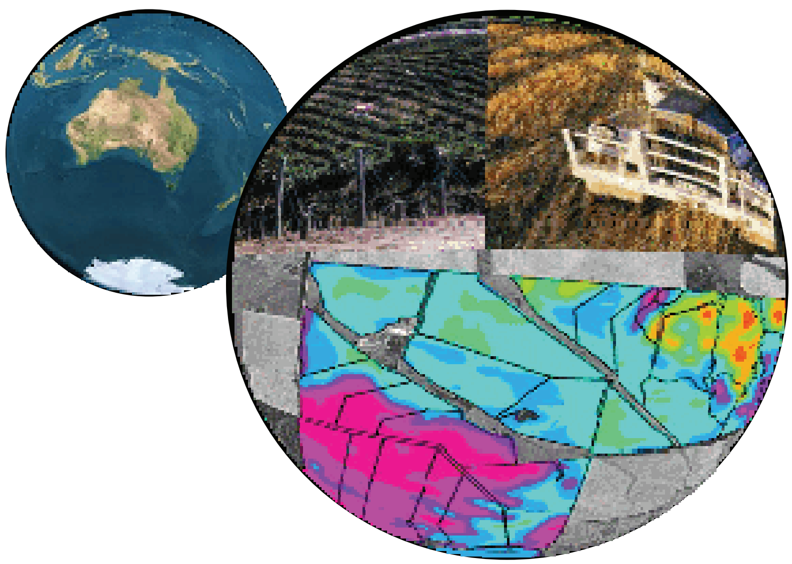
12th Annual Symposium on Precision Agriculture Research & Application in Australasia

The Australian Technology Park
Eveleigh, Sydney
Friday 19th September, 2008



Proceedings

Australian Centre for Precision Agriculture

SIDERE MENS EADEM MUTATO

SPAA
Southern Precision Agriculture Association

Welcome

Welcome to the 12th annual gathering of PA practitioners in Australasia. Since the inaugural meeting in 1997, the technology to which we have access has changed dramatically, and our ideas for using it have similarly advanced. While we have all been working on ensuring that Australian agricultural industries benefit from these developments, the global economy has been exerting an ever increasing influence.

The cost of fuel, fertiliser, pesticides and finance has risen dramatically over the last 8 months and in all likelihood they are unlikely to return to 2007 levels. The hike in input prices has been matched in some industries by a reasonably substantial increase in the price paid for crop commodities. However, the substantial rise in input costs has significantly increased the risk for farm production: the outlay for crop establishment and maintenance is now a much greater burden.

So with an increased financial risk now associated with production and the possibility of changes in environmental conditions affecting the production outcome, it is little wonder that the use of site-specific crop management (SSCM) is higher in the minds of farm managers. It is under these testing financial and environmental conditions that information on variability relevant to the farm enterprise itself becomes ever more important. Regional or average production prescriptions become less useful as price sensitivity increases.

A testimony to this is the fact that alongside the well known industry users of SSCM we have a number of new industries represented today. There is also evidence of a wider use of the tools and application in the presentations relating to ecological, environmental and animal aspects of farm management.

But while the benefits of SSCM are becoming more widely understood in the agricultural community, it is in the general community that the message needs to be more strongly broadcast. Cost efficiency, resource-use efficiency as well as the production and traceability of vastly more detailed consumer marketing information make SSCM a very positive story for agriculture in the community.

And the opportunities continue to be enormous.

Enjoy the day, meet your colleagues and participate in the discussions. It is this interaction that will ensure the 13th Symposium will be even better and more useful.

The ACPA and SPAA teams.

9.00am	Welcome *Alex McBratney*
9.05am	Exploring spatial variation in sweet corn production. *James Taylor, Sam Hedges & Brett Whelan (ACPA)*
9.20am	PA in the sugarcane industry. *Lawrence Di Bella (Herbert Cane Productivity Services Ltd) – presented by Rob Bramley (CSIRO)*
9.40am	Overview of Precision Agriculture Research in Victoria. *Peter Fisher & Abdur Rab (DPI VIC)*
10.00am	Robotic solutions for autonomous farming - joint efforts of precision agriculture and autonomous systems. *Ray Eaton, Jay Katupitiya, Kim Song Dang (UNSW) & David Ruiz (CSIC/ACPA)*
10.20am	Using electroconductivity sensors for precision farming zones of Malaysian paddy fields. *MSM Amin & W Aimrun* (UPM)
10.40am	Morning Tea
	Chair: Rob Bramley
11.15am	Variable-rate irrigation. *Ian Yule (NZCPA)*
11.35am	Steering implements and web-based data processing and delivery of prescriptions. *Brendan Williams (GPS-Ag)*
11.55am	GPS cattle tracking for understanding the impact of grazing on grain and graze rotations and for improving pasture utilization. *Dave Lamb (UNE)*
12.15am	Site specific weed management - a case study with ryegrass (*Lolium rigidum*) in southern Australia. *Sam Trengrove (Allan Mayfield Consulting)*
12.35am	Southern Precision Agriculture Association (SPAA) – promoting the development and adoption of PA technologies. *Mark Branson (SPAA)*
12.40pm	Lunch
	Chair: David Lamb
1.40pm	Yara N-Sensor: a multi-purpose platform for on-line variable-rate application of fertilisers and other agrochemicals. *Stefan Reusch (Yara) (sponsored by Topcon Precision Agriculture)*
2.05pm	Is it your first time? Opportunity for PA in dryland grain farming using different data layers. *Ronaldo de Oliveira (EMBRAPA & ACPA)*
2.25pm	The economics of adopting PA technologies on Australian farms. *Malcolm Sargent (SPAA)*
2.45pm	Using precision agriculture technologies in grain farming landscapes for ecological objectives. *Mike Robertson (CSIRO)*
3.05pm	Targeting fertilizer management for improved environmental outcomes in the sugar industry. *Rob Bramley (CSIRO)*
3.25pm	Afternoon Tea
	Chair: Brett Whelan
4.00pm	Impressions from the 9th International Conference on PA in Denver, Colorado (July 2008). *Ashley Wakefield (SPAA)*
4.15pm	Precision Agriculture: moving beyond the early adopters to the masses. *James Hassall ("Kiewa" Gilgandra NSW)*
4.35pm	PA Opportunities. *Alex McBratney (ACPA)*
4.55pm	Close

Exploring Spatial Variation in Sweet Corn Production

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Summary

For site-specific crop management (SSCM) to be viable a production system must exhibit a sufficient magnitude and spatial structure in crop response to make differential management economically feasible. The crop response may be a yield or quality response. Prior to committing to larger projects, a preliminary investigation into the variability within sweet corn production systems was undertaken. The intention was to quantify how variable crop response was, which spatial technologies are most applicable to variable rate management and how successful decision support systems to assist growers may be.

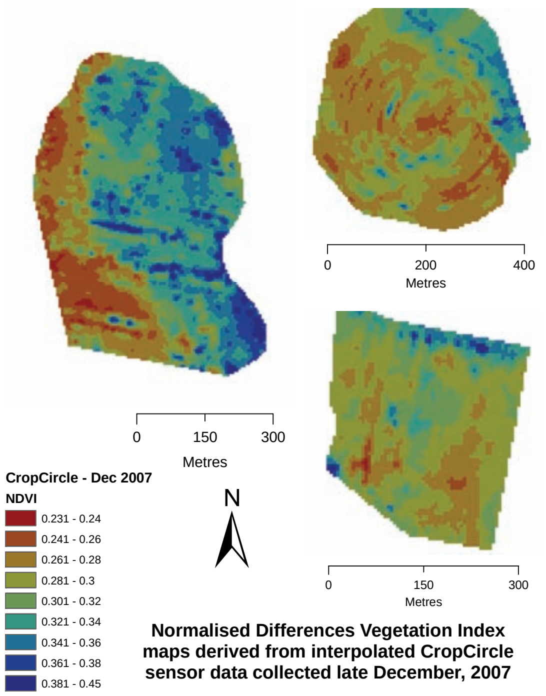
Both yield and quality attributes exhibit large ranges and spatial coherence under this irrigated cropping regime. Yield in particular was spatially structured providing opportunities for SSCM. Quality attributes exhibited less spatial structure but enough to suggest that they could be managed spatially. The range in yield response (from 6 to 30 $ton.ha^{-1}$) in a uniformly treated production system, provides opportunities to better manage fertiliser. A simple economic analysis, based on applied nitrogen and possible yield response, shows potential savings on fertiliser of $122 - $243 per hectare in the three fields. This is without incorporating any spatial management. Further savings are possible when information from mid-season biomass sensors is included.

An analysis of the applicability and best way of constructing management classes was undertaken. Information from early and mid season canopy sensors provides the best data for constructing management classes and in 1 out of the 3 paddocks, the addition of information on soil ECa improved the classification. This indicates that current on-the-go variable-rate fertiliser systems, such as the N-sensor, Greenseeker and CropCircle, may be readily adapted to these irrigated production systems and possibly negate the need for management classes. Information from soil sensors did not consistently assist in agronomic decision making, possibly due to the presence of irrigation (removing issues associated with variation caused by variable soil moisture holding) and probable excess nutrition in the system. For any growers interested in investing in SSCM, a proximal canopy sensor or aerial image acquisition appears to be the best option (provided sufficient spatial agronomic support is available).

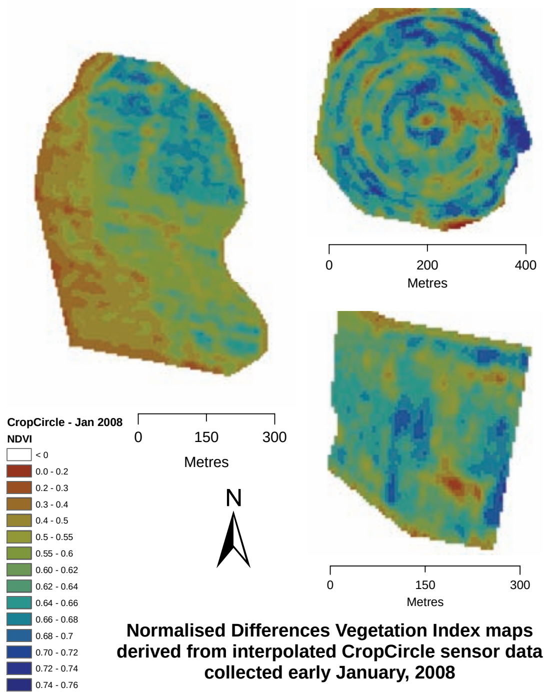
To be used effectively these variable rate fertiliser systems need decision support systems which in turn require good crop models to predict potential yield and fertiliser requirements. Preliminary modelling indicates that canopy sensor data, coupled with plant density data, does provide good predictions of yield. This data is preliminary but concurs with recent published information that looks at adapting maize crop models to sweet corn. It appears that information on plant density is a prerequisite for progress in this area. Non-destructive methods for measuring or

estimating plant density are a priority. Modelling of the yield-quality interaction was also undertaken. The models indicate that quality, in this case cob length, can be manipulated by managing yield. This may be of more significance in the fresh market sweet corn industry.

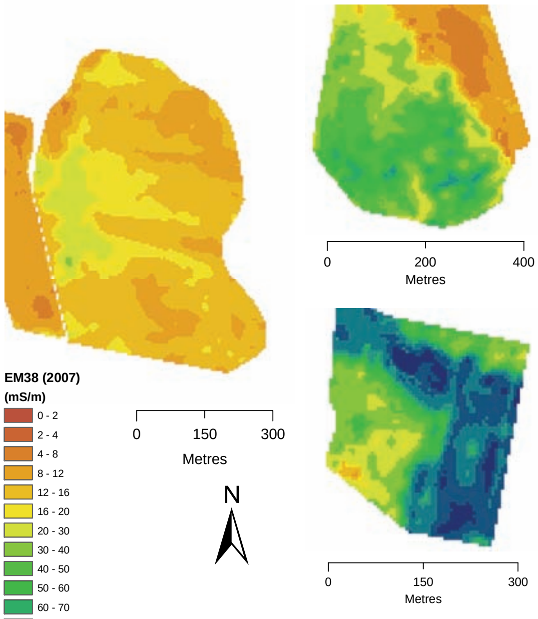
The adoption of new technologies and methodologies is dependent on growers being able to recognise a positive return on investment. Without a yield or quality sensor at harvest it is difficult to quantify the effect of SSCM. The development/adaptation of yield sensors for a sweet corn harvester is a major step in making PA work in sweet corn. If a viable sensor is available/developed, the effect should be positive as the harvest is centrally contracted. Therefore, a few sensors will be able to service a large proportion of the industry. The vertical integration of the industry and interest by the processor, Simplot Australia, in SSCM means that advances in this area should be well received and adopted by growers.



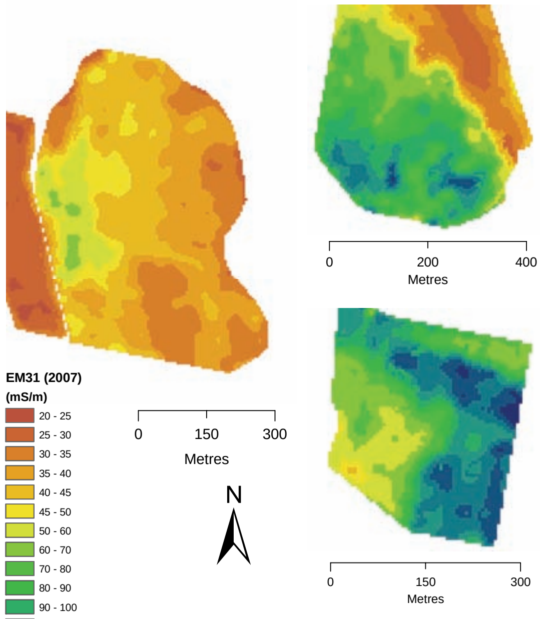
Normalised Differences Vegetation Index maps derived from interpolated CropCircle sensor data collected late December, 2007



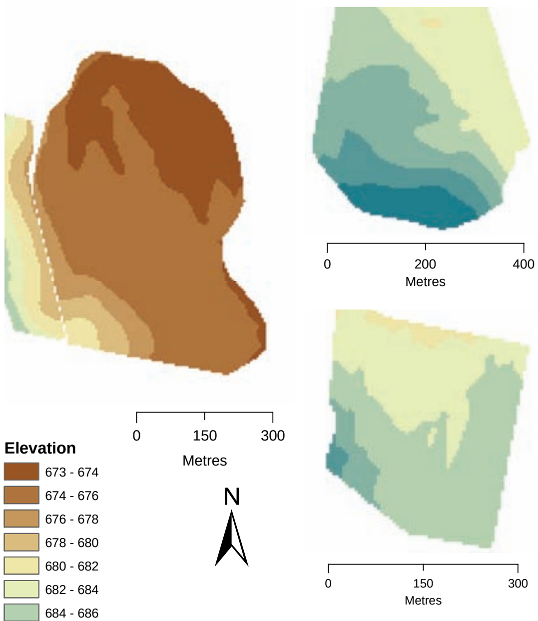
Normalised Differences Vegetation Index maps derived from interpolated CropCircle sensor data collected early January, 2008



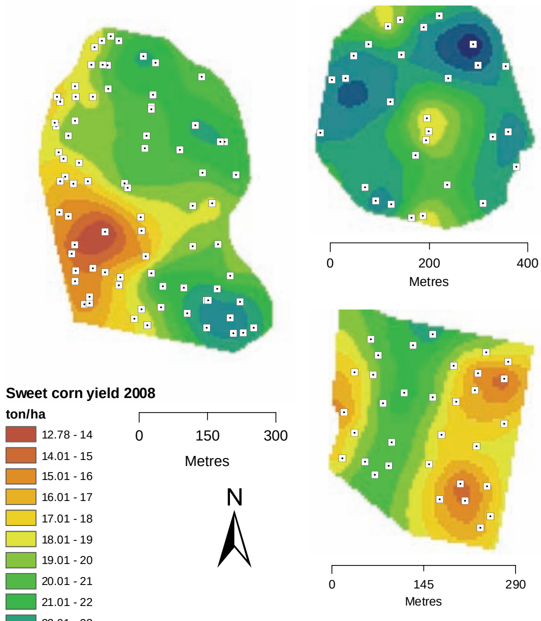
Maps of the apparent Electrical Conductivity of the soil profile (0 - 1.5 m) interpolated from a Geonics EM38 survey September, 2007



Maps of the apparent Electrical Conductivity of the soil profile (0 - 6 m) interpolated from a Geonics EM31 survey September, 2007



Elevation maps derived from interpolation of Omnistar HP-GPS data collected September, 2007



Yield maps for the three fields created from kriging with a global variogram. The location of yield sample points are shown

Acknowledgement

We would like to acknowledge the support of Mr Jeff McSpedden and his staff for assistance and access to fields and sweet corn crops during this study. The assistance of Simplot Australia and Mr Evan Brown for technical advice and consultation during the project is also appreciated. Finally, the authors would like to acknowledge again the financial support of Horticulture Australia Ltd and AUSVEG through the Australian Vegetable Industry Levy. The Australian Government provides matched funding for all HAL's R&D activities.

