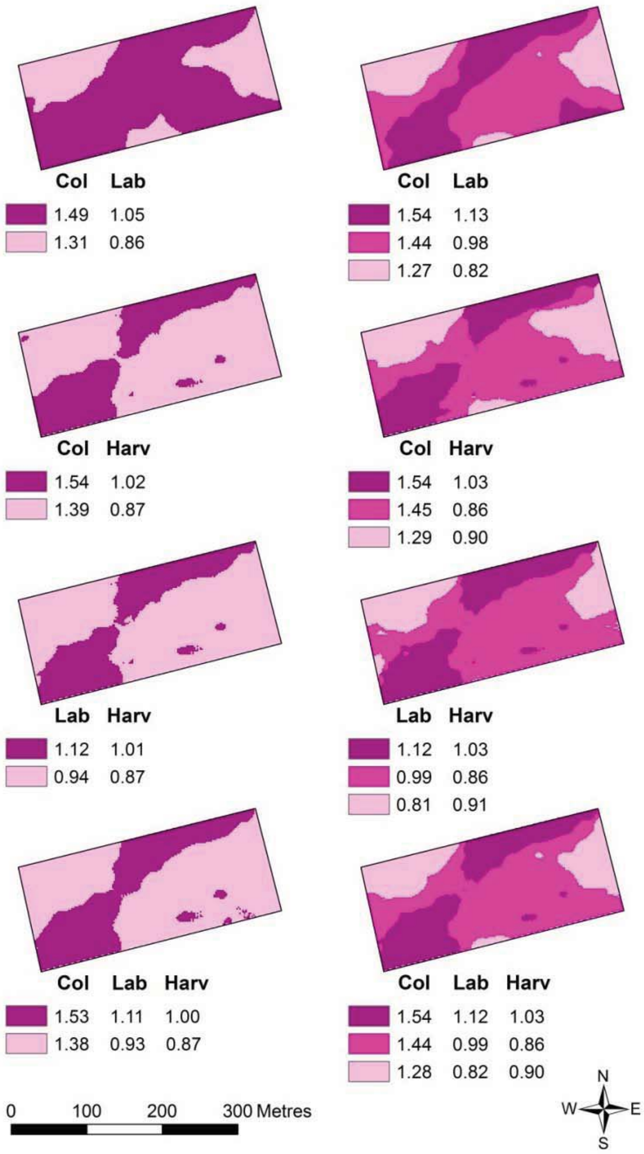

Figure 2: Results of *k*-means clustering (2 and 3 cluster solutions) interpolated measures of grape anthocyanins measured in the laboratory (268 berry samples) using either the industry standard 'wet' method (Col), or a Multiplex (Lab), and on-the-go during harvest using a Multiplex mounted on the harvester discharge conveyor (Harv). Data of Bramley et al. (2011).

Given the benefits of selective harvesting seen in the wine industry, price premiums that are paid to Australian grain growers for grain of specified protein contents, and the availability of on-the-go protein sensors, the obvious question arises as to whether grain growers can also take advantage of selective harvesting ? Recent work aimed at addressing this issue has unfortunately been much less successful (Bramley et al., 2012). Figure 3 illustrates results from a site in the mid-North of SA at which the Accuharvester (Zeltex Inc., Hagerstown, USA) was unable to reproduce results obtained from grain analysis in the lab. The Cropscan instrument (NIR Technology Systems, Condell Park, NSW) performed much better in terms of enabling patterns of variation in grain protein to be identified (Figure 4).

However, the data density derived from both sensors conspired against the delineation of protein zones which could form a robust basis for a selective harvesting decision; the map confidence interval was typically greater than 1% protein which is a potential problem given that the acceptable range for malt grade barley is only 3% (9-12%). Thus, whilst selective harvesting remains a philosophically sound proposition for the grains industry, these results suggest that considerable further sensor development is needed for it to become a reality. (Note also however, that Brett Whelan and James Hassall have had much more encouraging results when using the Zeltex Accuharvest with wheat).

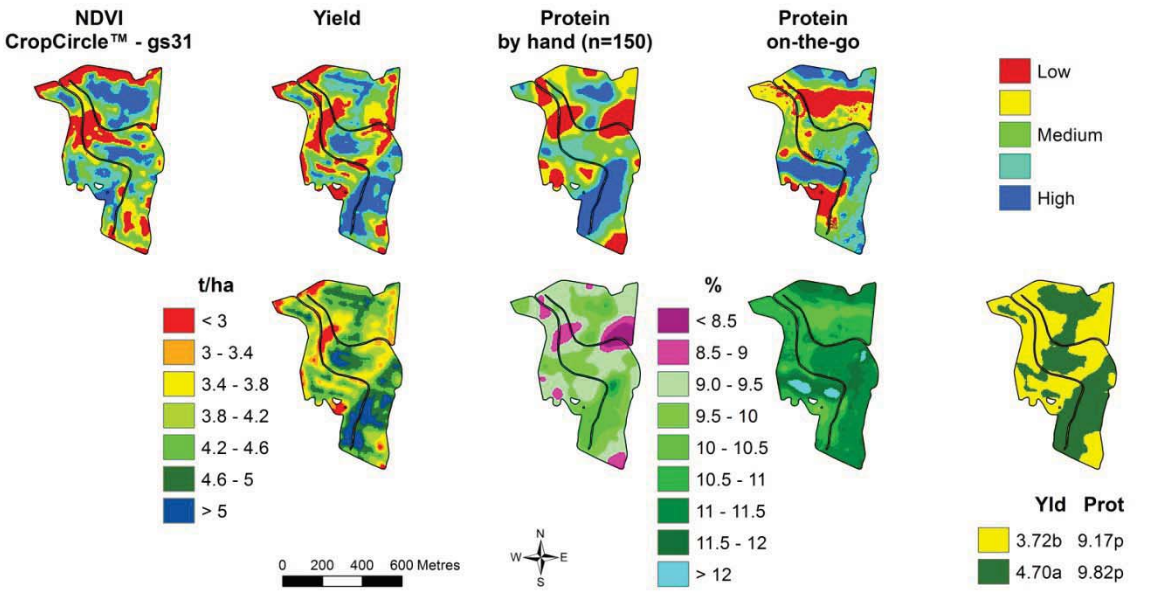

Figure 3: Crop performance in a 34 ha mid-North (SA) paddock in 2011 as measured by NDVI (proximal sensing at gs31 using a CropCircle), yield monitoring and grain protein measured using either laboratory analysis of samples collected by hand or on-the-go sensing using the 'Accuharvest' sensor. In the top row of maps, data have been classified on the basis of 20th percentiles. The bottom row of maps depicts the same data with a more conventional classification. The map at bottom right shows the results of clustering the yield and protein data (hand sampling) – 2 zone solution. This map shows almost identical patterning to that seen when yield maps (2006-2011) are clustered with an EM38 soil map.

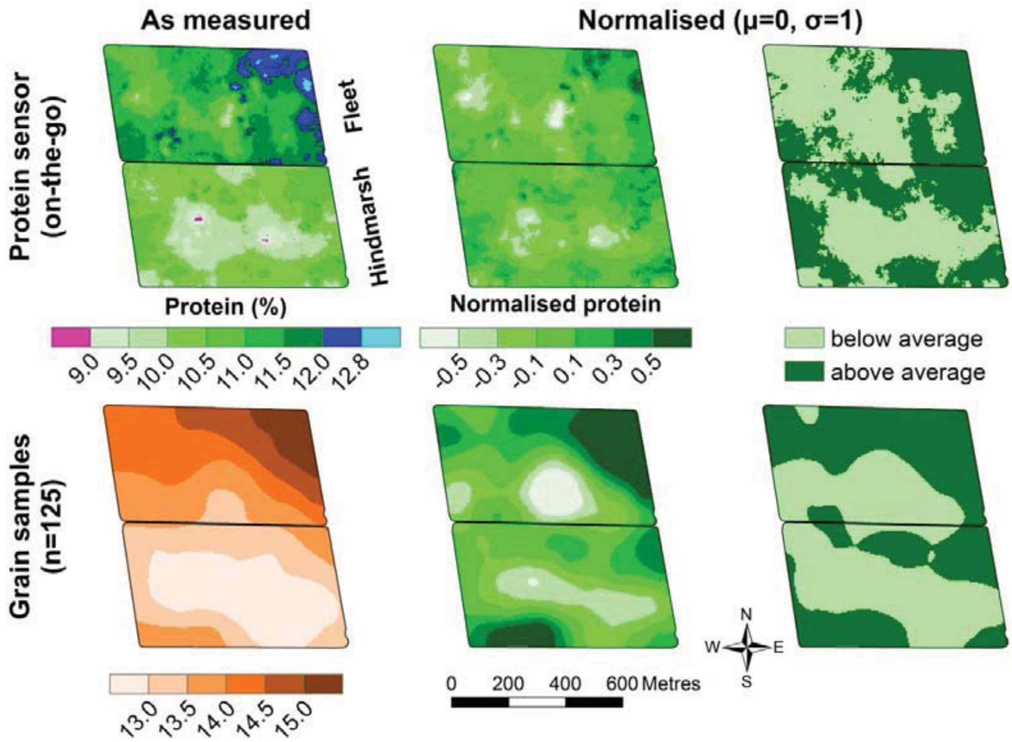

Figure 4: Protein variation (2011) in two Yorke Peninsula paddocks of feed barley (60.6 ha in total), assessed using either on-the-go sensing during harvest (Cropscan sensor) or laboratory analysis of samples collected immediately prior to wind-rowing, three weeks earlier. As the paddocks were sown to different varieties, the data underpinning the maps in the centre and right columns were normalised on a per paddock basis to remove variety-specific effects.

Questions of crop quality also have resonance in the sugar industry given that canegrowers are paid on the basis of the sugar content (CCS) of cane in addition to its yield. Indeed, calculations based on maps of yield and CCS variation in a 6.8 ha sugarcane field in the Bundaberg district characterised by limited soil variation, suggest that in 2011 at this site, 23% of the within-field variation in farmer income was due to CCS variation. At a more variable site, the importance of CCS variation might be considerably greater. The motivation for a sugar sensor to complement cane yield monitoring therefore seems clear and it is to be hoped that a future symposium will reflect further work in this area.

Acknowledgments

This work was variously funded by CSIRO (through its ‘Sustainable Agriculture’ and ‘Food Futures’ Flagships), Force-A (Paris, France), Taylors Wines, the Grains (GRDC) and Sugar (SRDC) Research and Development Corporations, BSES Ltd and the National Centre for Engineering in Agriculture (University of Southern Queensland). The assistance and cooperation of many colleagues and collaborators in this work is gratefully acknowledged, with the good humour and forbearance of Colin Hinze (Auburn, SA), Mark Branson (Stockport, SA), Ashley Wakefield (Urania, SA), Randall Wilksch (Yeelanna, SA) and Jay Hubert (Bundaberg, Qld) particularly appreciated.

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WEEDit a Winner in Paruna

Jock McNeil – farmer – Paruna SA

According to Ian and Jock McNeil at Paruna in SA the WEEDit is the key to their summer weed management. They farm 7,600 ha at Paruna in SA Mallee. They grow 45% wheat 25% barley and 35% canola on sandy loam soils.

Jock says that summer weed control is vital in capturing any moisture that is present. In a summer like the one just past we typically make 3-4 passes with Roundup based herbicide mixes. In these lighter soils it only takes a few mls of rain to get a fresh germination. We like to get right onto controlling weeds so we can store all the rain that falls. Once the moisture is stored its like money in the bank so we go all out to maintain that moisture.

Controlling summer weeds is very costly and time consuming but it pays huge dividends in extra yield. A few years ago we had melons the size of a car growing but now they don't get past 10cm round. When we first started with the WEEDit we found the system could easily identify and spray these large weeds but then we started to get out their sooner when the weeds were smaller it had more difficulty identifying these small weeds and so we upgraded to more powerful sensors and so the WEEDit now has no difficulty detecting small weeds. Just like any summer spray operation dust and heat are still issues we have to contend with.

