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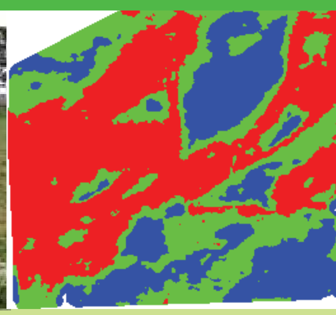
16th Precision Agriculture Research Symposium in Australasia







Monday 26th and Tuesday 27th August 2013

WACA, East Perth WA

Increasing the Adoption of Precision Agriculture in Australia

16th Symposium on Precision Agriculture in Australasia

Welcome!

The expanding human population, projected resource limitations and tougher environmental regulations are exerting an increasing pressure on crop production systems. This pressure continues to drive investigation and investment in new technologies and techniques that aim to increase total production, while optimising production efficiency and addressing the growing environmental concerns of society.

Precision Agriculture (PA) is well placed to offer suitable channels for such investments, and has certainly reached a level of development where it can now provide useful technologies and techniques that support the targeting of these goals. The trade display and presentations at the Symposium testify to this.

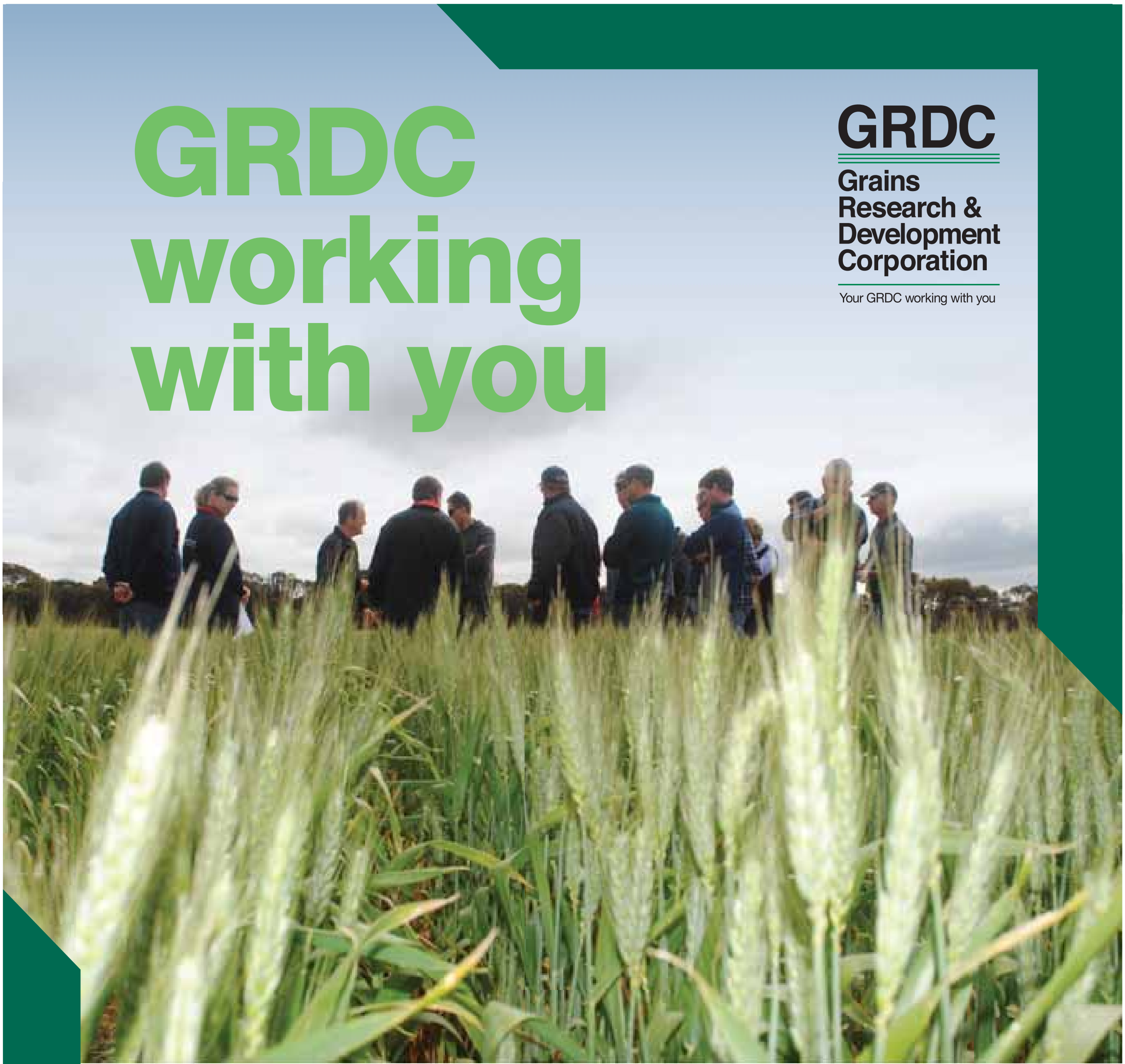
While the current level of PA adoption that we will hear about at the Symposium has been built on a long history of innovators and pioneers, exciting challenges lie ahead for PA practitioners in areas such as:

- fine scale, real-time, cost-effective estimation of soil profile/crop nutrients;
- fine scale, real-time, cost-effective estimation of soil profile moisture content;
- localised weather predictions;
- efficient, integrated crop quality monitors;
- spatial yield prediction/simulation models;
- combining crop reflectance sensors with an independent biomass sensor;
- better understanding of the agronomic impact of fine-scale resource variability and interactions;
- autonomous weeding;
- targeting PA for increased water-use efficiency and improved farm C and N emission management;
- improving PA GIS capabilities;
- improved integration of multiple data layers for real-time decision making in nutrient/irrigation applications;
- product tracking and production information traceability; and
- secondary and tertiary education.

As the research efforts continue and the promising PA technologies and techniques are adopted and adapted to suit local requirements and conditions, it is obvious that the PA philosophy is becoming a crucial component in sustainably (commercially and environmentally) managing all inputs, natural retentions and emissions across inherently variable agricultural enterprises.

The presentations in this year's PA Symposium will confirm the strong and continued focus of the PA industry on improving the management of agricultural operations. You will be exposed to developments in sensors, application technologies, software, management techniques and education platforms. Please enjoy the interaction and inspiration the Symposium offers to all participants.

The PA Lab and SPAA teams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Contents

Acknowledgments
This event has been made possible by the generous support of industry. SPAA and PAL wishes to thank the following organisations for their financial assistance in putting this event together, and assisting with the travel arrangements of our key note speakers. GRDC, Incitec Pivot Ltd, John Deere, Graingrowers Ltd, Case IH, Farm Weekly, Topcon, Precision Cropping Technologies, Precision Agronomics Australia, precisionagriculture.com.au, PA Source, Geosys, Wellards, Trimble, CSBP, FarmscanAg.

Presentation program

MONDAY 26th SEPTEMBER 2013

12.00pm Arrival, Registration & Lunch
12.55pm Welcome
1.00pm Autonomous machines: SmartSeeder prototype and game changing concepts Jay Katupitaya (UNSW)
1.20pm Modelling Consequences of Uneven Fertiliser Distribution *Matthew Roesner (Roesner Pty Ltd) and David Gobbett (CSIRO)*
1.40pm Precision Ag adoption trends: who's been doing what, where and for how long? Frank D'Emden (Precision Agronomics) and Rick Llewellyn (CSIRO)
2.00pm Mobile devices – the next step in PA adoption *Tywen Dawe (Farmanco)*
2.20pm Industry news – John Deere
2.30pm Afternoon Tea
3.10pm Industry news – Case IH
3.20pm Microspectrometers for soil and crop monitoring *Dilusha Silva (UWA)*
3.40pm Developing precision systems for potato crops in Australia *Frank Mulcahy (Simplot)*
4.00pm Assessing the economics of VRT fertiliser applications *Luke Dawson (CSBP) & the Liebe Group*
4.20pm Open-data repositories, expert exchange platforms and standardisation as tools to enhance adoption of Precision Agriculture *Armin Werner (Lincoln Agritech)*
4.40pm H-sensor weed identification and treatment *Hermann Leithold (Agri Con - Germany)*
5.10pm Close

5.20pm SPAA Annual General Meeting

6.15pm *PA Connections @ WACA Perth (sponsored by Topcon)*

TOPCON Precision Agriculture

7.00pm *Symposium Dinner @ WACA Perth (sponsored by Precision Cropping Technologies)*

TUESDAY 27th SEPTEMBER 2013

8.45am *Welcome*
8.50am Industry news – Incitec Pivot
9.00am PA trials - design and analysis
Nigel Metz (SEPWA)
9.20am Precision Viticulture – how vignerons are using spatial information in vineyards Tony Proffitt (PVA)
9.40am Digital homestead: delivering end-user value from real-time on-farm monitoring Greg Bishop-Hurley and David Henry (CSIRO)
10.00am Report from the 2013 Digital Rural Futures Conference
John Stanley (UNE PARG)
10.15am Applying PA in Pingrup
Paul Hicks (Craiglinne Estate, Pingrup)
10.45am *Morning tea*
11.15am PA education news - PA for Grain Production Systems *(Brett Whelan, PA Lab, USYD)*
PA: building knowledge, linking agronomy, growers profiting *(Brooke Sauer, PCT)*
11.30am Industry news – GrainGrowers
11.40pm Allocation of Cropping inputs according to PAWC (Farming to the Bucket) = lower risk and greater ROFE *Craig Topham (Agrarian Management)*
12.00am Quad Copter unmanned aerial vehicle (UAV)
Warren Abrams (New Era Ag Tech)
12.15pm Economics of PA and future research
Roger Lawes (CSIRO)
12.35pm A global view of PA research and opportunities for Australia
Emma Leonard (AgriKnowHow)
1.00 pm *Close and Lunch*

1.45 pm *Field Trip: board bus for 2pm departure to Brookton*

Autonomous machines: SmartSeeder prototype and game-changing concepts

Jay Katupitiya

School of Mechanical and Manufacturing Engineering, The University of NSW

Contact: j.katupitiya@unsw.edu.au

Summary

The primary driver behind the development of autonomous machines is to put forth systems capable of greatly advancing today's broad acre farming via "Precision Autonomous Farming". Precision autonomous farming refers to the ambition to use unmanned machinery in agriculture with much greater precision than is possible using today's techniques. While there are many researches that are taking place in the autonomous system's world, the progress towards the precision autonomous farming has to be not only well thought out and rich in scientifically proven content useful for broad acre farming, but also be able to carry with it the growers as well as the farm machinery manufacturers. As such this research has developed a pathway to move forward and has taken the first step in completing the development of a fully functional, highly precisely guided prototype of an autonomous seeder. Seeding is considered the first significant step of a broad acre cropping cycle.

Broad acre farming presents a reasonably structured scenario that is amenable to the application of precision autonomous farming. "Structured" in this context refers to the extent of uniformity and predictability associated with the agricultural operation. However, despite being structured to an extent, broad acre farming scenarios are still substantially different (and variable) compared to those in which automated systems have been well established e.g. a factory floor or a well laid out cargo/material handling area. Thus, there still remained a considerable degree of unpredictability and lack of structure to deal with.

In order to transform today's broad acre farming practice to future precision autonomous farming it requires a new way of thinking and a true quantum leap in machinery technology. The principle that underpins the new approach is the guidance of agricultural machinery with high precision. The traversing of an agricultural machine with a lateral deviation (deviation in the direction perpendicular to its direction of travel) of ±2-5 cm is considered precision navigation. This is the precision required to ensure highly spatially accurate and economical metered agronomical substance application. It is important to note that precision navigation at the time of seeding partitions the land into two areas, the areas that are cropped and the areas that are not cropped, with extremely high spatial accuracy.

This knowledge can be used to significantly improve the efficiencies through highly targeted substance application and thereby minimising wastage and maximizing the effectiveness. As an example, instead of blanket fertilizer application, crop row targeted fertilizer application can be carried out. As the crop is planted in geo referenced known locations no sensing for crop localization is needed. Further, as the machines can traverse with greatest accuracy, the crop rows can be accurately targeted. In this example of fertilizer application, there are other advantages. First, less fertilizer is

needed. Next, fertilizer is not applied to the inter-row space. Any weeds that grow in the inter-row space is now starved of fertilizer. This will help the crop to battle out the weeds in the inter-row space easily. A by product of this level of accuracy in navigation is that these machines may no longer be driven by human operators for the simple reason that such accuracy cannot be maintained by the human operators for prolonged periods of time. As such it is inevitable that the machine has to be autonomously guided.

Figure 1. The SmartSeeder prototype in action.

While the example given above is for fertilizer application, weeding is just as precise and economical, even if it is herbicidal weeding. Blanket spraying can be replaced by spot spraying which require traversing at lower speeds, however, in the case of autonomous machines there will be no labour cost involved. Thus the proposed precision guidance allows precision spot spraying, hence increased effectiveness, reduced herbicide costs due to spot spraying instead of blanket spraying and reduced environmental damage due to reduced herbicide use. Further advantages can be harnessed through mechanical weeding which is now feasible due to extremely highly precise guidance of tools attached to the weeding implement.

As for driverless machines, a major concern of the farming community is safety when a human operator is not present. When autonomous machines of full scale are demonstrated to growers, manufacturers and general public, they only see the motions of the machine. It must be strongly emphasized that, in the case of UNSW developed autonomous machine, almost a year has been spent in ensuring safety subsystem's safe operation which is not visible to general public. There are numerous sensors, interlocks, redundancies, data encryption and watchdog systems incorporated to the system so that all possible failure scenarios such as, sensor malfunction, sensor disconnection, network failure, software crash, complete control computer shutdown and many other situations including hostile agent intrusion has been taken care of. At worst, it achieves, human operated safety - not less.

The presentation will include a complete description of the operational concepts of the machine and the pathway towards achieving the best of benefits of autonomous precision machinery use in broad acre farming.


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Modelling consequences of uneven fertiliser distribution

Matthew Roesner[1], David L Gobbett[2], Dr Michael J Robertson[3], Dr Ross Waring[4]

[1]Roesner Pty Ltd, Lot 101 Turnbull St, Harvey 6220 WA Australia.
[2]CSIRO Ecosystem Sciences, PMB 2, Glen Osmond, SA 5064.
[3]CSIRO Ecosystem Sciences, Private Bag 5, PO Wembley, WA 6913, Australia.
[4]Proxima Consulting, Suite 37 Chelsea Village 145 Stirling Highway, Nedlands 6009 WA Australia.

Contact: matt@roesner.com.au

Abstract

Spinner type fertiliser spreaders are versatile implements which can be used to apply granulated fertilisers and non-granulated soil ameliorants. Thousands of fertiliser spreaders are in use across the Australian wheat belt. Fertiliser spreaders do not apply fertiliser in a perfectly even manner, and the evenness of spread is influenced by a range of factors including wind conditions, fertiliser properties, spreader setup, pattern overlap and bout width. A national certification procedure (AFSA 2001) is used to test the performance of fertiliser spreaders. The test consists of weighing the material spread over a set of collection trays and then plotting a coefficient of variation (CV) curve for a range of bout widths. For granulated fertiliser the maximum CV threshold is 15%, whilst for soil ameliorants 25% CV is permitted.

This paper outlines a computer based tool developed by CSIRO in collaboration with Roesner Pty Ltd, the manufacturers of the Marshall Multispread fertiliser spreader. Providing a method to investigate the relationship between nitrogen fertiliser, bout width, soil quality (i.e. the crop available water capacity of a soil) and season type, the tool was used to model wheat crop yield and economic return for different background soil N levels, a range of idealised spread patterns along with different soil and season types.
The different scenarios demonstrate the influence of several factors on the partial net income (PNI) for nitrogen fertiliser applied to wheat using idealised spread patterns. In many cases bout width has less impact on predicted PNI than soil quality or season type.

Definitions

Background soil N: Level of exploitable N stored in soil prior to fertiliser application
Bout width: Distance between the centrelines of successive spreader passes in the field
Coefficient of variation (CV): Measure of the evenness of spread pattern and predicted crop yield.
Fertiliser properties: Particle properties including bulk density, moisture content and particle size distribution
Granulated fertiliser: Fertilisers consisting of a conglomeration of discrete solid, macroscopic particles for example Urea and Superphosphate
Non-granulated soil ameliorants: Fertilisers consisting of a range of particle sizes and shapes, typically in an unprocessed state such as Lime and Gypsum
PNI: Partial net income. Crop income calculations that only consider a subset of operation costs

Soil quality: An indication of the crop available water holding capacity of a soil
Spread pattern: Distribution of fertiliser output from the spreader
Ye: Economic Target Yield. 80% of Yw
Yw: Soil Water Limited yield potential, where nutrients are non-limiting and weed and pest stresses are effectively controlled.

Design and Development

The tool was developed using Microsoft Excel and Visual Basic for Applications (VBA) code. Figure 1 illustrates the main inputs and factors incorporated into the tool which combines a model of wheat crop response to N fertiliser, with simulation of fertiliser application based on driving patterns and spread patterns.