Implementing Precision Agriculture in the Herbert Sugarcane Industry, Queensland, Australia.

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Abstract

The Herbert River district is currently establishing and implementing Precision Agriculture (PA) techniques to ensure industry viability and sustainability into the future.

During the past 15 years, the region has been developing tools and strategies to allow the region to move towards the implementation of precision agriculture.
The two main drivers for the push to implement precision agricultural techniques are:

- The Herbert sugarcane growing region is located between the World Heritage listed Great Barrier Reef and rainforests of Northern Queensland; a very environmentally sensitive area.
- The current cost price squeeze with low commodity prices for sugar and escalating costs of fuel, fertiliser and herbicides.

The implementation of precision agriculture will assist the industry to reduce or contain costs, whilst ensuring the industry meets environmental best practice.

The Herbert region is undertaking a cross regional focus to PA instead of individual growers working in isolation. This concept is fundamentally different from the other regions within the Australian sugarcane industry.

Introduction

The concept of Precision Agriculture in sugarcane is relatively new; however its principles have been used by farmers worldwide for long time. It has become a reality with the development of spatial information and mechanization technologies (Esquivel, 2007a).

PA offers cane growers the opportunity to apply site specific management practices to a cane paddock. PA provides growers with new sources of information about their land and crop performance as well as the opportunity to control operations like fertilising, herbicide applications or planting more precisely (*Bramley et al*, 1997).

Laying the foundations for PA in the Herbert

Eight important events in the Herbert River sugar industry's history have laid the foundations for the opportunity to implement site specific management of sugarcane blocks now and into the future. These events were:

1. The commencement of detailed soil mapping in the early 1980's at a scale of 1: 5,000 across the district. This work was undertaken by CSR Technical field staff under the direction of Dr. Andrew Wood.
2. Research involving the development of a prototype cane yield monitor was conducted by Dr. Rob Bramley (CSIRO) and the late Ray Quabba in 1996-97, which clearly demonstrated significant cane yield variability within cane blocks.
3. The establishment of the Herbert Resource Information Centre (HRIC) in 1996. The HRIC was developed as a central collection point for spatial data for the Herbert River and to manage collaborative arrangements between its partners to share the data.
4. The implementation of a cane productivity block recording system in the late 1990's, where cane yield, CCS and other productivity data were captured at a cane block level. Herbert Cane Productivity Services Ltd. (HCPSL) currently manages this system and ensures data integrity.
5. The recent adoption of new technologies such as a network of community GPS base stations and yield monitoring equipment on sugarcane harvesters for yield map generation. The purchase of this equipment was achieved under the Federal Government Sugar Package.
6. Collaboration with Cuban precision agriculture specialists (Techagro pacific) and the adoption of their technologies and systems.
7. Evolution of a precision agriculture team in the Herbert in 2007 to implement and investigate precision agricultural techniques for the region. The team includes staff from the HRIC, HCPSL, CSR Sugar, BSES and Techagro Pacific.
8. The commencement of two new research projects funded by the Sugar research and Development Corporation:
   - Establishing geo-referenced management zones within sugarcane paddocks;
   - A co-ordinated approach to Precision Agriculture RDE for the Australian Sugar Industry.

Managing spatial variability

Although PA research began over 12 years ago in the Herbert district, site specific block management is only now being considered in the sugar industry. The reasons for this include:

- A general trend from whole of farm nutrient management to block-specific management with each block managed according to its requirements and characteristics (Wood *et al*, 2003a).
- The cost of the technology has become much cheaper. This includes GPS equipment, computers, sensors, data communication, management and storage of spatial information, and aerial photography.
- Government funding became available through the Federal Government Sugar Package and Regional Community Partnerships Program. This assisted with the purchase of precision agriculture equipment.
- With continuing low sugar prices, increased productivity and reduced input costs are vital for maintaining industry viability.
- The sugar industry is increasingly under the environmental spotlight and needs to conduct and demonstrate environmental best practice.

- Recent access to expertise and technology from other countries such as Cuba and Brazil and other industries.
- The decision by HCPSL to lead the adoption of precision agriculture in the Herbert and employ a team dedicated to making it work.

The combined resources of the Herbert Cane Productivity Services, HRIC partners and Techagro Pacific are now being used to develop systems to assess yield variation, develop an improved understanding of the drivers of yield variation and interpret the interrelationships between different drivers. Ways to manage blocks variably and evaluate and promote the benefits PA can deliver will progressively be developed.

Research Needs

Research and development of PA strategies will continue in the Herbert, with PA systems being implemented across the region over time. In the short to medium term research in the Herbert will concentrate on further development of cane yield monitoring systems, an evaluation of the reasons for yield variability and the introduction of commercially available technologies like auto steering, harvester tracking and other GPS-based systems.

The region will continue to seek opportunities to develop relationships for advancing PA in the region through joint venture partnerships. An industry working group has been established and this will continue to meet on a regular basis to further develop PA concepts.

Ongoing research will be directed towards developing solutions to the following questions:

- What are the main reasons for infield yield variability and what opportunities are available to manipulate the system?
- Can spatial variability be managed to allow variable rate applications and will it be cost effective to implement?
- What is the most suitable yield monitor method?
- Should we be using a yield monitor to measure yields of cane actually in the field or the amount of cane delivered to the mill through a sugarcane harvester?
- How can PA systems be implemented to enable smaller growers to be involved?
- The measurement of infield variation in sucrose content across a field through an automated processes.
- How can the rate of acceptance of PA by cane growers be accelerated? This was a question posed by Jhoty and Autrey (1998) and is very relevant to the Herbert and Australian sugarcane industry.

Conclusion

The Herbert region is on a pathway to develop effective PA systems for cane growers. Unlike most other cane growing regions in the Australian sugar industry, the Herbert region has already established effective working relationships between all of the industry groups, through the HRIC, for the storage, analysis and management of spatial data. These relationships offer the multi-disciplinary approach that is required to develop PA systems.

PA should be considered as part of a local industry plan aiming to make the Herbert region more productive, sustainable, environmentally compliant and internationally competitive. Whilst PA is occurring in other agricultural industries successfully (like grain, and cotton), it is still in it infancy in the sugarcane industry. The view of most involved with sugar industries globally believe that it will happen in the sugarcane industries of the world (Bramley and the late R Quabba, 2002). The Herbert region seeks to embrace PA early to gain advantage of the potential benefits.

PA cannot guarantee beneficial outcomes by merely providing more information for growers to use (Cook 1997). The data need to be used to assist decision making in crop management. In this way the opportunities to develop a more sustainable and viable sugar industry into the future will be enhanced.

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Advances in Precision Agriculture in South-Eastern Australia

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Introduction

FOUR INTERLINKED CONSTRAINTS SIGNIFICANTLY HINDER THE GREATER ADOPTION OF PRECISION AGRICULTURE IN SOUTHERN AUSTRALIA, THESE ARE:

1) Confidence: growers have insufficient confidence that the variability within their existing operational zones (generally whole paddocks), is sufficiently large to be economically worth managing.
2) Understanding: the agronomic causes of crop variability are difficult to identify and understand.
3) Treatment: options for managing within paddock variability that enable growers to increase gross margins and income security are often difficult to devise.
4) Predictability: variability in yield maps from season to season means that recommending management solutions is far more risky, especially if the consequences might negatively impact on occasional good seasons.

The project, run by DPI-Victoria as part of a national GRDC initiative on improving our understanding of precision agriculture, has addressed these four constraint areas, the results of which are discussed in Sections 1 to 4 below. The majority of the work has been carried out using a key focus paddock of approximately 160 ha, located near Birchip (35° 47′ 22.2″ S and 142° 58′ 39.7″ E) in the northwest of Victoria. This area has an average annual rainfall of approximately 370 mm with a growing season rainfall of approximately 250 mm.

Section 1 Improving farmer confidence in precision agriculture by using rapid whole farm variability analysis

Crop yields vary both within paddocks (spatially), and across seasons (temporally). However, many growers are uncertain whether the level of variability on their property justifies significant capital investment in precision agriculture (PA) technology. The cost of PA equipment and concern over the cost-benefit of investing in it are the two major reasons why growers are cautious about adopting PA, according to a 2004 GRDC survey. Other growers may already be investing in PA technology, but would like to understand the nature of their paddock variability more rapidly than can be obtained by collecting annual yield maps.

To help inform growers of the economic importance of crop variability on their farm, a low cost analysis tool has been developed that provides an estimation of yield variability across an entire enterprise. The output from the tool is a yield map similar to that obtained from harvester-mounted yield monitors, but the yield variability is modelled from relationships rather than measured. This analysis is referred to as Simulated Yield Mapping (SYM).

SYM uses historical satellite images and also relies on growers having a detailed rotation history for each paddock, and records of the average paddock yield for as many seasons as possible. Using this information, satellite images are selected for seasons that have similar crop types. This is important because the reflectance from a pulse or cereal crop can be very different and should not be analysed together.

The SYM approach has been tested on 12 paddocks in the southern Mallee. The remotely sensed data for this study was sourced from the Landsat satellite series between 1991 and 2004, and from SPOT-4 data for 2005. The spectral information was utilised to derive the normalised difference vegetation index (NDVI). NDVI measured close to anthesis is expected to predict the relative variation (spatial and temporal) of crop biomass. The aggregate of temporal NDVI values when mapped, provides a long term pattern of crop biomass distribution within and across paddocks. NDVI data is normally displayed as a relative value, i.e. the description is only in terms of 'low' 'medium' and 'high' (Figure 1). What's more important to remember is that 'high', 'medium', and 'low' zones are only relative to each paddock. Therefore a 'high' zone in one paddock could be equivalent to a 'medium' or 'low' in another paddock.

The DPI Victoria project team developed the Simulated Yield Mapping approach to provide quantitative yield values to the satellite mapping process. This enables growers to not only identify paddock variability, but also to economically prioritise which areas will provide the best return from more precise agronomic management. In order to quantify the NDVI information, some additional input was needed. This input came from the growers in the form of records on crop average yields of individual paddocks for as many seasons as possible. The assumption was made that the average yield (t/ha) of a paddock in a particular season could be linearly related to a globally standardised average NDVI measure for the same season. To establish the linear relationship a minimum of two seasons of data are needed, but more is ideal. The final stage of the analysis is to use this relationship between the remotely gathered biomass data and the actual average yield recorded by the grower to generate a map of simulated yield.

The estimated average pseudo yield map obtained in this way for the study site is shown in Figure 2, grouped in ¼ t intervals. The results show the average yield at different locations across these paddocks varies from one tonne per hectare to 2.75t/ha. The map produced by the PYM approach agreed closely with the comments of the farmer and showed that some paddocks were generally better yielding than others. It also showed that variability within each paddock fluctuates considerably. Some paddocks had very uniform production, while for others the average yield over time varied from one part of the paddock to another. PA tools such as variable rate technology would provide the greatest cost benefit in those paddocks with greatest variability.

The simulated yield mapping approach develops an individual relationship for each paddock for the conversion of biomass, measured by NDVI, into final yield. These differences in the efficiency of converting biomass into yield can be due to spatial variation in general soil and site differences and usual management practices, such as micro climate, underlying soil fertility, water holding capacity, or the terrain characteristics of each paddock. It is particularly important to develop individual paddock relationships as good correlation between remotely sensed data and biophysical parameters seem only to work for single or localised paddocks.

In this study it has been possible to construct a whole farm (1,348 ha) map of mean sub-paddock yield variability. Because 15 years of historical satellite data is available in Australia, a range of weather and rotation effects can also be accounted for in the simulated yield mapping technique provided growers have historical paddock yield records.

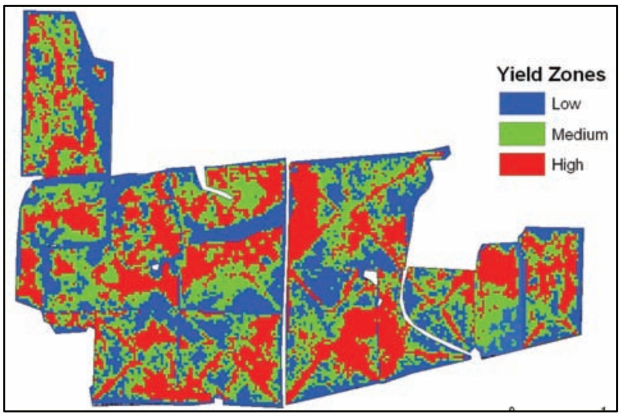

Figure 1 Yield zones defined using only the satellite data. The relative positions shown here by nominal classes refer to individual paddocks.

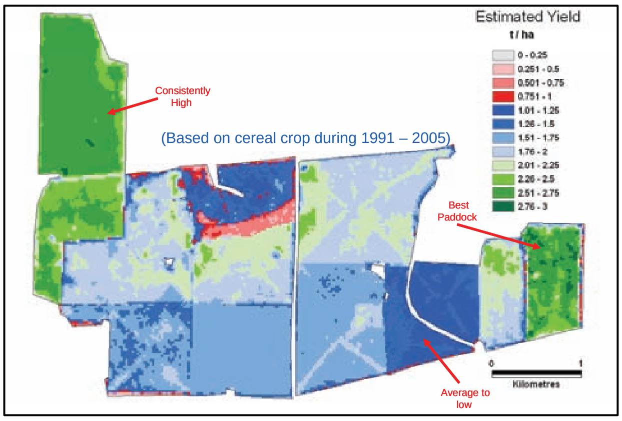

Figure 2 Estimated Yield categories based on satellite data and minimal information from growers.

Validation of the technique was carried out by comparing a map of simulated mean yield from 6 years of satellite data with the actual mean yield from 4 years of harvester yield maps for a 167 ha paddock. The difference between the 2 maps, expressed as percentage error from the actual mean yield, showed that 53% and 94% of the paddock area had an error of < 20% and <40% respectively. The biggest differences were noticed in the relatively low yielding areas.

Conclusion

A map of estimated yield variability from the Simulated Yield Mapping approach can be used by growers and agronomy consultants to investigate the causes of yield differences. It is then possible for growers to consider the most appropriate and economic remedies and prioritise the areas that will provide the best return from more precise agronomic management. This could include further soil testing or investment in PA technology.