We went for the WEEDit because of its fast travel speed – that makes a big difference when you have to cover 7,000ha 3-4 times a year. We typically operate at around 18-20 kph. We have seen as low as 8% of the area sprayed and ranging up to 25%. This means we can still use high water rates and still get 500ha out of a 5000L tank load – this really delivers huge productivity gains.

Couch grass is a problem in our area but the WEEDit makes short work of it – you can dose up the brew and wipe out the patches very economically. So couch grass is basically a weed of the past now.

According to Jock's father, Ian, the economics of the investment speaks for itself at an average cost of $10/ha for a blanket spray that means each pass over the farm costs us $76,000 so you have to think twice about when you blanket spray but with the WEEDit the cost is $7-15,000 per pass so that's a massive saving in chemical that easily justifies the capital expense and you spray when the weeds first appear – no more waiting for the next shower to hopefully get a fresh germination.

The WEEDit allows us to use the more expensive chemicals so we are not so reliant on Roundup. Its a real worry to think of the amount we use and rely on Roundup "we're playing with fire". Our farming system couldn't survive widespread resistance to this chemical. We see the WEEDit as the key tool to keeping this threat at bay.

For further information contact Brendan Williams of Hawkeye Precision on 0428 428708

Precision Ag pays – a journey of learning.

Robert Blair

Kendrick, Idaho USA

Contact: Robert@threecanyonfarms.com

Background

Blair Farms is designated a Century Farm in Idaho consisting of 600 hectares in the Palouse Region of Idaho. The operation raises Winter Wheat (Red and White), Spring Wheat (Red and White), Malt Barley, Peas, Lentils, Garbanzo Beans, Alfalfa Hay, and Cows. Robert, wife Rhonda, sons Dillon (16) and Logan (13), and a full time hired man work the farm.

Deep Clay/Loam soils make up the majority of the profile with shallow/rocky areas on the edges of canyons. Soil pH ranges from 5.7 to 5.4. Steep slopes and rolling hills are predominating with farmed slopes exceeding 45%. Mean temperature is 15°C (high) and 5°C (low). Elevation is 762 m above sea level.

Yields

Crop	**Yield (t/ha)**
Winter wheat	6.8
Spring wheat	4.1
Barley	4.5
Lentils	1.4
Field Peas	2.3
Garbanzo beans	1.6

Crop rotation consists of roughly 1/3 in winter wheat, 1/3 in spring grain, and 1/3 in a legume. There is also 24 Ha of alfalfa that rotates every 5-8 years. After harvest, winter wheat stubble is mowed then chisel ploughed, spring wheat stubble is chiselled, and legume ground is fertilized and seeded. Everything receives an application of RoundUp. Tillage practices are considered minimum till. Residue management is an issue along with water erosion due to high rainfall with the steep slopes.

Robert has a B.S. in Agriculture Business from the University of Idaho, is the 2009 Precision Farmer of the Year (Precision Ag Institute), 2011 Eisenhower Fellow in Agriculture, 2012 McCloy Fellow in Agriculture, National Association of Wheat Growers (NAWG) board member, Vice Chair of NAWG Research and Technology Committee, Joint U.S. Wheat/NAWG Biotech Committee board member, and Nez Perce County Farm Bureau President.

The vision

In 1995, I was farming full time with my father. We were running a 9500 John Deere combine and GreenStar was coming out. I rode with a farmer in the area to see his system in operation and saw the potential for data gathering.

Like most young farmers I was at the mercy of the parental purse strings. Dad said “Not only no, but hell no!” to having that on the farm. To further my frustration, I was told if I put the books on the computer I might as well find another job.

This scenario is one of my top five reasons for lack of precision ag adoption still today. Someone who has a hand in the farming operation (usually older) does not see the potential benefits for the technology. This mind set needs to change for agriculture to take its natural progression.

Humble beginnings

In 2003 I contacted a person who was looking for farmers interested in precision ag. The University of Idaho had a program that provided financial assistance to farmers to learn new skills. I jumped at the opportunity.

We started out with a Compaq PDA, and SST receiver, and ARC Pad. Using both hands to run this little device led me to rivet a piece of metal to the bill of my hat to hold the antennae. This was a very complicated system and only the instructor had the full ARC View program. Not a waste of time but I learned what I didn’t want.

Diving in

In 2004 the instructor and I were able to procure funding for a yield monitor and precision ag tests. I purchased an AgLeader PF Advantage and installed it on a Case IH 2388 combine. This was the first year of useful precision ag data.

The yield information allowed us to set the harvested legume ground into three zones (Poor, Med, Best) and we did three different nitrogen rates through all three zones in two fields. The plots were replicated three times in one field and twice in another. This allowed me to have a starting point for variable rate nitrogen.

That year we also did a flight over the farm in a Cessna to try NIR photography. I went along for the ride to point out fields and was amazed at the information my brain was processing just from being an observer. IMAGES DURING THE GROWING SEASON ARE NEEDED!

The flights left me frustrated because we were three weeks late getting the plane and the images didn’t come back until just before harvest. Couple that with poor quality images left me wondering where my $9,000 went. TIMELY IMAGES ARE NEEDED!

The year was not a complete bust. The yield monitor paid big dividends because of early and excessive fall rain. Because of the moisture sensor I was able to find three broken moisture testers at grain elevators. This allowed me to keep cutting while neighbors were shut down. I sold my spring wheat before the market tanked and protein discounts skyrocketed. IT MADE ME MONEY!

In 2005 I replaced the PF Advantage with an AgLeader Insight to do application as well as monitoring. I added a Rawson controller and hydraulic drive to my drills along with AutoSteer with terrain compensation to the tractor. We did VR nitrogen in two small fields and also winter wheat seed.

During harvest I used the Insight to start creating weed maps with flags. However, the greatest benefit was dropping flags for animal damage and trailing. After harvest I connected the dots, used the SMS software to find the linear damage, converted to acres, and calculated the damage. I was paid $7,000+ for damages that year. PRECISION AG MADE ME MONEY!

Bleeding edge

I continued testing on the farm with VR Nitrogen in 2006 but found that VR seed does not work for dryland wheat, legumes, or barley. Seed population is important to keep up.

In July I saw an advertisement for a UAV while waiting to talk with my crop advisor. I took the magazine home and immediately called on it. This seemed to be the solution to obtaining timely, high resolution images. That fall I was the owner of a miniature UAV and went to Winnipeg, Canada for training. March of 2007 was the first flight of the UAV.

In 2008 we built our own airframe and used a different autopilot because the initial UAV could not hold up to field use. Also, the initial UAV only had one camera not allowing for Near Infrared (NIR). To keep costs low we installed two Panasonic Lumix cameras with one being modified to capture the NIR.

That year was also a dry year and food stocks for wildlife dried up in the canyons. I had garbanzo beans and peas along a canyon. Utilizing the images with yield map flags overlaid (faded the yield data) I was able to verify $50,000 of animal damage. PRECISION AG REALLY PAID OFF!

(a)

(b)

Figure 1: (a) Yield data and damage flags overlayed on an image and (b) elk and deer trails in a pea field where the arrows show trails and bedding areas.

Challenges

The biggest challenge that I faced with getting into precision ag was lack of support and knowledge in my area. Couple that with being the first farmer in the U.S. to own and use a UAV involved a very steep learning curve.

(a) (b)

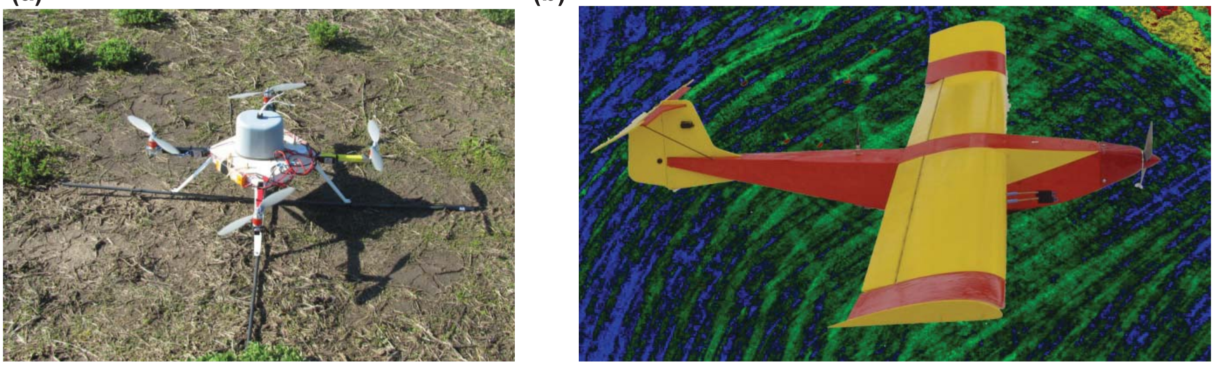

Figure 2: (a) Quad Copter (b) UAV.

Currently the biggest hurdle that I face is dealing with the Federal Aviation Administration (FAA) for commercial UAV rules and regulations…there really are none. I have learned firsthand how federal bureaucracy works and how little vision they have for utilizing technology. Rules should be out by 2015.

Financial strain and my hired man contracting cancer have not allowed me to progress as fast as I would like with UAV tests. While the data and theory have been sound and works, expanding my tests to weeds, insects, and/or diseases in crops has had to take a backseat to making sure the work gets done on the farm that needs to be done.

Finally, how do I help to promote the adoption of precision ag to farmers in the U.S.? There are several different reasons for not adopting: Lack of understanding, money, support network, and horror stories to name a few. But all of that can be overcome if a goal is set for the technology.

Precision Ag pays

I don't know if I am unique in my experience, but my initial emersion into precision ag paid off in ways I would never have dreamt. Being able to find broken moisture sensors and to track animal damage was not even considered.

However, when I was able to slowly work my on-farm tests with the data collected I started seeing the benefits. Autosteering can save 5-7 percent and is the lowest payoff of all the technologies (remember I have very steep terrain). Autoboom can save an additional 7-15 percent depending upon field shape. Finally VR nitrogen can save 20+ percent over a whole field.

As a business my UAV adventure has not paid off but when it comes to the farm it has been like hitting a jackpot. Being able to verify what is in the image with yield data has been beneficial from a historical information standpoint, scouting for general crop health, wildlife damage claims, and for crop insurance.

When I look back to my start with precision ag to where I am now, the payback period for the equipment has been less than a year for each component. However, when you are trying to develop technologies the payoff is longer due to more costs and time.

An alternative precision payback has been two different Fellowships. I have been able to travel to South America to meet with researchers, farmers, businesses, and government officials to learn about precision agricultural practices. I was also fortunate to attend the Nuffield Scholars Conference in Holland and England. This was a great experience to talk with farmers from different parts of the world. This fall I will be travelling to Germany and Belgium.

In the future

My travels and speaking keep one thought at the front of what I do: “How does agriculture feed 9.5 billion people by 2050 on the same or less amount of land while conserving resources and being environmentally conscious?”

I believe technology will get us there. Equipment and software will only take us so far on the output side of things but can play a huge role in with inputs. We will also need to have crop variety breakthroughs and biotech seems to be the answer.

On my farm I will continue to utilize the technology that is available, continue on farm testing, pursue harder UAVs and their applications, and hold field days to show the benefits of precision agriculture. Also, I hope to leverage my experiences to all audiences within agriculture and to those that do not farm at all. We all have to eat and be responsible whether we farm or not.

Large scale trials - using PA for research.

McNee T, Martin P, McIntosh G, Haskins B, Brill R, Jenkins L, Fowler J, Menz I, Burley T, McMaster C and Roberts K.