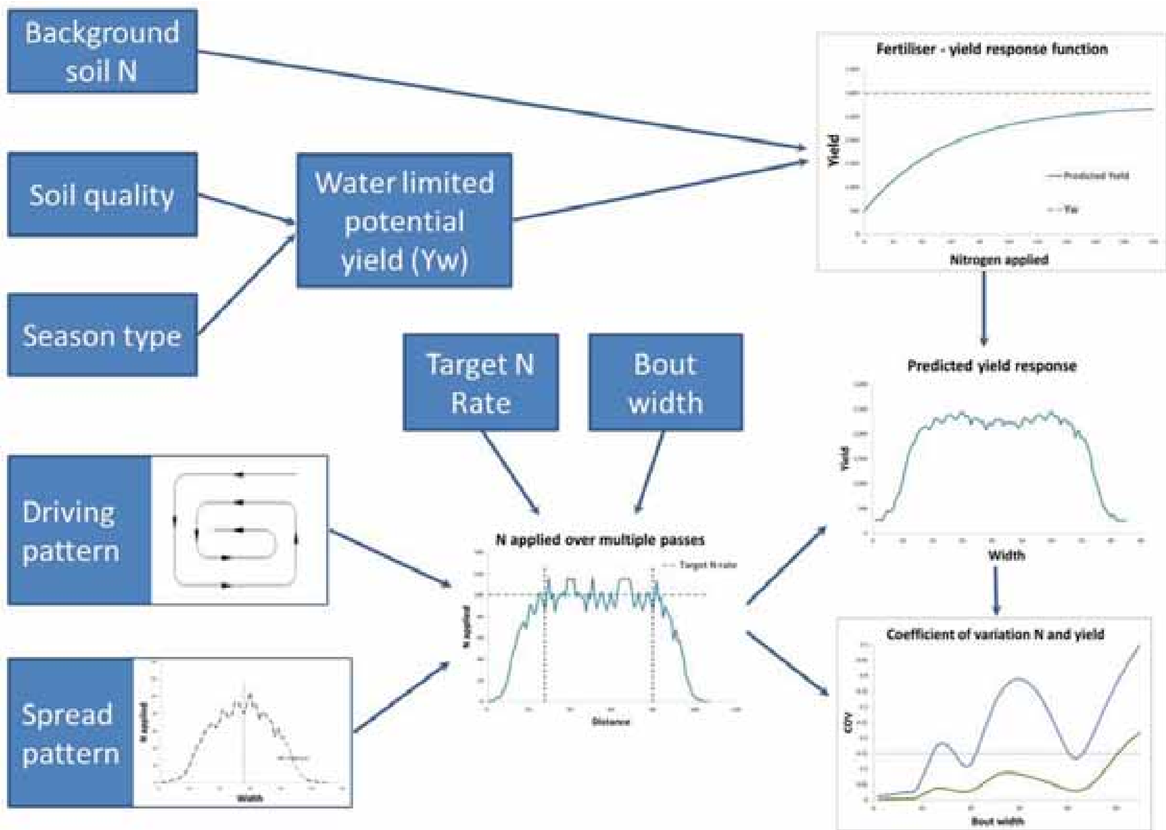

Figure 1. Diagrammatic representation of the main components of the spreadsheet tool.

Soil water limited yield potential (Yw) is the yield of a well-managed crop that could be grown on a soil in a given season if all nutritional needs are met throughout the growing season, and there are no weeds, pests and diseases. Figure 1 shows that both soil quality and season type are used to derive an estimate of Yw and in Table 1 typical Yw values for a range of soil and season types are shown. Since Yw is not an economically realistic target, 'exploitable' yield or 'economic target yield' (Ye) is calculated as 80% of Yw. With fertiliser levels required to achieve yields above Ye, the costs of extra fertiliser are unlikely to be recovered.

A key component of the tool is a Mitscherlich fertiliser-yield response function (Robertson et al. 2008) which is a model of crop yield as a function of applied N, Yw, and background soil N. Typical background soil N values are shown in Table 2. The Mitscherlich function represents a 'law of diminishing returns', whereby incremental

Table 1 Typical Yw values (potential crop yield in t/ha) for WA wheat crops based on soil quality and season type.

	Soil Quality		
Season type	**Poor**	**Average**	**Good**
Below-average	600	1500	1900
Average	900	3000	3800
Above-average	1400	4500	5000

Table 2. Table of Indicative background soil N values used in the spreadsheet tool.

Descriptive soil N level	Kg N/ha
Low	10
Average	50
High	80
Very high	200

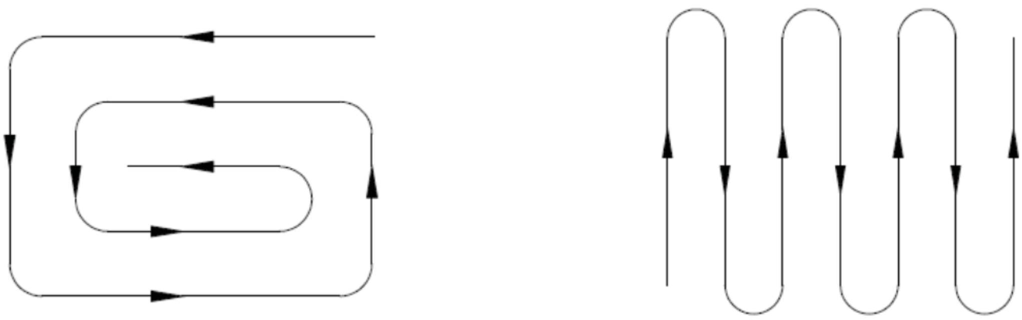

Figure 2. Example spreader driving patterns (a) racetrack and (b) to-and-fro.

application of a fixed amount of N will result in smaller and smaller responses in yield. Higher rates of N applied will result in yields approaching but not exceeding Yw. The model is parameterised for wheat crop response to N fertiliser, but could be generalised with other crop species and nutrients/ameliorants.

As shown in Figure 1, background soil N levels, and a Yw value derived from soil quality and season type, are used to parameterise the fertiliser yield response function. The N application rate across the assessed range (i.e. between the centre lines of parallel passes of the spreader) is determined as a function of selected spread pattern, and driving pattern. 'Racetrack' and 'to and fro' driving patterns are implemented (Figure 2). The fertiliser yield response function is used to predict the yield response across the assessed full width. Assessment of N application (proportion above and below target rate), yields (relative to Ye) and basic economic analysis resulting in PNI are carried out across the assessed range. The tool also iterates across a range of bout widths to calculate PNI, mean proportion of Ye, and CV of N applied and of yield.

The tool makes a number of assumptions, including that all N is applied preseason, soil type is uniform and all other nutrients are non-limiting.

Sample Case

A sample case is illustrated below using the inputs in Table 3.

Table 3. Sample spread sheet inputs

Spread Pattern	M-shaped	**Background Soil N**	Average
Fertiliser	Urea (N=46%)	**Crop Type**	Wheat
N Rate	100 N kg/ha	**Urea Cost**	$563/t
Bout Width	36 m	**Wheat Price**	$304/t
Soil Quality	Average	**Labour Cost**	$45/h
Season Type	Average	**Fuel Cost**	$1.4/l

Selected tool outputs showing N rate applied across the spread width, predicted yield response across width, coefficient of variation of applied N and yield, and partial net income (crop income less spreading costs) are shown in Figure 3. Vertical dashed lines in (a) and (b) correspond to the assessed width (i.e. the width over which fertiliser, crop yield and economic calculations are performed in the tool).

An M-shaped fertiliser distribution such as is used in the test case is commonly caused by a combination of fertiliser inconsistencies, wind effects and incorrect machine setup. The CV of applied N has a large peak above the 15% CV threshold between 20 m and 36 m, however the CV of yield remains below the 15% CV threshold and the PNI value dips slightly around 30 m bout width.

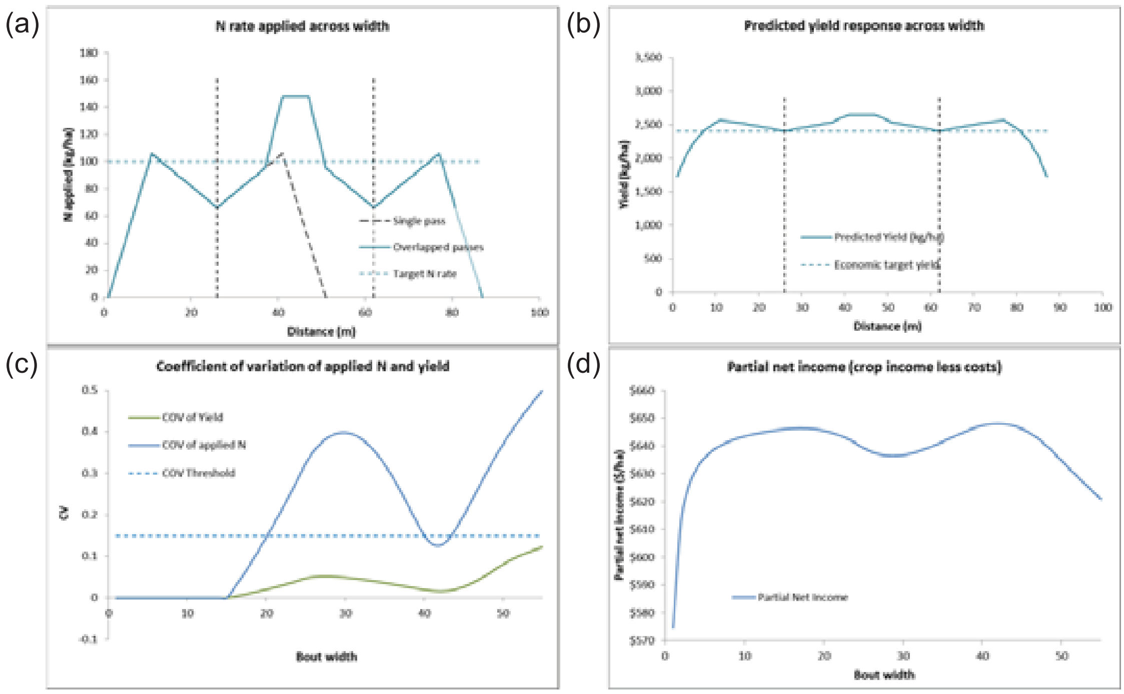

Figure 3. Tool outputs for a sample case with input parameters shown in Table 3. (a) N applied across the direction of spreader travel with an M-shaped spread pattern (a single pass pattern is shown as a dashed black line) and a racetrack driving pattern, (b) crop yield predicted across the same width (c) CV of applied N and yield plotted over a range of bout widths, and (d) PNI over a range of bout widths. Vertical dashed lines in (a) and (b) show the width over which fertiliser rate, crop yield and economic calculations are made.

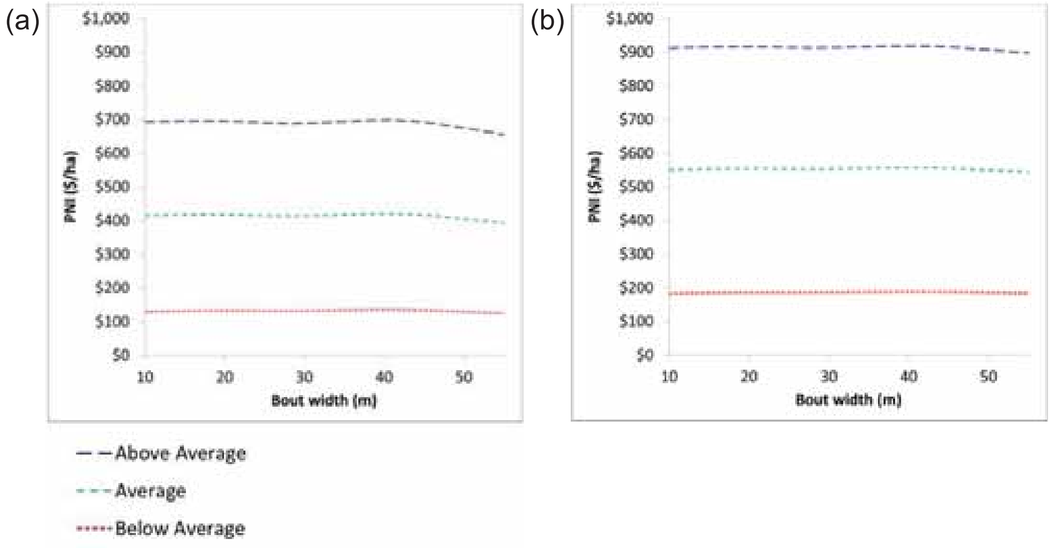

Figure 4. Partial net income over of a range of bout widths and three season types, a trapezoidal spread pattern, N application rate of 50 kg/ha and an 'average' soil (see Table 1) with background N levels of (a) 10 kg N/ha and (b) 50 kg N/ha. Note: the PNI outputs of the spreadsheet tool are for comparative purposes only, and are not intended as a guide to fertiliser application rates.

Sensitivity to bout width

A sensitivity analysis performed with the spreadsheet tool looked at the effect on PNI of different bout widths (10 m to 55 m), using an idealised trapezoidal spread pattern. This spread pattern is an example of a 'good' pattern. Example outputs of the sensitivity analysis are shown in Figure 4 (due to space constraints, only a few examples of these outputs are included here). These results show that season type have a far more substantial impact on PNI than bout width. The effect of bout width is more noticeable with a low background N of 10 kg N/ha, than at a higher level of 50 kg N/ha.

Discussion

Physical testing considers the performance of the spreader and doesn't take into account the factors that affect the response of the crop to nutrients contained in the fertiliser. These factors include season and soil type and background soil nitrogen (N) levels. Furthermore, economic factors (e.g. crop prices and fertiliser costs) influence optimal fertiliser application rate, and therefore the optimum bout width may not correspond to that at which the spreader is certified according to the physical tests. In the sample case, there is a noticeable PNI penalty at small bout widths, which are primarily a result of higher fuel and labour costs associated with increased driving at narrow bout widths.

A sensitivity analysis was run using the spreadsheet tool to determine how the fertiliser bout widths and spread patterns affect crop yield for given soil quality and season type. For the bout widths tested in the sensitivity analysis, and for a given soil quality, the season type has a far greater influence on PNI (through its effect on Yw) than the bout width (within the range of application rates simulated).

Based on the sensitivity analysis, the impact of wider bout widths, and consequently less-even fertiliser application is greatest when background N is low and when high levels of fertiliser are applied. In these cases poor distribution of fertiliser results in yield losses, and therefore results in an economic disadvantage. When background N is higher the negative impact of poor distribution is reduced, reinforcing the message that knowing background soil N levels is valuable. It is therefore important that farmers understand background soil N levels before making decisions on fertiliser application rate.

Acknowledgements

Dr Roger Lawes contributed helpful advice and assistance in relation to the Mitscherlich fertiliser yield response function.

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Precision agriculture adoption trends: what, where and for how long?

Rick Llewellyn[1] , Jackie Ouzman[1] , Frank D'Emden[2]

[1]CSIRO; [2]Precision Agronomics Australia

Contact: Rick.Llewellyn@csiro.au

Abstract

This paper provides a brief preliminary summary of PA adoption trends from a survey of broadacre grain growers across southern Australia. While autosteer adoption approaches peak levels in most regions, spatial management increases steadily but is highly region-specific. The results come from a broader study identifying opportunities to target support for more rapid adoption of profitable learning-intensive innovations.

Introduction

There are many aspects to the adoption of precision agriculture by Australian farmers. For some simpler components such as GPS guidance, adoption has been relatively rapid and widespread, while adoption of precision agriculture technology for site-specific management has been considered to be relatively slow but on a rising trajectory (Robertson et al 2012). Compared to the more uniform benefits of GPS guidance and autosteer, adoption of variable rate management and reasons for its relative advantage are expected to be far more 'site-specific'. As part of a broader GRDC–supported study of practice change by grain growers, the path to PA adoption across a range of southern Australian regions has been investigated. The study placed particular emphasis on the role of advisers and the perceived benefits of future adoption. The study collected data on various PA component practices and technologies ranging from yield mapping, variable rate fertiliser through to soil and crop mapping technologies. A key aim is to help identify where potential lies to most effectively facilitate future profitable use of PA practices, and more complex farming practice change generally. The focus of this brief preliminary summary is on the rate of adoption of different practices over time.

Methods

In September-October 2012 a survey of 573 growers across Australia's southern grain growing region was conducted by telephone with respondents chosen at random from a database of growers with greater than 500ha of grain crops. Regions covered included SA (Central, Mallee, Upper and Lower Eyre Peninsula); Victoria (Loddon, Wimmera, Mallee); NSW (Riverine Plains; Central West) and WA (Southern; Northern Central; Southern Central). Among a large number of questions eliciting farm, farmer and perception information, farmers were asked to report on what year they first started using a particular practice or technology.

Results

Respondents were asked what year they had first used autosteer, varying fertiliser rates within a paddock, collected yield map data, acquired yield monitoring technology and acquired seeding machinery with variable rate technology. The results clearly show the surge in autosteer adoption over the past 5 years and the much lower but steady uptake of variable rate technology (Figure 1).

The use of varying fertiliser rates within paddocks on identified zones is consistently higher than the use of VRT seeding equipment. The results show that a substantial number of growers have been varying fertiliser rates on identified paddock zones in a ‘low-tech’ way without the use of variable rate seeding technology (Figure 1). Use of varying fertiliser rates is now increasing at about the same rate as uptake of seeders equipped with variable rate technology

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A high proportion of growers have yield monitoring equipment but only about half have collected yield map data (Figure 1). This difference does not appear to have narrowed over the past decade. The adoption of yield mapping is very closely associated with adoption of variable rate seeding technology (Figure 1) and varies greatly across regions (Figure 2). Autosteer adoption shows higher and more consistent uptake across regions with the rate of increase in adoption slowing in some regions as adoption rates approach 70-90% (Figure 3).