Section 2 Identifying the causes of yield variability

An understanding of the underlying causes of within paddock spatial variability in grain yield, and its interaction with seasonal (rainfall) conditions is a prerequisite to the development of appropriate agronomic management strategies for precision agriculture. Grain yields in the Wimmera and Mallee regions of southeastern Australia, as is the case throughout much of the Australian grain belt, are principally controlled by soil water availability. Understanding the spatial distribution of soil hydraulic properties and their impact on crops is therefore becoming increasingly important if yield variability is to be understood and predicted. At the project's focus paddock DPI Victoria have been evaluating the most important soil hydraulic properties for explaining yield variation.

Plant available water capacity (PAWC) is the maximum amount of plant available water that can be stored in the root zone. The magnitude of PAWC is often considered an important parameter for determining where high and low yielding areas are situated and varies with soil texture, organic matter content and the crop species. PAWC is defined as the difference between the upper soil water storage limit (field capacity) and the lower extraction limit of a crop (permanent wilting point) over the depth of rooting. At the project's focus paddock, PAWC varies spatially between 50 - 200 mm in the soil's top 600 mm (Figure 3). It can be seen that the largest values of PAWC are along the southern edge of the paddock, which is the area that corresponds to higher clay content soils.

A theoretical consideration of soil hydraulic properties however, suggests that the value of PAWC will only control crop yield if the soil water content frequently reaches field capacity (FC), which is nearly at saturated conditions. Unfortunately, soil water contents near field capacity is not a common occurrence in recent seasons in north western Victoria. Instead, seasons have been characterised by below average rainfall, late breaks, and a high ratio of frequent and small precipitation events. Under these conditions soil types traditionally regarded as fertile and with high yield potential in 'normal seasons' eg. Vertosols, have performed poorly compared to the sandier soil types that characterise large areas of the Mallee.

When the soil water content does not frequently reach FC, theory would suggest that spatial variation in permanent wilting point (PWP) should be a better predictor of yield variability than PAWC. Any water stored in the soil below the PWP is not available to plants. Soils that have a low PWP do not tend to have a high PAWC. In practice this means that when the PWP is small, a relatively light rainfall event (< 25 mm) can provide effective, plant available water. This is particularly the case after a long dry summer fallow when the soil water content is significantly below PWP. The spatial distribution of PWP at the project's focus paddock varied between 50 - 150 mm in the soil's top 600 mm (Figure 4). It can be seen that the lowest values of PWP are along the northern edge of the paddock, which is the area that corresponds to higher sand contents in the soil.

Although PWP provides some useful base data for predictability of yield variability, it is not a measure of actual soil water content (SWC). Causes for variation in actual soil water content include: non-uniform rainfall, slope causing flow to lower areas, differences in infiltration rate, the size of dry matter production causing difference in transpiration, and differences in unsaturated hydraulic conductivity causing differences in drainage and evaporation. The spatial distribution of soil water content at sowing at the project's focus paddock varied between 80 - 180 mm in the soil's top 600 mm (Figure 5). It can be seen that the highest values of soil water content are i) along the south-eastern area of the paddock, corresponding to higher clay contents, and ii) the north-western area, possibly due to lower elevation. The best prediction of variability in crop yield needs to take into account both this spatial variability in soil water content and the variability in PWP. This parameter is referred to as the plant available water (PAW). It is defined as the amount of water in the soil at any particular time that is available to the plant, ie the difference between the water content and the PWP. The spatial distribution of PAW in the focus paddock during the 2005 sowing varied between 0 - 70 mm in the soil's top 600 mm (Figure 6). The lowest values of PAW are along the south-central area of the paddock. If these areas of low PAW continued throughout the season they should correspond to areas of lower yield. Nominal production zones have been previously identified across the paddock using header data from a yield monitor and biomass information from satellite images (Figure 7). This information is an average for several seasons and not specifically for the same year as the PAW map, some similarities between the two maps are clear, and illustrates that PAW is the best parameter for estimating yield variability.

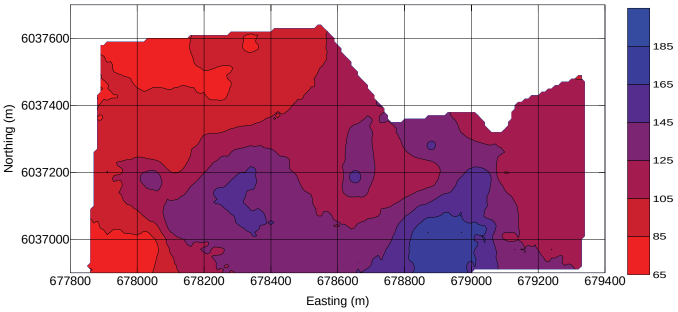

Figure 3 Spatial variability of plant availability water capacity (mm) for a 0-60 cm soil profile for the focus-paddock.

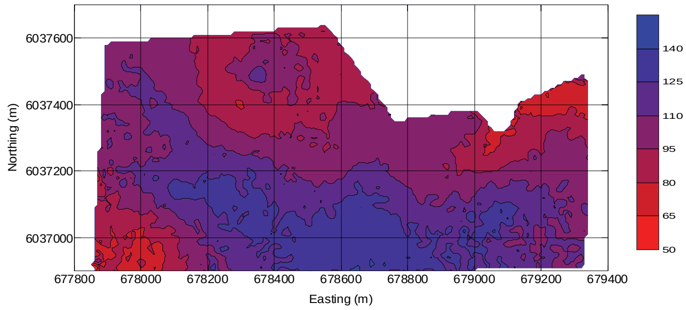

Figure 4 Spatial variability of permanent wilting point (mm) for a 0-60 cm soil profile.

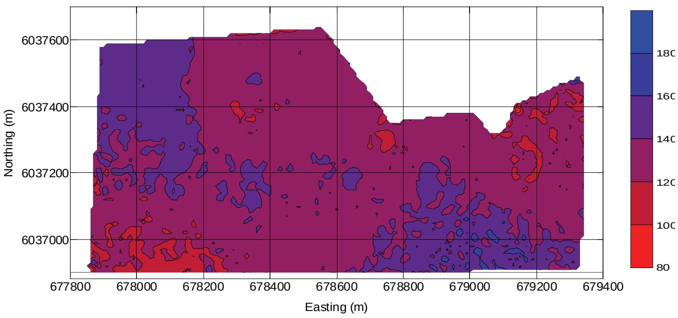

Figure 5 Spatial variability of soil-water content (mm) for a 0-60 cm soil

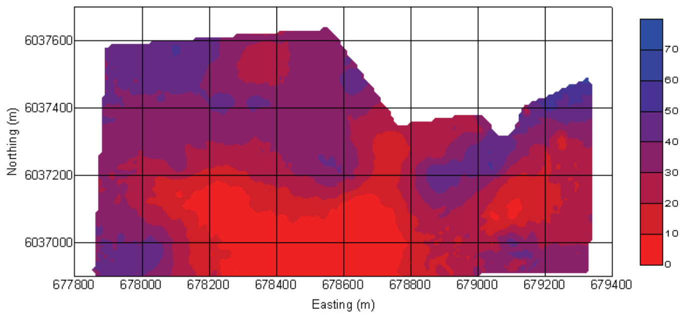

Figure 6 Spatial variability of plant available water for a 0-60 cm soil profile (mm) at sowing during 2005 taking into account spatial variability in permanent wilting point.

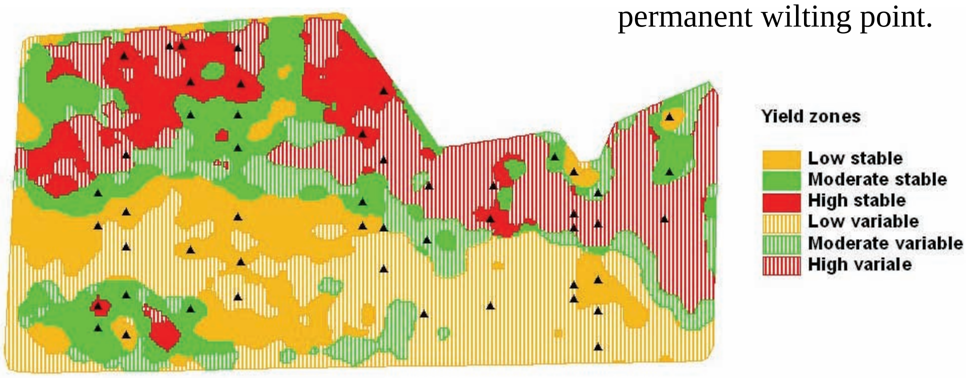

Figure 7 Yield zones at the focus paddock

Conclusions

To model and predict yield, accurate information is required on the soil hydraulic properties. In high rainfall or irrigated conditions variability in PAWC may provide a good prediction of yield variability. However, in much of Australia's grain belt the rainfall is less than that required to reach FC, and therefore PAWC will not be the most useful parameter of crop yield. The most accurate prediction of yield variability comes from understanding the plant available water (PAW). This accounts for both the variability in soil water content, due to slope, differences in evapotranspiration, unsaturated hydraulic conductivity, etc., and the variability in the quantity of water unavailable to crops (PWP). At the project's focus paddock, the map of PAW at sowing provided a reasonable prediction of the expected yield variability show in the yield zone map.

Section 3. Development of agronomic management options for within paddock variability

For grain production in the Mallee and Wimmera regions of Victoria, and in many other areas of Australia, managing spatial variability is principally linked to managing the variability in available soil water (see Section 2). Two principal options are available for managing this variability. Firstly, by matching the size and structure of the crop canopy to ensure optimum soil water is available at critical physiological stages, and secondly by optimising the level of inputs (principally nitrogen) to provide the maximum gross margin in all parts of the paddock.

Nitrogen fertiliser is probably the single largest variable input cost for grain production in many parts of Australia. Optimising the nitrogen input is therefore important, not only to prevent the waste of expensive inputs, but also if the nitrogen supply is out of balance the water use efficiency is also adversely affected by either too little or too much leaf area. In high rainfall zones, the management of canopy structures in cereal crops has been manipulated by changing sowing densities and by applying nitrogen at critical stages of plant development. Although there has been a lot of work on obtaining optimal paddock sowing densities, there is a lack of information on the effect of nitrogen, and its interactions with sowing rate, on wheat crops under various production zones within a paddock. During 2004 and 2005 the Victorian DPI team have been testing the interaction between within paddock yield zones and optimal sowing rate and nitrogen application, to develop better management strategies for growers interested in using precision agriculture technology.

2004 Treatments

A factorial design comprising of four nitrogen rates and two different sowing densities were used to produce a range of crop canopies. The sowing rate treatments were low (30 kg seed/ha) and normal seeding rate (80 kg seed/ha). The sowing depth was 5 cm and row spacing was 17.8 cm. Nitrogen was applied by top-dressing granular urea on 13 August 05, between sowing and anthesis so that initial seasonal conditions (especially rainfall) could be evaluated. The nitrogen rates used for topdressing were: N0 = 0; N1 = 14; N2 = 26; and N3 = 50 kg N/ha. These rates were based on APSIM modelling of the required nitrogen for different projected rainfall conditions for the remainder of the season. Application strips 500-700m long and the width of the grower's header were used. Poor rainfall following the application of the nitrogen treatments meant that little impact was expected from these treatments. Poor seasonal conditions (GSR < Decile 2) resulted in extremely low grain yields, and consequently a special low-flow adaptor for the yield monitor had to be used to measure the quantity of grain produced.

2004 Results

Zonal differences

- Grain yield (t/ha), number head/m^2, number grains per head, and 1000 grain weight were significantly greater in the High Yielding Zone than the Low Yielding Zone, but did not differ significantly between Variable and Stable zones for a particular Yield zone.
- Screenings were markedly higher in the low production zones than the high production zones.
- Harvest index was significantly higher in high production zones than low production zones. No differences in harvest index were found between High Variable (HV) and High Stable (HS) zones, and Low Variable (LV) and Low Stable (LS).
- No significant influence of production zones on grain protein was found, however, biomass nitrogen was significantly higher in low production zones than high production zones at both sowing rates. No differences in total crop nitrogen were found between HV and HS, and LV and LS.

Influences of sowing rate treatments

- Sowing rate resulted in marked differences in the number of seedlings established as expected. For all zones the number of plants/m^2 at anthesis were greater in high sowing rate treatments than the low sowing rate treatments.
- In the high sowing rate final dry matter was 2.41 t/ha while the low sowing rate, despite the lower number of plants was still 2.36 t/ha.
- In all production zones, the number of grains per head, the 1000-grain weight, and the grain yield were significantly higher in low sowing rate treatments than compared to high sowing rate treatment, although the differences were still small.
- Screenings were greater at the high sowing rate than low sowing rate in all zones except in High Variable zone.
- In all zones the harvest index for the low sowing rate treatment was higher than high sowing rate treatment.
- There was no significant influence of sowing rate on either grain or biomass nitrogen content.
- The low sowing rate across all zones did result in a 23% increase in the grain yield, although yield was still only 0.5 t/ha.

Influences of nitrogen treatments

- No significant effects on nitrogen treatments were found on all yield components.

2005 Treatments

To be able to more accurately apply different N rates, and due to the lack of nitrogen response in 2004 which was partly attributed to the lack of rainfall following topdressing, in 2005 it was decided that the nitrogen treatments would be applied as UAN through a spray boom. Four rates of N (0, 25, 33 and 50kg N/ha) were applied to Barley (VicSloop).

The 2004 results demonstrated that altering the seeding rate resulted in the plants appearing to largely compensate for reduced seed levels. For 2005 it was therefore decided not to repeat the different sowing rates. However, the 2004 result does not diminish the project's hypothesis that the primary cause for yield variability is differences in seasonal plant available water. The question that arose from the 2004 results was 'can it be expected that plants do a better job at selecting the optimal crop canopy to account for the variable conditions in plant available water than humans can?'. In the 2005 experiment it was therefore decided to 'pit plant against human' and produce a more rigorous comparison of the impact of canopy cover. The hypothesis tested was that by reducing the total number stems per unit area at an early stage of crop growth (through 2 treatments: removal of all tillers leaving only the main stem, and removal of every third row), soil water could be conserved to be used by the crop at the more critical growth stages, in particular at anthesis and grain filling. The 2005 season was also poor (GSR < Decile 3).

2005 Results

Zonal differences

- Crop dry matter at maturity and grain yield were significantly higher in the High than in the Low zones, but Variable/Stable zones had no effect.
- Grain protein and screenings did not vary between the different yield or variability zones. High grain protein across all paddock yield zones resulted in the grain being downgraded from malting to feed grade.

Influences of nitrogen treatments

- No significant effects on nitrogen treatments were found on all yield components.

Conclusions

In these seasons the addition of top dressed nitrogen provided no benefits in any of the zones within the paddock. However, it must be remembered that most growers make most of their money in a few good seasons. Therefore unless good seasonal climatic forecasts are available it may not be economically sensible for growers to reduce nitrogen applications. Screenings in 2004 increased from less than 10% on the high yielding zones to 30 - 70% in the low yielding zones. This may have important consequences to growers on the potential benefits of selectively harvesting in poor seasons.

For the sowing rate experiment in 2004, despite the much reduced sowing rate, the total biomass at harvest was the same for both treatments. The low sowing rate did result in a 23% yield increase. This meant that the lower sowing rate also had a 33% increase in harvest index. However, it is difficult to speculate how these results would compare in a normal rainfall season.

Section 4. Predicting within paddock crop variability

One limitation of point-based modelling is that the required input data cannot be economically measured at a spatial resolution needed to achieve sub-paddock scale yield mapping. Consequently, in this work we explored the possibility of applying, in a spatial context, a modified form of the French and Schultz potential yield model. This is a point-source model but with far less data needs than other models. Such an approach appears to offer an alternative method of explaining spatial variance in crop performance where water supply is the major determinant of yield, particularly where subsoil constraints like salt are involved (Figure 8). Further testing over a range of environments will be necessary.