NSW Department of Primary Industries.

Contact: tim.mcnee@dpi.nsw.gov.au

Key findings

- Technical skills with the use of precision agriculture technology are highly variable within the industry. Leading growers and agronomists would likely benefit from training to get more use out of yield mapping, NDVI, EM38 and zone technology and subsequently improve productivity.
- Correlation between NDVI and grain yield ranged from low (R^2 = 0) to moderate (R^2 = 0.5).
- Grain yield of varieties was significantly different (P=0.05) in 5 of the 7 trials harvested.
- The extension component of these trials was very successful with 565 attendances at field days.

Introduction

Kearns & Umbers (2010) reported the adoption of controlled traffic in the main grain growing regions in Australia is approximately 15% of both area and number of farmers. Uptake of autosteer is between 50 and 75 %. Uptake of variable rate technology is around 12 to 13% and peaks at 20% in the Victorian and South Australian Mallee regions. Yield mapping is generally around 20% of farms. NSW DPI farmer groups posed the question ‘can we conduct our own variety performance evaluation and can zoning of paddocks be used to improve profitability?’ Innovation is the process to maintain adoption of new and existing information, essential to maintain productivity growth (Ritman *et al* 2011). An innovation worth investigating is varietal comparisons using farmer scale equipment and zone management knowledge and confidence is one innovation worth investigating. Trengove (2008) reported a methodology to help growers establish broad acre PA trials.

A series of 10 wheat variety trials each including between 3 and 5 varieties and planted and harvested with commercial equipment were planted across NSW in 2011. The aims were to:

- Road-test Precision Agriculture (PA) as a research tool
- Report on the relative performance of at least two new wheat varieties compared to a local standard variety using field scale methodologies
- Identify and measure in-paddock variation and the effect it has on yield
- Measure relative grain yield of varieties using farmer scale equipment
- Provide a platform for a range of extension activities

Materials and methods

Ten commercial scale wheat variety experiments were conducted in the 2011 growing season. They were conducted by NSW DPI district agronomists working with Farming system groups. These experiments were located throughout the wheatbelt of NSW, Australia (Table 1). All experiments were randomised complete block designs with 3-5 varieties and 3 replicates. Experiments were planted and managed using farmer equipment and standard agronomic practices for each district. Individual treatment plots ranged from 0.5 – 2ha in size. The majority of plot widths were 12m wide (one run of the seeder) the widest was at Merriwagga at 36 m (3 runs of the seeder). The plot lengths were commonly 500m with the longest plots being 1000m at Jamesville.

Experiments were divided into zones representing expected high, medium and low yielding areas based on the measures of variability. Variation in soil characteristics or previous plant growth was assessed using either EM38 (EM38 vertical dipole) soil maps (Figure 1a), previous NDVI (Normalised Difference Vegetation Index) maps or by farmer knowledge. These assessments were used as the basis for the division into zones (Figure 1b). For example Jamesville varied from 1 to 295 mS/m and was divided into 9 distinct bands (Figure 1a). These 9 ranges were joined to make three zones: Zone 1: sandier soil for cropping denoted by green colour EM38 ECa mS/m 1- 47, Zone 2: mid slope soil for cropping denoted by blue colour EM38 ECa mS/m 48 – 64, Zone 3: swale (poorest soils) denoted by red colour EM38 ECa mS/m 65 – 295. Soil nutrient and disease tests were conducted for each zone to quantify differences between zones (Table 1).

A series of plant measurements were made throughout the season. These included established plant counts, tiller counts and a normalised difference vegetation index (NDVI) in September 2011 (Figure 1c) at or near anthesis.

Grain yield was measured by header mounted yield monitors, weigh bins, plot harvesters or head/grain counts. Several methods were used for some experiments producing 2 separate estimates of grain yield. The methods used included, counting heads per unit area and grains/head and measuring grain weight then calculating expected yield and harvesting strips of known area out of each plot with a small plot harvester weighing grain and calculating grain yield and harvesting plots with a commercial header weighing the grain in a weigh bin or on a weigh bridge.

Yield maps were produced at some sites and this data was combined with NDVI map data to produce a set of estimates of yield and NDVI at a series of points across the experiment. These estimates were then used to calculate correlation coefficients between grain yield and NDVI.

Yield data was not collected at 3 sites because of either equipment failure or flooding.

Field days were conducted at some of the sites.

Table 1: Experiment and site details of large scale trials in NSW in 2011

Location	Trangie	Coonamble	Nyngan	Condobolin	Tichborne	Merriwagga	Rankins Springs	Deniliquin	Jamesville
2011 Rainfall (mm)	580 (240^A)	426 (233^A)	407 (175^A)	559 (130^A)	721 (325^A)	312 (137^A)	449 (176^A)	502 (138^A)	522 (68^A)
Previous crop	Canola	Chickpeas	Chickpeas	Wheat	Canola	Wheat	Vetch/Safflower^B	Wheat	Wheat
Soil type	Red chromosol	Grey vertosol	Clay loam	Sandy loam	Red brown earth	Sandy loam	Sandy loam	Clay loam	Sandy loam
Soil pH ($CaCl_2$)^D	5.1^1, 4.7^2, 4.5^3	7.0^1, 6.8^2, 7.0^3	6.1^1, 6.2^2	4.9^1, 4.8^2, 5.0^3	6.2^C	6.0^1, 5.1^2, 5.3^3	6.9^1, 7.5^2, 5.3^3	4.8^1, 5.2^2, 7.1^3	6.9^1, 7.3^2, 7.4^3
Take-all (pgDNA/g)	Nil	0^1, 4^2, 2^3	Nil	2^1, 0^2, 0^3		Nil	2^1, 0^2, 0^3	3^1, 7^2, 5^3	Nil
***Bipolaris* (pgDNA/g)**	Nil	3^1, 8^2, 8^3	Nil	25^1, 3^2, 0^3		2^1, 0^2, 4^3	2^1, 0^2, 0^3		17^1, 9^2, 30^3
***Pythium* spp. (pgDNA/g)**	147^1, 142^2, 147^3	8^1, 6^2, 2^3	40^1, 47^2	34^1, 11^2, 25^3		2^1, 10^2, 6^3	63^1, 112^2, 19^3		4^1, 9^2, 9^3
***Pratylenchus neglectus* (Nematodes/g)**	Nil	Nil	Nil	1^1, 6^2, 1^3		3^1, 5^2, 8^3	2^1, 1^2, 0^3	23^1, 0^2, 0^3	6^1, 2^2, 1^3
***Pratylenchus thornii* (Nematodes/g)**	0^1, 1^2, 0^3	0^1, 12^2, 11^3	Nil	Nil		Nil	Nil	3^1, 8^2, 24^3	Nil
Cereal Cyst Nematode	Nil	Nil	Nil	Nil		Nil	Nil	Nil	Nil
Crown rot (pgDNA/g)	Nil	0^1, 3^2, 5^3	Nil	Nil		Nil	Nil	2^1, 2^2, 3^3	Nil
Fusarium culmorum				Nil		Nil	Nil	Nil	Nil
***Rhizoctonia solani* (pgDNA/g)**	Nil	Nil	Nil	Nil		Nil	Nil	Nil	Nil
Common root rot (pgDNA/g)	Nil	3^1, 8^2, 8^3		Nil			Nil	Nil	Nil
Number of Zones	3	3	2	6	3	3	3	3	3
Method of Zoning	EM38 Map	EM38 Map	EM38 Map	EM38 Map	Farmer Knowledge	Previous NDVI	Previous NDVI	EM38 Map	EM38 Map
Number of Varieties	4	4	4	4	3	4	3	4	5
Planting Date	16th May	20th June	14th May	18th May	22nd May	6-10th May	11th May	11th May	17th May
Harvest Date 1^E	15th Nov	30th Nov	14th Nov	29th Nov	17th Dec	16th Nov	28th Nov	5th Dec	18th Nov
Harvest Date 2^F	16th Dec	23rd Dec	15th Nov						
Field day attendees	45	30	95	56	18	118	98	25	68
Notes for Superscripts	^{1} = Zone 1		^{A} = Growing season rainfall			^{D} = 0-10cm			
	^{2} = Zone 2		^{B} = Brown manure crop			^{E} = Subsection harvested with plot harvester			
	^{3} = Zone 3		^{C} = pH (H_2O)			^{F} = Remaining area harvested with commercial equipment			

Results & Discussion

Data from Jamesville is presented as an example of within experiment variation measured at the sites. EM38 values (Figure 1a), Production zones for farm management purposes (Figure 1b), NDVI assessed in September 2011 (Figure 1c) and yield estimate in the case of Jamesville yield data using an in header yield monitor (Figure 1d).

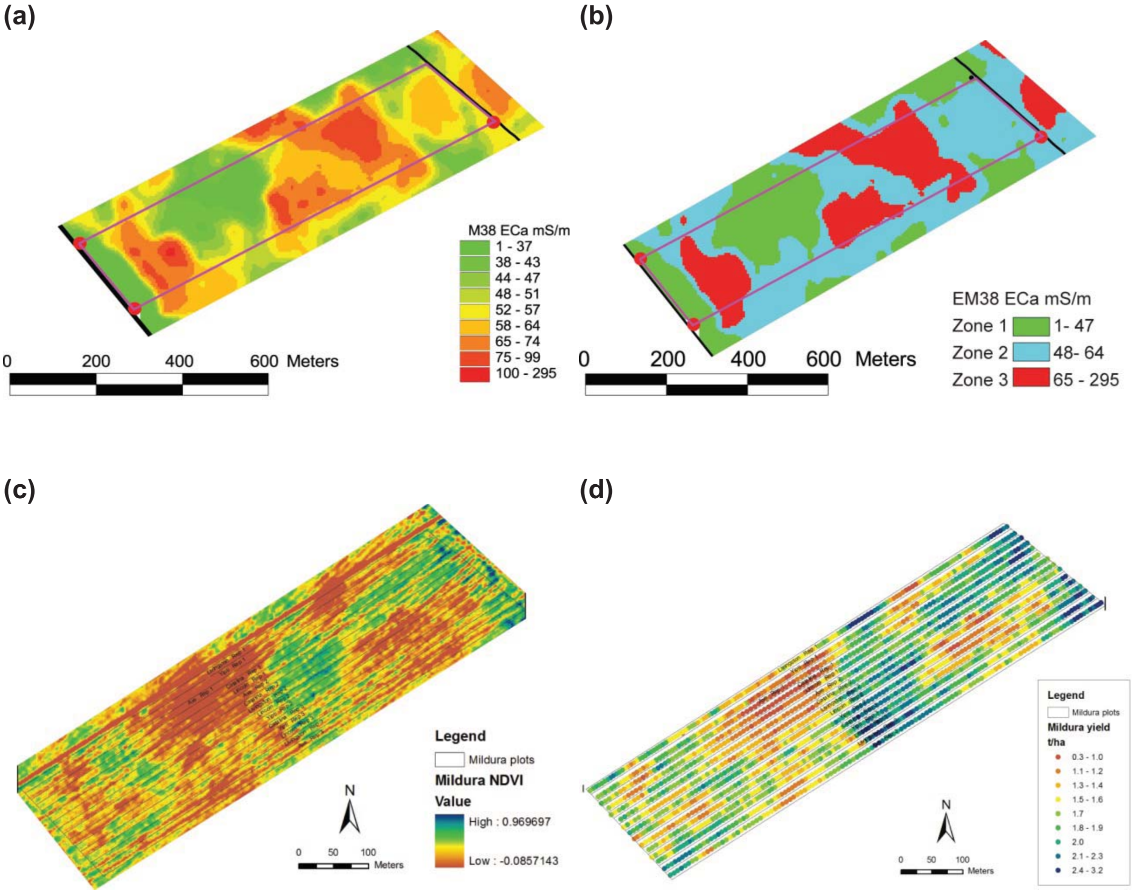

Figure 1: Maps of variation at Jamesville(a) EM38 map ECa mS/m of trial area, May 2011 (b) zone map of trial area, May 2011 (c) NDVI map, September 2011 (d) Yield map, November 2011.