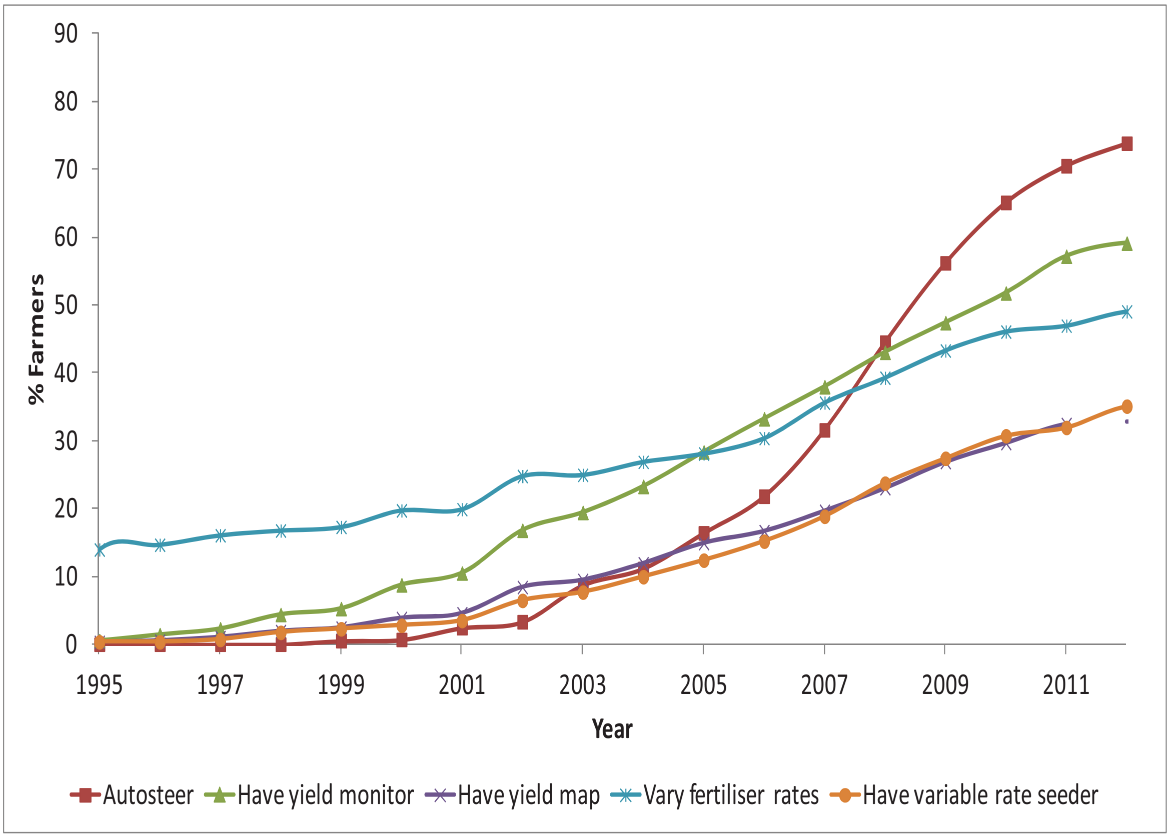

Figure 1. Cumulative adoption of autosteer, yield mapping and variable fertiliser application (i.e. application of different fertiliser rates within a paddock), also showing proportion of farmers with yield monitor and seeding machinery equipped with variable rate technology.

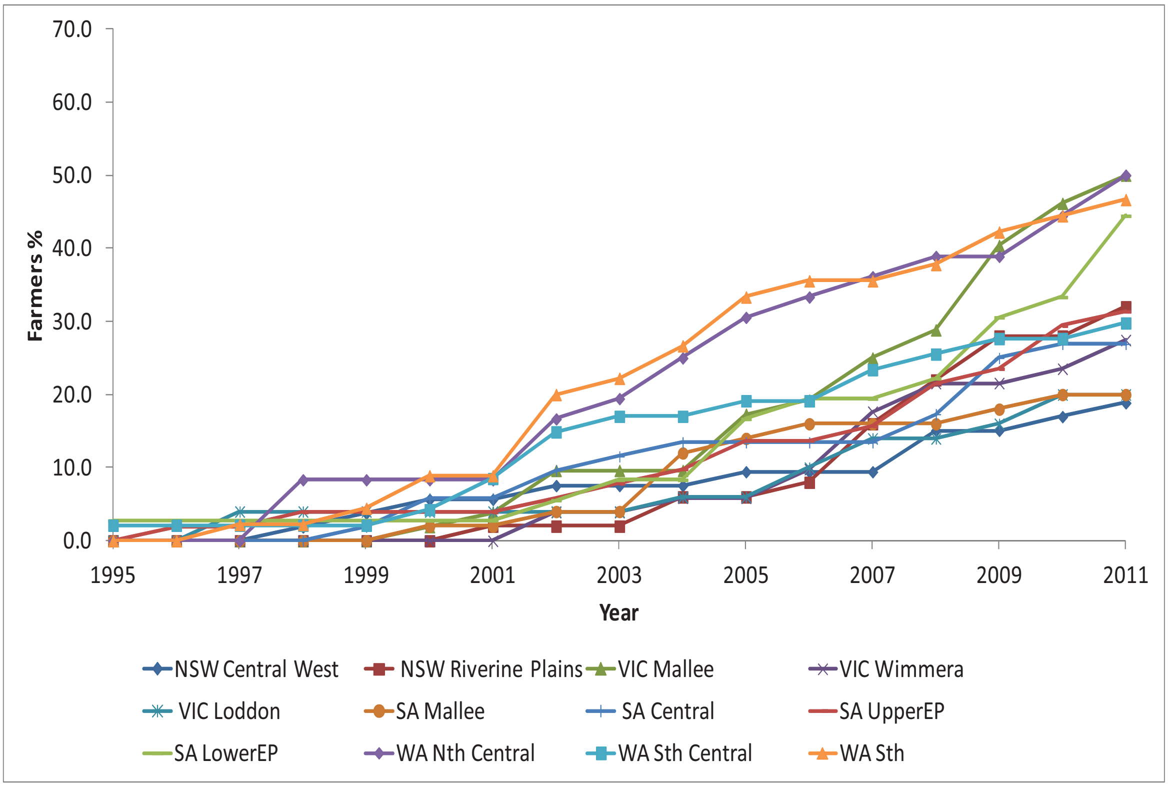

Figure 2. Cumulative adoption of yield mapping by region based on proportion of farmers who have collected crop yield map data.

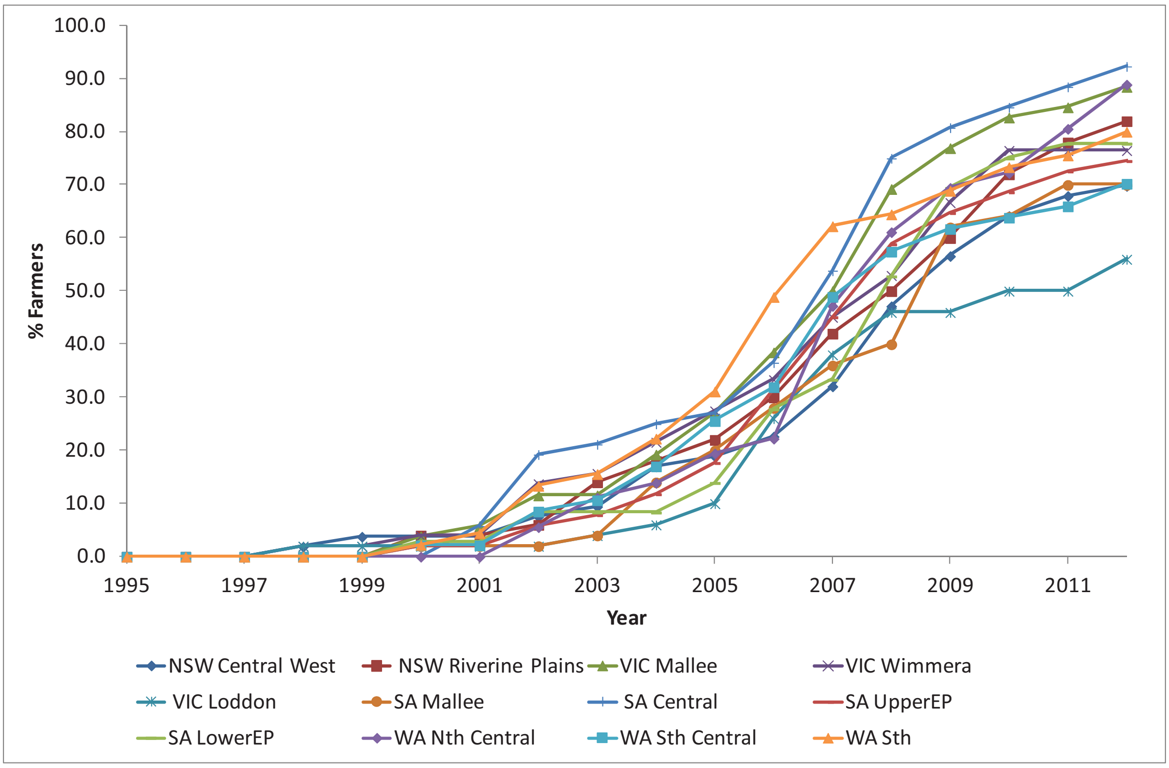

Figure 3. Cumulative adoption of autosteer by region based on proportion of farmers who have used autosteer.

Conclusion

The rate of increase in autosteer adoption appears to be slowing as peak adoption levels are approached. Steady increases in the adoption and use of VRT components have occurred and are expected to continue over the next five years but there are major differences between regions in both current uptake and future expectations. Yield mapping is also increasing steadily but the proportion of farmers with yield monitoring capacity but not collecting yield monitoring data does not appear to be reducing. The adoption and expectations for a range of other PA-related innovations such as soil and crop mapping technologies are also being analysed, together with major drivers and opportunities for more targeted strategies for supporting profitable use of PA-related technology.

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Mobile devices – the next step in PA adoption

Tywen Dawe

Farmanco, Unit 1/113 Dempster Road, Esperance, WA

Contact: tywen@farmanco.com.au

Introduction

In early 2012 following the swarm of interest from SEPWA 's tech head day 2012, there was a recognition by SEPWA and Department of Agriculture and Food WA (DAFWA) Esperance that the mobile device (i.e. the iPad and smart phone) offered significant opportunity to enhance and speed up the adoption of variable rate technology (VRT) in precision agriculture for Australian grain growers.

After initial meetings between SEPWA, DAFWA and GRDC on how to further this concept, it was decided that SEPWA would undertake a rapid assessment over 8 months (late 2012) to assess the status of farmers' paths to variable rate adoption and their mobile device usage habits. In this process a review of all farmers' use of apps was conducted while keeping a look out for apps which had specific mapping ability that would assist VRT adoption.

Results

It comes as no surprise this project has found high usage rates of smart phones and tablet devices amongst many in the WA grain growing industry. The age of technology has been widely embraced by society and farmers are no exception.

With this technology adoption comes opportunity to improve information management of farmers businesses. Survey information indicates that there is rapid adoption of apps by farmers, and GRDC can safely assume that information will be commonly managed in this format for as long as the mobile device continues its daily presence in people's lives.

During the review of apps, the project witnessed first-hand the rapidly changing nature of this technology. In the past 12 months the numbers of farming and mapping apps available have sky rocketed. Capabilities and functionality are also being continually improved via updates and pro version releases.

Throughout this project a list of 62 farming apps (as at November 2012) was collated. This can be found at the following link:
http://www.sepwa.org.au/index.php/2011-11-14-06-37-56/current-projects

This number is growing daily. Each app on the list is given a rating and comments on its pro's and con's.This is aimed as a guide only, make sure you read the description before you dismiss it as it may be exactly what you are looking for.

In regards to PA and specifically VRT this project has identified several mapping based apps (see the 'Mapping' category in the full list) that although are not perfect will enhance farmer's and agronomists adoption of VRT.

Of all the mapping apps reviewed, GIS Kit (upgrade – GIS Pro) seemed to be the best. This app allows you to create points, line and polygons, apply attributes and export as shape files. It also allows you to import files (shape, kml, kmz & GPX) from desktop software and edit these out in the field. It doesn't replace the desktop software i.e. AFS, PFS, SMS Basic, Apex etc. but it will provide valuable layers that assist in ground truthing prescription maps.

In regards to paddock data recording apps (see the 'Record Keeping' category in the full list) although there are a number of players in the market it appears that no one is offering a 'middle of the range price. That is, it goes from cheap and simple to expensive and complicated. When reviewing these types of apps ensure they have the following attributes;

- Ability to export data if you want to move programs
- Ability to import data, if you are moving over from another program or have bulk info (e.g. soil test data)
- Good support
- Ability to copy scenarios and/or plans to all paddocks, so you don't have to enter data individually for each paddock
- User friendly and readable reports that add value to your business and assist in planning
- Ability to sync data with a main computer and others (e.g. Agronomist)

Conclusions

The incorporation of mobile devices into the farming business is happening at a fast pace. Not only will this help create efficiencies within the admin and data recording side of things it will also offers great opportunity for grain growers to simplify the PA process.

Microspectrometers for soil and crop monitoring

Dilusha Silva

University of Western Australia

Contact: dilusha.silva@uwa.edu.au

Summary

Infrared spectroscopy is now a standard technology for process control in a large number of industries. By measuring infrared spectra from complex samples such as soil, grains, food processing mixtures etc., and comparing these spectra against appropriate spectral libraries, detailed compositional information can be obtained. Examples of the measurable quantities include, levels of protein, starch, oil and moisture content of grains, and total carbon and mineralisable nitrogen in soils.

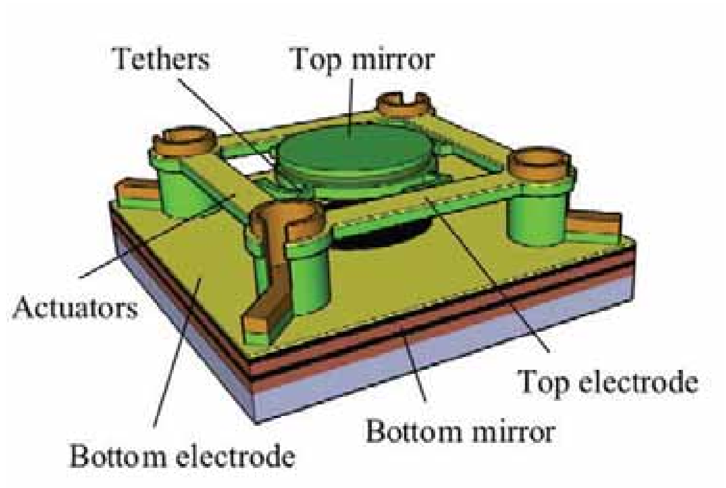
This measurement process is computationally expensive but high-power, low-cost computing platforms have made this process possible. The main limiting factors to widespread deployment of this technology are presently:

Cost of equipment – With low cost computational hardware available, the spectrometer is the greatest cost in a spectral analysis tool. Spectrometers are still expensive both because of the manufacturing costs, and because of the need for specialized personnel to perform the calibration of the system. Additionally, servicing costs are high because of the same requirement of re-calibration after any service.
Sensitivity to vibration, shocks, etc. – Generally available spectrometers tend to be bulky and fragile. In order to use these spectrometers in an industrial environment, they need to be ruggedised. Ruggedisation adds further to the bulk of the unit and also to its cost.

Calibration maintenance – The spectrometer needs at all times to maintain its calibration against the spectral library data needed to extract the information from the spectral data. Any drift in the wavelength puts the entire system out of calibration and, introduces error into the results.

Microelectromechanical systems (MEMS) based microspectrometers have the potential to address all of these issues. They can be low cost, are intrinsically mechanically rugged, and are potentially self-calibrating. The MEMS microspectrometer, developed at UWA, is depicted with its optical response in Figure 1. The microspectrometer, shown in Figure 1a, is based on a MEMS micromachined Fabry-Perot optical filter, integrated with a photodetector. The photodetector is not visible in Figure 1a, but is located directly below the bottom mirror of the filter. The optical filter consists of two mirrors separated by an air-gap, and an actuation mechanism to vary the size of the air-gap. This filter allows only a narrow band of optical wavelengths to pass through onto the photodetector.

(a)



(b)

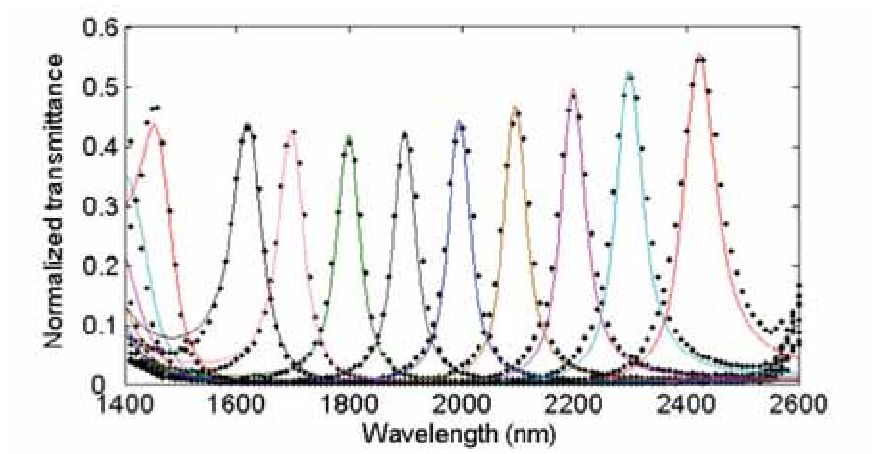


Figure 1. (a) Micromachined Fabry-Perot filter and (b) filter tuning response.

The structures being actuated on the microspectrometer are four beams, each suspended on either end by two posts. Metal electrodes are deposited on top of each beam and, on top of the bottom mirror below the beam. The actuation is achieved electrostatically, by application of a voltage between the two electrodes. The electrostatic force causes the beams to deflect towards the bottom mirror. Four thin tethers, attached to the four beams, suspend the top mirror. As the beams deflect downwards, they move the top mirror with them.

Figure 1b shows the typical spectral response of the microspectrometer at various applied voltages. The device here shows a wavelength-tuning range of roughly 900 nm, corresponding to 50% of the un-deflected mirror separation. Note, the spectral resolution of the microspectrometer is only of the order of 40 nm in this spectral range. This is a limitation of MEMS spectrometers when compared to benchtop laboratory spectrometers. However, for detection in complex organic samples, this resolution has been shown to be sufficient.

In this talk, I will be presenting some of the latest work on the microspectrometer, including the results of a new mirror designs aimed at significantly improving spectral resolution and range.