To use the French and Schultz model in a spatial framework the transpiration efficiency was assumed constant while the soil evaporation assumed to vary spatially according to soil type. The value for soil evaporation varied linearly with the value of ECa obtained from an EM31 survey. For the focus paddock example evaporation was assumed to vary spatially between 20 and 200 mm. The soil water content at sowing is also required to construct the model. This was obtained by calibrating an EM31 survey at sowing against volumetric soil water content measured at selected points in the field to represent the whole range of water contents across the paddock. An underlying assumption is that changes in apparent electrical conductivity (ECa) at any point in the paddock varies primarily with changes in water content during the season and that the spatial error of the soil water content due to confounding factors such as salt and clay content is relatively low. The spatial variability in crop lower limit was obtained in a similar fashion by calibrating the EM31 survey to the soil water content at harvest. Spatial variation in crop water use, and thus yield, was then derived by subtracting the lower limit value and soil evaporation value from the sum of water content at sowing and seasonal rainfall.

It is also feasible to relate ECa from an EM survey to soil nitrogen. Such a calibration applied in space across the paddock whilst not used in our simulations here, provides an additional data layer that should prove useful in predicting spatial crop yield when nitrogen deficiency is important. Our method makes a number of assumptions that need further testing. The most important is variable soil evaporation (Es) across the field. We assumed a linear relationship between ECa and Es that would give realistic estimates of seasonal Es. Further work would need to show that this is indeed a good assumption if the method were to be used widely. Actual measurements of Es and ECa are needed. Whilst we used an EM survey to obtain the sowing water content of the field, doing this for each paddock and year will not be economic. Although we think that a short-cut method to increase or decrease values across a whole map from an original survey might be feasible, it needs to be successfully demonstrated.

Farmers can benefit from such analyses because the more responsive zones can be targeted with additional inputs as the season allows. Our analysis also highlights the importance of subsoil constraints identified by the divergent calibration lines between the soil water content and lower limit in Figure 8. In this case the highest yield did not occur on the wettest soil.

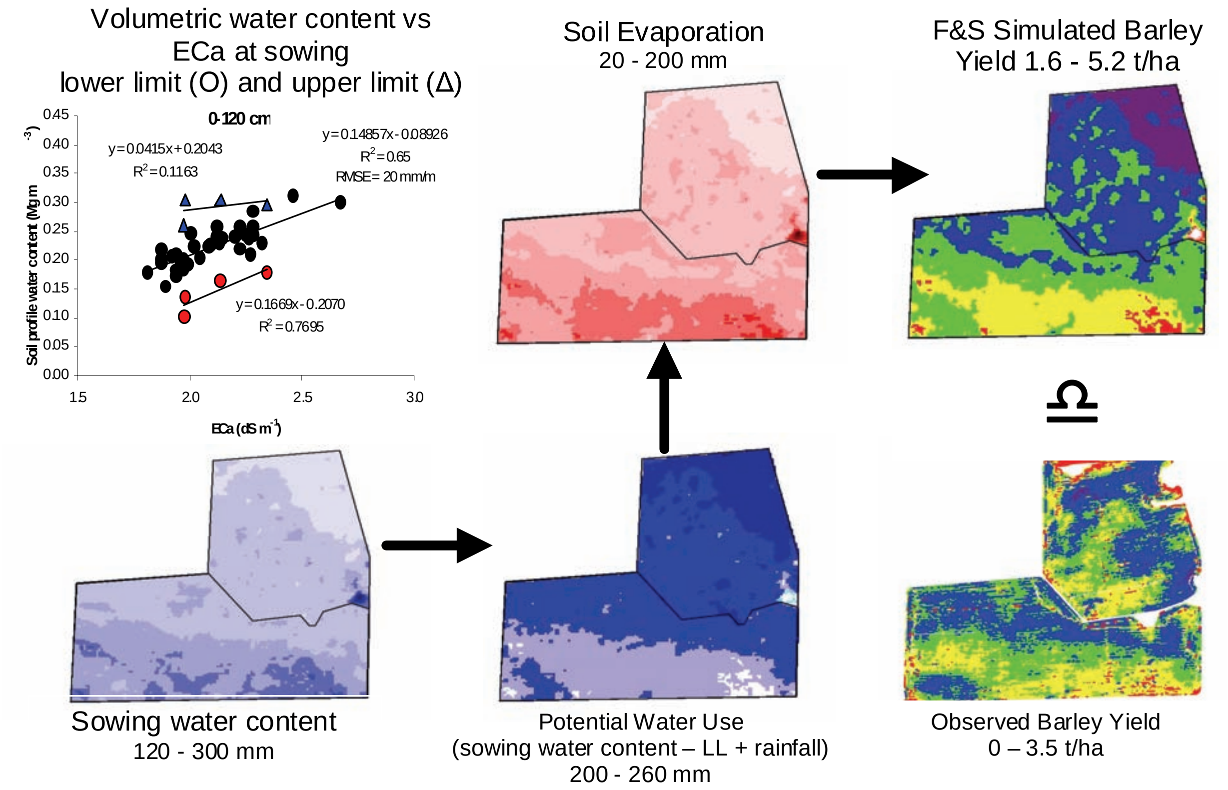

Figure 8 The sequence of generating a potential yield map using a French and Schultz model approach and the comparison with the observed yield map of Barley. Constructed from soil water content at sowing, potential water use and soil evaporation maps. The darker monochrome colours and purple colour in the yield maps indicate the highest values.

Acknowledgements

This research was supported by funding from the Grains Research and Development Corporation through its Precision Agriculture Initiative (SIP09), and the Victorian Department of Primary Industries. The authors acknowledge Ian McClelland and Warrick McClelland for allowing access to their paddock; C. Aumann, G. Boyle, J. Fitzpatrick, A. Waite (DPI, Victoria), C. Reilly and B. Liston (BCG) for providing technical support. The authors are grateful to S. Chandra, M. Kitching for assisting with statistical and mid-infrared analysis respectively.

Robotic Solutions for Autonomous Farming - Joint Efforts of Precision Agriculture and Autonomous Systems

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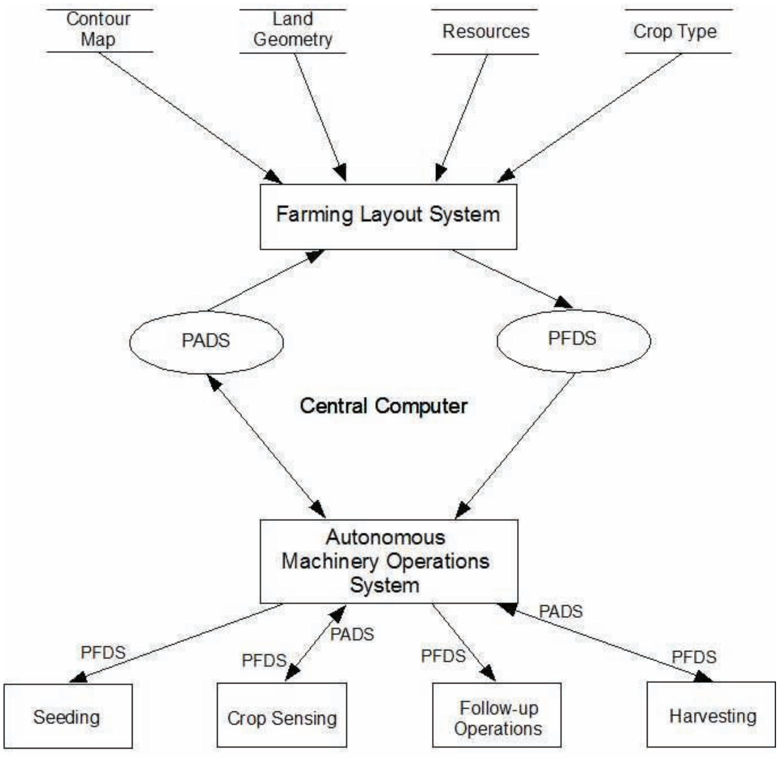
Look into the not too distant future, and try to imagine a broad-acre farm which runs with optimal efficiency, and produces an optimal crop, both in terms of yield and quality. In addition, try to also imagine that most, or all, of this is achieved with a fleet of autonomous robotic farm vehicles, carrying out all of the required agricultural tasks with precision, efficiency, and adept coordination, but also in such a way that all Precision Agriculture specifications and goals are met in a similarly optimal fashion. Meanwhile, the farmer has the choice of either monitoring and supervising operations from a central command center, or being out in the field, perhaps overriding autonomous operation as he/she takes charge of one of the vehicles for old times sake. This view of the future broad-acre farm is one of the main driving forces behind research undertaken into Precision Autonomous Farming by the authors.

The extent of such automation is not necessary right now, however with a cultural shift towards a more "corporate" style of farming, where global competition plays a bigger role, and with a reducing labour workforce, the farming industry can take immediate benefit from robotic and autonomous solutions. It is true that the more structured the environment is, the easier it is to introduce robotic solutions and the more effective they can be. Broad-acre farming provides a good starting point for the use of robotic and autonomous vehicles. And with the precision and autonomous operation of such vehicles, the structure will only be improved.

The research proposes a system-of-systems approach to broad-acre farming, where the farm is made up of smaller sub-systems, coordinated and communicating with each other in a unified way. There will exist a seamless integration of requirements, bringing together the areas of robotics for autonomous farming, and Precision Agriculture (PA) for issues of agronomy. These areas must rely, and indeed thrive, on each other. A high level architectural depiction is shown in Fig. 1 below, and briefly described following.



Central to the system is the existence of a *Precision Farming Data Set* (PFDS) and *Precision Agriculture Data Set* (PADS). It is proposed that the PFDS will describe the navigation and spatial accuracy requirements for the crop and provide a basis for all farming machinery sub-systems where spatial accuracy is required. In the case of broad acre farming, the PFDS will take the form of a route map for the tractors. The PADS will work in conjunction with the PFDS to ensure the agronomy requirements of the crop are satisfied. The PADS is a continually evolving entity, developing as the crop growth continues and when crop sensing and other follow-up operations are taking place. It specifies such information as fertiliser type for a specific crop, application rates, weed eradication information, as well as ongoing monitoring information such as crop growth rates and soil conditions, all with respect to the spatial data.

Surrounding the PFDS and PADS are the various farming sub-systems. These include the farming layout system, carrying the vital responsibility of determining the most optimal crop layout given the various inputs and farm and resource constraints, as well as the autonomous farming machinery sub-systems, which carry out all farm operations such as seeding, crop sensing, follow-up operations, and harvesting.

Current research by the authors is focussed specifically on the operations of precision autonomous seeding, and non-herbicidal autonomous weeding.

For the operation of seeding, traditionally a tractor pulls along an attached seeding implement. There are quite stringent accuracy demands for seed placement, and robotic operation is in relatively uncertain environments, meaning that autonomous guidance of the tractor and implement needs to be precise as well as robust. This is a challenging task in which the authors are making steady progress. A John Deere agricultural tractor has been retro-fitted for autonomous operation, with intelligent and robust path tracking controllers, designed and tested in simulation, currently being experimentally tested and verified. Current progress and results to date will be presented.

Similarly important is the operation of weeding. The process of weed eradication is split up into weed detection and weed destruction. Weed detection is an area that has already received significant research attention, and there are systems that are currently operating employing crude means of detecting weeds. Weed destruction on the other hand is mostly carried out via the use of herbicides. The current practices do not allow the herbicide treatments to be optimized to suit the weeds to be eradicated as there are no means of identifying the individual weed types. Hence there is a need to develop methodologies to detect the prevalence and the individual weed types so that the correct treatment and dosage can be applied to individual weed types.

A more advantageous approach is to find non-herbicidal methods. Methodologies such as electrocution, electroporation, microwaving, heating and cooling, to name a few, should be considered as alternatives. This immediately eliminates the need to determine the herbicide formula and dosage and therefore, the need to identify the weed type. These methods are particularly suitable for crop that is planted according to a PFDS. In general, the weeds that grow on the crop row itself will be defeated by the crop. However, all plants, weeds or otherwise, that grow in the inter-row space will absorb nutrients that were meant for the crop and will cause growth retardation of the crop.

The authors have completed preliminary developments of a non-herbicidal weeder that has PFDS/laser/vision guided crop tracking capability with an electrocution system producing high voltage plasma arcs targeting all plants in the inter-row space. For the destruction of weeds, the five electrode plasma arc generation system is attached to a well insulated cradle that extends out at the back of the robot. Important collaboration between The University of New South Wales and the Australian Centre for Precision Agriculture is facilitating the investigation into weed destruction methods, and in particular, electrocution, as currently offered by the robotic weeder. Again, progress in the development of the robotic weeder and its utilisation for weed destruction will be presented.

Using an Electrical Conductivity Sensor for Precision Farming Zones of Malaysian Paddy Fields

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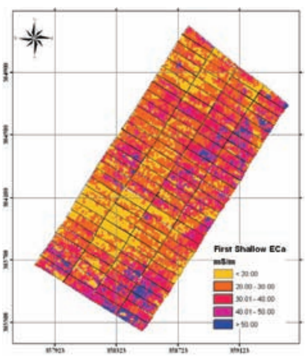
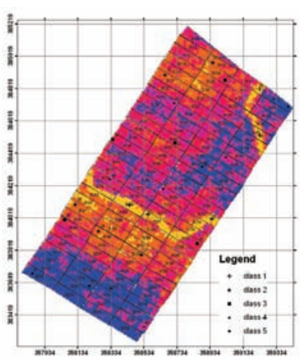
Abstract

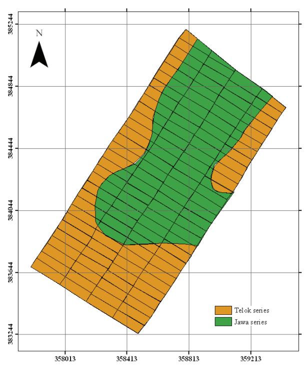
Traditional soil sampling is laborious and time consuming. It leads to delays in applying the precision farming cycle. EC_a sensor (VerisEC 3100) was introduced to zone the contrasting areas of paddy soils for site-specific management of fertilizers. This study was conducted to zone the area by EC_a and to predict some soil properties for rapid assessment. The area was 145 ha lowland paddy fields in Selangor Malaysia. In a typical plot size of 1.2 ha, the EC sensor was pulled by a tractor to collect EC_a data in 4 passes spaced 15 m apart. Soil samples were then collected at 2 points per lot on the track within the area. Results show that due to the numerous EC_a data points, a former river was able to be discovered. A total of 21 parameters were significantly predicted by using EC_a. This shows that the EC sensor can predict multi-variables. The zoning technique, known as MAZDEC was developed based on the results of the study. MAZDEC reduces time for soil sampling and analyses.

MAZDEC components include a tractor, ECa sensor and Data Logger, Robust PC, DGPS antenna and receiver

MAZDEC processes include running the EC probe in the field, interpolation by kriging, mapping and classification using smart quantile technique, and sampling for soil properties after zoning.







Variable-Rate Irrigation

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Introduction

Water demand under a centre pivot or lateral irrigator is often spatially variable. This is due to variable soil available water holding capacities, different crops placed under the irrigator with varying water demands, slope effects, and farm infrastructure such as raceways on dairy farms. VRI (Variable Rate Irrigation) is the ability to control the rate of water application of every sprinkler or banks of sprinklers along part or the entire length of an irrigator.