The sites were very different in the nutrient status and pathogens present (Table 1). Between sites, soil pH ($CaCl_2$) varied from 4.5 -7.5, with pathogens like nematodes present at some sites but not others. Rankins Springs and Deniliquin showed considerable intra site variation in pH while Deniliquin and Coonamble showed intra site variation in relation to nematodes.

Differences between varieties for grain yield measured with commercial header grain monitors was statistically significant ($p<0.05$) at all sites except Merriwagga and Deniliquin. Differences between varieties for grain yield measured with a plot harvester were significant at Trangie and Coonamble but not Nyngan (Table 2). The lack of significance of the plot header data, when yield measured using commercial header yield monitor was significant, at Nyngan was most likely due to greater variation between measurements than for the commercial header yield monitor data.

Table 2: Grain yield of farmer scale yield trials at Trangie, Coonamble, Nyngan, Jamesville, Deniliquin, Merriwagga and Rankins Springs in 2011.

	Region and location and yield measurement method						
	Northern NSW				Southern NSW		
Variety	Trangie	Coonamble	Nyngan	Jamesville	Deniliquin	Merriwagga	Rankins Springs
	Commercial harvester						
Axe				1.65			
Crusader						2.96	
Catalina				1.56			
EGA Gregory	3.41	3.4	2.75				
Lincoln	2.97	2.5	2.66	1.65	1.27	3.29	2.03
Livingston	2.67	3.0	2.45	1.73	1.92	3.04	1.52
Merinda					1.71	3.08	1.87
Spitfire	2.93	2.6	2.57				
Ventura					2.54		
Yitpi				1.57			
lsd ($P<0.05$)	*0.09*	*0.33*	*0.08*	*0.1*	*ns*	*ns*	*0.28*
	Plot harvester						
EGA Gregory	3.49	3.3	3.22				
Lincoln	3.02	2.4	3.00				
Livingston	2.67	3.1	2.61				
Spitfire	2.98	3.2	2.98				
lsd ($P<0.05$)	*0.11*	*0.16*	*ns*				

The correlation coefficients between NDVI and grain yield (Table 3) were very low for Deniliquin (R^2 = 0.00 - 0.06), Merriwagga (R^2 = 0.17 - 0.27) and Trangie (R^2 = 0.11 - 0.33). The correlations for Jamesville ranged from 0.30 – 0.56. It's not clear why these correlations differ so markedly between experiments nor is it clear why the correlations differ between varieties within an experiment. The explanations for the differences between varieties is a combination of all the variables in the paddock like disease, soil type, starting soil moisture, other factors and their possible interactions.

There was generally a low correlation between NDVI and Grain yield in this dataset. These data suggest that NDVI is useful as a means of predicting yield at some locations but not others. The reasons for these differences are not clear.

It is possible that the correlation between NDVI and grain yield could be improved by reducing the error associated with aligning the data to the exact GPS coordinates. Our inability to control the variables is a limitation to this type of experiments. To some extent this is a function of the large-scale of these experiments.

Table 3: Correlation coefficients (R^2) between NDVI and grain yield at Trangie, Rankins Springs, Deniliquin, Merriwagga and Jamesville in 2011.

Variety	Trangie	Jamesville	Deniliquin	Merriwagga	Rankins Springs
Axe		0.35			
Crusader					
Catalina		0.49			
EGA Gregory	0.27				
Lincoln	0.33	0.56	0.01	0.17	0.27
Livingston	0.23	0.3	0.03	0.27	0.27
Merinda			0	0.21	0.47
Spitfire	0.11			0.18	
Ventura			0.06		
Yitpi		0.51			

Correlations between EM38 and yield and NDVI and yield were only calculated for the Jamesville experiment. The correlation between EM38 and yield at this site was 0.07, effectively 0. NDVI imagery quantified the variation in vegetative growth in the field. When all data was compared Yield and NDVI were correlated (R^2 = 0.37). This demonstrates an association with NDVI and yield changes within the paddock and supports the suggestion that dry matter at anthesis is a predictor of grain yield. The most striking of these is Yitpi (Table 4) with an R^2 of 0.01 for EM38 and grain yield and NDVI with grain yield of 0.5.

Table 4: Correlation coefficients (R^2) of Yield with EM38 and NDVI values in a trial at Jamesville in 2011.

	Correlation coefficient (R^2)	
Variety	Yield with EM38	Yield with NDVI
Axe	0.15	0.35
Catalina	0.16	0.49
Lincoln	0.05	0.56
Livingston	0.07	0.30
Yitpi	0.01	0.51
Mean	0.07	0.37

Is there a role for using precision agriculture technologies to conduct commercial scale variety trials? EM surveys and previous NDVI or yield measurements allow paddock variation to be identified. Machine guidance technologies allow treatments to be planted with great precision within a trial and header mounted yield monitors allow automatic yield determination. It is good for site specific trials but the effort is considerable. It is unlikely to be viable in conducting commercial scale variety trials.

The technology does however have application in commercial scale trials where the number of treatments is limited and/or changing treatments is comparatively easy. For example, a seed rate trial involving one variety at five seed rates would only involve changing the planting equipments gearbox 5 times, this operation is comparatively easy.

Large scale variety and paddock variation management trials are useful as an extension tool rather than research tool. Field days were run at most experiments (Table 1). A total of 565 attendances at the large-scale trial field days were recorded. The extension component at these sites provided a platform for extension of other regional agronomic issues. Individual trial results have been distributed to a wide range of stakeholders.

Conclusion

Achieving statistically significant results from large scale variety trials is possible however the resources required per entry is high. Large scale trials may have more potential where the number of treatments is low and/or changing between these is comparatively easy. There was generally a low correlation between NDVI and Grain yield in this dataset.

Acknowledgements

These trials were conducted as part of the Variety Specific Agronomy Packages (VSAP) project funded by the Grains Research and Development Corporation. The contributions of Tim Neale (precisionagriculture.com.au) and our farmer cooperators Mark Byrnes and Alan Whyte (Jamesville); Michael Hughes (Deniliquin); Jeffrey Muirhead (Merriwagga); Michael Pfitzner (Rankins Springs); Bruce Watson and Mark Swift (Tichbourne); NSW DPI Staff (Condobolin); Wass Family (Nyngan), NSW DPI Staff (Trangie) and Andrew Windsor (Coonamble) in conducting these trials are gratefully acknowledged.

At the Jamesville site the EM38 mapping was conducted by Ken Bates, Advanced Soil Mapping and Trimble hand held GPS units and expertise were supplied by Lower Murray Darling CMA

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Monitoring and managing landscape variability in grazing systems.

Mark Trotter[1,4], Mark Yerbury[1,4], Joshua Barron[1,4], Samantha Anderson[1,4], Amy Cosby[1,4], Jessica Roberts[1,4], John Stanley[1,4], Derek Schneider[1,4], Greg Falzon[1,4], Steve Walkden-Brown[1], Chris Guppy[1,4], Clare Edwards[1,2], Rebecca Haling[1], Tieneke Trotter[1], Graham Donald[1,5], Robin Dobos[1,2], Kevin Powell[1,3], Rebecca Bruce[1,3], David Henry[5], Kerry Taylor[5], Laurent Lefort[5], Darren Moore[5] and David Lamb[1,4]

Precision Agriculture Research Group, University of New England[1], NSW Department of Primary Industries[2], Victorian Department of Primary Industries[3], CRC for Spatial Information[4] and CSIRO[5]

Contact: mtrotte3@une.edu.au

Abstract

Precision agriculture (PA) technologies and applications have largely been targeted at the cropping and horticultural industries. Little research has been undertaken exploring the potential for PA in grazing systems. This paper reports on the results of five studies examining PA technologies and techniques in grazing systems including: spatial variability in soil nutrients and fertiliser response across the grazing landscape; spatial landscape utilisation in relationship to individual animal productivity and health; spatial variability in pasture pests; and the development of a sensor network for monitoring spatial soil moisture, soil temperature and ambient temperature across a grazing landscape. The large variability exhibited in our trials suggests there is an enormous opportunity for precision agriculture in grazing systems. Sensing and responding to this variability will require careful application of modern PA technology and a substantial investment in research to better understand spatial variability in our grazing landscapes.

Introduction

Precision agriculture (PA) technologies and applications have largely been targeted at the cropping and horticultural industries. Little research has been undertaken exploring the potential for PA in grazing systems. Introducing PA techniques to grazing systems is complex as consideration needs to be given to the variability in soil and plant systems as well as the heterogeneity between individual animals and the variability in the way they use and impact on the landscape (Trotter, 2010). This paper reports the preliminary results of a number of projects examining techniques for monitoring and managing variability in the soil, plant and animal systems of the grazing landscape.

1. Spatial variability in soil nutrients across the grazing landscape

There is a growing interest in understanding the spatial variability of nutrients in pastures with a view to exploring the potential of Site Specific Nutrient Management (SSNM) to assist in increasing the fertiliser use efficiency in grazing systems (Simpson et al., 2011). However, there have been few studies exploring the spatial variability of soil nutrients in grazing systems (Stefanski and Simpson, 2010). This study aims to explore the spatial variability of soil nutrients and investigate how common PA tools such as soil EM38 and plant vigour sensors along with GPS tracking information from livestock relate to this and might be used for zonal SSNM in pastures.

Materials and methods

Two paddocks were selected for monitoring, the first is a 40ha, extensively fertilised, rotationally grazed cattle paddock. The second being a 47ha, sparingly fertilised, set stocked, sheep paddock, both located near Armidale, NSW, Australia. Soil EM38 and several Crop Circle® surveys of both paddocks were undertaken. Twenty GPS collars were placed on steers grazing in the cattle paddock and 20 collars on wethers in the sheep paddock. Samples were taken across a 1 hectare grid of each paddock and analysed for key soil nutrients. Nutrient maps were generated to examine for spatial variability and correlations with the various PA sensors undertaken.

Results and discussion

EM38 and CropCircle® surveys demonstrated 5-10 fold levels of spatial variability within each pasture paddock. Nutrient levels were also found to vary considerably across the paddocks with phosphorus (Colwell) ranging from 19mg/kg to 111mg/kg in the cattle paddock and 13mg/kg to 121mg/kg in the sheep paddock. Mean P levels of 30mg/kg were observed for the sheep paddock and 50mg/kg for the cattle paddock. In the northern tablelands, P levels below 30mg/kg are generally considered responsive for pasture, suggesting that 56% of the sheep paddock may be responsive to fertiliser but only 8% of the cattle paddock. Therefore, a large proportion of both paddocks may not benefit from P fertiliser additions. Preliminary analysis of the EM38, elevation, NDVI and livestock tracking data has not yet revealed clear correlations with soil nutrient levels, however we are exploring multiple regressions and are collecting further survey data.

2. Spatial variability in fertiliser response across the grazing landscape

Whereas the previous trial examined the spatial variability in soil nutrients, this experiment examined the variation in response to varying nitrogen N fertiliser rates. EM38 and elevation surveys were also carried out to see whether N response correlated to these descriptors.

Materials and methods

This experiment was undertaken on a one hectare pasture paddock located on the University of New England's Laureldale Property at Armidale NSW Australia. The paddock was originally part of a larger 10ha field sown to tall fescue (*Lolium arundinaceum Schreb.syn Festuca arundinacea cv. Dovey*) and periodically grazed with by sheep and cattle since 2010. In January 2012 the paddock was surveyed using a Geonics EM38. The EM38 and elevation data were used to develop zones in which N response blocks were established. Each block received 17kg of phosphorus and 22 kg of sulphur to overcome any phosphorus (P) and sulphur (S) limitations. The N response blocks consisted of five adjacent plots (2x3 metre area) with 0, 50, 100, 200, 400 kg N/ha applied as urea. Pasture production was monitored using whole plot cuts (with a lawn mower) with sub-samples taken for drying to determine total dry matter production.