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Developing precision systems for potato crops in Australia

Frank Mulcahy

Simplot Australia Pty/Ltd.

Contact:frank.mulcahy@simplot.com

Introduction

Simplot Australia is home of many famous processed food brands including Edgell, Birdseye and John West. We are the last remaining processor of frozen vegetables in Australia with a factory located at Devonport, Tasmania. The main game for Simplot is processed potatoes where 250,000 tonnes of raw product is converted to French fry and associated products, at Ulverstone, Tasmania.

The farm gate value of potatoes in Tasmania exceeds $100M.

Tasmania has highly variable soils, from volcanic Ferrosols, duplex sand/clays to coastal sands. Often the transitions between soil types occur within short distances creating a Picasso of colour. This is intermixed with undulating topography (Figure 1). We have the positives of plenty of high quality irrigation water, progressive farmers, a cool forgiving climate and a clean production environment.

Figure 1. Variability in soil and landscape in Tasmania

Australia is a very high cost global location and there is considerable leverage on the Australian food market from cheaper imports. Approximately one quarter of processed potato consumed in Australia is imported and generic branded products from Europe can be found in Australian supermarkets at half the price of Australian equivalents.

Australian farmers are efficient, but our cost structure whilst relevant to Australian society is expensive when compared to overseas competitors. A fully irrigated high yielding potato crop costs between $13,500 and $15,000 per hectare to grow. The break even yield is around 42 tonnes per hectare, a yield that exceeds the average maximum of many of the origin countries supplying cheaper imports. There are anomalies in the potato industry just as there are for all Australian agri-industries competing against cheaper imports. The risks are high and sometimes the rewards are slim.

Our contracted potato growers have lifted their average yields to around 58 tonnes per hectare, but remember the first 42 tonnes are swallowed by costs and for an average of 58, it means there are growers who are on the fringe of 42. Potatoes are unsustainable for the marginal growers, so efficiencies must be found, methods must improve, mindsets must be altered.

For years Simplot has supported an R&D department working with growers to increase returns and drive down production costs. The new tools associated with precision farming are being evaluated on the back of research that reveals crop yield variances often exceeding 300%.

The road so far with precision systems

The EM38DD is being used to determine apparent soil electrical conductivity (ECa) variances (Figure 2a). Fortunately for us, conductivity is associated with things other than salinity, mostly soil texture, depth to clay and stone. It is imperative to utilise EM mapping to determine the real impact of soil textural change and create an understanding of accurately applied irrigation water on a micro scale combined with efficient drainage to avoid water logging.

Of the 1,000 or so centre pivot irrigators in Tasmania, thirty have fully variable application capability. The sale of VRI (variable rate irrigation) equipped pivots will increase dramatically as will retrofitting VRI to other irrigation systems. Tasmanian potatoes can require 6 megalitres of water per hectare and in dryer, hotter locations of Australia it is as much as 8 megalitres, but it needs to go in the correct places within the crop. VRI pivots can make up to 500 decisions in a single pass and the outcome in improved crop recovery is quite spectacular.

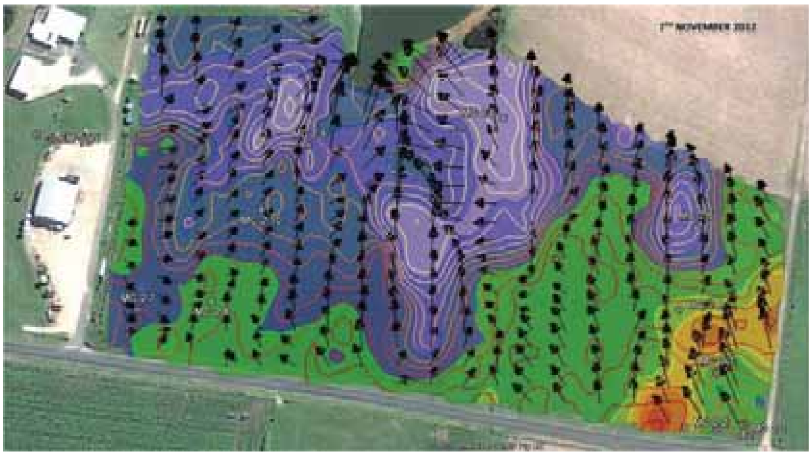
Aerial imaging using eNDVI by local technician, Neil Meadows of Terrapix® has the growers very interested as Neil has been able to provide a 24 hour turnaround from aircraft to a usable image to the grower (Figure 2b). A lot more work will be applied this coming season to refining the process and supporting the growers with image evaluation.

Yield mapping

Harvesters are being fitted with load sensing to identify variable production points (Figure 2c). The complete set of maps will lead the growers to better decision making, leading to better crop husbandry to achieve the next level of production.

Simplot is working closely with Brett Whelan of PA Lab, Sydney University on a two year Horticulture Australia funded project to evaluate the best way forward with precision systems in potato crops. These benefits will be extended to growers and will quickly flow to all horticultural crops being produced in Tasmania.

(a)



(b)

(c)

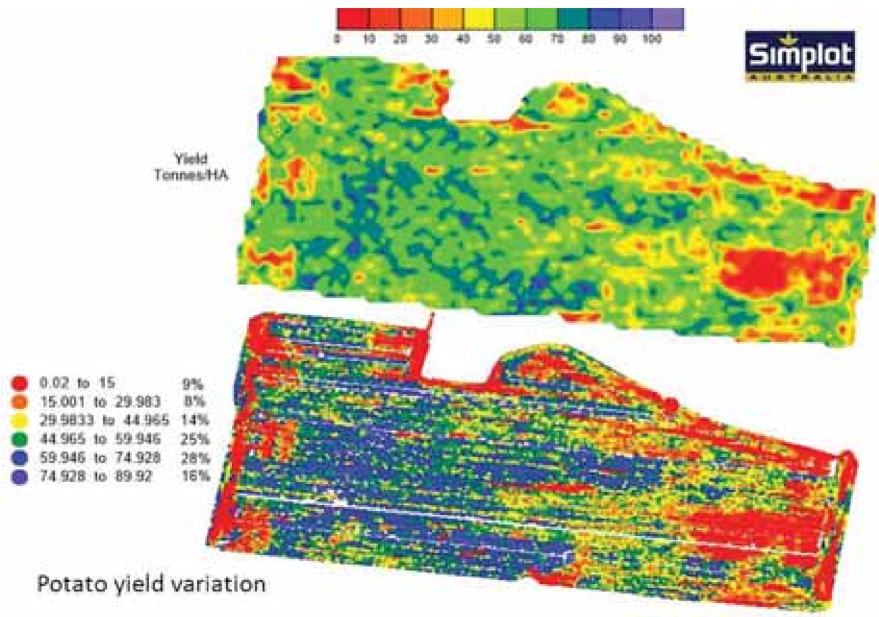


Figure 2. An example of (a) soil ECa measured by EM38; (b) potato crop vigour from aerial imagery overlain with the soil ECa contours; (c) potato yield as measured by a harvester-mounted yield monitor.

Assessing the economics of VRT fertiliser application

Luke Dawson

CSBP, Northam, WA.

Contact: luke.dawson@csbp.com.au

Key findings

The main messages to be taken from these trials over the last 2 years were:

- These trials have proved that varying fertiliser inputs over different zones of a paddock can provide economic benefits over using a "blanket" application approach. These trials have also highlighted the value of zone management using the tools available to us.
- In 2011 Nitrogen was the major limiting factor in each of the zones. The value of applied nitrogen was really highlighted when other limiting factors such as rainfall were taken out of the equation. In seasons like this nitrogen is a low risk decision.
- The omission of nitrogen from a large part of the paddock in 2012 provided a cost saving due to input reduction. Without VRT management, the whole paddock would have received nitrogen that was not required in some areas. Soil testing and NUlogic analysis improved targeting of nitrogen applications.
- By zoning up the paddock and testing each of the zones, our knowledge of the paddock has improved and this should help us make better decisions on nutrient management going forward.

Aim

To evaluate the economics of a variable rate approach to fertiliser applications over the 2011 growing season. This trial was also designed as a proof of concept trial for CSBP's Fertlogic Variable Rate Technology platform.

Background

Fertiliser is usually the highest cropping input cost, so it makes sense to target applications to increase fertiliser use efficiencies and return on investment.

Fertiliser requirements depend upon nutrient supply via the soil reserves, and demand which is determined by yield potential. Yield is ultimately dependent upon rainfall, but soil constraints such as soil acidity, compaction and sodicity need to be managed to maximize yield potential.

These trials have been conducted by CSBP for the last 2 years in conjunction with the Liebe Group in Dalwallinu. In 2011 and 2012 a paddock on the Liebe Group main trial site was assessed for variability using CSBP's Fertlogic. Using biomass imagery, the paddock was zoned up into 3 production zones- 'High', 'Medium' and 'Low'. The biomass imagery that we used was derived from multiple years of biomass for each paddock taken at or around peak biomass for each year. In each year the host farmer was consulted to check whether the biomass imagery was consistent with their knowledge of past paddock performance.

Discussions also led to realistic yield potentials being set for each of the zones. The paddocks were then soil sampled using the zone map created to ground truth each zone and to understand any nutritional factors that could explain the variation across the paddock. Soil testing and realistic yield targeting are two of the more important aspects of variable rate farming. Soil test results were run through CSBP's NULogic program to vary nutrient rates according to our yield targets. Each trial had 4 treatments: Nil fertiliser, Farmer practice (blanket application), NUlogic recommendation using the realistic yield potentials determined with the grower, and 'High' fertiliser inputs.

Results and Economic Analysis

2011 Results

Table 1. 2011 fertiliser trial results by management zone.

Low Zone										
		Banded	Z13/14	Z30			Yield	Protein	Hl Wt	Scrns.
Trt		(kg/ha)	(L/ha)	(L/ha)	N	P	(t/ha)	(%)	(kg/hl)	(%)
1	Nil	-	-	-	0	0	1.49	8.8	78	1.9
2	Blanket	70 Agstar	-	88 Flexi-N	47	10	2.88	8.5	79	1.6
3	NUlogic (1.5 t/ha)	50 Agstar	55 Flexi-N	-	28	7	2.52	8.9	78	1.5
4	High (3.5 t/ha)	110 Agstar	100 Flexi-N	80 Flexi-N	92	15	4.36	8.4	79	1.3
						Prob	<0.001	0.22	0.44	0.033
						Lsd	0.17	ns	ns	0.33
Medium Zone										
		Banded	Z13/14	Z30			Yield	Protein	Hl Wt	Scrns.
Trt		(kg/ha)	(L/ha)	(L/ha)	N	P	(t/ha)	(%)	(kg/hl)	(%)
1	Nil	-	-	-	0	0	1.96	9.4	79	1.9
2	Blanket	70 Agstar	-	88 Flex-N	47	10	3.36	9.0	78	1.9
3	NUlogic (2.0 t/ha)	65 Agstar	65 Flexi-N	-	37	9	3.10	8.2	78	1.7
4	High (3.5 t/ha)	110 Agstar	100 Flexi-N	80 Flexi-N	92	15	4.54	9.0	79	1.7
						Prob	<0.001	0.17	0.27	0.16
						Lsd	0.22	ns	ns	ns
High Zone										
		Banded	Z13/14	Z30			Yield	Protein	Hl Wt	Scrns.
Trt		(kg/ha)	(L/ha)	(L/ha)	N	P	(t/ha)	(%)	(kg/hl)	(%)
1	Nil	-	-	-	0	0	2.71	8.2	78	1.3
2	Blanket	70 Agstar	-	88 Flex-N	47	10	4.21	8.8	78	1.2
3	NUlogic (2.5 t/ha)	80 Agstar	55 Flexi-N	55 Flexi-N	79	11	4.99	8.1	79	1.4
4	High (3.5 t/ha)	110 Agstar	100 Flexi-N	80 Flexi-N	92	15	5.49	8.8	79	1.4
						Prob	<0.001	0.47	0.81	0.46
						Lsd	0.18	ns	ns	ns

2011 Economic analysis

Table 2. 2011 economic analysis of fertiliser trial results.

VRT	**Area ha**	**Yield t/ha**	**Yield t/Zone**	**Cost $/ha**	**Cost $/Zone**
Low	36	2.5	91	66	2,367
Med	34	3.1	107	82	2,820
High	36	5.0	182	146	5,339
Total	**107**		**380**	**98**	**10,526**
Total Paddock Return- Wheat @ $180/t	$68,365				
Blanket	**Area ha**	**Yield t/ha**	**Yield t/Zone**	**Cost $/ha**	**Cost $/Zone**
	107	**3.5**	**372**	**98**	**$10,519**
Total Paddock Return- Wheat @ $180/t	$67,025			Difference (Blanket-VRT)	-$6.57 **(A)**
(The average blanket yield of 3.5t/ha was calculated by averaging the yield from the blanket treatments across all 3 zones.)					
Difference (VRT - Blanket Return)	$1,340 **(B)**				
Comparison (Total Possible Return Difference + Cost Saving of Fertlogic(A+B))	$1,334				
Benefit- $/Ha.	**$12.46**				

Table 2 indicates the potential cost savings to be had from using Variable Rate Technology. Even though the total cost of nutrients using VRT was marginally higher ($7 over the paddock) than the ‘Blanket’ application, the variable rate approach grew another 8t of wheat. This equates to an economic benefit of about $1334 or $12.46/ha.

2012 Results

Table 3. 2011 fertiliser trial results by management zones.

	Low Zone							
		Banded	**Z13/14**	**Z30**				**Yield**
Trt	**Description**	**(kg/ha)**	**(L/ha)**	**(L/ha)**	**N**	**P**	**S**	**(t/ha)**
1	Nil	-	-	-	0	0	0	0.85
2	Blanket (1.8 t/ha)	85 Agstar Extra	50 Flexi-N	25 Flexi-N	44	12	8	1.27
3	NUlogic (1.6 t/ha)	70 Agstar Extra	-	-	10	10	7	1.19
4	High	140 Agstar Extra	100 Flexi-N	50 Flex-N	104	20	13	1.38
							Prob	<0.001
							LSD	0.114

	Medium Zone							
		Banded	**Z13/14**	**Z30**				**Yield**
Trt	**Description**	**(kg/ha)**	**(L/ha)**	**(L/ha)**	**N**	**P**	**S**	**(t/ha)**
1	Nil	-	-	-	0	0	0	1.28
2	Blanket (1.8 t/ha)	85 Agstar Extra	50 Flexi-N	25 Flexi-N	44	12	8	1.41
3	NUlogic (2.0 t/ha)	65 Agstar Extra	-	-	9	9	6	1.50
4	High	140 Agstar Extra	100 Flexi-N	50 Flexi-N	104	20	13	1.63
							Prob	0.12
							Lsd	ns

	High Zone							
		Banded	**Z13/14**	**Z30**				**Yield**
Trt	**Description**	**(kg/ha)**	**(L/ha)**	**(L/ha)**	**N**	**P**	**S**	**(t/ha)**
1	Nil	-	-	-	0	0	0	1.39
2	Blanket (1.8 t/ha)	85 Agstar Extra	50 Flexi-N	25 Flexi-N	44	12	8	1.71
3	NUlogic (2.5 t/ha)	120 Agstar Extra	50 Flexi-N	25 Flexi-N	48	18	12	1.81
4	High	140 Agstar Extra	100 Flexi-N	50 Flexi-N	83	20	13	1.90
							Prob	0.012
							Lsd	0.24

2012 Economic analysis

Table 4. 2012 economic analysis of fertiliser trial results.

Fertlogic VRT Zones	Area (ha)	Yield (t/ha)	Total (t/zone)	Total Cost ($/ha)	Total Cost ($/zone)
Low	24.6	1.19	29.27	46	1,137
Med	18.6	1.5	27.90	43	798
High	16.3	1.81	29.50	126	2,054
Total	**59.5**		**86.68**	**72**	**3,988**
Total Paddock Return-Wheat @ $300/t	**$26,003**				
Blanket	**Area (ha)**	**Yield (t/ha)**	**Total Yield (t)**	**Total Cost ($/ha)**	**Total Cost ($)**
	59.5	1.46	86.87	103	6,123
Total Paddock Return-Wheat @ $300/t	**$26,061**			**Difference (Blanket minus Fertlogic)**	**2,134 (A)**
Difference (Fertlogic minus blanket)	**-$57.90 (B)**				
Comparison (Total Possible Return Diff + Cost Saving of Fertlogic (A+B)	**$2,076**				
Benefit/Ha	**$35**				

Table 4 indicates the potential cost savings to be had from using Variable Rate Technology. Even though the total production off the paddock was the same the benefits from using variable rate technology as compared to a blanket approach are due to top up nitrogen not been used in the medium and low zones. Top up nitrogen was left off these zones due to the high levels of nitrogen present in the soil at soil testing time. Without using a variable input approach to the paddock these zones would have received nitrogen that was not required.

Open-data repositories, expert exchange platforms and standardization as tools to enhance adoption of Precision Agriculture

Armin Werner

Lincoln Agritech Ltd., Lincoln, New Zealand

Contact: armin.werner@lincolnagritech.co.nz

Abstract

The dispersion of precision agriculture technologies (PA) is happening globally on different pace. Evidence of a broad 'General PA' technology is easy to be found in many places as it implies all aspects of using sensors, positioning systems with GNSS, digitally controlling equipment as well as information and communication technologies in agriculture. Whereas the 'Strong-PA' that applies farming input variable in space over a paddock or field (VRA) is being only used in few regions.

Establishing of PA-technologies in a region needs to take into account agronomic and institutional constraints: the special growth conditions, the training and extension systems, as well as the dominating farm management types. Recognition that patterns of information usage change from farm to farm let alone region to region is necessary when introducing and adopting new technologies.

PA is unique in linking different disciplines, techniques or functional knowledge and to allow the realization of reasonable compromises in divergent goal setting. Such integrative capacity can only be developed regionally because involving of stakeholders is a precondition. This requires appropriate mechanisms to spread PA-experiences of farmers and specialized systems to provide user specific information when adopting or applying PA on a farm or in a region.