Indications are that significant water savings can be made. Two case studies are described where the potential savings in water applied were 23 and 27% using soil water availability as the determining factor in irrigation decisions. In New Zealand the main savings come from reduced pumping costs, but in areas where water is purchased then more significant savings can be made. The method of providing VRI has been developed by Wheremycows.com and is in the testing phase. The system operates by providing a solenoid valve to each nozzle, nozzles are controlled in banks of 4, each controller is within a wireless network with a unique address. The system is controlled by software which is used to determine the application at any point under the irrigator. Thus allowing the valves to be turned on, off, or pulsed to adjust water application rate over any part of the farm.

Soil Mapping

Spatial variability of soil water supplied to a crop is an important factor in determining irrigation requirements. This was modelled and mapped by relating high resolution soil apparent electrical conductivity (ECa) maps to soil available water holding capacity (AWC), and demonstrated at two contrasting field sites. At each site, zones selected from the ECa maps were characterised by measuring: (i) ECa values at a range of volumetric soil water contents (θ) between field capacity and wilting point, and (ii) a weighted mean value for soil texture to ≤ 600 mm. This data was used to derive a relationship between EM, θ, soil texture and available water holding capacity (AWC). Field site 1, a pastoral farm, had soils with wide ranging AWCs (115-230 mm/m); whereas field site 2, a 33-ha maize field, had soils with very similar AWCs (160-164 mm/m).

The derived AWC maps were adjusted on a daily basis using a soil water balance model with daily inputs: rainfall, irrigation and evapotranspiration for any known AWC. In addition, drying patterns of the soils at site 2 were investigated by TDR survey. There was typically a 13 % difference in soil moisture between the wettest and driest sites when measured to 45 cm depth (n=47) at any one time, despite having similar AWCs. Therefore it is important to characterise spatial soil drying patterns, which are largely determined by soil textural differences and microtopography. The drying pattern was temporally stable (R^2= 0.8).

Programming

Programming the VRI system is done remotely using a personal computer. The software which is a Geographical Information System (GIS) holds various mapping layers which can be used for decision making. Soil drying patterns can be used as the basis for irrigation scheduling. If a mix of crops is to be grown then the geographic positions of the crops must be entered. Information is relayed to the irrigator control system. The computer then sends information to the irrigation controller which turns valves on and off at the appropriate times.

Benefits

Improved control of irrigation should give higher water use efficiency. The ability to improve yield has not yet been tested. Improvement in water use efficiency by adjusting irrigation application to available water capacity of the soil suggests savings in water of around 25%. This would allow a farmer to increase their area under irrigation by 25%, from the same resource consent. Pumping costs per hectare would also be reduced, in some cases. In Australia this could help reduce the cost of irrigation considerably (Table 1). Additional water savings could also be achieved by avoiding farm infrastructures such as roads and raceways, drains, low lying ponding-prone areas, trough areas etc. This would be especially valuable on dairy farms where there would be further benefits from avoiding applying water to areas where animals walk. A VRI system would also add considerable flexibility to cropping operations and cropping patterns could be more profitably matched to underlying soil patterns.

Irrigation events will be recorded under the irrigator and communicated to the farm office computer, real time information can also be relayed back to the farm office on the current performance of the irrigator.

A simple estimate of benefits and payback is illustrated in Table 1. This is based on a similar level of variability to the case studies provided.

Table 1 Variable Rate Irrigation – Economic Analysis Summary (Based on the cost of modification (Range $640/ha - $1,300/ha.Price used $980/ha)

Site	mm water saved/ha using VRI	$/ha saved * (NZ now)	$/ha saved ** (NZ projected)	$/ha saved *** (South Australia, Now)	$/ha saved **** (South Australia, Projected)
160 ha pastoral	38	49	99	999	1049
Payback period		20 yr	10 yr		
53 ha cropping	70	91	182	1841	1932
Payback period		11 yr	5 yr		

* Irrigation operating costs = $1.30 mm/ha (FAR 2008)
** Double operating costs = $2.60 mm/ha due to increased energy costs etc., 2009)
*** $1.30 operating costs plus $25/mm/ha water charge (South Australia, 2008)
**** $2.60 operating costs plus $25/mm/ha water charge (South Australia, 2009?)

Steering Implements and Web-Based Data Processing and Delivery of Prescriptions

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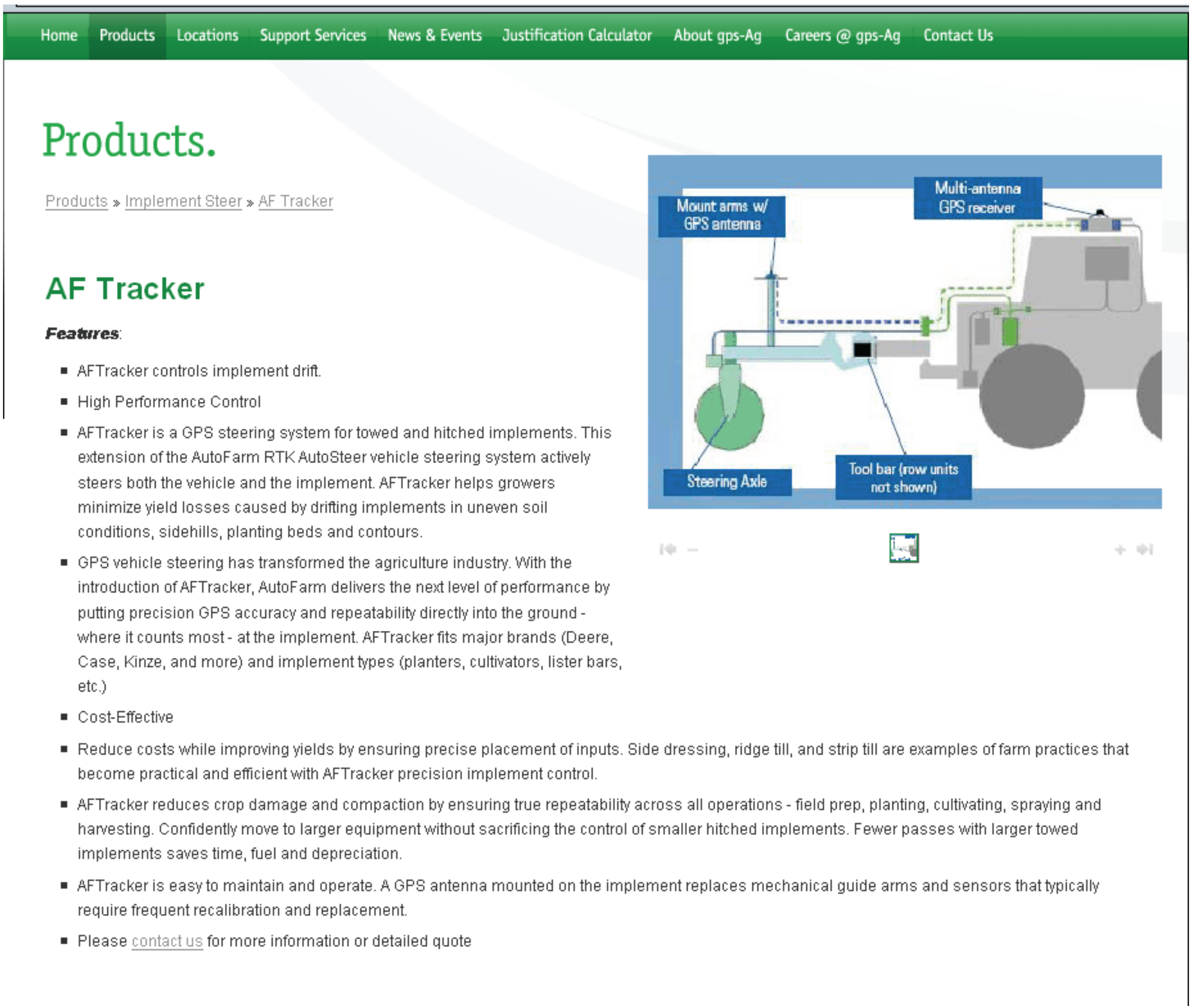
In 1999 GPS-Ag was established with an aim to provide agricultural producers with competitively priced guidance and auto steer systems that can be moved from vehicle to vehicle irrespective of make or model.

This strategy has resulted in GPS-Ag becoming the largest independent supplier of guidance and auto-steer systems in Australia. We believe that choice is important, and that's why we offer a range of solutions from manufacturers worldwide.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Products.

Products » Implement Steer » AF Tracker

AF Tracker

Features:

- AFTracker controls implement drift.
- High Performance Control
- AFTracker is a GPS steering system for towed and hitched implements. This extension of the AutoFarm RTK AutoSteer vehicle steering system actively steers both the vehicle and the implement. AFTracker helps growers minimize yield losses caused by drifting implements in uneven soil conditions, sidehills, planting beds and contours.
- GPS vehicle steering has transformed the agriculture industry. With the introduction of AFTracker, AutoFarm delivers the next level of performance by putting precision GPS accuracy and repeatability directly into the ground - where it counts most - at the implement. AFTracker fits major brands (Deere, Case, Kinze, and more) and implement types (planters, cultivators, lister bars, etc.)
- Cost-Effective
- Reduce costs while improving yields by ensuring precise placement of inputs. Side dressing, ridge till, and strip till are examples of farm practices that become practical and efficient with AFTracker precision implement control.
- AFTracker reduces crop damage and compaction by ensuring true repeatability across all operations - field prep, planting, cultivating, spraying and harvesting. Confidently move to larger equipment without sacrificing the control of smaller hitched implements. Fewer passes with larger towed implements saves time, fuel and depreciation.
- AFTracker is easy to maintain and operate. A GPS antenna mounted on the implement replaces mechanical guide arms and sensors that typically require frequent recalibration and replacement.
- Please contact us for more information or detailed quote

Products » Implement Steer » EcoDan

EcoDan

ECO-DAN's guidance system for farming and vegetable growing offers great advantages to both conventional and organic growers.

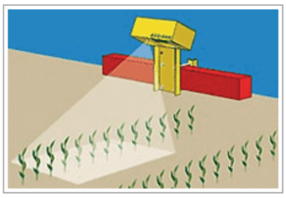
Advantages

- Speed and working capacity can be increased by up to 50 %, dependent on the work being done
- Driving at night by artificial light further increases capacity
- Operator stress is greatly reduced and the driver can direct his attention to the essential field operation
- More effective weed control by cleaning closer to the rows
- A reduction of up to 75% in the use of pesticides when band spraying
- Earlier weed control in partially emerged crops
- Can be mounted on new or on existing equipment

- Works by following plant rows, tracks or ridges
- Operates without any physical contact with either soil or crop
- Is far more precise than satellite-based DGPS systems

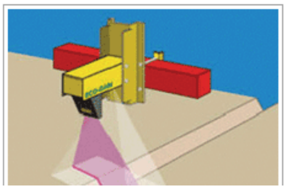
Plant Camera

The vision camera is the backbone of the ECO-DAN guidance system and is continuously taking pictures of the plant row it is tracking. For most crops one camera will be sufficient. In beet and other similar crops, where gaps in the rows may occur, double cameras are used. Each of the cameras tracks a different row, ensuring that the guidance system always has a reference line.



Plant and Track Camera

In certain crops, especially in organic farming, it is essential to be able to commence weeding at an early stage. To meet this requirement ECO-DAN has developed a special camera, incorporating a laser, which can follow either a plant row or a marker track. The laser camera makes it possible to band spray or inter-vow cultivate before the plants have fully emerged. It can also be used to follow ridges, in, for example, potato crops.



GPS Cattle Tracking for Understanding the Impact of Grazing on Grain and Graze Rotations and for Improving Pasture Utility

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This paper is based on *Trotter, M. & Lamb, D.W. (2008). A low-cost GPS tracking device for monitoring animal, plant and soil interactions in livestock systems. In: Proc 9th International Conference on Precision Agriculture, Denver Colorado.*

Introduction

The cost of GPS chip-sets have been substantially reduced in recent years. However, commercially-available animal tracking units, especially those that rely on remote interrogation/data download still command a high price tag (>US$2000). A low-cost, store-on-board GPS tracking collar (UNEtracker), based on a commercially-available GPS chip-set, has been developed to monitor the movements of livestock in a paddock-scale trial.

Materials and Methods

The UNEtracker collar (Figure 1) comprises a low cost (~$50), integrated GPS and data logger chipset encapsulated, along with supporting hardware in resin and mounted in a waterproof polycarbonate housing (dimensions: length 65mm, width 65mm, and height 40mm). The UNEtracker can be programmed to sample continuously or at any specified time interval. The sampling interval configuration and conditions under which the GPS unit operates ultimately determines deployment duration which is limited by battery life or available data storage, which is up to 45,000 positional data records. Under optimal conditions the UNEtracker can obtain and record a location fix within 10 seconds however, this extends out to 30 seconds if there are insufficient satellites in view. Tree cover and topography are the main contributors to reducing GPS satellite signals. Treeless plains provide optimal conditions for a fast GPS fix whilst mountainous and heavily timbered areas increase the time it takes to record a positional fix. The GPS unit can be programmed so that if a fix is not achieved within a certain period of time it returns to sleep mode, thereby prolonging battery life (Table 1).

Figure 1. Photograph of the UNEtracker collar. Note the receiving antenna is located out of view on the top of the collar. The polycarbonate box housing the hardware and battery acts as a counterweight to maintain the GPS receiver antenna on top of the animal’s neck.

Table 1. A summary of the deployment periods that can be achieved at different sampling intervals and under varying conditions.

Sampling interval (minutes)	Maximum days of deployment under varying conditions		
	Optimal (10 second fix)	Average (20 second fix)	Poor (30 second fix)
5	156*	118	79
10	313*	236	157
30	938*	708	472
60	1875*	1417	944

* Under optimal conditions the data storage limit of 45,000 records is achieved before the energy supply is exhausted.

The GPS antenna itself is located in a separate enclosure (dimensions: length 45mm, width 30mm, depth 12mm) positioned on top of the collar. The battery and chip-set located on the bottom of the collar act as a counterweight ensuring the antenna remains at the top (Figure 1). A static accuracy test found the mean error from actual receiver position was 4.14 metres with a standard deviation of 3.04 metres, with 99.9% of points falling within 20 and 97.3% within 10 metres of the known point.

Preliminary field trials were conducted at the university’s Douglas McMaster Research Station, a 1500 ha mixed cattle and cropping enterprise located in the northwest slopes region of NSW Australia (Lat 150^{o}36’0”S, Long 29^{o}17’6”E). Four collars were deployed in a herd of 20, 12 month-old Angus steers over a period of 14 continuous days (2nd to the 15th February 2008). The UNEtracker collars were configured to a sampling interval of 10 minutes with a sleep after non-fix period of 30 seconds. The herd was allowed unimpeded access to five adjoining fields with at total area of 247 ha.

The positions recorded by the four UNEtracker collars were combined into a single data file and processed in ArcGIS 9 (ESRI, 2006). Some of the logged points fell outside the boundaries of the paddocks; these obvious errors may have been due the GPS unit or the inaccuracy of the digitised paddock map. To account for these errors a buffer zone of 20 metres extending outwards from the paddock boundaries was created and points outside this deleted as these were considered be genuine errors of the GPS.

In order to evaluate the potential for integrating the collar data with other, contextual spatial information, a 7 day composite MODIS (National Aeronautics and Space Administration, USA) normalised differential vegetation index (NDVI) satellite image was obtained for the second week of the study. A digital elevation map of the paddocks was generated using data collected from an RTK GPS unit (Trimble, Sunnyvale, California, USA).

Results and Discussion

Figure 2 depicts the recorded cattle locations over the 14 day interval. The most obvious feature apparent in Figure 2 is the frequent occurrence of recorded positions in paddocks 3 and 4 whilst paddocks 1 and 2 have been largely ignored. Field observations suggested that there was a strong behavioural component to this distribution. Another herd of cows was pastured in the paddocks adjacent to the southern end of paddocks 3 and 4. It is thought that much of the steers' time was spent in these areas so they could be close to this herd. Despite this strong behavioural influence there appears to be additional contributing factors to the distribution of steers across the paddocks. As Paddock 5 was dominated by the excluded area and the steers appeared to use it primarily as a means of transitioning between other paddocks it was excluded from further analysis.