Results and discussion

Preliminary analysis indicated no significant difference between the blocks, or different EM38 or elevation zones. However, there was a large amount of variation recorded at the block and plot level. The Nil N plots, which represent the natural variability present without N addition, varied by as much as 2,040kg/ha (minimum 849kg/ha, maximum 2,889kg/ha). There was also a wide range in the maximum biomass produced across the blocks from 2,759kg/ha to 4,699kg/ha. This suggests that important levels of variation do exist that we were unable to identify statistically. Further research is warranted to explore the scale of variability in nutrient response in pastures and better understand the methods that best identify areas for zonal management.

3. Spatial landscape utilisation in relationship to individual animal productivity and health

This study explored the relationship between individual animal performance, health and spatial landscape utilisation. Individual animals are known to vary in the way they use the landscape for grazing, camping and travelling activities. There is also clear evidence of variability in production traits between individual animals. However there are few studies linking these two traits and no known studies in sheep.

Materials and methods

To explore these issues a study was undertaken in a 47 ha paddock at Kirby Research Station, Armidale. Twenty individuals from a mob of 346, 18-month-old fine wool merino wethers, were selected based on race order and weight. UNEtracker GPS collars were attached to log their position at 5 minute intervals. The collars were deployed in mid-February 2012 and wethers were tracked until mid-May 2012. Once a month the sheep were brought back to the yards where they were weighed, mid-side dye-banded to record wool growth and individual faecal samples were collected to perform a faecal worm egg count (WEC) for gastrointestinal nematodes followed by a pooled larval differentiation test.

In this preliminary analysis the paddock that the sheep were grazing was divided into different landscape classes based on livestock movement data. These included camp, peri-camp and non-camp areas. The growth, wool production and worm egg count of individual sheep was evaluated in relation to utilisation of the different landscape classes to see if there were significant associations.

Results and discussion

Preliminary analysis found a negative relationship between sheep use of camp areas during grazing periods and worm egg count i.e. sheep using the camp sites the most for grazing had the lowest worm egg count. This appeared counter-intuitive as the sheep grazing the camps were expected to be ingesting a higher number of larvae. However, it has been suggested that sheep move off areas of known infective larvae as their own worm infestation increases and this may be the cause of this observed behaviour (Cooper et al., 2000).

We anticipate that livestock tracking will help graziers to better understand the interactions between landscape classes, the behaviour and performance of their sheep allowing them to improve their management. This research paves the way towards better paddock design and possibly the development of diagnostic tools that make the most of real-time spatial monitoring systems.

This study was supported by the Australian Wool Education Trust.

4. Monitoring the spatial variability of pasture pests across grazing landscapes

The redheaded cockchafer (Adoryphorus couloni) (Burmeister) (RHC) is an important, native soil-borne pest of improved pastures in South Eastern Australia. The aim of this project was to determine whether commonly used Precision Agriculture (PA) sensors could identify landscape attributes that correlate with RHC population density.

Materials and methods

Soil apparent electrical conductivity (soil ECa) measurements were derived from EM38, relative photosynthentically-active biomass via the normalised difference vegetation index (NDVI) derived from an Active Optical Sensor (AOS) and elevation measurements derived from differential global positioning system (DGPS) mapping. Eight paddocks across seven properties in the Gippsland region of Victoria were surveyed using a Geonics EM38, CropCircleTM AOS and a DGPS. Eighteen to twenty sample sites in each paddock were selected based on different zones of soil ECa, and the RHC (and other cockchafer species) populations were assessed at each of these sites.

Results and discussion

The general trend observed is that populations of RHC are found at higher elevations, which is possibly due to these areas having better drainage leading to shorter periods of waterlogging. It also appears that low ECa is favoured by RHC with larvae found where ECa is lower than 15 mS m-1. However, a value below this does not guarantee the presence of RHC larvae, instead appearing to be the threshold level for RHC larvae to occur. In Victoria, RHC appear to favour acidic sandy or sandy-loam soils over clay (Douglas, 1972) and as apparent soil electrical conductivity is influenced by soil texture (Padhi and Misra, 2011), EM38 surveys may be able to predict more susceptible areas of the paddock.

This project was supported by Dairy Australia, GippsDairy and the Gardiner Foundation.

5. Monitoring spatial variability in key climate and soil attributes through a sensor network

In a collaborative project involving CSIRO and the Australian Centre for Broadband Innovation a UNE property has been established to demonstrate the value of emerging technologies including distributed climate and soil sensors across grazing landscapes. This SMART (Sustainable Manageable Accessible Rural Technology) Farm sensor network provides real-time data on soil moisture, soil temperature and ambient temperature as well as rainfall and wind speed from weather stations. This ongoing project will examine a number of applications of the sensor network.

The SMART Farm sensor network uses Decagon 5TE digital probes (moisture, temperature and EC) probes and the Sensor Hub network developed by CSIRO. The sensor network has been used to demonstrate the spatial and temporal variability present in grazing landscapes in real time (Figure 1 and Figure 2). There have been substantial variations in soil temperature, soil moisture and ambient temperature observed and the potential of these data streams is enormous. This information has a number of applications for producers including providing a better understanding of sowing times for crops and pastures and management of animals which succumb to adverse climate conditions such as off-shears sheep and lambing ewes. Future research will integrate spatial livestock monitoring and remote sensing of biomass data.

Live links to data are available at http://www.sensornets.csiro.au/deployments/684.

(a) (b)

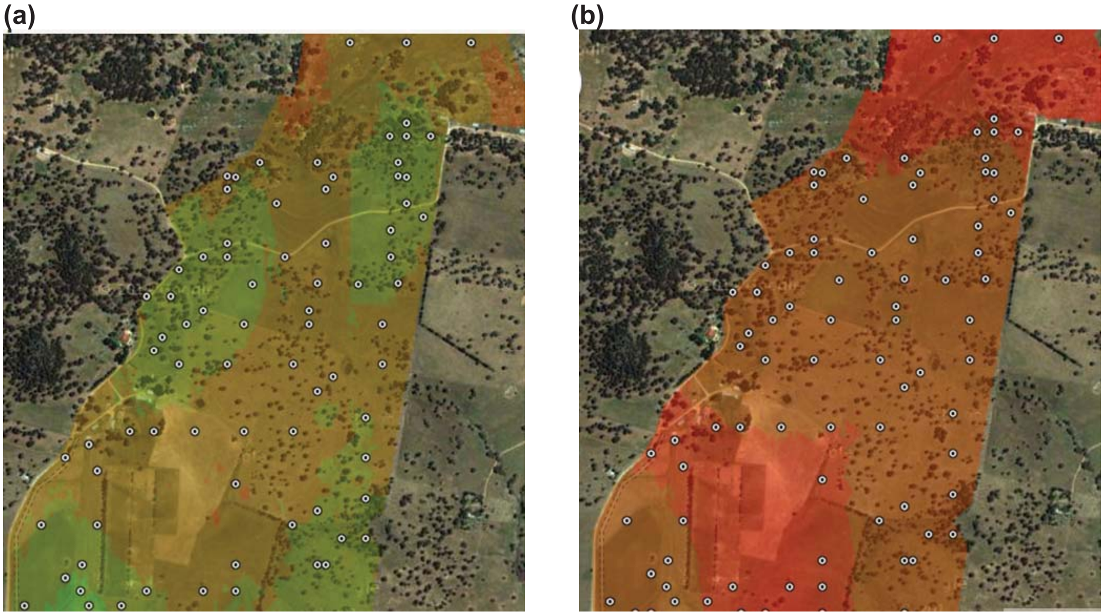

Figure 1: (a) The online map representing the spatial variability in ambient temperature from the SMART Farm sensor network. (b) The online map representing the spatial variability in soil volumetric water content from the SMART Farm sensor network.

Conclusions

Precision agriculture technologies intuitively offer an opportunity to refine the measurement and management of grazing landscapes. There are a range of sensors available that relate to the fundamental processes that underpin pasture and the animal production. These studies have highlighted the enormous variability that pervades these systems, but also the difficulty with simple, direct attempts to identify this variation with PA tools. Study 1 demonstrated large variations in soil nutrient levels which provide an opportunity for SSNM. However, in this and study 2 or preliminary analysis has found that PA sensors did not relate in an obvious way to nutrient levels. Both experiments were quite small which reduces our ability to see important differences that may exist. Likewise, studies 3 and 4 have exhibited high variability but again there were no outstanding relationships between the PA sensors deployed and the animal and pasture pests of interest. GPS tracking was able to identify significant differences in landscape utilisation by animals with different worm loads. As the accuracy of GPS tracking improves, the prospect of diagnosing animals with illness will surely increase. Technologies such as the wireless sensor networks in study 5, are now being deployed across grazing landscapes. The opportunity to track soil moisture levels in relation to pasture growth should give a much clearer indication of production potential for management decisions.

The complex interactions between the soil, plant and animal systems pose a formidable challenge for the interpretation of data provided by PA sensors. The large variability exhibited in our trials suggests there is an enormous opportunity to manage individual animals or different areas of our rural landscapes with site specific strategies. Sensing and responding to this variability will require careful application of modern PA technology and a substantial investment in research to better understand spatial variability in our grazing landscapes.

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Crop yield simulation across space: using ancillary terrain and edaphic variables to reconcile APSIM crop yield predictions with yield maps.

Konrad Muller, Brett Whelan and Alex McBratney

Precision Agriculture Laboratory, Faculty of Agriculture and Environment, University of Sydney, Australia.

Contact: Konrad.muller@sydney.edu.au

Background

The Agricultural Production Systems sIMulator (APSIM) was developed in the Australian agricultural environment for the reproduction of crop yield potential using soil and climate parameters for a spatially generalized (non-distributed) point in a field. The model's application to agriculture has been limited by its ability to approximate the within-field spatial variability in yields seen in real-world cropping environments which are subject to various yield influences outside of APSIM's modelling scope. These influences include pests and diseases, lateral water movement and water logging and heterogeneity in soil (edaphic) and terrain attributes.

Figure 1 is an example of the differences in whole profile average soil water content measured over a growing season for seven sites across a field. It shows significant variability which is driven by the heterogeneity in soil and terrain attributes. The impact of these differences on predicted crop yield are expected to be substantial.

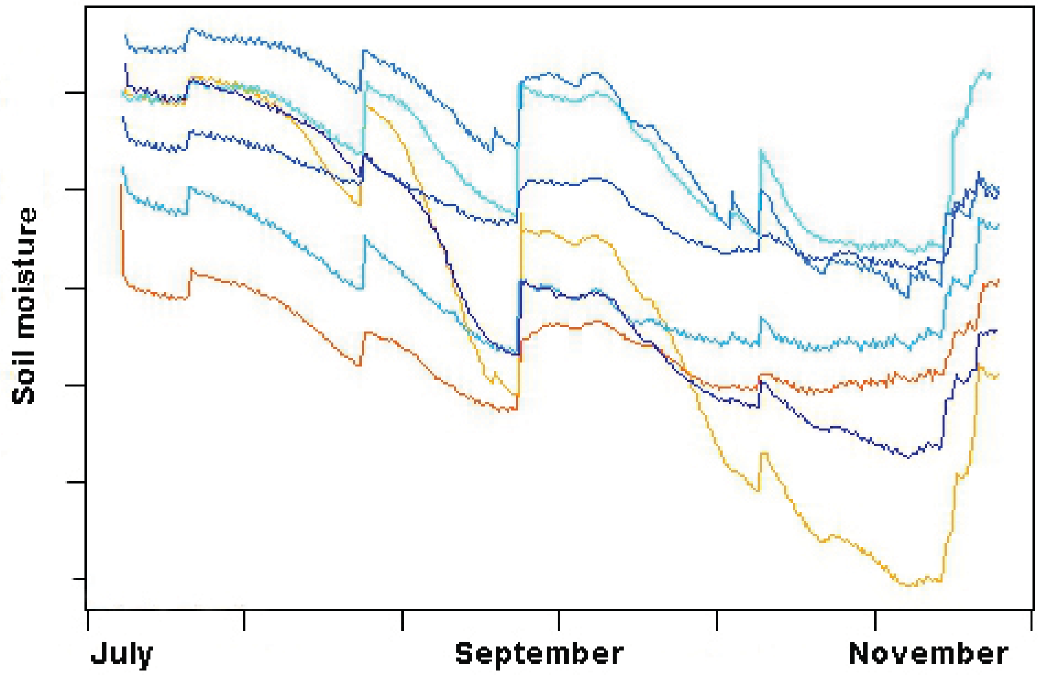

Figure1: Profile average (0-90cm) soil moisture content measured over a cropping season for seven sites across a paddock.