Innovative approaches in information management as well as new tools are discussed in this paper that could be of help for promoting and adopting PA.

Introduction

Precision Agriculture has its specific quality in using, providing and exchanging data and/or information. Thereby not only the typical data ('key figures') in agricultural production are being utilized. Also very new types of data emerge from that information is being made available and being implemented into the production processes. All these data have to be collected, stored, exchanged, processed, evaluated and the extracted information has to be used for decision making. Because this manifold of new data it needs tools and methods of information and communication technologies (ICT) to access, to store, to transfer, to utilized in software and to communicate the data or information with (different) user (e.g. for decision support). Thus PA is intrinsically linked with ICT and the corresponding technologies (Gelb and Offer, 2005) but not exclusively. As PA is seen fundamentally information based, non-electronic versions of PA are feasible and are developed, mainly for developing countries (eg. Mandell et al., 2012).

Technically speaking, PA is 'digital agriculture' (Werner et al., 2013) and thus part of 'electronic agriculture' (Lamb, 2012). This broad view of PA comprises in arable farming and grassland management a set of techniques that use information from many, mainly new sources that could be combined with existing data and that use agronomic rules to manage the fields or paddocks. The new 'precise' quality of PA is a result of consistent use of information to derive decisions and to conduct actions in a more controlled way than possible even with the 'best management practices'.

Substantial adoptions of PA are found mainly in areas with high productivity in crop production (e.g. France, Germany, United Kingdom), regions with a high proportion in contracted fertilization, including soil sampling (e.g. USA) or regions where PA-based resource protection is effective (e.g. Controlled Traffic Systems for soil water conservation in Australia).

For achieving higher PA-adoption rates it is necessary to accept this diversity in PA-approaches and provide mainly ICT-based solutions to introduce and support PA in regions with low adaptation.

Information and Communication Technologies and PA

Emerging trends in PA

Three trends link PA with ICT and are enhancing PA-dissemination and adoption:
To a growing extent global fertilizer retailer as well as lately some seed companies are providing typical PA-services and technical PA-solutions, utilizing mainly internet based approaches: preparing VRA-maps for applications of their fertilizer and seeds.
New technologies in GNNS allow to replace expensive RTK systems with cheaper, just satellite based solutions providing high mobile accuracy of below 10cm (e.g. Schrock, 2012).

Applications on SmartPhones (small software programs: Apps) will enhance the usability of digital information and provide new tools in agronomic production actions for the farmers (see e.g. Delgado et al., 2013). These new PA-tools allow easy access and easy combination of information in the production process, linking also information from farm databases to equipment and vice versa (anonymous, 2013, e.g.[1]).
The focus in research and development (R&D) for PA moved in the last years mostly from a soil perspective or research based on single sensors to integrated, interdisciplinary studies, often with stakeholder involvement (Gebbers and Adamchuk, 2010, Bullock et al., 2007, Oliver et al., 2010).

All these changing frame conditions support PA-usage indirectly. The applied tools and systems in these trends will favor open repositories and open data exchange and thus PA-dissemination. All this adds to the continuous transformation of making farming digital.

Knowledge Repositories and IT-Infrastructure for PA

A major prerequisite for quick checking and adoption of PA-technologies will be the availability of modern, digital communication systems (Poddar, 2006). The capabilities of the world-wide-web (WWW, in the 'internet') provide vast options to search and store

[1] http://www.croplife.com/article/32159/13-new-mobile-agriculture-apps-for-2013
http://ppt.4istudent.com/Ppt-Presentation/applications-agricoles-pour-smartphone/

information for innovations in agriculture. The WWW is also an important medium to enable flow of knowledge from experienced farmers and consultants to interested PA-beginners. Soon 'Apps' will play an important role to serve as knowledge sharing tools for farmer and consultants (Dvorak et al. 2012). As neither experienced farmers nor consultants for PA are available in a PA-new region, these options for knowledge collection have to be initiated and set up by the industry purposefully.

As websites for sharing such information are sometime limited to a closed user group this resource is also limited in their capacity to enable new farmers interested in PA. Valuable systems to store and provide knowledge and empirical information in a free accessible way are Open Data Repositories (e.g. Murakami et al., 2007). These are available already for many geo-information (e.g. weather data, some soil data ...). To use this approach for a new way of sharing evidence (data) in the application of PA and experience between farmers is not yet exploited. In order to allow cross-regional use and analysis of the valuable information in such repositories a standardisation of their data-description should be ensured (e.g. Subirats et al., 2008).

In the traditional approach farmers often take the experience that a technology is accepted through other farmers and make their own decisions to innovate a technological step. Open PA-Data repositories should be enhanced by platforms that allow communicating between farmers in order to get actual problems solved or pressing questions answered. In other industries there are some examples of such well established platforms[2]. For farming only very few examples exist and are either run by public institutions like university extension services[3] or are commercially operated[4].

Recommendations for Adaptation of PA

Involve Stakeholders

Innovations for rural areas are predominantly successful when involving the stakeholders (farmers, consultants, manufacturers, administration) in defining the problem, in designing the path to solutions and in collaboratively maintaining the necessary communication and cooperation schemes within the farming community. For this participatory process the 'roadmapping' approach may be a good start to identify the interests in PA in the region and design the path for introducing a specific PA-technology. (Schwerdtner, 2011). In regions with only few participants a direct nomination of the participants is possible. For addressing larger groups some public financed or levy paid bodies could be supportive in representing the interest of farmers in the group of stakeholders.

Providing Evidence of Benefits

Especially farmers expect empirical proof that PA technologies can provide economic benefit before they decide on this innovation. Such results are reported by science as well as by farming (e.g. Mayfield et al., 2008), but they may not be convincing enough for stakeholders in other regions. Reasons could be that the benefits are too low or the results may not be directly transferrable. In such cases only analogical reasoning or own experiments can overcome this dilemma. This would be subject to convincement

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[2] e.g.: http://en.allexperts.com/; http://www.justanswer.com; http://www.wer-weiss-was.de/
[3] e.g.: http://extension.oregonstate.edu/extension-ask-an-expert; https://agnr.umd.edu/ask
[4] e.g.: http://www.thecombineforum.com; http://www.expertanswers.co.uk/

and commitment of the participating stakeholders and thus results of confidence in the agronomic plausibility of PA-concepts and in PA-technologies. Base for that is adequate teaching and training of farmers in integrated crop production.

Sharing Knowledge and Experiences

Regional experience of farmers and researchers pioneering PA-use is a very important source for adopting PA. Researchers know in most cases the existence of such activities in their region, but it is not always easy for other farmers to get to know where such an ongoing innovation happens. Also experience and knowledge of the first PA-farmers should be shared. User groups as well as internet based forums and professional social media are effective tools to enable a broad and open exchange of knowledge. In addition thematic portals or knowledge collections (Berges et al., 2012) allow storing and easy accessing knowledge and thus supporting stakeholders' interaction and learning. A rarely utilized approach for exchanging experience in PA is the use of information exchange portals that work with the knowledge of the participants to answer specific questions. Such expert gates would bring up answers from experienced PA-users to problems that other farmers have.

Open Data

Farmers often use the acceptance of a technology through other farmers to make better, informed decision. In the adaption of precision farming through farmers a major role plays the communication and the co-operation between farmers (Kutter et al. 2009). This pattern can be superimposed by the level of education of the farmers and the introduction to that PA-technologies in their vocal or academic training (Reichardt et al. 2009). Thus presumably an important instrument to support adoption of PA is the system of Open Data Platforms (Stellato, 2012), as they are encouraging stakeholders to provide their own data to make them available for the community of those being interested in applying PA. In the platform they can store data from on-farm-research experiments as well as those from research projects. In addition farmers and consultants can store data of calibration exercises and tool-specific information to share them with other farmers.

Education and Teaching

Especially researchers assume that an important lack in adoption of PA is the awareness of the technologies as well as the understanding of the possibilities and the limits to overcome. This needs appropriate teaching of integrated crop production agronomy as well as an outlook to landscape ecology. Besides the general agronomic introduction capacities for specific training in the different techniques, tools and products of PA have to be offered in a region in order to be able to adopt PA. Some of these educational and training schemes can be provided by private organizations (consultants, retailers, manufacturers) other need to be implemented in the general agricultural curricula (Reichardt and Jürgens. 2009).

ICT-Infrastructure

A region has no chance to elaborate the potentials of PA or adopt PA, if the ICT-infrastructure, especially broadband connection for the internet is not adequate (Lamb, 2012). In addition, with 'smartphones' very high numbers of farmers can easily be reached for transfer of knowledge (Swamy, 2006). Providing sufficient bandwidth is not easy in some remote rural areas (Kauffmann and Kumar, 2008). Yet farmers are also tax-payers and they should make their point in publically requesting this prerequisite for modern farming, not only for using PA.

Research and Development

Any regional adoption of PA-tools and PA-technologies should try to make best use of the systems to be 'imported' with the treasure trove of experience from other localities. But then it will always be important to identify also demands and options that can be solved only with very regional specific, own solutions. To encourage this, the stakeholders should be informed on the availability of suitable R&D capacities.

Small groups of farmers

As smaller groups of farmers are not easy to be informed with typical extension products as brochures, conferences and internet websites it is helpful to access their interest through regular consultations (such as workshops, newsletters, special material in extension ...) (Franke-Dvorak et al., 2010).

Summary and Conclusions

We expect that VRA-PA-adoption will happen most probable in areas with high endogenous as well as exogenous pressure on transition in farming due to farm reorganization, environmental constraints, traceability requirements or just changing generations in the management. On the other side, the introduction of 'General PA' will happen most likely anyhow.

Adopting PA requires overcoming (i) agronomic and (ii) institutional barriers. Regional adoption of PA therefore needs to empower the stakeholders and the organizations of the industry in their capability and their willingness to discuss, evaluate and adopt the different tools, components and systems of PA. This involves not only training on PA-specific technologies, but primarily in an integrated understanding of crop production. To ensure success of VRA-PA a good agronomic training is necessary in analysing and handling interactions between growth factors, natural resources and the outcomes of the plant production systems.

An important step in these adoption processes is seen in using new instruments to exchange knowledge and experiences of stakeholders through the internet (Werner and Yule, 2013). *Open Data repositories* and as well as platforms with *farmers as experts* are promising instruments as they give answers or advises from farmers to other farmers.

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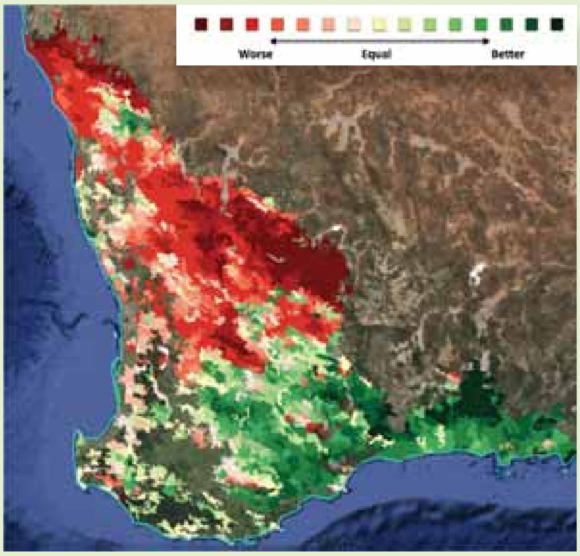
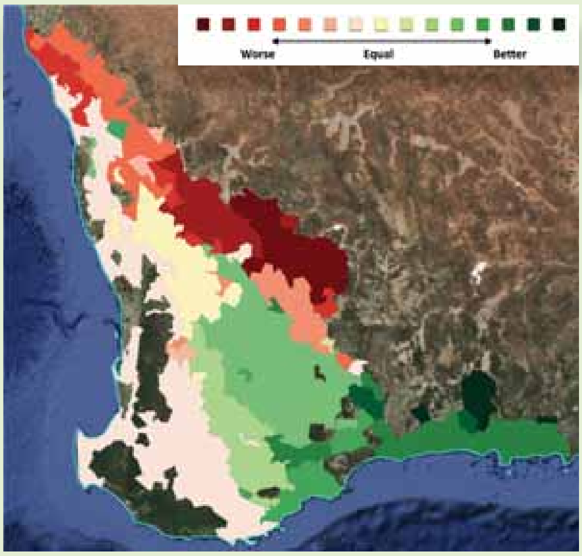
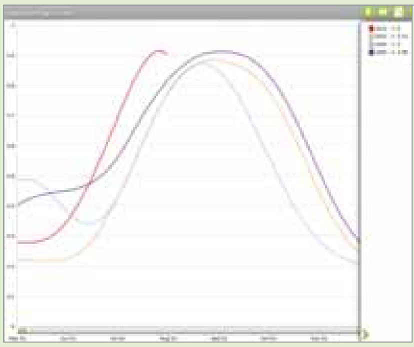
Crops Falling Below Average Due To Lack of Rainfall



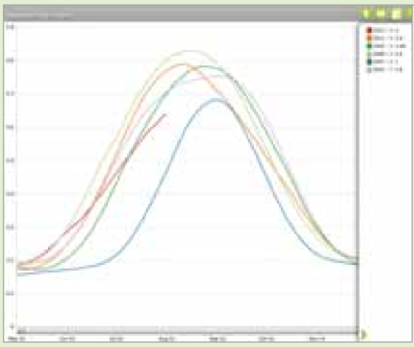
2013 NDVI



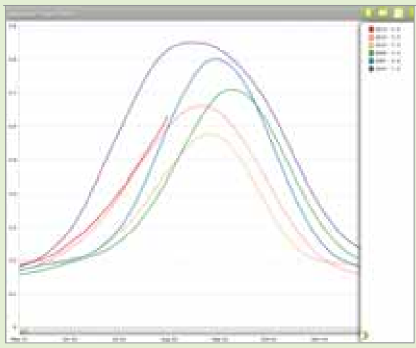
Average NDVI



South WA - This paddock is located just South of Borden and the crop of Winter Wheat is growing well. It jumped up at the start of the season. Crop progress is ahead of all years except last year. The next few weeks will determine if average or above average yields will be achieved and it all rides on the rain.



Central WA - Located just west of Bolgart, a Winter Wheat paddock looks like it will fare below average given the current trend. This graph shows the crop starting strong, but a recent challenge with moisture likely pulled the trend line down. Average results are indicated on the maps above for the region, but this paddock is faring worse than average.



North WA - Just west of Tenindewa, a Winter Wheat crop struggles to best the 2009 crop. This region's moisture deficit has capped the potential for yield but it won't be the worst year on record. Crop progress is tracking on a regular curve pattern, so planting must have occurred similar to the other reference years.

Contact Jim Castles your GEOSYS representative at jim.castles@geosys.com or call 0427 428 700.

After a promising start in most of the west, fewer rains have resulted in stressed crops and dwindling soil moisture. Satellite NDVI imagery shows the crop progress in Western Australia is generally falling behind the norm, with few exceptions of above average crops as can be seen in the green areas on the maps.

NDVI is the Normalized Difference Vegetation Index. This measurement indicates the photosynthetic capacity and the biomass production of the paddock, and directly related to the health of a crop. NDVI values range from 0 to 1, with 0 being a low/poor value and 1 being a high/good value. We would expect a fallowed paddock to have an NDVI value close to 0 while a thriving crop at peak biomass/maturity will have an NDVI value closer to 1.

This NDVI data at the paddock level is reflected in the charts to the left. Each paddock tracked is compared to previous years progress at a similar time. In this way, a farmer can see how his crop is progressing in each paddock.

This information is provided by GEOSYS. We are working to bring the decision-making tools you need for your farm. The GEOSYS Crop Health Monitor™ watches your paddock as they grow and lets you track progress compared to years past. New CROPtical™ is a GEOSYS app available on iTunes™ which provides a mobile access to track your paddocks progress on a daily basis. Learn more at www.croptical.com.

GEOSYS

Precision plant protection –state of the art and future prospects

Hermann Leithold

Agri Con GmbH, Crop Protection Division, Im Wiesengrund 4, 04749 Jahna

Contact: Hermann.leithold@agricon.de

Key findings

- Precision Plant Protection will be one of the driving factors in precision farming the next years.
- Cost awareness and legal requirement force farmers to optimize and back up for every application.
- Online sensors in combination with agronomic knowledge and a seamless infrastructure can be a important component to cope with it.
- Compatibility, usability and proofed agronomic knowledge are the main points for the success of precision plant protection.

Introduction

Agri Con is a German company specialized in precision farming solutions since 16 years. As one of the few manufacture independent companies it is market leader in Germany with partners all over Europe.

Starting with soil sampling and GPS technologies the product portfolio soon broadened to cover all needs coming from our customers. From the beginning Agri Con is one of the main distributors of the YARA N-Sensor and became one of the biggest worldwide. After the success of variable rate fertilization it soon became apparent that there is at least the same potential in variable rate plant protection. Together with partners new agronomic algorithms were developed for example for growth regulator application, haulm killing and many more.

Results

Precision plant protection is going to be one of the driving factors of precision farming for the next years. Increasing cost pressure, resistance problems and legal requirements are setting high demands on plant protection for future. Variable rate application will be an important component to cope with these challenges.

Agri Con developed together with its partners a sensor family dedicated to crop protection. It includes different types of sensors all seamlessly working on the same terminal platform, using the same harness and working with specialized modules for all relevant applications. The spray boom mounted sensors like the RX, US and the H-Sensor working with the same foldable arm that ensures that the spray gets exactly to the place seen by the sensor. The quick fix mounting brackets makes it easy to switch from one sensor type to the other.