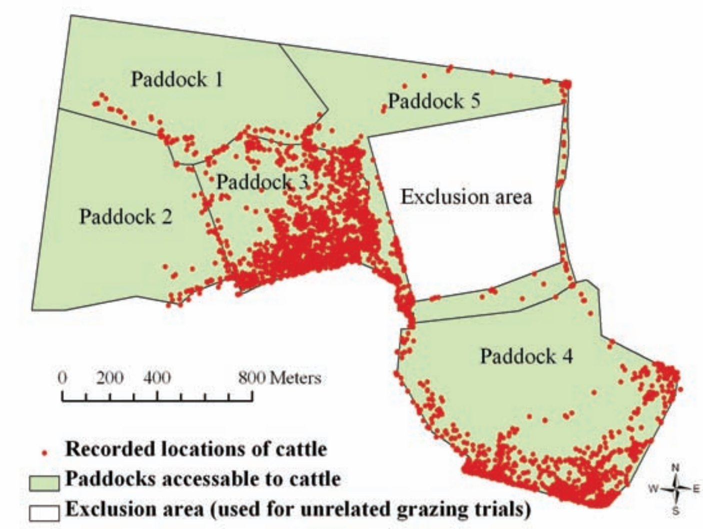

Figure 2. GPS positions as recorded by the 4 UNEtracker collars over 14 consecutive days (Trotter and Lamb, 2008).

Cattle activity, as determined by calculating the average distance travelled over a 60 minute interval for each hour of the day (average of 4 steers and 14 consecutive days) is graphed in Figure 3. This graph indicates two significant periods of activity; consistent with the observations of other researchers (for example Tomkins et al. 2006). Both Ungar et al. (2005) and Charmley et al. (In press) suggest distances travelled between 200 and 360 meters per hour coincide with travelling/grazing behaviour. Given that distances travelled in excess of 250 meters per hour occurred during the periods 0600 – 0900 hrs and 1600 – 2000 hrs, and that observational studies of Roath and Kruger (1982) suggest these times coincide with peak livestock grazing activity, it can be speculated that the peak activity sections of Figure 3 are actually peak grazing activity. Moreover, seminal work by Langlands (1965) (albeit in sheep) indicate morning and afternoon grazing activity can be further linked to temporal-variations in nutrient versus bulk demand by grazing animals, thus pointing the way to the potential of inferring forage quality coincident with these grazing windows. Interestingly, Figure 3 suggests some midnight activity. Such pronounced movement at this time has not been reported by other researchers and there is some conjecture that this may be due to the fact that cattle often move around in the middle of the night to restore blood circulation etc. This nonetheless requires further investigation.

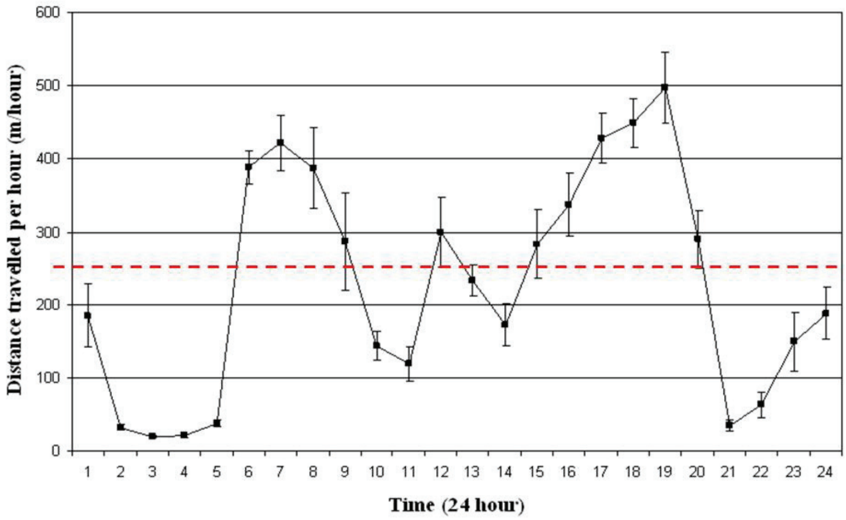

Figure 3. Mean distance travelled in 1 hour intervals by all steers over 14 days. Data plotted against time of day where 0/24 = midnight (±standard error of mean). Red dashed line indicates 250 m per hour high and low activity threshold (Trotter and Lamb, 2008).

A Livestock Hour Index (LHI) can be calculated to reflect the number of head recorded at a given location over time (Trotter and Lamb, 2008). A 50 x 50 metre polygon grid is created across the combined paddocks and the raw (10 minute-interval) position counts in each 50 metre grid square subsequently converted to an integrated livestock hour index (LHI_{50}) using:

$$\mathrm{LHI}_{50} = \sum_{\text{hour no.}} \left(\sum_{\text{grid no.}} \frac{\text{number of position solutions}}{6} \right)$$

A map of LHI_{50} is depicted in Figure 4. Again it is apparent that the tracked steers spend much of their time on the paddock boundaries and particularly the southern borders of Paddocks 3 and 4, and investigation of the movement data suggests this is coincident with rest periods (Trotter and Lamb, 2008).

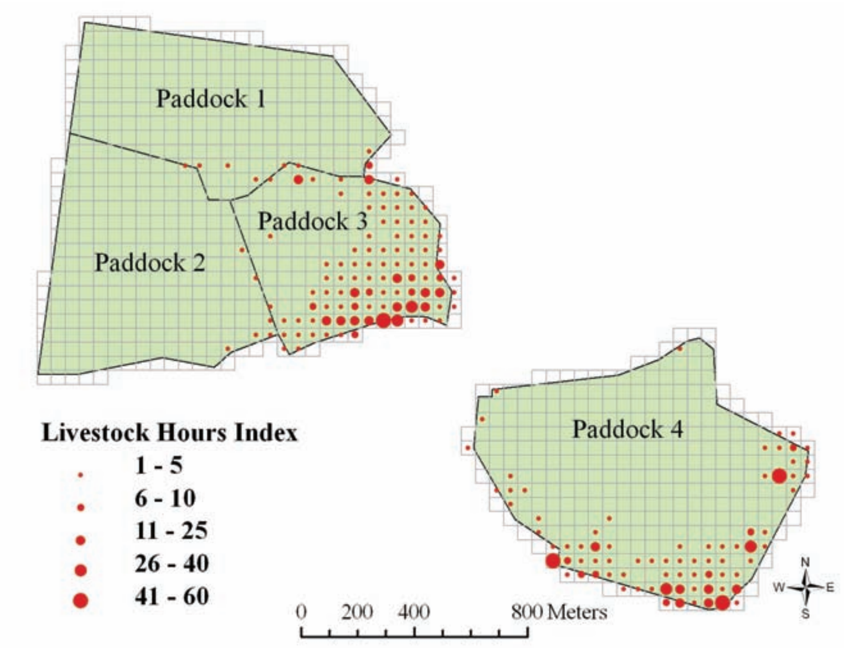

Figure 4. Livestock Hour Index on a 50 x 50 m grid (LHI_{50}) for paddocks 1 to 4 (Trotter and Lamb, 2008).

Figure 5 illustrates the LHI_{50} data superimposed on a 7-day composite MODIS satellite NDVI image acquired in the second week of the trial. The low NDVI values, which generally indicate low photosynthetically-active biomass (PAB), associated with Paddocks 1 and 2 explain the absence of livestock activity in these areas. Paddocks 1 and 2 were, in fact, in spray fallow following winter cropping in the previous season. In comparison, Paddocks 3 and 4 show a high NDVI (relatively high PAB) with Paddock 3 and the northern area of Paddock 4 revealing the highest NDVI (and relative PAB) readings. The values most likely reflect higher levels of green feed available, explaining the greater periods of time spent by the steers in each paddock. Interestingly, although the northern area of Paddock 4 reported a high NDVI, virtually no cattle activity was recorded. There are several possible causes, in particular this area is partly covered by trees, the canopy of which may be contributing to the higher NDVI readings in the MODIS data. Thus there may actually be less available green pasture in this area than in Paddock 3. Moreover, from a behavioural perspective the steers may have been unwilling to move far from the other herd occupying the southern paddocks adjacent to Paddocks 3 and 4. Figure 6 reveals another possible cause; the northern area of Paddock 4 is the highest elevation of all the paddocks and so it may be that the steers were unwilling to traverse this slope in search of pasture resources. Similar topography-based restrictions on movement have been observed by Tompkins and O'Reagain (2007).

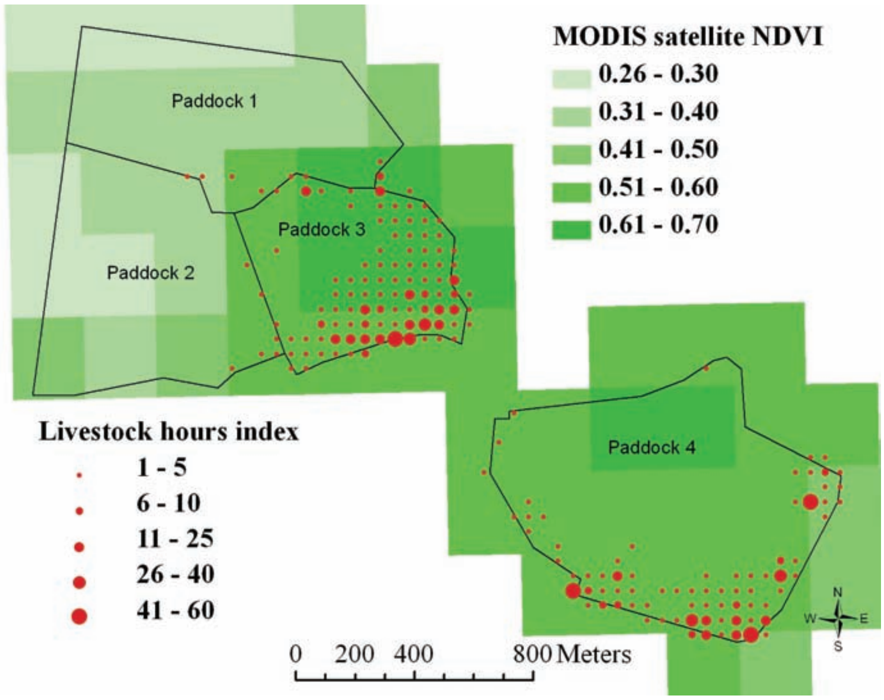

Figure 5. LHI_{50} data superimposed on 7 day composite MODIS satellite NDVI image for paddocks 1 to 4 acquired for the second week of the trial (Trotter and Lamb, 2008).

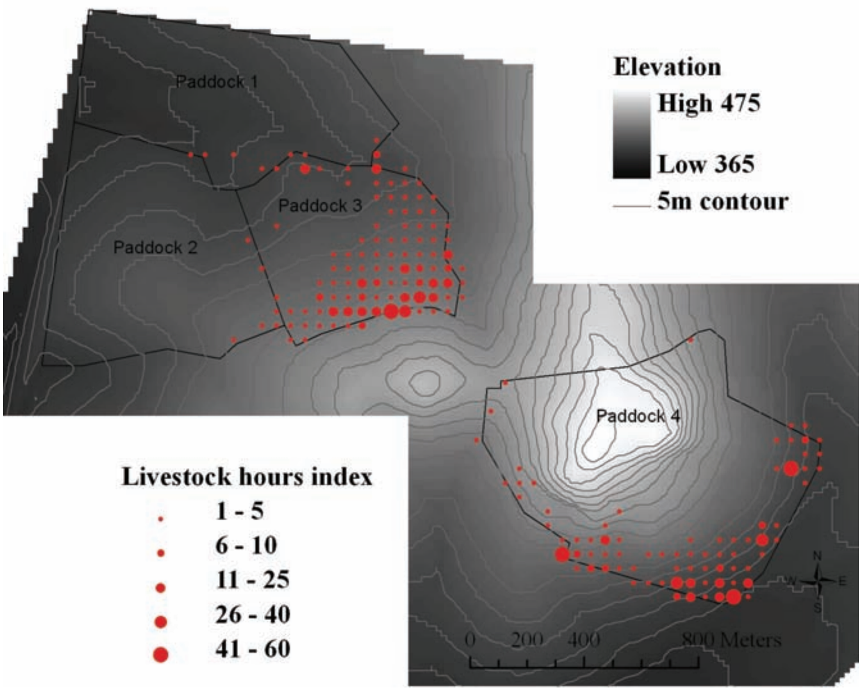

Figure 6. LHI_{50} data superimposed on elevation for Paddocks 1 to 4 (Trotter and Lamb, 2008).

The high LHI_{50} values in the southeastern corner of Paddock 3 is consistent with field observations of a greater abundance of more palatable pasture species and a relatively large amount of surface water. Certainly, other research has highlighted the importance of water availability in driving the spatial distribution of livestock activity (Agouridis et al., 2004; Tompkins and O'Reagain, 2007). Furthermore, the presence of trees within and bordering this area may have encouraged preferential grazing in these areas (Agouridis et al., 2004).

Conclusions

A low-cost GPS livestock tracking collar with tested accuracy of approximately 4 metres (UNEtracker) has been developed with the potential to collect GPS location records over extended periods of time (~1 year with 10 minute tracking intervals). Raw data can be directly used to create livestock activity maps, or filtered, based on published criteria to create grazing/travelling or rest activity maps. A Livestock Hour Index (LHI) has been proposed as a means of quantifying and mapping the impact of livestock activity on the landscape. Integration of LHI data with third-party data such as PAB (as derived from satellite or airborne imagery), elevation, and even information concerning neighbouring herds provides significant interpretation power to the collected data.

Acknowledgments

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Potential for Site-Specific Weed Management (SSWM) of Annual Ryegrass (*Lolium rigidum*) in South Eastern Australia.

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Weeds are a major cost to Australian cropping systems. The 15 most important weeds of seven winter crops in Australia were estimated to cost A$1182 million in 1998-99, and the greatest component of this cost (A$571 million) was herbicides (Jones *et al.* 2005). Annual ryegrass (*Lolium rigidum*), wild oats (*Avena fatua*) and wild radish (*Raphinus raphinistrum*) were the most economically important weeds across all regions.

There are some important features associated with annual ryegrass and its control that make it suitable for site specific management. They are:

1. Patchy distribution across paddocks.
2. Patch location is stable between seasons; however consideration should be given to the wax and wane of patch boundaries between seasons.
3. Herbicides are expensive. Cost of pre-emergent herbicide ranges from $7.75/ha to $37.25/ha depending on the level of control that is sought.
4. Trials with pre-emergent herbicides in wheat and post-emergent herbicides in lentils have demonstrated the benefit of targeting more expensive herbicides only to where higher density patches are.
5. High density ryegrass patches can be mapped in some crops using vegetative indices such as NDVI. Reliability of this approach is best when ryegrass is mapped in crops with slow early growth (i.e. canola and some legume crops) with uniform emergence and where ryegrass is the dominant weed species.

Site specific management of ryegrass will benefit from on-going developments in weed detection and mapping systems. These systems will allow ryegrass to be mapped at lower densities in a wider range of crop types and where it exists in mixtures with other weed species.

Boom sprayers capable of variable rate application of herbicides also need development. Boom sprayers are currently capable of ON/OFF applications or variation of chemical mix by varying the water volume applied. However, to apply variable rates of two herbicides independently of each other requires either

1. Separate passes over the paddock to apply the two different chemicals,
2. Direct injection systems, with two or more boom lines, or
3. Multiple tanks, pumps and boom lines.