Summary

To account for processes outside of APSIM's scope as well as to compensate for spatial variability in soil and topographical attributes, a combined APSIM-empirical model is presented. The empirical model utilises APSIM predictions in conjunction with ancillary terrain and edaphic variables to reconcile APSIM-predicted yields with multiple years of real-world yield maps. The detail of the combined model will be discussed and an example used to illustrate the operation. The example field is located in Yarrawonga VIC where 6 years of yield map data over 130ha was collected covering 2 rotations of canola-wheat-barley in that order.

Due to the extensive work required to parameterise a soil profile for an APSIM simulation, the APSIM simulation was run using a single representative soil profile rather than spatially-distributed soil-parameters. Spatial-yield predictions were provided by kriging yield maps and terrain and edaphic variables to a 5-metre over the field. The data mining algorithm Cubist was used to select variables and build rule-based predictive models to predict either the real yield or the prediction error of APSIM (thus forcing APSIM predictions into the model) for each point in the grid. Various selections of covariates were presented to Cubist for selection and model construction, including all terrain, edaphic and climatic variables (such as annual rainfall) as well as restricted selections of variables including relatively uncorrelated covariates and principle components of covariates.

The rule-based nature of Cubist allows for the influence of terrain and edaphic variables to be conditional on the climatic conditions for the year of prediction, meaning the model has the potential to identify that under some climatic scenarios APSIM under-predicts for a part of the field and in other scenarios over-predicts. The Cubist approach also has the potential to disregard APSIM as a predictor of yield, instead predicting crop yield from climatic, ephatic and terrain covariates.

In our approach, APSIM was always included as a covariate of yield for the rule-based model, confirming it is well correlated with crop yield. The best model used proximally-sensed electromagnetic inductance (EM38) in conjunction with the slope aspect of the grid cell to estimate the prediction error of APSIM. Correlations in the range of 0.55 were found with crop yield when a leave-one yield map-out validation analysis was conducted. Further iterations of the data mining approach are ongoing and aim to improve the correlation with crop yield as well as to illicit what spatial processes may be causing APSIM to mispredict real-world crop yields.

The ability to distribute APSIM spatially as well as compensate for misprediction means that long-term synthetic yield maps can be constructed using historical climatic data to account for greater range of climatic variability when making decisions regarding spatial crop management.

Research progress of intelligent variable equipments for Precision Agriculture.

Zhang XiaoChao

Chinese Academy of Agricultural Mechanisation Sciences (CAAMS)

Contact:

Summary

This presentation reports the research progress on intelligent variable equipments for precision agriculture developed by the precision farming research group of Chinese Academy of Agricultural Mechanization Sciences(CAAMS). The research group on precision farming of CAAMS mainly engage in precision farming technology and application, including the study on intelligent equipment of precision farming, agriculture robots, quick and automatic monitoring instruments for the quality of agriculture products, mechatronic equipment, etc.

The automatic mix variable fertilizer applicator uses the new techniques of closed-loop feedback weighing control and online dosing multi-fertilization. The test result showed that the precision of variable fertilization was more than 95%. The large intelligent variable spray machine used the novel technology of weed detection based on virtual spectrum and feedback precision flow control. The test result showed that the adjustment accuracy of variable spraying amount was ±5%, the precision of weed detection was more than 80%. The combine yield monitor system used the new methods of grain mass flow monitor based on weighing and grain loss monitor based on PVDF sensor. The test result showed that the relative error of grain yield was less than 3%.

The automatic mix variable fertilizer applicator was applied on the Hongxin farm of Heilongjiang province. Comparing with the uniform fertilizer applicator, the grain yield of variable fertilizer applicator was obviously increasing. The increasing grain yield percentage of soybean and maize field was 2.33% and 9.32%, respectively.

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Applying Precision Agriculture to pastoral systems.

Ian Yule, Reddy Pullanagari, Pip McVeagh, Stefanie von Bueren, Matt Irwin, and Mike Tuohy.

New Zealand Centre for Precision Agriculture, Massey University, Palmerston North, New Zealand.

Contact: I.J.Yule@massey.ac.nz

New Zealand is highly dependent on the pastoral sector for dairying, sheep, beef and deer production. Achieving good animal productivity from grazed systems not only requires an adequate quantity of feed, but also high quality fodder. So far there has been little opportunity for farmers to have near real time information on pasture quality or quantity and grazing practises are likely to be characterised by suboptimal grazing utilisation and failure to maximise consumption of high quality feed.
Research published by Pullanagari et al (2011, 2012a, 2012b) demonstrated how hyperspectral and multispectral sensing could be used to measure in-situ pasture nutritive value. This work was completed on dairy pasture, further work was commissioned through the C. Alma Baker Trust and Massey University and carried out on a large grazing property called Limestone Downs, located near Raglan, on the North West coast of the North Island. This work was to examine and evaluate the variation in pasture quality on that hill country property. The work centred around a field study carried out in January 2012 of the property, taking samples and subjecting them to a number of means of analysis. The database was developed from sites around the farm that had different slope, aspect, grazing and fertiliser histories. The annual pasture productivity is estimated to vary between 0 and 13t of DM ha-1, depending on a number of factors across the farm.

Management of the farm is a complex logistical exercise, rotating mobs of cattle and sheep around the various paddocks on the farm. While seasonal trends of pasture cover and quality are taken into account and informal estimates of pasture cover are made, it is likely that further improvements in grazing utilisation could be achieved. The terrain is often steep with limited or no vehicle access, fertiliser application is completed through aerial topdressing. The farm has a good and documented history of fertiliser application.

A total of 105 samples (7 distinct sites, 15 samples per site) were taken on this field study. Samples were optically sensed using an ASD Field Spec® Pro (ASD Inc., USA), it has wide spectral range from 350-2500 nm, FieldSpec HandHeld 2TM (ASD Inc. USA) with a spectral range of 325-1075 nm and Crop Circle (Model-ACS470) (Holland Scientific Inc., USA) with three channels. Samples were then cut to ground level and sent to the laboratory for chemical analysis. The following range of pasture quality parameters were considered; crude protein (CP), metabolisable energy (ME) and In vitro organic matter digestibility (OMD).

Figure 1: A field measurement site, illustrating the type of terrain on Limestone Downs.

The spectral data from the above instruments were analysed and regressed against analytical values using partial least squares regression (PLSR) method. The results from the analysis indicated that the sensor with wide spectral range has a high level of explanation of the pasture quality data from the chemical analysis. Figure 2 illustrates the results from samples analysed by the ASD Field Spec Pro, using a laboratory prepared, dried and ground sample. Figure 3 illustrates the relationships between the same sites, this time measured in-situ. This was completed using the Canopy Pasture Probe (CAPP) developed by Sanches (2010) to block ambient light and illuminated using a Tungsten-Quartz-Halogen light source. It shows a strong relationship although there is greater variation than with the laboratory measured samples. Figure 4 shows the results for the same samples when measured against the FieldSpec HandHeld, this has a reduced spectral range and relies on ambient light for illumination.

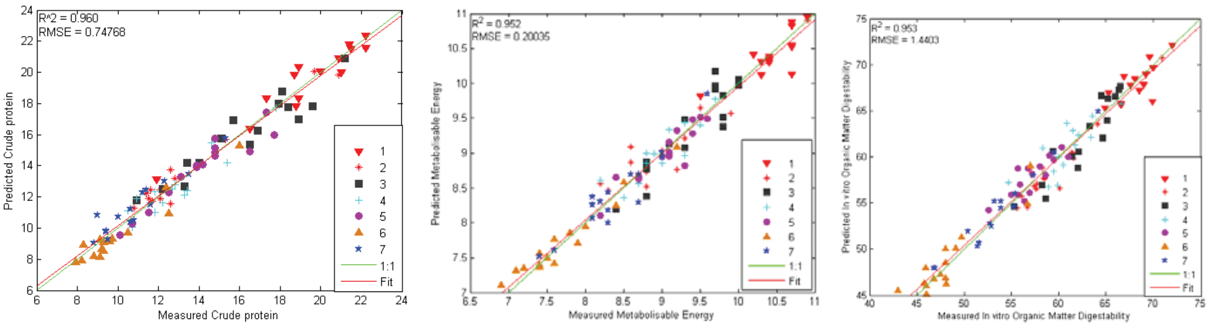

Figure 2: Calibration model between dry vegetation spectra and reference values using PLSR

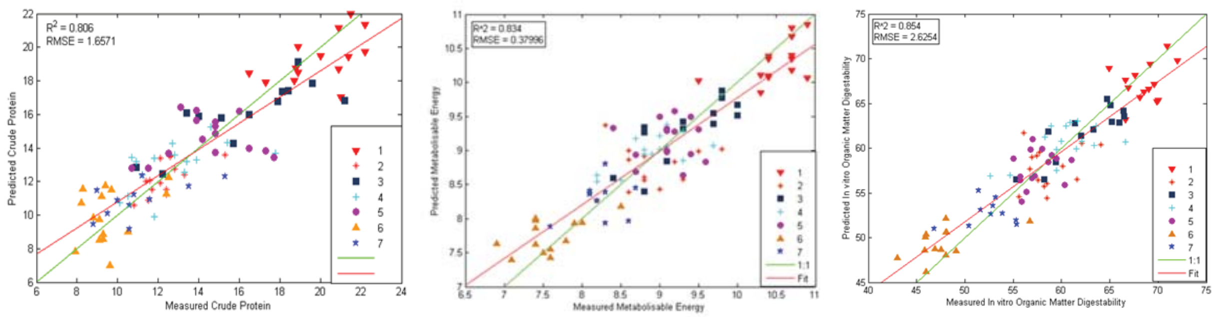

Figure 3: PLSR models between green vegetation spectra (ASD Field Spec® Pro) and reference values.

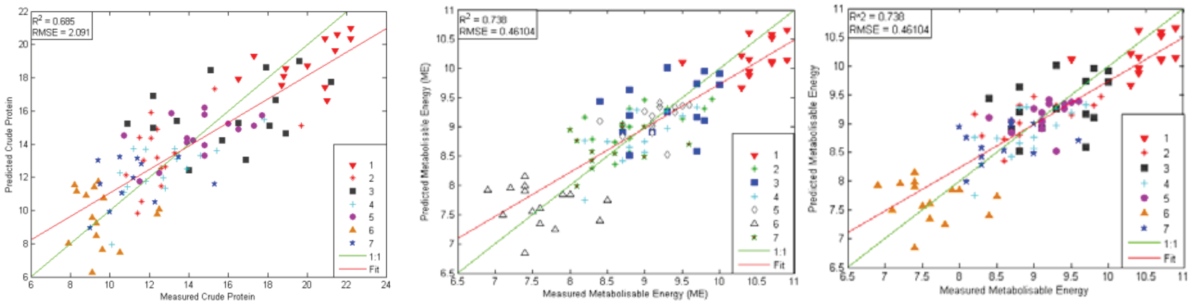

Figure 4: PLSR models between reference values and green vegetation spectra obtained by Handheld-2™.