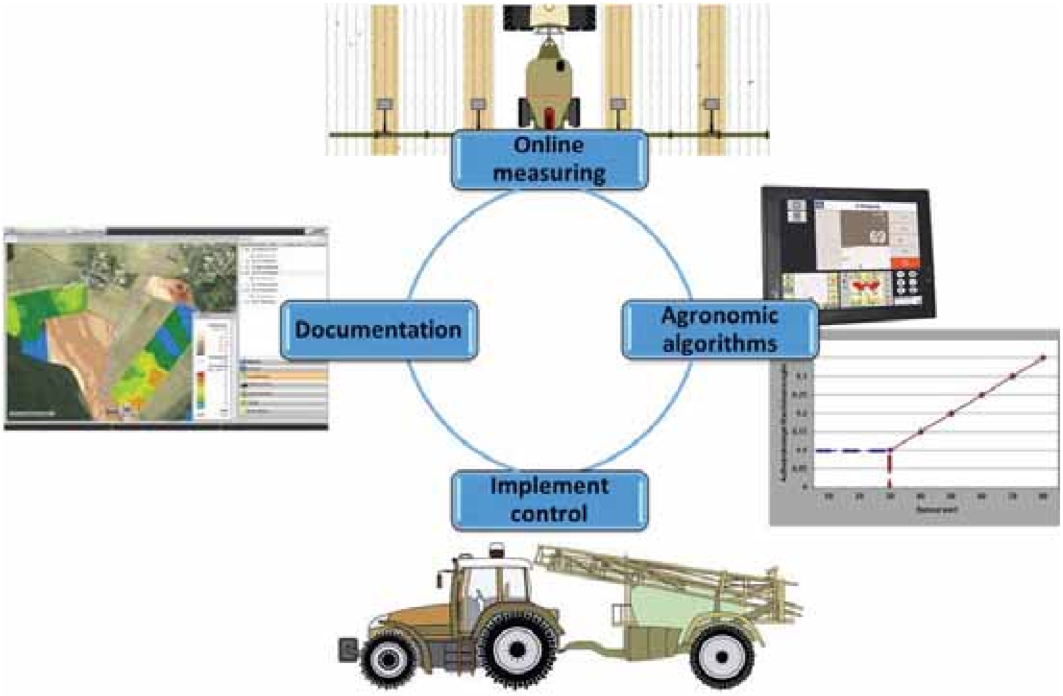


Figure 1. Work flow for precision plant protection application.

P3-Sensor ALS

Featured by YARA technology the P3-Sensor ALS is a reflection sensor with the biggest screened area on the market. Its selected wave lengths are chosen to give best information about nitrogen uptake and vitality of all crops. The sensor consists of two sensor heads mounted on the sprayer body. Its powerful optics allows long distance measurement. In combination with the angular view the P3-ALS has a very large field of view and secures representative measurements.

P3-Sensor RX

Like the ALS the P3-RX plant sensor uses reflections of special wavelengths to gather information about plant vitality and n-uptake of all crops. Due to its low weight and small size it enables to be mounted on a spray boom. Depending on the size of a boom up to 12 sensors can be installed and independent boom section controlling leads to a new level of accuracy in application.

P3-Sensor US

The starter plant sensor is the P3-Sensor US. Developed to allow a cheap and easy start in precision farming applications it is suitable for applications in cereals from the end of tillering. The technology behind is ultrasonic. A patented algorithm provides information about plant height and biomass in real-time. The measurement is independent of daylight and therefore able to work all around the clock.

H-Sensor

The H-Sensor is the first weed sensor on the market which is able to distinguish crops, grass weeds, herbs and special weeds as needed. Its camera frontend generates pictures of the field, separates single plants and analyses them. The algorithm behind the H-sensor allows us to adapt it to all kinds of scenarios and weeds. Four or more H-sensors can be mounted on a spray boom. If the system detects weed patches it automatically switches on or off the related sections. It helps farmers to cut down their herbicide costs by securing high efficacy of the application. Reductions in grass weed control can be up to 90 % and in herbs up to 60 % in Europe.

Table 1. Agronomic modules in combination with online sensors.

	Basic	Growth regulator	Fungicides	Haulm killing	Herbicides	N-fertilization
P3-Sensor ALS	●	●	●	●		●
P3-Sensor RX	●	●	●	●		●
P3-Sensor US	●	●	●			
H-Sensor	●				●	

Implement control

It is typical for European farms to have a machine park with many different brands. Controlling the implement is necessary for the success of a variable rate application. The Agronomic terminal combines control of all Isobus implements as well as agronomic knowledge and algorithms in on display. As the central software platform the PF-Box contains all agronomic modules sensor based (N-application, growth regulator etc.) and with a mapping approach (basic fertilization, seeding etc.). The PF-Box XL makes it a full grown Isobus task controller.

Agriport

Managing data is one of the major challenges in precision farming. Sensors, soil mapping, yield monitors or applications generate a huge amount of data. Agricon is geared towards storing them properly for documentation purposes and more important to generate additional value out of it. The cloud based portal Agriport helps farmers to store, display and get the most out of their data. An automated import feature allows uploading all kinds of data. Only few steps are necessary to generate for example recommendation maps. In combination with the PF-Box as the data exchange works automatically in the background.

Agridoc

Knowing where your machines are running, what they are doing and record all the work is the designated target of the web based service Agridoc. Independent from different manufactures data logger in your machines are sending continuously time, position, working state and many more information to the portal, sorted and processed it supplies different analysis to examine efficiency of machine working time and logistics. In combination with stored field boundaries all works are related to a field. The result is an automatically filled field diary.

More information can be found at www.agricon.de

The paddock guide to PA trials

Nigel Metz

South East Premium Wheat Growers Association (SEPWA),
DAFWA office, Melijinup Rd, Esperance WA

Contact: nigel@sepwa.org.au

Key findings

Precision agriculture tools offer significant opportunity for on farm experimentation. Care however needs to be taken in the design lay out and data collection from PA style experiments to ensure that results are credible and real.

Introduction

A simple well designed trial can help you determine the best step forward in solving an agronomy problem in your farming system. Correctly used, PA farming tools such as guidance, variable rate and yield mapping can greatly assist the implementing of on farm trails.

'The paddock guide to PA trials' was the result of the work from a DAFWA - GRDC funded research project 'The Agronomy Jigsaw'. The pamphlet is a basic guide for farmers and consultants wanting to set up on-farm trials using precision agriculture (PA) equipment. It contains condensed information on the design, implementation, harvesting and analysis of PA style trials.

This guide captures the Agronomy Jigsaw project's findings from implemented farm PA trials on the south coast region of Western Australia. The Agronomy Jigsaw would like to acknowledge the work of Precision Agronomics Australia (PAA), who implemented a number of these trials, as well as the previous research done in this area by CSIRO.

View: http://youtu.be/uSXSJG3agyw

Results

The aim of a trial is to assess the effect on crop yield of a particular treatment. In terms of PA we want to find out if the treatment affected crop yield? And did this effect on crop yield vary between different soil zones in your paddock?

Trial design

There are some key rules in trial design:

Keep it simple! Fewer treatments are generally better. From an analysis approach one or two treatments present a relatively simple analysis in which yield differences can be easily detected. A simple trial design prevents the trial becoming too big and more prone to the results being affected by paddock variation.

Build in control strips (a constant or nil treatment) – this is a must for comparing variation across the trial.

Repeat or replicate the trial By conducting the trial treatments twice or more within the trial or simply repeating the trial in another part of the paddock, you can have greater confidence in your results.

Make your treatments very different so that the effect on crop yield should be easily detected. For example double or nothing treatments against the standard paddock rate. Trial strips need to be wide enough for at least two (ideally three) header runs for yield data collection. By ensuring 3 harvester widths for each treatment, there will always be at least two harvester run lines which fall completely within a treatment strip.

Locating your trial – site selection:

Pick an even, representative site Some historic yield maps or other PA data can greatly assist in the locating of your trial to ensure each treatment applied is represented in each of your targeted soil zones.

Avoid areas which may affect yield results for example fence lines, trees, headlands or other obstacles.

View: http://youtu.be/buZ1wkAdADs

Trial layout

The Agronomy Jigsaw Project encountered various trial designs in its study of PA-style trials.
Classic strip trial - with control strips The classic strip trial is designed to run the length of a paddock and if possible pass over two or more soil zones. Ideally at least 2 treatment strips should be designated as control treatments.

Classic strip trial – harvesting across the treatment strips A variation of the standard strip trial is harvesting across the treatment strips. In this scenario treatment strips will need to be made wider to allow for a buffer between treatments in yield data points, yet there still needs to be sufficient data points falling within a treatment area.

The trial window design The trial window design is the placement of several treatment windows (or blocks) in designated parts of the paddock to measure the treatment effect compared to the surrounding area. Treatment blocks should be around 100m long at the standard 3 header widths wide to make them sufficient size so that yield data can be extracted for comparisons. This is ideal for costly or slow to implement treatments and enables flexible placement of the treatment windows so that it falls within a particular soil zone.

View: http://youtu.be/8YWRAxcbG6o

Soil zones in a paddock and the trial layout

Soil or production zones can be defined by any PA data source which clearly defines two or more parts of a paddock as being agronomically different. The critical criteria is that the soil zones identified are sufficiently different in their agronomic characteristics and hence will more than likely also vary in response to your trial treatments.

The use of PA technology enables us to assess the variation in response of crop yield between soil zones and trial treatments. For this to be possible it is vital your trial passes over each soil zone in the paddock (or is repeated in multiple locations) to enable measurement of any treatment x zone effects on crop yield.

Marking out your trial with a GPS

If your trial is not part of a prescription map, you will need to record its location with a GPS device for overlay on the yield map data. You can use a hand held GPS or mobile device such as smart phone or tablet to capture the GPS coordinates and record your trial's location.

You need to check your map datum and the units of your device. The most universal map datum is WGS84 (World Geodetic System 1984), which works all locations on the planet. In Australia you can also use GDA 1994 which is within 1m of this.
We recommend you set your map datum units in decimal degrees with at least five (ideally six) decimal places. Most PA equipment works in decimal degrees and this eliminates the need for conversions.

View: http://youtu.be/GYf8yzCyJzg

Harvesting your trial

To use the yield data from your harvester to record the results of your trial, there are some simple tips to consider:

- Use a single header to harvest a trial.
- Harvest the entire trial in the same direction,
- Keep the harvester moving at a constant speed.

View: http://youtu.be/Ubf2yz22Yp0

Guidelines for Yield data extraction and trial analysis

Once you have harvested the paddock and read your yield data into your PA software you can analyse the yield results.

The Agronomy Jigsaw project has found that working with raw harvest data (dot points) enables you to avoid selecting data which may have been affected by overlap, stoppages, harvest directions or turnarounds. Interpolated yield data displayed as a continuous contoured map tends to smooth over possible errors in data and could affect a trial result.

It is advised that you top and tail yield data on reading it into your PA software. This removes yield data outside the realistic biological limits of the crop. For example, filtering and removing data < 0.3 t/ha and > 7 t/ha for a cereal crop across the whole paddock before commencing analysis.

The basic steps in your PA software for extracting yield data for analysis are:

- Define the trial layout and treatments from the prescription map or GPS marker points.
- Overlay your yield data in point form.

- Define yield data run lines which fall clearly within treatment areas (and zones if present).
- Identify your different soil zones (if present).
- Extract yield data points from within the treatment x zones areas, average and summarise these in a table for graphing.

Yield data points to avoid
Some yield data points could be affected by harvesting irregularities, avoid data points that are:

- Within 30 m of a turnaround/headland.
- Within 10 m of passing over a treatment boundary.
- Too close together or more widely spaced (indicates speed irregularities).
- Near obstacles or affected by harvester overlap.

More in-depth and accurate analysis is possible under guidance from a biometrician.

View: http://youtu.be/extGjA3Kc9M
http://youtu.be/ZxnHz5ntCc0
http://youtu.be/h4DBN_8DdHE

Conclusions

The presence of PA technology offers significant opportunity for farmers to measure true effects of crop agronomy treatments in their farming systems. Care does however need to be taken to ensure that trials are set up correctly and analysed with some degrees of caution to ensure "real" results are observed. This work by the Agronomy Jigsaw project should be viewed as preliminary and more than likely refinements to methodology and approaches will be made as a whole industry as we improve our use of PA technology.

Precision Viticulture – how vignerons are using spatial information to improve their business

Tony Proffitt

AHA Viticulture / Precision Viticulture Australia, PO Box 215, Dunsborough, WA 6281

Contact: tony@ahaviticulture.com.au

Key findings

- Wine grapes are a 'high value' crop with the focus on producing *consistent yield and quality* rather than on maximising yield.
- A recent industry survey indicates that 66% of respondents believe that precision viticulture technologies are already delivering, or will deliver, a benefit to their business.
- Use of high resolution spatial data has generally focused on 'output'. Selective harvesting has been shown to be highly profitable whether used in small or large production wineries.
- Vineyard variability is not always considered as something to remove – it is often regarded as a 'positive feature' to produce grapes that suit certain wine styles.
- Due to low crop prices and high production costs, there is an increasing use of spatial information to differentially manage 'inputs' (irrigation water, fertilizers, canopy management, soil amendments, sprays and labour) to achieve commercial economic benefits.
- Other vineyard uses of high resolution spatial information include sampling and monitoring practices, vineyard design and re-design, and field experimentation.

Introduction

Following the introduction of Precision Viticulture (PV) technologies to the Australian wine industry in the late 1990's, and the associated research during the intervening years, an increasing number of vignerons are recognising the value of understanding the inherent variability in the performance of their vineyards in order to achieve commercial economic benefits. This paper gives a brief overview of how PV is perceived by the industry and how high resolution spatial information is being used in vineyards and the benefits that are being derived.

Technology adoption

A 2013 survey of grape and wine industry attitudes to Precision Viticulture (PV) and its adoption indicate that, across a broad spectrum of industry involvement (grapegrowers, winemakers, consultants, contractors and industry association representatives) and business sizes, 66% of respondents believe that PV is already delivering, or will deliver, a benefit to their business. Furthermore, 74% of respondents expect to be using at least one element of PV in the next three years (Bramley, in press). The responses to the survey also indicate that the two major limitations to further adoption of PV are implementation costs and the lack of technical advice/support and easy-to-use tools and software (Bramley, in press).

Application of spatial information in the vineyard

Selective harvesting

Selective harvesting to improve the uniformity of fruit delivered to wineries continues to deliver significant commercial benefits. Numerous commercial examples exist that demonstrate an increased profitability using this approach (Smart, 2005; Proffitt et al., 2006). The economic benefits for four case studies are shown in Table 1 (Bramley et al., 2005).

Table 1. Economic benefits of selective harvesting for grape production and/or wine production. The benefits shown are based on the harvesting of fruit from different zones of the vineyard on the same day. Note that increased benefits are sometimes realised by harvesting zones on different days.

Region	Variety	Income benefit ($) - grape production	Income benefit ($) - wine production
Clare Valley, SA	Riesling	54,904 (+77.8%)	
Padthaway, SA	Shiraz	4,657 (+3.2%)	272,971 (+20.5%)
Margaret River, WA	Shiraz	12,300 (+12.5%)	
Margaret River, WA	Cabernet Sauvignon		139,480 (+19.2%)

Yield monitor data in conjunction with knowledge about the costs of grape or wine production has also been used to construct gross margin maps (Bramley and Proffitt, 1999; Bramley, 2010). These are powerful and currently under-utilised tools for identifying and addressing poor and/or variable financial performance in vineyards.

Targeted management

Managing inputs (eg. irrigation water, fertilizers, canopy management, soil amendments, sprays and labour) has not been the major objective for vignerons who have generally concentrated on managing outputs (ie. yield and quality). This is changing in response to low crop prices, increasing production costs and environmental constraints such as the lack of irrigation water. Numerous commercial examples exist of targeted management, including the application of irrigation water, fertilizer and mulch/compost to manage vine vigour and associated crop yield and fruit quality, and pruning, leaf removal and herbicide spraying to reduce costs. Some of these are described in Proffitt et al. (2006).

Sampling and monitoring

Sampling and monitoring are key activities that are required throughout the year and include yield forecasting, berry maturity analyses, tissue and soil collection for nutritional analyses, and bud fruitfulness, pest, disease and vine health assessment. The availability of high resolution spatial data has improved the accuracy and reliability of such activities (Proffitt et al. 2006), as well as reducing costs in some instances.

Vineyard design and re-design

High resolution soil maps have been used to provide insights into the spatial variation in soil properties at scales which are applicable when designing new vineyards or re-developing older vineyards. The information has been shown to be a cost-effective means of positioning inspection pits. Accurate boundaries delineating changes in soil properties, coupled with topographical information, have assisted with matching grape varieties to desirable soil types, designing irrigation and drainage systems, and locating infrastructure (eg. roads, dams, frost fans and buildings) and instrumentation (eg. weather stations and soil moisture/salinity monitoring devices).

Airborne imagery has been used to redesign irrigation systems to improve vine uniformity and fruit quality. In one example (Leonard 2009), the outcome resulted in significant wine show achievements. Imagery, coupled with elevation and soil property changes, has been used in the design of a vineyard re-development project (Bramley et al. 2010). In a further example of the use of spatial information in this category of vineyard application, the location of frost fans using a digital elevation model (DEM) and GIS routines to map the predicted flow of cold air across the landscape resulted in the saving of fruit estimated to be of a value similar to the total cost of the project ($250,000) (Proffitt and Bramley 2010). Hence, the frost fans paid for themselves in the first year of installation.

Field experimentation

Spatial variability within vineyards presents problems for researchers and grape growers wishing to conduct field experiments. It is also problematic for vineyard managers when deciding where to apply changes in management that will deliver benefits. The commercial availability of spatial data, coupled with geostatistical methods, has led to the use of whole-of-vineyard block experimental approaches being used rather than small plots (Bramley et al. 2011; Panten and Bramley 2011).

Conclusions

Through the use of high resolution spatial data over the past 14 years or so, vignerons have and continue to demonstrate that knowledge of the inherent variability of their vineyards can improve their management practices and gain benefits (economic or otherwise). This is verified in a 2013 wine sector survey. The survey suggests that if the technology becomes cheaper and the technical advice/support and accompanying tools and software become easier to use, then the adoption rate should increase. To some extent, this will also depend on how and when the industry addresses the current over-supply problem and associated low grape prices.