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SPAA is a non-profit and independent membership based group formed in 2002 to promote the development and adoption of precision agriculture (PA) technologies.

The association aims to be the leading advocate for PA in Australia and through this role improve the profitability and sustainability of agricultural production systems via the adoption of PA.

PA management offers many Australian farms the potential for a quantum increase in production efficiency.

Our mission is to facilitate research, extension and the adoption of precision agriculture.

Current SPAA members include those involved in the production of grains, winegrapes and horticultural crops, including growers, consultants, equipment manufacturers, contractors and researchers. SPAA's wide membership base is a reflection of the potential that is offered by PA.

SPAA has an Australia-wide focus and this is achieved by partnering with other organisations and becoming part of national and industry alliances.

Visit www.spaa.com.au for more information.

Yara N-Sensor: A Multi-Purpose Platform for On-Line Variable-Rate Application of Fertilisers and Other Agrochemicals

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Abstract

In the year 2000 the Yara N-Sensor has been introduced into the market as a tool for variable-rate application based on optical canopy reflectance measurements. Since then it has been widely used by European farmers to improve their fertilizer applications mainly in cereals and oilseed rape. In 2005 an active version of the N-Sensor has been commercialized. This version contains its own light source to make measurements independent of the availability of daylight.

Both versions of the system are based on a modular structure which allows to implement additional agronomic algorithms for sensor-controlled application of fertilizers and other agrochemicals. Today these new algorithms comprise a so-called "Target Rate" mode to redistribute a given amount of fertilizer according to the sensor readings, a module for growth regulator application and a module for the application of haulm killing herbicides in potatoes. Further modules can be easily added as all basic functions like GPS, data logging, map handling, spreader and sprayer control and user interface are readily available and can be used by the module.

The "Target rate" mode offers a solution for those cases where a predefined amount of fertilizer needs to be applied variably on a field. Normally with on-line sensors this is difficult to achieve unless the field is first scanned completely, then processed and finally applied in a second pass. To avoid this and to sense and apply in one pass, a "self-learning" algorithm has been developed to continuously adjust the overall level of the application depending on the data already recorded.

In "Growth regulator" mode growth regulator will be applied in cereals based on the current crop biomass. Simply speaking, the more biomass is detected by the system, the more growth regulator will be applied to ensure a uniform concentration per leaf area and to avoid lodging. Areas with less biomass are not prone to lodging but may suffer yield losses due to over-application and therefore the application rate will be reduced. Trials have shown that average application rates can be reduced without increasing the risk of lodging.

The "Potato haulm killing" mode is used in a potato crop in order to kill the above-ground biomass a few weeks before harvest. The haulm killing herbicide is reduced in areas where the crop density is low or where the leaves have already turned into yellow or brown. As a result, the average application can be reduced by up to 50% without reducing the effect of the herbicide.

Is it Your First Time? Opportunity for PA in Dryland Grain Farming using Different Data Layers.

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Introduction

More than 15 years of fast technological developments in crop monitoring processes and auto guidance by means of integrated robotics significantly contrasts with the recognized underdevelopment of management tools to fine-tune dense data sets into pragmatic information that can serve farm managers as resources for efficient action (McBratney and Whelan, 2000; Cook and Bramley, 2001; McBratney *et. al*., 2005). The characterization of spatial variability in production has been well explored, but instability in spatio-temporal yield variations and the profitability of investments in PA technology have been inhibiting adoption.

Studies on the characterization of factors influencing the opportunity for SSCM technological adoption and the information flow within main streams of SSCM decision processes are limited (Whelan and McBratney, 2001; Garcia et. al., 2001; Pringle et. al., 2003; Fountas et. al., 2006; Tisseyre and McBratney, 2007). Whelan and McBratney (2000) have described a decision process based on the study of field variability, suggesting that traditional, uniformly applied management practices may be optimal where a lack of well structured spatial variability is observed.

Methods

A decision-tree to support the use of field variability indices is investigated to formulate and validate quantitative methods that simultaneously evaluate the magnitude and the pattern of within-field production variability. A new yield variability index (Y_i) quantifying the opportunity for adoption of SSCM technology was obtained through a revision of methods used for a preliminary opportunity index (O_i) in Pringle *et. al.*(2003). The applicability and validity of the methods formulated using yield monitor datasets was also tested using alternative input data sets generated by remote and proximal monitoring devices commonly used in SSCM. Parametric methods were developed using variogram analysis of the input data to quantify the degree of within-field variability as a function of the magnitude of variation (M_v) as well as the cohesion of spatial variability patterns relative to the present ability of variable-rate machinery to react (S_v) (*Equation **1***). For full description of the method for the yield variability index, the Yieldex (Y_i), refer to De Oliveira *et al*. (2007).

$$Y_i = \sqrt{M_V \cdot S_V} \qquad \textbf{\textit{Equation 1}}$$

Indices from imagery (I_i) and soil ECa (S_i) were correlated with absolute values of the yield index (Y_i) for field-year analysis, and with mean yield index values from all seasons per field for farm-field analysis. Mean values of different indices and correlation coefficients between them were used as thresholds to establish a decision-tree that could support more efficient within-field variability management with options of variability assessments via post-harvest production data, in-crop growth monitoring data, or soil attribute data.

Data

A historical data set (1997-2004) of available dryland grain yield monitoring was gathered from farms of grower's organizations in Australia. From 80 broad-acre fields on 16 farms, a total of 218 field-year yield monitoring samples were used to formulate the Yieldex (Y_i). Additional soil ECa and crop reflectance imagery datasets summed up 14 broad-acre fields within the previous set. Datasets were respectively monitored with electromagnetic induction (EMI) sensors, at three depths of observations (using EM31V, EM38V, and EM38H from 2004 or 2006), and multispectral airborne imagery (AVNIR from 2003 to 2006). Ten vegetation indices (NDVI, GNDVI, PCD, PPR, PVR, VI, OSAVI, MSAVI, VI, TrVI) were computed according to the best correlated vegetation index from previous work, between imagery and interpolated yield data, for the process of determining the opportunity index from imagery.
Datasets were located in 3 different agroclimatic zones and are part of the following farmers' organizations: the Southern Precision Agriculture Association (SPAA), the Conservation Farmers Inc. (CFI), and The Riverine Plans Inc. The total number of field-year samples by cultivated grain crops included: Wheat (129), Canola (30), Barley (20), Sorghum (13), Faba Beans (9), Chickpeas (9), Lupins (3), Triticale (2), Lentils (1), Field Peas (1), and Corn (1).

Results

The observed stable range of index values from the imagery and soil ECa as compared to that obtained from the crop yield data confirms the robustness of the process across data sources (**Table 1**). **Table 2** shows a higher contribution from the magnitude component using the imagery data which is considered consistent with the finer resolution and response characteristics of the imagery data which provides more information on small scale variability. A higher observed contribution from the spatial structure component from the ECa data sets is consistent with the lower sampling resolution and the more continuous nature of soil properties being detected by the sensors. Further details on the correlations between Y_i, I_i and S_i can be found in De Oliveira and Whelan (2008)

Table 1. Yieldex (Y_i) distributions from different data sources.

Index	Minimum	Median	Maximum
Yield (Y_i)	1.6	5.5	20.2
Imagery (I_i)	2.1	6.5	18.4
ECa (S_i)	2.2	4.7	9.0

Table 2. Yieldex (Y_i) component correlations with the final index from different data sources.

Y_i	M_v	S_v
Yield (Y_i)	0.67	0.59
Imagery (I_i)	0.83	0.24
ECa (C)	0.47	0.83

A preliminary decision-tree suggesting the incorporation of field variability indices in routine management decisions is presented in **Figure 1.** It reflects the opportunity for using different indices according to different stages of technological adoption of differential crop management technology. The null hypothesis of PA, homogeneous crop management (Whelan and McBratney, 2001), is verified if threshold conditions of specific indices are not matched. Special conditions (limitations or opportunities) for each final branch of the decision-tree are shown in **Table 3**.

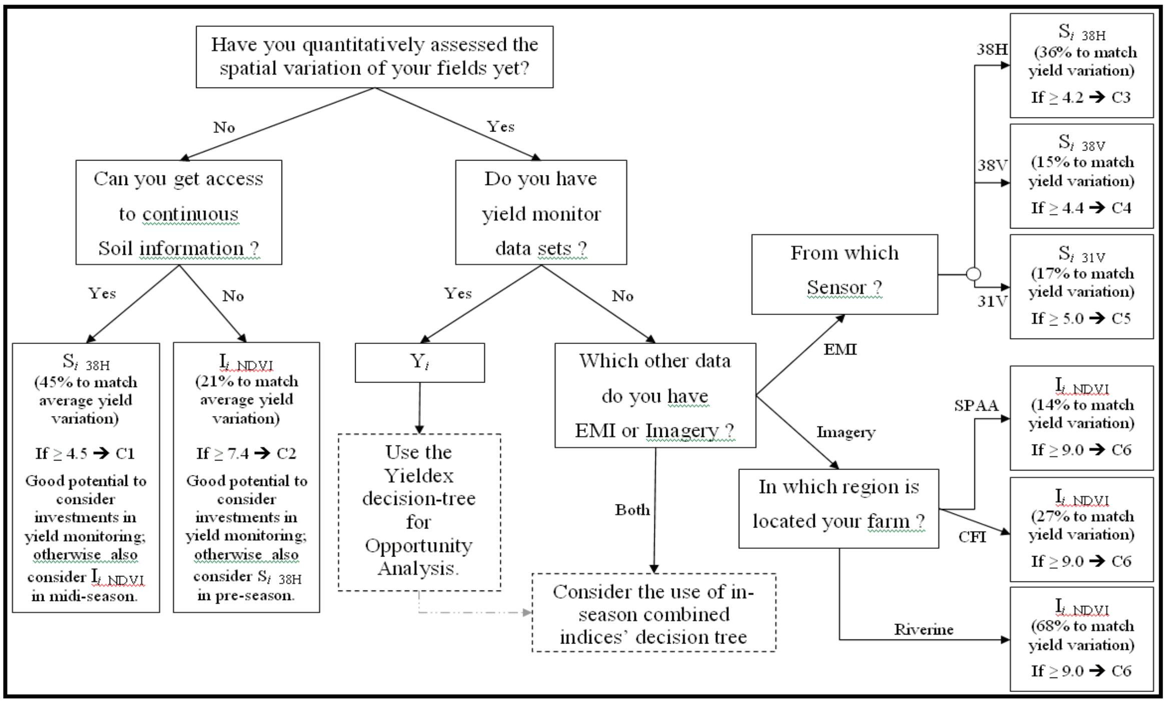

Figure 1. A decision-tree incorporating variability indices in crop management decisions.

Table 3. Special Conditions for final branches of the decision-tree.
* Percentages in brackets are relative to correlations between indices from alternative data sources (EMI and Imagery) and the index from the actual yield variation.

Code	Condition	Special Case	Specific by Crop
C1	$S_{i\_38H} \geq 4.5$	Riverine (93%)	Canola (51%); Faba Beans (62%); and Sorghum (97%)
C2	$I_{i\_NDVI} \geq 7.4$	Riverine (71%)	Barley (85%); Canola (96%); and Wheat (60% for Riverine)
C3	$S_{i\_38H} \geq 4.2$	Riverine (95%)	Canola (58%); Chickpeas (56%); Faba Beans (87%); Sorghum (97%); and Wheat (23% for Riverine)
C4	$S_{i\_38V} \geq 4.4$	2004 Season (49%)	Chickpeas (87%); Faba Beans (55%); and Sorghum (97%)
C5	$S_{i\_31V} \geq 5.0$	2004 Season (60%)	Canola (52%); Faba Beans (67%); and Sorghum (97%)
C6	$I_{i\_NDVI} \geq 9.0$	-	Barley (85% for SPAA); Faba Beans (50% for SPAA), and Wheat (100% rank for Riverine)

Discussion

Present thresholds have been standardized to 3 Australian agroclimatic zones, requiring data from different contexts (biophysical and managerial) in order to standardize a general index for pragmatic decision support. Importantly, all applications of the index have shown an ability to incorporate both the magnitude and spatial nature of the encountered production variability in a manner that matches the physical understanding of the data produced by the respective sensing systems.

The potential for assessments using different within-field variability indices has shown to be a useful tool supporting crop management decisions involving new investments in SSCM technology. The methods proved both to have stable distribution across different input sources, and to be robust when addressing cases of strong non-stationarity. However, more datasets for some crops and regions could improve the significance of quantitative and ranked correlations between all data sets, providing more reliability on the use of alternative indices (I_i and S_i).

The I_i calculations appear to be most useful in single season assessment between paddocks and farms. S_i results suggested it to be a better indicator of the 'opportunity' realised in the final crop yield expected across seasons. Finally, the S_i and I_i show potential for use in situations where no yield monitor data is available.

Conclusion

The extraction of management information from fine-scale data monitoring activities is crucial to the adoption of PA. The accurate measurement of within-field variability and the ranking of the opportunity given by the quantity and patterns of variation would be useful to farmers contemplating further investment in site-specific crop management. Opportunity indices calculated from crop yield, soil ECa, and crop reflectance imagery have shown promise to support farmers in instances where spatially dense data on crop yield are unavailable. The characterization of variability indices across different crop systems, crop seasons, and agronomic regions could support a simple decision-tree model for evaluation of the opportunity for adoption of SSCM technology.

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The Economics of Adopting PA Technologies on Australian Farms

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Introduction

There has been a rapid adoption of Global Positioning Systems (GPS) guidance and autosteer in Australia in the last five years. It is estimated that 30% of broadacre crops in Australia are now sown and/or sprayed using GPS technology. However, other PA technologies such as yield mapping and variable rate is less common with <1% of adoption across cropping regions in Australia. One of the major reasons for this is the lack of evidence that the investment in variable rate technology (VRT) can provide sound financial returns to farmers. The aim of this study was to quantify the economic benefits of PA on eight farms across southern Australia. The PA technology evaluated included yield mapping and VRT, as well as GPS guidance and autosteer. It is hoped this information will provide farmers and advisors valuable background information in deciding whether an investment in PA will improve individual farm profitability.

Methods

Eight farmers were interviewed from different cropping regions of southern Australia and with varying levels of PA experience (Table 1). Information was collected on,

- Area of cropping program, crops grown, crop yields, gross margins, rainfall, soil types
- Variable input costs (fuel, fertiliser, seed, pesticides, machinery, labour) per hectare (ha)
- GPS equipment purchases and purpose
- Evidence that PA is working on their farm in regard to less overlap, VRT etc
- Other benefits of PA e.g. conducting own agronomic experiments

This information was collated, analysed and a case study written on each individual farmer.

Table 1. Location, rainfall, farm size, and PA experience

Farmer	Location	Rainfall (mm)	Farm operation (ha)	Years of PA experience
1	Waikerie	250	3000	7
2	Crystal Brook	400	1600	8
3	Yeelana	425	2700	2
4	Snowtown	400	2340	10
5	Buckleboo	300	4475	5
6	Stockport	475	1200	10
7	Urania	400	1300	10
8	St Arnaud	400	2400	11

Economic analysis

A relatively simple economic approach was used in this study. The total cost and annual benefit of GPS equipment for each farming operation was calculated and expressed as a total and in $/ha. From this, a “payback period” was determined which is the time taken for the equipment to “pay for itself”. The payback period is a function of the annual benefit relative to the initial cost of the GPS equipment and the time taken for the benefit to be instigated. After this payback period, income generated from the GPS equipment becomes profit. The quicker the payback period, the better the investment. The total cost of equipment for each farmer was simply calculated from the original purchase price (gst exclusive). Savings on input costs were based on reduced overlap using GPS equipment. This was calculated using the farmers’ figures on the individual paddock area that was sprayed, fertilised etc before and after GPS equipment was used. Savings using VRT were calculated from comparing variable rate fertiliser application with a previous “blanket” rate of fertiliser used before PA was employed. Production increases from VRT were calculated from higher yields achieved by increasing fertiliser rates on low fertility areas of paddocks. On-farm trial data was used for this purpose. Production increases from inter row sowing were estimated using trial data. Actual farmer data on grain prices and input costs was used in the majority of calculations. Estimates were used when this was unavailable.