Strong correlations (R2:0.95-0.96) were observed between reference and spectral values obtained from dry vegetation (Figure 2). Figure 3 has reasonable correlation (R2:0.80-0.85) between reference and spectra obtained in the field. However, the level of explanation with the Handheld unit (R2:0.68-0.73) was decreased with the short spectra range sensor and use of ambient light. The study demonstrates the likely performance of currently available instruments. In the above figures, different symbols represent different site locations and pasture nutritive values clearly changed with location as observed from the grouping of symbols on the figures. This indicates that there could be significant management value in this information if it could be used in a near real time way.

Conclusions

This research demonstrated the potential of hyperspectral sensing to determine the nutritive value of pasture in this extensive grazing system. The earlier dairy work was completed with a much larger data set with extensive validation, however this initial study in hill country does appear to offer some optimism that it should also be possible to determine the characteristic of hill pastures from optical means.

Having the ability to quantify pasture quality and quantity will be a considerable advantage to hill country farmers and allow them to better plan their grazing decisions as well as deciding which groups of animals are best suited to the varying qualities of pasture. The results of the study indicated very large differences in pasture quality in terms of CP, OMD, and ME. It is doubtful that farmers fully consider the implications of these large differences

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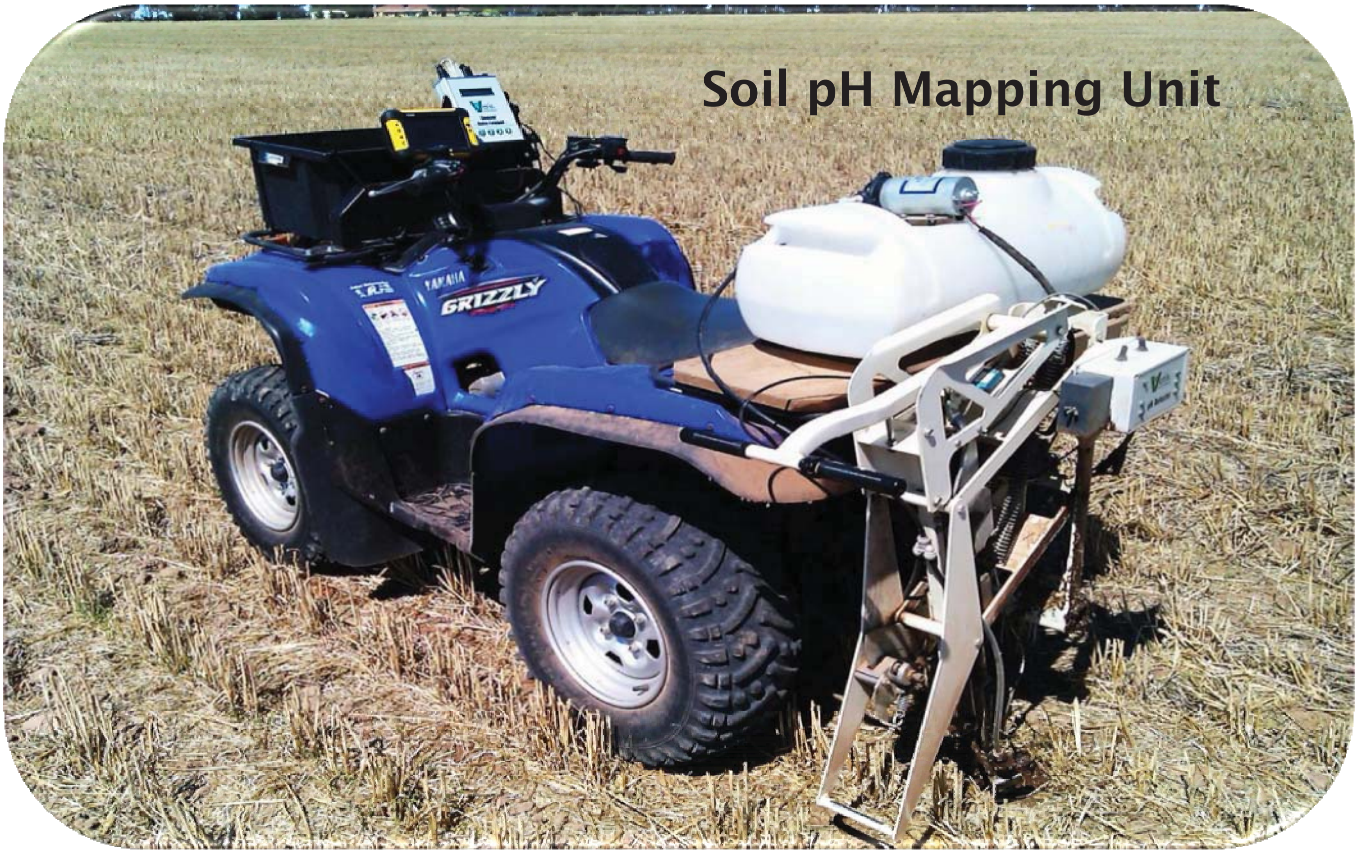
Rapid soil pH mapping for variable rate lime has become extremely popular throughout Southern Australia



Andrew Whitlock
andrew@precisionagriculture.com.au
0458 312 589

Brendan Torpy
brendan@precisionagriculture.com.au
0432 203 715

Precision irrigation – a uniquely Australian perspective.

Rod Smith

National Centre for Engineering in Agriculture (NCEA), University of Southern Queensland.

Contact: Rod.Smith2usq.edu.au

Take home message

- (i) Precision irrigation is not a particular application system.
- (ii) Precision irrigation is a way of thinking about and managing irrigation.
- (iii) The dominant position held by surface irrigation demands its development as and acceptance as a precision irrigation system.

Precision irrigation

The traditional irrigation application systems (surface and pressurised) are at the limit of their irrigation performance under current management practices. But future gains in performance can be achieved through the use of advanced technologies and management, in particular the use of adaptive control, thus converting them to precision irrigation systems. Adaptive control systems automatically and continuously re-adjust ('retune') the irrigation application system to obtain and retain a desired performance, and thus account for any variability (temporal or spatial) in crop water requirements or water intake across the field.

A 2010 review of precision irrigation conducted by the NCEA (Smith et al., 2010) described precision irrigation systems as those that can:

- (i) determine the timing, magnitude and spatial pattern of applications for the next irrigation to give the best chance of meeting the farmer's seasonal objective (i.e. maximisation of yield, water use efficiency or profitability);
- (ii) be controlled to apply exactly (or as close as possible to) what is required;
- (iii) through simulation or direct measurement know the magnitude and spatial pattern of the actual irrigation applications and the soil and crop responses to those applications; and
- (iv) utilise these responses to best plan the next irrigation.

In other words, a precision application system:

- knows what to do;
- knows how to do it;
- knows what it has done; and
- learns from what it has done.

Precision irrigation requires real-time knowledge of the factors which are limiting production at any time in all areas of the field. The experience from precision agriculture suggests that the variables controlling crop yield are those that require within season management (e.g. water, nitrogen, pests and diseases), all of which can be addressed with an automated response. The precision agriculture experience also suggests that the temporal variations (within and between seasons) are greater than the spatial variability that the variable rate technologies attempt to address.

Precision irrigation implies a system that can adapt to the prevailing conditions. Also implied is the idea that the system will be managed to achieve a specific target which, for example, may be maximum water use efficiency, maximum yield or maximum profitability. This requires access to detailed data regarding the crop, soil, weather, environment and other production inputs, the interaction of these variables and the agronomic responses to these inputs at the relevant spatial scale.

Crop simulation models provide the first step towards the identification of optimal strategies. These models are an essential part of the real-time decision systems required for precision irrigation by incorporation into controllers on irrigation application systems. Models able to simulate the behaviour and performance of the application system are another necessary feature of the precision irrigation 'toolkit'.

The pressurised application systems (drip and sprinkler) are often claimed to be the more efficient application systems and hence are sometimes incorrectly given the status as precision systems. Similarly, precision irrigation is often equated incorrectly with spatially variable irrigation applications, which at this stage are a possible, technically feasible but non-essential component of precision irrigation. Spatially varied irrigation is also yet to be proved cost effective.

Determining the potential for spatially varied irrigation requires an understanding of the spatial scales inherent in the various application systems (Table 1) and the spatial scale associated with the variability in the crop water requirements. It further requires an ability to sense in real-time the water requirements of the crop and its responses at the appropriate scale.

Table 1: Spatial scales of common irrigation systems (from Smith et al., 2009)

System	Spatial Unit	Order of magnitude of spatial scale (m^2)
Surface - furrow	single furrow	1000
Surface - furrow	set of furrows	50000
Surface – bay	bay	10000 to 50000
Sprinkler – solid set	wetted area of single sprinkler	100
Centre pivot, lateral move	wetted area of single sprinkler	100
LEPA[#] – bubbler	furrow dyke	1
Travelling irrigator	wetted area of single sprinkler	5000
Drip	wetted area of an emitter	1 to 10
Micro-spray	wetted area of a single spray	20

LEPA – low energy precision application

It can be argued that any application method has the potential to part of a precision system providing it meets the definition given above. However moving from the traditional management to precision irrigation is not easy. The difficulties presented by the issues of scale, the data requirements, and the role of simulation or decision support modelling can be well visualised from the work on the VARIwise simulation framework of McCarthy et al. (2010).

The uniquely Australian perspective that gave the present paper its title is the notion that precision irrigation can be extended to any irrigation application method and in particular to the much maligned surface irrigation systems of bay and furrow. Hence, the remainder of the paper aims to demonstrate that notion by describing the current NCEA work directed at the real-time adaptive optimisation and control of surface irrigation.

Surface irrigation as a precision method

Past performance and potential for improvement

Surface (bay and furrow) irrigation is one of the most commonly used methods for irrigating crops and pastures in Australia and around the world due to the low cost and low energy requirements. While well designed and managed surface irrigation systems may have application efficiencies of up to 95%, many commercial systems have been found to be operating with significantly lower and highly variable efficiencies. Previous research in Australia in the sugar and cotton industries (Raine and Bakker, 1996, Smith et al., 2005) found application efficiencies for individual furrow irrigations ranging from 10 to 90%. Fewer data were available for bay irrigation of pasture and fodder crops but a similar performance is indicated (Smith et al., 2009).

The efficiency of surface irrigation is influenced by the field design and the infiltration characteristics of the soil, but is primarily a function of the irrigation management. However, the complexity of the interactions makes it difficult for irrigators to identify optimal management practices. The infiltration characteristic of the soil is a dominant factor in determining the hydraulic behaviour of surface irrigation and both spatial and temporal variations in the infiltration characteristic are a major physical constraint to achieving high irrigation application efficiencies and also limit the usefulness of generalised management guidelines for surface irrigation.

Improvement of furrow irrigation performance through the process of evaluation and simulation with the IRRIMATETM suite of tools developed by NCEA has been widely adopted in the cotton industry. Real-time optimization of individual irrigations can help to overcome the effect of these spatial and temporal variations and provide an even greater improvement in irrigation performance. Coupling this real-time optimisation with automation gives ‘smart automation’ where the time to cut-off (and possibly flow rate) are varied automatically in response to the behaviour of an irrigation to give the maximum performance for that irrigation. A number of simulation studies (e.g. Raine et al., 1997, Smith et al., 2005, Khatri and Smith, 2007, Gillies et al., 2010) have quantified the potential improvement in irrigation performance achievable through real-time optimization and control. When the management parameters were optimized to simulate perfect real-time control of individual irrigations, average application efficiencies in excess of 90% resulted along with storage efficiencies also greater than 90%.