Acknowledgements

Symposium organisers for providing me with the opportunity to represent the grape and wine industry and demonstrate how Precision Agriculture technologies are benefiting vignerons across the country. CSIRO Sustainable Ecosystems and the referenced vineyards and wine companies for allowing me to use their data.

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Digital homestead: delivering end user value from real-time on-farm monitoring

Greg Bishop-Hurley [1], David Henry [2], Leslie Overs[3], Luciano Gonzalez[4], Angela Anderson[5], Philip Pearce[6], Clinton Fookes[7]

[1]CSIRO Animal Food & Health Sciences, St Lucia QLD 4067; [2]CSIRO Animal Food & Health Sciences, Werribee, Vic 3030; [3]CSIRO ICT Centre, Pullenvale, QLD 4069; [4]CSIRO Animal Food & Health Sciences, Townsville QLD 4814, [5]Department of Agriculture, Fisheries and Forestry, Charters Towers, QLD 4820; [6]James Cook University, Townsville, QLD 4811; [7]QLD University of Technology, Brisbane, QLD 4001.

Contact: Greg.Bishop-Hurley@csiro.au

Summary

Sustainable and viable primary industries must be capable of regularly producing a margin above the costs of production. The real challenge is achieving this in an increasingly dynamic and challenging environment where resources are limited whilst demonstrating improved efficiency to the wider community with respect to environmental stewardship and animal welfare. Viable and resilient farm businesses in the future will make use of a wide range of data to make accurate and timely decisions. More accurate, timely and efficient management (operational, tactical and strategic) across the farm business would be improved by the timely, accurate and objective measurement of resources (from soil and water to feed, animals and product quality and quantity) and the operating environment coupled with sound interpretation and understanding.

In a joint initiative between CSIRO, James Cook University (JCU), Qld Dept Agriculture Fisheries and Forestry (DAFF) and Queensland University of Technology (QUT), the Digital Homestead project is investigating how electronic services enabled by connectivity to the National Broadband Network can support greater productivity for farming enterprises, as well as providing related support and social services to rural residents. Based at CSIROs Lansdown Research Station near Townsville, QLD researchers are implementing sensor and related technologies to provide information to simple and usable cloud-based decision support systems for farmers and agriculture advisers. It is anticipated that key technological solutions will then be evaluated on a commercial scale at QLD DAFFs Spyglass Beef Research Station near Charters Towers, QLD.

A demonstration site has been established at Lansdown to monitor growing steers in an extensive grazing environment. Three groups of thirty steers each graze one of three 15 ha paddocks in rotation. Each group of three paddocks has one permanent water point that is fenced off and has two spear gates, one for entry and one for exit. A walk over weigh station connected to wireless sensor network is located behind the entry spear gate. The sensor network relays data from a range of static sensors including animal live weight, climate data and soil moisture and pasture/soil reflectance values. Livestock monitoring devices record animal location and activity continuously. The data are uploaded to a central server and can be viewed in real time via the web.

A web-based ‘dashboard’ has been developed to integrate and present information obtained from both internal (e.g. LW, weather, animal location and behaviour) and external sources (e.g. climate forecasts and market information). The key requirement is that information is presented in a timely and informative way, can be tailored to individual users’ needs and preferences and enables more informed decisions. The design and functionality of the dashboard was based on the ongoing input of industry stakeholders.

Acknowledgement

We gratefully acknowledge funding through the Queensland Government Smart Futures fund.

Report on the inaugural Digital Rural Futures Conference 26-28th June 2013

John Stanley, David Lamb, Mark Trotter and Derek Schneider

Precision Agriculture Research Group, University of New England, Armidale NSW 2351

Contact: jstanle4@une.edu.au

Summary

The inaugural Digital Rural Futures Conference, held from 26 to 28 June 2013 at the University of New England, asked 160 delegates from Australia and New Zealand to think “How might our farmers and rural service providers benefit from the increased connectivity of the National Broadband Network (NBN)?” Precision Agriculture (PA) is bound to become accessible to a far larger number of our farmers. Field-to-specialist video conferencing and data sharing is on the cards. Will a puzzled farmer crouched over a sick animal in northern Australia activate his ‘head-cam’ to have an entomologist in Brisbane identify a serious pest incursion. Pie in the sky? An NBN wireless network of 25 megabits down and 5 up can achieve this. But wait, the conference also heard that many of Australia’s farmers are still waiting for reliable mobile coverage. And the remote areas of Australia will only get satellite NBN. Are we doing enough?

As expected, the conference showcased an enormous array of ideas, with presentations from national leaders, business innovators, policy makers, farmer peak bodies and large and small farmers. Topics ranged from; farm-to-customer retail, remote on-farm product support, tele-services like veterinary and agronomic and business support, precision agriculture, remote diagnostics and trouble-shooting (example above), assisted living, tele-health and education. We even discussed the ‘personality’ of different web platforms; was Twitter or Facebook more like a conversation at a BBQ or in a pub? Who cares? Well apparently, if you want your information to travel far and be well received, you’d better.

Farms are also a rich source of environmental data, for farm managers and their external advisors, and for those involved in monitoring the health of our landscapes. And add to these, the benefits from crowd sourcing and ‘citizen science’. It all comes down to how we manage data and information; how we store and secure it, derive value-add products from it and exchange it. Finally, of course, none of this will ever fly unless it stacks up economically.

Our rural regions have the lowest population (hence potential subscriber) density. Yet the enormous array of applications mentioned above means that, head-for-head, our reliance on, and demand for data (not bits per second but actual the bits exchanged) may outstrip our city cousins. Are the dimensions of our communications infrastructure sufficient and efficient? Remember, some of our farms are larger than the ACT.

Conference proceedings are available for ‘at-cost’ purchase from the conference website at www.une.edu.au/smart. All oral presentations will also soon be available on that site. We look forward to continuing this discussion with you at the next Digital Rural Futures Conference in Toowoomba, hosted this time by the University of Southern Queensland 25th to 27th June 2014.

Applying PA in Pingrup

Paul Hicks

Craiglinne Estate, Pingrup, WA

Contact: paul@precisiontech.com.au

Summary

iTiLL (Intelligent Tillage) is a steerable drawbar system that allows the grower to seed into the moisture zone established in the previous year's stubble row. The iTiLL system takes two seasons to establish and once set up will greatly enhance crop germination and establishment, reduce weed competition, improve fertiliser uptake and should the season dry off, reduce crop burn off. iTiLL utilises a specially designed SEEKER seed boot that precisely places soil wetter in the seed row. The soil wetter used has a residual effect that helps establish the moisture zone for the following years crop. A sensor fitted to the seeder 'feels' the previous year's stubble row and steers the seeder independently of the tractor to place the tyne and seed boot precisely in the already established 'moisture zone'. This technology will give growers more confidence sowing into otherwise marginal conditions. For more detailed information go to www.itill.com

Background and results

Paul farms in the Great Southern, and has developed a precision seeding system, iTill®, to help overcome the productivity constraints that affect thousands of growers across the country. His system places the seed precisely into last year's row, or a 50mm wide and 100mm deep "moisture zone", established from the previous year's crop (Figure 1). This increases germination and establishment, overcoming the major challenge posed by non-wetting sands and gravels.

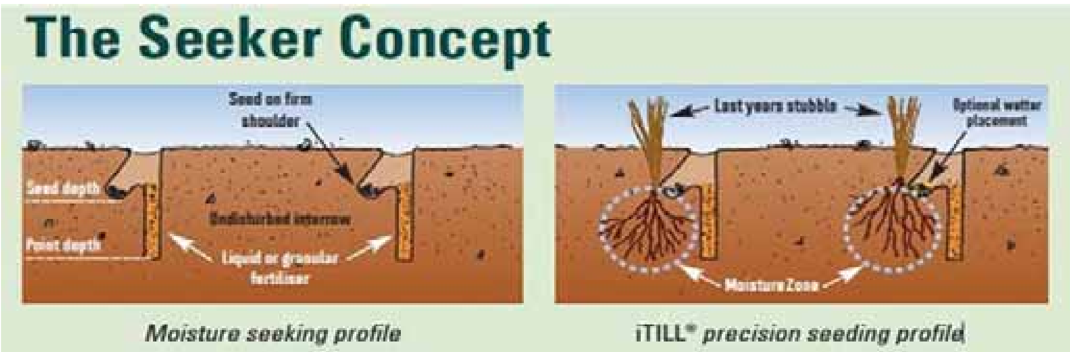


Figure 1. The placement of seed in the previous seasons crop row.

The invention was many years in the planning. Paul had experimented with soil wetter technology for years with varied results. It was not until he applied a wetter beneath the soil, as opposed to applying it behind the press wheel, did results show improvement. Trials using this technique recorded an 18 to 20 per cent yield increase over the control.

The real breakthrough though came about in 2008 when Paul corrected his auto steer settings on his tractor removing an overlap of about 20 centimetres between passes. Later that season when the crop emerged, the passes that were seeded in the previous year's row achieved excellent germination whereas the passes not in the previous year's row germinated poorly. Paul soon realised that in order to use this carry over moisture, the seeder needed to place the seed in the previous year's row. The concept for iTill® was born - a hydraulic steering system which fits to a tractor draw bar to sow seed in an exact location (Figure 3a).

(a)

(b)

Figure 2. The soil moisture profile under the row (a) and the AgMaster seeker boot (b).

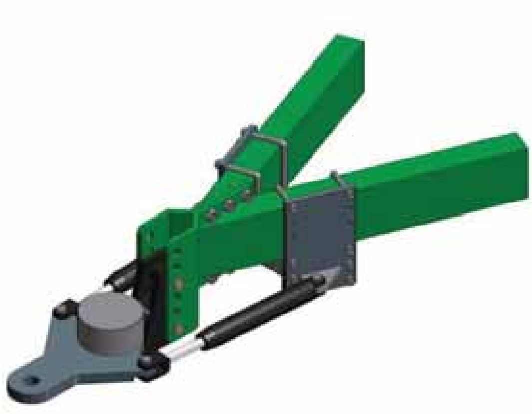
Results have varied depending on soil type and climatic conditions, with excellent results achieved on non-wetting sand and gravels. For the moisture zone to be noticeable, 10 to 20mm of rainfall is required, ideally less than a month before seeding if soil wetter has been used in the previous year.

Paul sees the advantages of iTill® as:

- an effective tool to aid superior crop establishment
- when seeding into a row, the previous year's fertiliser is utilised
- if using soil wetter and the season dries out, the crop tends to hang on better because of the presence of soil wetter.

Paul is also involved in productivity trials testing a range of treatments with the CSIRO and GRDC. He has purchased an NDVI camera to capture reflectance imagery of his crops to provide early information on crop development and treatment responses (Figure 3b).

(a)



(b)

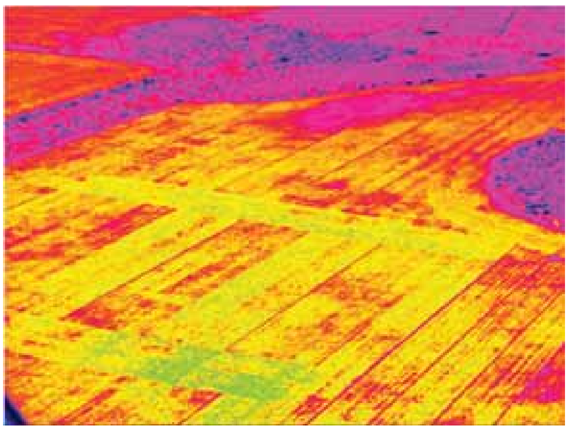


Figure 3. The iTill hydraulic implement steering design (a) and an early season image of a production trial (b).

Precision Agriculture for grain production systems

Brett Whelan[1] and James Taylor[1, 2]

[1]Precision Agriculture Laboratory, University of Sydney
[2]Department of Horticulture, Cornell University

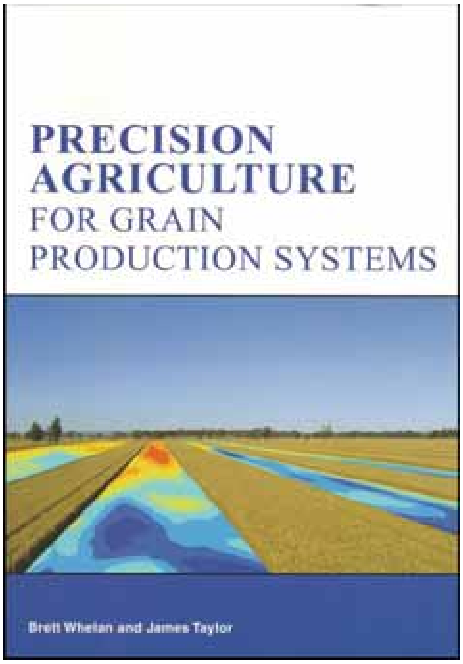
Summary

This book explains general Precision Agriculture theory, identifies and describes essential tools and techniques, and includes practical examples from the grains industry. Readers will gain an understanding of the magnitude, spatial scale and seasonality of measurable variability in soil attributes, plant growth and environmental conditions. They will be introduced to the role of sensing systems in measuring crop, soil and environment variability, and discover how this variability may have a significant impact on crop production systems. *Precision Agriculture for Grain Production Systems* will empower crop and soil science students, agronomy and agricultural engineering students, as well as agronomic advisors and farmers to critically analyse the impact of observed variation in resources on crop production and management decisions.

CSIRO Publishing, 208 pages, paperback ISBN 9780643107472, also eBook.

The book

The authors, in partnership with the Grains Research and Development Corporation (GRDC), have been extensively involved in the research, development and application of PA in grain crop production. The collaboration has produced this book, which aims to provide an understanding of the principles that underpin the major technologies and techniques being used in PA, and use production examples to explain their applications, and value, in grain crop management. However the concepts, and many of the tools described here, will have relevance to most other agricultural industries.



Contents

PA: building knowledge, linking agronomy, growers profiting

Brooke Sauer

Precision Cropping Technologies Pty Ltd

Contact: brooke@pct-ag.com

Introduction

The team would like to thank GRDC for funding the project: Precision Agriculture - Building knowledge, linking agronomy, growers profiting. Practical training for practical outcomes (Project: PCT00001), which has enabled PCT to deliver and launch two extremely useful resources for PA practitioners.

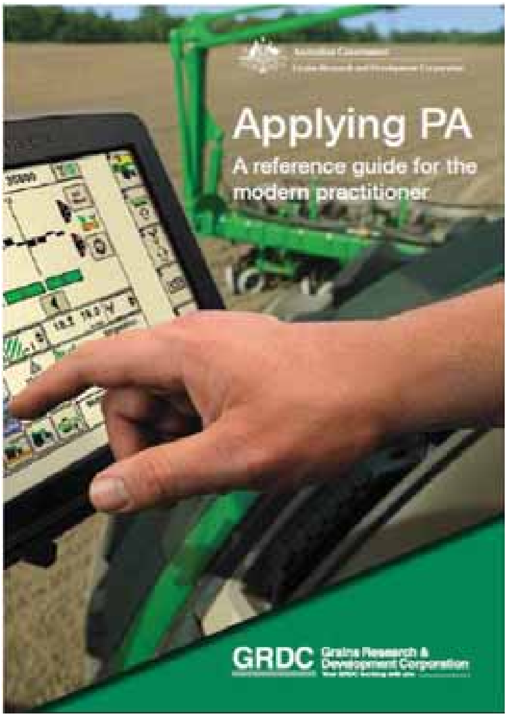
Website Launch: PA Help Desk (www.pahelpdesk.com)

This help desk is all things PA from machinery to services. There is a comprehensive PA Library to help you find information to answer your questions. Resources, if you're looking for more formal and comprehensive reading. The training materials will provide you the means to develop your analytical skills and the latest software news and developments will ensure you stay on top of the technology.

If you have a specific question – they often arise with PA – you can try the help desk. You can post a question which will be viewed and answered by any website user or you can send it privately and the PA Help Desk team will endeavour to get you a timely response.

You can Like us and login via Facebook : PA Help Desk or follow the news updates on Twitter: @PrecAgHelpDesk or if social media is not your thing, but want to keep informed, you can contact us and join the mailing list and we will send you quarterly newsletters with all the latest information. Lastly if you prefer not to control things yourself you can always just periodically check in and see what's new.

Book Launch: ***Applying PA: A reference guide for the modern practitioner***



This a small, but robust A5 reference book that aims to identify and describe a common-sense approach to using precision agriculture to maximise whole farm profit. The book is divided into three concise sections to direct the reader specifically to the information they want. Part one covers all the introductory, yet important information including the causes and impact of field variability, interpreting and managing data as well as some useful tips to help understand why different data formats exist and the issue of data incompatibility.

Part two discusses the most commonly used spatial agronomy tools and provides basic information about each tool, including important considerations and benefits and where to get started using these tools to generate valuable spatial information. Part three of the book is the largest section and addresses the specific application of spatial agronomy PA tools in much defined ways. Each article specifically addresses an "application", such as simpler PA tasks such as creating a map to guide the placement of a moisture probe to more complicated processes such as identifying subsoil acidity using gamma radiometrics.


OUR EXPERTISE AT
YOUR FINGERTIPS.

Allocation of cropping inputs according to PAWC (farming to the bucket) = lower risk and greater ROFE

Craig Topham

Agrarian Management

Contact: craig@agrarian.com.au

Key findings

Improved cereal enterprise profitability and enhanced risk management can be achieved with the implementation of a targeted variable rate cropping system, which allocates inputs according to variation in soil plant available water capacity ("PAWC"). The allocation of crop fertilisers, seed and soil amelioration inputs in accordance with variation in PAWC can result in increased return on funds employed ("ROFE") for broad acre cropping operations in WA.