Results and Discussion

Costs and Benefits

The costs and benefits from PA in this study are summarised below (Tables 2 and 3). For all cases the annual benefit from cost savings and increased production was enough to cover the cost of guidance and autosteer equipment within three years on average (range of 1-7 years). The payback period for yield monitoring and VRT equipment was longer, some seven years on average (range of 1-10 years). This is mainly because of two reasons. Firstly, the initial high price of yield monitoring in the mid to late 90’s before the equipment became standard on most modern harvesters less than ten years old. Secondly, for most farmers it was some years before a VRT program was implemented because farmers were not confident to go full VRT until they had evidence it would work. The first step in gaining confidence was targeted soil testing which revealed that varying rates of phosphorus (P) fertiliser was a viable option because low yielding areas were high in P, and high yielding areas were low or adequate in soil P. Some of the farmers were reducing their overall fertiliser input using VRT, while others were increasing production on low P areas within paddocks e.g. sand dunes. Involvement with organisations such as SPAA (Southern Precision Agriculture Association) was important in verifying potential returns from PA. Farmers looking to adopt PA in the future are better positioned to make VRT pay within two to three years because of access to lower cost equipment (yield monitor, VRT equipment) and more information on the likely financial returns.

Table 2. Summary of costs and benefits of GPS equipment

Farmer	Cost of PA equipment ($/ha)	Annual benefit ($/ha)	Payback period (years)	
			Yield monitor and VRT equipment	Autosteer and guidance
1	23	11	1	4-5
2	62	13	10	1-5
3	27	21	-	1-2
4	15	15	6	1
5	12	10	-	5
6	62	37	9	3
7	104	19	-	2-7
8	44	19	-	2-5
Average	44	18	7	3

Table 3. Breakdown of PA benefits

Farmer	Annual benefit ($/ha)			
	Savings in overlap	Fertiliser savings using VRT	Increased production using VRT	Other production benefits[A]
1	4	-	7	-
2	5	5	-	3
3	3	-	-	18
4	5	10	-	-
5	2	-	-	-
6	10	9	8	18
7	19	-	-	-
8	6	-	-	19
Average	7	8	7	15

[A] inter row sowing, reduced soil compaction, shielded spraying

Other major benefits of PA

The reduction in fatigue was highly rated as a benefit of guidance and autosteer amongst all eight farmers. The ability to conduct your own agronomic experiments was an important benefit for three farmers, which has the capacity to lead to better whole-paddock or whole-farm decisions that increase profit.

Management time spent by farmers on PA

Most of the farmers interviewed spent between three and seven days per year organising yield and variable rate maps. Most used basic software supplied by manufacturers and machinery dealers. Although the software was basic, it is fair to say the level of computer and GPS literacy amongst these farmers was high. This may be a significant barrier for further adoption of VRT. Some farmers used the advice of a PA or agronomic consultant in preparing variable rate maps. In contrast, guidance and autosteer takes very little training and on-going management.

Conclusion

PA technology offers farmers opportunities to increase their profitability if they make a sound investment in the equipment required. An initial simple feasibility study is an important first step. In regard to VRT, farmers today are well-placed to take advantage of the knowledge gained from the growers in this study who have been the early adopters of PA technology. Also, the cost of PA equipment has become rapidly more affordable in the last five years which will enhance the profitability of adopting PA for many farmers.

Acknowledgements

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Using Precision Agriculture Technologies in Grain Farming Landscapes for Ecological Objectives

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Abstract

The application of precision agriculture (PA) technologies and approaches has been mostly at questions relevant to the (sub-) paddock scale. There are few examples where PA tools have been applied to land management questions at greater scales, such as farms, catchments and landscapes. In this paper we describe two examples where PA approaches have been applied to address natural resource management questions in Western Australia.

The addressing of such questions with PA approaches comes about from the impetus to re-vegetate components of the West Australian wheatbelt to address salinity and improve ecosystem function.

In one study we identify poor performing patches for three farms using historical yield maps to assess the ecological value associated with their re-vegetation. We also investigate how these patches changed with varying definitions of poor performance. Overall poor performing patches were rare and occupied 11.3, 13.5 and 25.3% of farmland across three farms using the most aggressive definition of poor performance that included the greatest proportion of arable land. We subsequently assessed the impact re-vegetating these patches had on a suite of landscape metrics quantifying ecological value. On two farms mean patch sizes were less than 1.2 ha for all definitions of poor performance. On the third farm, mean patch size increased from 0.9 ha to 2.6 ha as the definition of poor crop performance was altered to include more arable land. Patches were generally small and dispersed, did not significantly enhance connectivity in the landscape and were therefore of limited ecological value.

In another study we used participatory approaches with two farmers to explore their attitudes to revegetate low yielding sub-sections of paddocks, identified with PA tools, to enhance connectivity between two neighbouring bush remnants. We show that use of PA approaches can potentially minimise the opportunity costs associated with such revegetation efforts.

In general we have found re-vegetating poor performing patches alone will provide little ecological benefit, when re-vegetation is restricted to unproductive land. The ecological value of re-vegetation strategies in this landscape will only improve if productive agricultural land is taken out of production and re-vegetated.

Targeting Fertilizer Management for Improved Environmental Outcomes in the Sugar Industry

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Abstract

Agriculture is increasingly under pressure to meet public demands for improved environmental performance – a term which is generally taken to infer minimisation of the impacts of agriculture on water bodies, whether these be groundwater, rivers and lakes, or the sea. An obvious question is: how might "improved environmental performance" be achieved and demonstrated ?

Precision Agriculture (PA) can be regarded as a means of increasing the chance that the inputs to production are applied in the right amounts in the right place at the right time. Intuitively, if farmers adopting PA are successful in achieving this objective, the likelihood of negative environmental impacts arising should be reduced. Conversely, where the likelihood of a negative environmental impact is shown to be high, the opportunity for reducing the amount of inputs used, and/or increasing their efficiency of use, should be apparent.

With the above ideas in mind, we were interested to explore the opportunity to use PA as an instrument for reducing the potential environmental impact of the sugar industry on the Great Barrier Reef and the coastal rivers which drain into it, and in particular, the potential benefit of targeting the application of nitrogen (N) fertilizer using either continuous variable rate application or zone-based management. The analysis is based on a yield map obtained in 1998 for a 6.7 ha block of sugarcane in the Herbert River district (Bramley and Quabba, 2001) and simulated yield maps for this block for other years in the 10 year period 1996 to 2005 (Figure 1a). These maps were used to estimate the potential loss of N to the environment, and its spatial variability within the block, based on crop removal of 0.9 kg N t^{-1} yield in the previous year (Thorburn et al., 2007).

Thorburn et al. (2007) proposed and tested a strategy for N fertilizer management for sugarcane based on the maintenance of nutrient balance through *replacement* and suggested that this may deliver significant environmental benefits over conventional practice without compromising profitability. Here, we compare 'standard practice' which, based on district average N use over the study period, was assumed to be uniform application of 190 kg N ha^{-1} y^{-1}, with the N replacement strategy of Thorburn et al. (2007) assuming uniform application of 1kg N ha^{-1} t^{-1} mean yield achieved in the previous year, with selected targeted strategies. These were: modification of the Nrep strategy with the paddock divided into 2 management zones (Figure 1a; zone based); modification of the zone-based strategy with N applied at rates of 0.7 or 0.8 kg N ha^{-1} t^{-1} yield in previous year to the higher and lower yielding zones but with 0.6 kg N t^{-1} removed in the crop (eff);

and the ‘eff’ strategy when implemented using continuous variable rate fertilizer technology (VRT; 1998 only).

a. b.

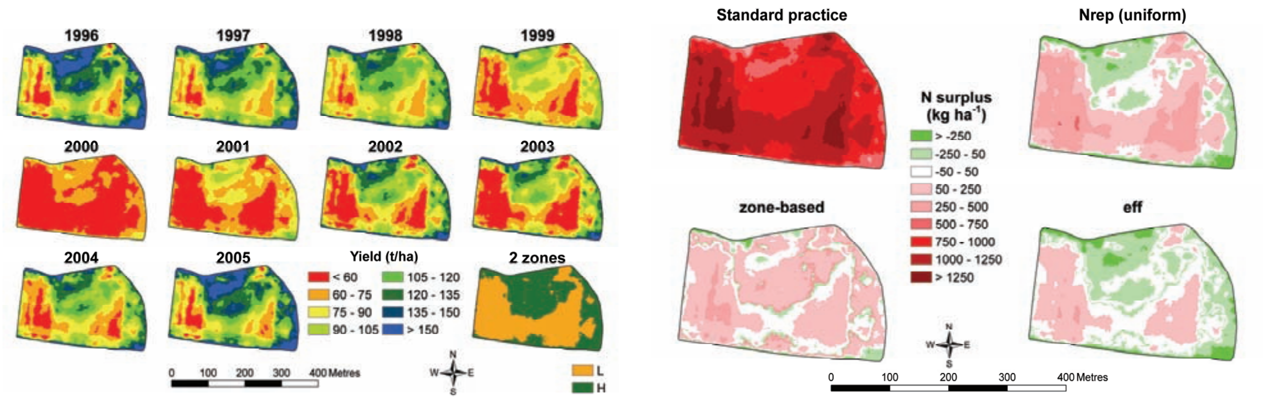

Figure 1. Estimates of (a) yield (1996-2005) and (b) N surplus (1997-2005) in a 6.7 ha sugarcane paddock. Note that in (a), the map for 1998 is actual yield; maps for other years were simulated.

Table 1. Summary of implications for profitability and environmental performance of selected N fertilizer management strategies in a Herbert River sugarcane paddock, 1997-2005.

	Std Practice		Nrep		zone based		Eff		VRT
	1998	97-05	1998	97-05	1998	97-05	1998	97-05	1998
N applied (kg)	1,273	11,457	704	5,327	725	5,368	547	4,071	502
N surplus (kg)	680	6,792	108	644	129	678	10	-168	104
Gross margin ($)	11,065	85,620	11,601	91,602	11,616	91,734	11,794	93,031	11,164

Figure 1b shows the implications for potential N loss to the environment of these various strategies (except VRT) over 9 harvest seasons from 1997. As can be seen, under standard practice, much of the paddock may potentially leak approximately 1 t N ha^{-1} over 9 years under uniform N application, whereas for each of the strategies based on N replacement, at least some parts of the block have no N leakage at all. Note however, that because the Nrep strategies (except VRT) depend on calculation of mean paddock yield, irrespective of whether this is partitioned into zones, the Nrep and zone based strategies yield almost identical results in terms of total surplus in the paddock (Table 1). Figure 1b therefore illustrates the effects of the different strategies on spatial variation in N use efficiency. However, the results presented strongly suggest that not only is ‘standard practice’ based on flawed agronomy, but that the Nrep strategy also assumes a higher requirement of sugarcane for N than is in fact the case. Thus, application of N following the ‘eff’ strategy results in further reductions in potential N loss without impacting on the financial performance of the paddock (Table 1). Also apparent from Figure 1b is that a lack of perfect knowledge about inter-annual variation in yield potential, driven primarily by variation in climate, results in the possibility of N being in deficit in parts of the paddock in some years. Surprisingly, in 1998 VRT led to a greater N surplus than the ‘eff’ strategy. However, the results for VRT (not shown) suggest that VRT may result in less spatially variable N use efficiency than the ‘eff’ strategy; the long term agronomic implications of this are unclear.

We conclude that the use of spatial data to better inform agricultural management can make a valuable contribution to reducing the risk of negative environmental impact. However, for the maximum environmental benefit to accrue through PA, existing regional management guidelines need to be replaced by guidelines for site-specific management. This in turn will require a considerable enhancement to existing agronomic understanding.

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Impressions from the 9th International Conference on PA in Denver, Colorado (July 2008).

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Abstract

The International Precision Agriculture Conference (IPCA) held in Denver Colorado July 20th-23rd was an exciting experience. There were scientists, grad students, researchers, professors and industry personnel from 43 different countries who presented 250 papers and exhibits on some interesting new technologies and some new ways of using technology to help agriculture deal with todays changing climatic conditions and tough economic climate.

- There was a large emphasis on crop scanning research with real time scanning, airborne imagery and satellite imagery all being used to varying degrees to target variable rate application of nitrogen fertilizers.
- There were presentations on real time protein measurement and even using this technology to predict test weight in cereals.
- Research is also being carried out using NDVI to determine wether crops are suffering from water stress or lack of nitrogen before applying nitrogen to the crop.
- Work is also being done on various on-the-go soil sampling techniques for different tests (pH, P, K, N & others) and even recognition of weeds to guide precision robotic weeding.
- Research into different coatings for urea fertilizer to reduce volatilaztion loss from calcareous sandy soils.
- A Korean group have been developing a mobile motorized digital cone penetrometer for measuring soil strength and compaction.

The conference also had a display area where companies could display there products including soil samplers, guidance, controllers, computer software, grain samplers, spatial data collection and education training.

Overall there were four rooms running 20 minute presentations concurrently for two and a half days so at best you only got to see twenty five percent of the presentations, even then the mind was almost numb by the end but excited at the potential of what could be developed for agriculture in the coming years.

Acknowledgements

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Precision Agriculture: Moving Beyond the Early Adopters to the Masses

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Abstract

James Hassall farms 4 spatially separate properties near Gilgandra so he knows a bit about the variability in production potential that can be found in the area. He is using PA technologies to experiment with variable-rate management options across the properties. His own experiments have provided invaluable information to quantify the changing responses that he must deal with as a manager.

James uses yield, soil ECa and elevation maps. He has been instrumental in work adapting a on-harvester protein monitor to Australian conditions and now gathers protein content information at harvest. He is also working on understanding the best way to use in-season crop reflectance information under Australian conditions.

James will share some of his experiences and provide suggestions on how to get the use of these tools out into the wider farming community.

PA Opportunities

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Abstract

I will try to remind everyone of the general opportunities there are for the precision agriculture approach.

We at the ACPA have concentrated on the development of a spatio-temporal crop opportunity index, i.e., yieldex. This is part of a wider consideration of opportunity for ‘value-adding’ . Value-adding opportunities essentially try to (1) increase efficiency (E = outputs/inputs) be it water energy, or financial; (2) increase profitability, e.g., P = value of product – cost of production; (3) increase amount and flow of information from the producer to the consumer and vice versa. Information has value.

Most of the value-adding work has concentrated on ‘incremental’ agronomy, e.g., designing systems to optimise inputs to get another 10-20 % yield or gross margin, but work should now move more widely to consider high(er) value crops, product separation, environmental stewardship and emerging opportunities. Each of these has particular barriers nevertheless they should be pursued. Irrigation and horticulture are key areas of future application of the PA approach. The product separation idea needs the development of a model which will carry information to the consumer and allied technology. Reverse information flows should also be part of the model. The use of PA for environmental stewardship is hampered by a formal scheme with payments for delivery of ecosystem services. Monitoring technologies require to be developed to justify and validate this. Emerging opportunities are afforded by biofuels, carbon sequestration and climate change. For biofuels areas of low productivity might be converted to perennial biofuel plantations. For soil carbon sequestration, differential soil carbon targets can be set for areas of varying productivity. Once again efficient measurement technologies need to be developed for auditability.

I will also highlight existing and emerging opportunities presented in today’s talks.

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