The vision

The conceptualisation of surface irrigation as a precision system is provided in Figure 1. In this case, ‘smart’ automation involving real-time optimisation of individual irrigation events is used to manage, optimise and control the application of water to each set of furrows. To optimise seasonal WUE a further layer of decision support using a modified version of the VARIwise model is required. The crop response to the irrigations needs to be monitored and modelled continuously through the season to determine the irrigation timing and amounts that give the desired response. This information also helps to determine the preferred strategy for management of the individual irrigation events and to account for the effects of spatial variability along the length of the field and between furrows or bays.

Real-time optimisation of furrow irrigation

Khatri and Smith (2006) provided the basis for simple real-time optimization using a model infiltration curve for the field in question and an event-specific infiltration characteristic determined during the irrigation being controlled from a single advance measurement and a process of scaling. The method is based on the premise that for any field the shape of the infiltration characteristic remains the same but the magnitude can vary spatially and temporally.

The automated real-time optimisation system developed at NCEA is described in more detail in Smith et al. (2012) and involves:

- automatic commencement of the furrow inflow and automatic continuous measurement of that inflow;
- measurement of the advance down the furrows mid-way through each irrigation;
- real-time estimation of the current soil infiltration characteristic from this single observation of the irrigation advance per set of furrows during the irrigation event being controlled;
- real-time simulation and optimisation of the irrigation to select the time to cut-off that gives maximum performance for that set of furrows for that irrigation, taking into account the current soil moisture deficit and any variation in behaviour across the set of furrows; and
- automatic cut off of the inflow at the designated time.

Decision support software is an essential part of the system and the software has to perform steps 3 and 4 without user intervention.

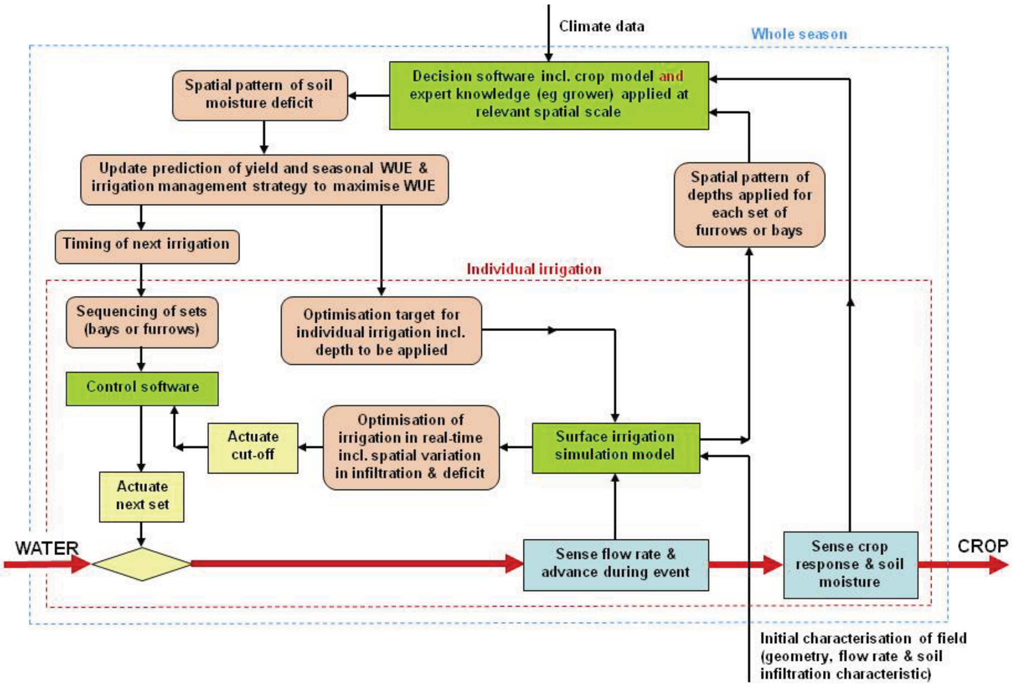


Figure 1: Surface irrigation as a precision irrigation method.

Trials of this system were undertaken on a furrow irrigated cotton property at St George in south-western Queensland. Four irrigations in the summer season of 2010-11 were monitored in a section of the field that used pipes-through-the-bank (PTB) to supply groups of 11 furrows that were 970 metres long and spaced 1 metre apart. The results showed that the irrigation times predicted by the system were shorter than those used by the farmer in irrigating the remainder of the field. This translated to reduced runoff and deep percolation losses and higher application efficiencies as a direct result of the real-time optimisation. Trials of the system are continuing.

Automation

While the real-time optimization can be operated as a manual system the greatest benefits occur when it is integrated with automation. The desired time to cut-off is transmitted to the control hardware. This hardware is commercially available for bay irrigation in the form of the Rubicon Water FarmConnect® system (Figure 2). Work on adapting the system to furrow irrigation and linking it to the real-time optimisation is underway and is due to be trialled in the coming 2012/13 irrigation season.

Figure 2: Automated bay outlet and water depth sensor for the FarmConnect® system (Rubicon Water publicity brochure).

Conclusion

Precision irrigation is defined to include all irrigation application systems providing they are managed according to the principles outlined in the definition. The dominant position held by surface irrigation in this country demands that it be managed in a way that will give maximum irrigation performance and maximum productivity, that is, as a precision system. The conceptualisation of that precision surface irrigation system is provided, and work on the development of the real-time optimisation component is described. Field trials have proven the concept and established the basis for commercialisation of the system. Integration of the real-time optimisation with a commercially available automation system is the subject of future work on the system. The final stage of the work will add VARIwise as the seasonal management umbrella over this event management system.

Acknowledgements

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A big 18 months with PA and agronomy.

Chris Hunt

'Wargan' Victorian Mallee

Contact: c.a.hunt@bigpond.com

Introduction

I grew up on the family farm, 30km west of Mildura. I left school and completed an apprenticeship as a diesel mechanic, then spent the next 8 years working various jobs in mining, AG, road transport and earthmoving.

I came home to be part of the farming business in November 2010 after 12 years away. Early 2011 started a big learning curve in the world of PA and agronomy for me as I started to question what we do and why. I work of a motto that 'you always get what you are giving if you always do what you do'. With this I was also looking to make some of the high dollar features on our equipment pay for use.

The farming business is based 30km west of Mildura. We farm both owned and share farmed ground that is average mallee country consisting of sand hills and heavy flats. For 2012 we have 4700ha of crop, wheat, feed barley, canola and export oaten hay, with field peas been bulked up to be included in the system.

PA starting point 2010

- Manual variable-rate fertiliser by eye, adjusting rate while sowing to hills and flats.
- Light bar guidance for spraying.
- RTK for seeding and harvest, aiming for inter row sowing.
- Yield mapping.
- MAP/urea blends for fertiliser.

Changes in PA for 2011

- Attended basic SPAA training day, this kicked all PA off.
- Convert air seeder box to Topcon X20 for VRC
- Use yield maps from header to build zones for VRC fertiliser at seeding, using MAP/urea blend.
- Manual variable rate were yield data was not available to build zones.
- Spread SOA and urea on targeted are with fixed rate spreader.

PA for 2012

- Convert air seeder box to 3 bins, 1 bin MAP for phosphorus, 1 bin urea for nitrogen and 1 for seed.
- VRC on all fertilizer at seeding, some zones of 2010 yield maps and some off elevation. 3 zones used for MAP and 2 zones for urea.

- Update spray tractor, full auto steer fitted and able to record coverage maps for all work carried out, fit pressure switch to boom spray for work control of coverage maps.
- Change to European style linkage spreader with the ability to variable rate manually.
- Carry out some seeding rate trials, aiming for higher plant numbers where the crop does not tiller. Lift seeding rate from normal of 30kg/ha to 50kg/ha in wheat and barley on these trials.
- Carry out some NDVI while spraying crop (Figure 1).
- Purchase hand auger to dig down and assess moisture at depth, to help understand each zones sub-soil moisture levels when making rate and crop decisions (Figure 2).

Figure 1: NDVI crop sensing while spraying

Figure 2: Assessing moisture in-zones for top dressing of urea.

PA next steps with what we have on farm for 2013

Establish/tidy up zones, using yield maps, NDVI, elevation, Google earth images and gut feel. The aim is for 3 or 4 phosphorus zones, 2 or 3 nitrogen zones, 1 or 2 sulphur zone and 1 or 2 seed zones in each paddock.

The zones (Figure 3) are defined as high, mid and low:

- High zone is the peaks of sand hills, they do also have high yield potential and also high input needs as they tend to be sand to sandy loam. This zone is high for nitrogen and phosphors rates and is also were the main amount of our topdressing of sulphur and nitrogen in crop is done.
- Mid zone is sides of sand hills or sandy rises and tend to be sandy/loam. These areas have good yield potential and do not seem to be as deficient N,P or S. This zone is the mid zone with urea and MAP rates at seeding. For top dressing this zone will get SOA when growing canola and also urea. With cereals this zone may get top dressed depending on the year, crop, history, weather and the budget.
- Low zone is the flats or swale between the sand hills. This ground tends to be heavy loam and the yield potential varies greatly with the year, the zone tends to have high nitrogen and phosphorus levels. The factors that limit yield here most are moisture and sub-soil constraints like boron. This is our low zone for all inputs, if the rainfall is with it the zone performs well without extra inputs.
- Heavy Zone these areas are heavy clay and better off not seeded, this is on some paddocks we share farm and would not make up 10% of the paddocks we present. We don't use any fertiliser here.

Figure 3: Crop production zones.

We are currently using flat seeding rates, 30kg/ha for wheat, oats 35kg/ha, barley 40kg/ha and canola 1.1kg/ha. With a change to seeding rate zones, the aim is to pick out hill tops that don't tiller due to being deep sand or heavy erosion in the past. We have carried out some tests at seeding and will review how this works, in the test the seed rate was lifted to 50kg/ha.

RTK and headers

We use RTK steering on the header, this works well, the one down-fall is we run on the same tracks every year and as we are not on controlled traffic this keeps the header tracks packed tight and paddock rough to cross. To overcome this we will start nudging our AB line at harvest.

How does PA pay in the Mallee?

- For a $1 dollar spent in the 2011 session phosphorus returns $1.20, nitrogen $3 and sulphur on sandy soils $5 and summer weed control $5 to $9.
- By using PA we can keep our summer fallows in check to have moisture to use in crop as well as cut down the amount of nutrient removed by summer weeds.
- Phosphorus zones always use to work off P replacement plus a bit, even though the return from phosphorus is low we like to build our levels not mine them.
- Zones for urea at seeding, SOA and urea at topdressing gets the nitrogen and sulphur to where we will get $ back for it.
- RTK steering may not have a $ return but aids trash flow considerably and also help to keep misses down (Figure 4), maximising chemical incorporation.

Figure 4: The effect of missing a summer spray.

PA into the Future on our farm

The wise list

- section control on boom spray
- update RTK steering system when tractor is updated
- grain sensor equipment for moisture and protein as we grow our on-farm storage
- Possible NDVI sensor equipment

- WeedSeeker spraying for fallow may have a place, the cost effectiveness of this is driven by glyphosate pricing. For a weedseeker to work they need to have flat rate ability with the weedseeker side giving the bigger weeds a hit.

Summary

In our business over the last 2 years we have come a long way with PA and can see where we are aiming to get to. Most of what we have done is to bring together the equipment and farming practise we already were using.

It has been a big two years for me in the world of PA and agronomy, SPAA has been a great organisation for us to be a part of due to the standard of training days run and the take home DVD is second to none.

Notes

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SPAA Precision Agriculture Australia
PO Box 3490 Mildura | Victoria 3502
P 0437 422 000 | F 1300 422 279
www.spaa.com.au

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