EM38 and Radiometric soil scanning in conjunction with an appropriate soil testing regime and Yield Prophet soil characterization can identify and map variation in PAWC across land management units. Yield Prophet can be used to model expected variation in crop yield according to variation in PAWC and other variables including variety, time of sowing, and nitrogen strategies.

Determination of PAWC variability through analysis of soil physical and chemical properties enables the primary cause of yield variation to be ascertained. Alternative methods of determining yield variability such as satellite biomass imagery or harvester yield maps record symptoms of variation in PAWC across a landscape.

Once the causes of PAWC and therefore yield variation have been identified, an economic analysis regarding choice of crop nutrition products and application rates and soil amelioration strategies can be conducted to ascertain strategies to achieve improved risk-weighted ROFE. Variable allocation of inputs at seeding and post-emergence in accordance with PAWC achieved the greatest ROFE benefits than either seeding only or post emergent only variable rate technology ("VRT").

Aims

a) To evaluate the concept of mapping variation in soil physical and chemical properties and how they relate to variation in soil PAWC
b) If the allocation of variable rate cropping inputs according to PAWC can reduce risk and whilst achieve greater ROFE compared with traditional flat rate applications of crop inputs.

Method

EM38, radiometrics, soil cores and tests, and harvester yield maps were used to develop fully automated large scale variable rate farming systems in 2010 and 2011
There were three low to medium rainfall sites for the project located at Pindar, Perenjori and Eradu in the northern wheatbelt of WA.

Decile 1 – 2 rainfall was received at all sites in 2010 with minimal pre-seeding sub soil moisture. The exception was the Pindar site which was sown into a 2009 chemical fallow. Rainfall from August – October at all sites was almost the lowest on record. Conversely, 2011 achieved decile 9-10 rainfall with significant summer rain (and high subsoil moisture at seeding), growing season rainfall well above average and a very mild finish to the season.

The research paddocks were mapped with EM38 and radiometrics and soil sampled to a depth of 1m. Sample sites were located according to statistical variation in EM and gamma radiation readings, which allows soil physical and chemical characteristics to be correlated with various EM and gamma readings. Figure 1 shows the results from the Eradu site, where the gamma total count and the 0-60cm clay percentage (a) and top soil (0-10cm) organic carbon ("OC%") (b) correlations allow the gamma total count to be used to identify the variation in clay and OC. Recent geo-referenced soil tests can also be added to improve the correlation. The greater the number of soil test sites the greater the confidence in the correlation between the soil physical or chemical property and the associated EM or gamma result.

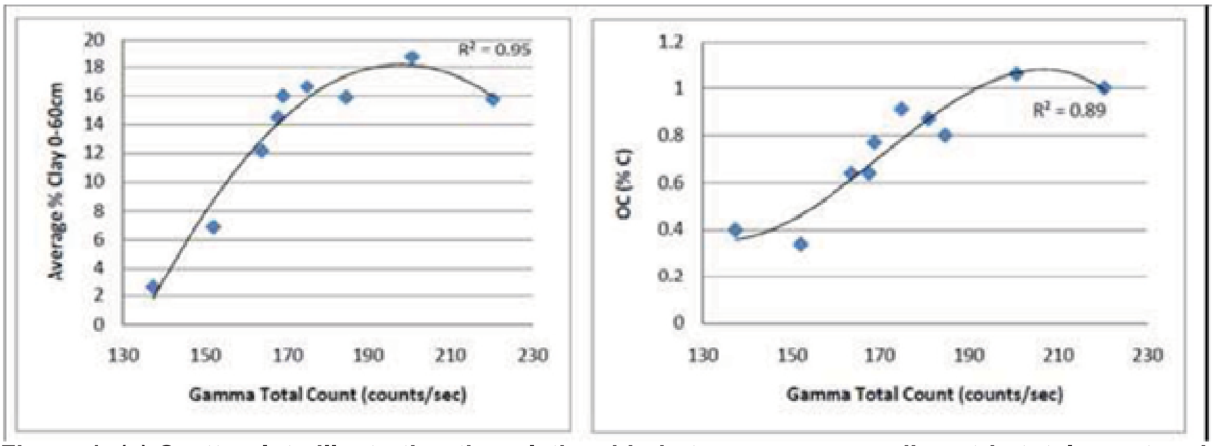


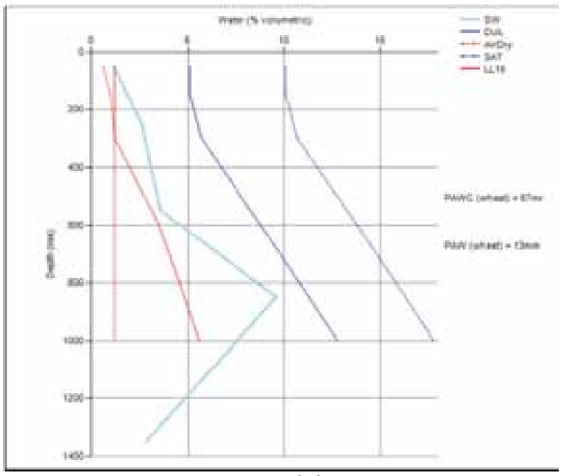
Figure 1. (a) Scatterplots illustrating the relationship between gamma radiometric total count and average profile (0-60cm) clay %; and (b) the relationship between gamma radiometric total count and topsoil (0-10cm) organic carbon (Walkley-Black method).

Inclusion of Yield Prophet Soil Characterization

The Eradu Sandplain site demonstrated a strong correlation between topsoil and mid-profile clay percentage, topsoil OC%, potassium (Cowell K) and gamma total count. Such attributes capture the majority of variability in PAWC. The paddock was zoned into three land management units representing high, medium and low production zones according to PAWC.

Yield Prophet sites were located at the midpoint of the gamma total count readings for each zone, with the soil at each site being characterized and loaded into the APSIM model to run the Yield Prophet simulations. The characterization process was conducted at Eradu and Pindar sites in accordance with APSIM protocol. Characterisation highlighted the variation in PAWC. Figure 2 demonstrates the variation in PAWC at Eradu with the low production site PAWC of 67mm (a), average production zone 99mm (b) and the high production zone 116mm (c). For example, the high production zone contains higher clay, potassium and OC% holds 57% more PAW than the low zone.

(a)



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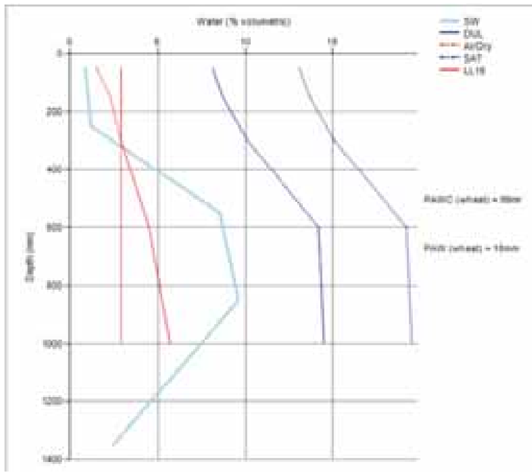

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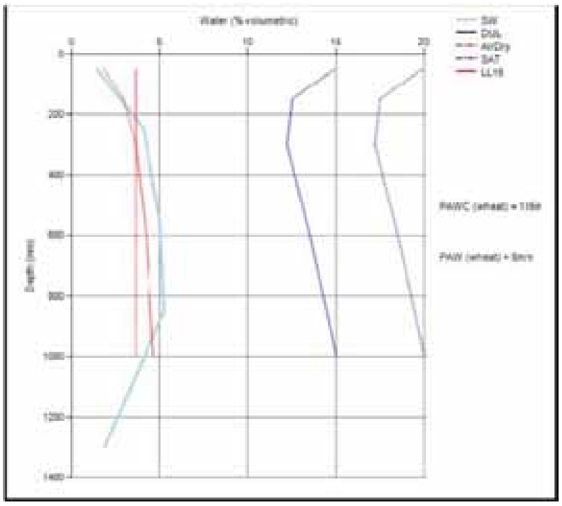

Figure 2. The variation in PAWC at Eradu with (a) the low production site PAWC of 67mm, (b) average production zone 99mm and (c) the high production zone 116mm.

Validation strips (strip trials) were set up at all sites in 2010 and 2011 to allow analysis of yields and financial performance of each soil class with regard to differing levels of inputs across the three zones. Validation strips are set up across the paddock so that each treatment runs through all three zones to provide data on response by treatment by zone.

In 2011 all locations were sown using variable rate zones developed in 2010, but with revised input strategies due to higher predicted yields from Yield Prophet at seeding 2011. Figure 3 shows the four production zones of the Pindar site with validation strips imbedded into the production zones. The area of each treatment ranges from 3 – 15 hectares depending on width of seeding machine and length of paddock. Strips are replicated 3 times but not randomized. Results can be used to validate and quantify the response of each treatment in each soil zone and to develop a database and intellectual property to utilise in future seasons.

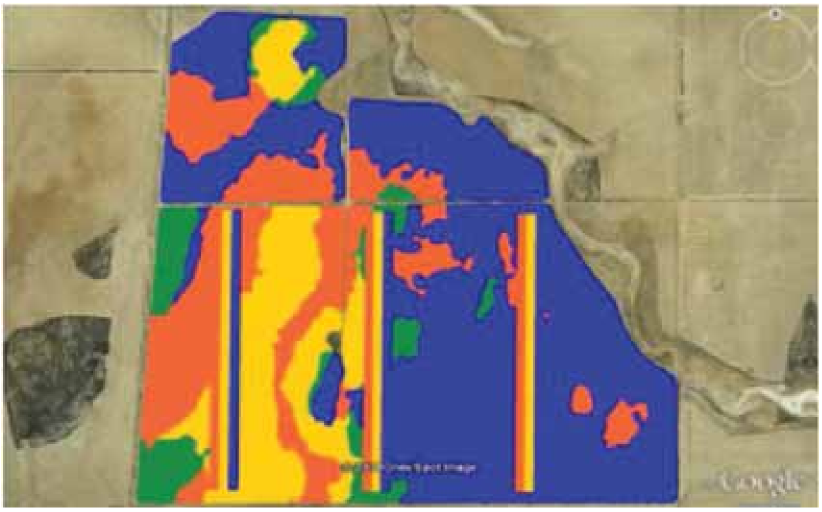

Figure 3. Pindar 2011 sowing zones and strip trials.

Results

In 2010 machinery capabilities limited the variation of inputs to seeding time at all sites. The low growing season rainfall and abrupt finish to the season caused the lowest input treatments to provide the most beneficial economic response. The exceptions were the medium zones at Eradu and Pindar which showed that the average inputs provided the most profitable return. This result highlighted the need to be able to respond to seasonal conditions with seeding and post-emergent applications. Note that in the absence of post-emergent VRT capabilities, higher levels of nitrogen tend to be applied by farmers at seeding. Post-emergent application of inputs according to PAWC provided the most beneficial improvement in ROFE. The soil zones that responded favourably to additional inputs in 2010 featured the deepest rooting depth and higher PAW.

Pindar Project

Four Yield Prophet sites were located across the 465ha Pindar site. All four soils were characterized in 2010 and said data loaded into the APSIM model. Long term weather data modelling through Yield Prophet suggests a long term average yield variation of ~1.2t/ha between the high and low zones. Analysis of yield maps over four seasons also confirmed yield variation of 1.2t/ha. Soil scans and core/soil tests enabled the ability to map sub-soil constraints such as very low sub-soil pH with toxic levels of Aluminium. Wheat root depth on such zones is limited to 20 – 25cm. The reduced root depth severely constrains the plant's ability to access sub-soil moisture, with consequent reduction of yield.

I

n 2010 the measured net benefit from the implementation of variable rate seeding inputs produced a $13/ha increase in gross margin. An additional $11/ha benefit was achieved through cost savings associated with implementation of a variable rate liming program. The Pindar project was divided into four production zones with high zone (blue),51% average (yellow) 18%,low (red – Aluminium toxic) 22% and an additional heavy clay zone of 10%. In 2011 the ability to vary sowing as well as post-emergent nitrogen was available. The 2011 strategy of matching inputs to soil types, rooting depth and PAW was developed with the use of Yield Prophet to help quantify the PAW and response to nitrogen. The input strategy implemented in 2011resulted in an input saving of $1.87/ha because additional inputs were applied to high and average zones due to favourable seasonal conditions. Exposure to risk was managed by targeting inputs according to PAW.

Margin analysis demonstrated a $39/ha increase in gross margin or 13% increase in ROFE was achieved by matching inputs to soil zone.

Eradu Project

Machinery capacity at Eradu permitted variable seed and fertilizer inputs at sowing and variable in-season liquid nitrogen. The early post-emergent nitrogen and potassium application was not able to be varied due to the inputs being applied by non-VRT contractor's equipment. Compound fertiliser and liquid nitrogen rates were varied at sowing by zone. This strategy applied higher P rates to the average zone due to lower soil P levels and high PAW at sowing. Nitrogen rates were matched to PAWC of each zone with the low PAWC zone receiving the lowest starting N rates. All zones had a blanket 3 leaf application of urea and MOP. Due to favourable PAW an additional non budgeted application of UAN was applied at Z31 to the medium (13kg/ha N) and high (19kg/ha N) PAWC zones. Nil was applied to the low zone. Yield Prophet modelling indicated that the response to additional N on the low PAWC soil was unlikely.

Results from two seasons trials over four properties confirmed higher nitrogen rates on low PAWC soils reduced yield. Higher nitrogen increased plant biomass and therefore created a higher demand for moisture during grainfill which plants could not extract from low PAWC soils. Total rainfall was 395mm of which 292 mm fell in the growing season. Analysis through Yield Prophet showed that 34% of growing season rainfall was lost through leaching on the low PAWC zone. Conversion of rainfall into grain varied from 8.29kg of grain per millimetre of rainfall on the low PAWC zone to 11.6kg/mm on the average zone and 12.3kg/mm on the high PAWC zone.

Gross margin per millimetre of growing season rainfall varied from $1.81/mm on the low zone to $2.49/mm on the average zone and $2.71/mm on the high zone. For comparison, blanket rate inputs on the high production zone produced a gross margin of $2.34/mm. The ability to target inputs according to PAWC and PAW resulted in an additional margin of $0.37/mm of rainfall which equates to 16% improvement in the conversion of rainfall into harvested grain.

The 983ha Eradu site consisted 28% of area in the high zone, 47% average zone and 24% in the low zone. The input strategy saved $5.48 in input costs for the season and additional gross margin of $63/ha or 20% improvement in ROFE. Further analysis of the 2012 strategy at Eradu shows that the ability to vary post-emergent urea/MOP would achieve input cost savings of $11.50/ha while maintaining the 20% increase in ROFE. This is assuming the same yield differences as achieved in 2011, with a constant grain price of $220/t on farm, and current fertiliser prices.

Conclusion

Return on funds employed from broadacre cropping operations can be improved by allocation of crop inputs in accordance with variation in PAWC across paddocks or entire farms. Farm risk profiles can be moderated by reduction of crop inputs and/or crop area in seasons when low PAW exists, and farm profitability can be enhanced by increasing inputs in seasons when favourable PAW exists.

EM38 and gamma radiometrics are an effective method of identifying the variation in soil chemical and physical properties that influence plant productivity. Mapping soil chemical and physical properties can be achieved with appropriate surface, mi-profile and deep soil testing, which can in turn identify other production constraints or risk factors. With detailed objective data on the key variables affecting crop performance, comprehensive input and soil ameliorant strategies can be developed with improved levels of confidence than in previous years. Fully automated allocation of input and soil ameliorant capital can be achieved irrespective of operator, which improves profitability on superior zones and moderates risk on inferior zones.

Satellite plant biomass maps and harvester yield maps identify plant growth and crop yield variability, but fail to identify the cause of such variation. By identifying the drivers and limitations to plant growth a greater level of production and risk management can be achieved. The use of the crop modelling tool Yield Prophet, and accurately characterized soils along with production zones empowers the farmer an improved ability to control gross margin by targeting inputs to production zone to maximise ROFE. Post-emergent variable rate capabilities such as modified spreaders and boom sprays to apply UAN, enhance the risk management ability of a zone management farming system.

The convergence of EM38, radiometrics, Yield Prophet, variable rate machinery capabilities, and associated proprietary software in conjunction with validation strips creates a transparent and accountable system that is continuously being reviewed and tested to ensure maximum return on investment. An unmeasured loss is more palatable than a measured loss. Validation strips enable the opportunity cost of flat rate inputs to be quantified, and therefore the benefit of fully automated VRT strategies as described to be ascertained.

The investment in the development of a variable rate cropping system based on EM38 and radiometrics combined with the ability to predict the variation in PAWC through Yield Prophet crop modelling, has demonstrated a payback period of one year were the ability to apply both sowing and post emergent inputs through variable rate is available. If the implementation of a variable rate liming program is included, significant additional benefits apply. Seasonal conditions as well as percentage of each soil class in a land management unit will influence these results.

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Improving production on moderate performing zones in a field; the other benefit of adopting PA technology.

Roger Lawes and Yvette Oliver

CSIRO Ecosystem Sciences

Contact: roger.lawes@csiro.au

Key findings

- Precision agriculture delivers economic benefits to farmers by allocating nutrients to parts of the paddock that can respond to that nutrient
- If the farmer can correct a constraint on part of the paddock, the economic benefits from adopting PA increase from ~ $15/ha to at least an additional $15/ha (for N fertiliser on wheat in medium rainfall environments). If a constraint is corrected entirely, the increase could be as high as $104 /ha.
- The challenge remains to firstly identify what the constraint is and then develop an economically sensible management strategy to ameliorate or manage that constraint on part of the field.
- A tool to assess the economic payoffs for variable nutrient application to wheat has been developed and available for download and use at: *http://environmentagriculture.curtin.edu.au/people/rmandel.cfm*

Introduction

To implement a spatially explicit management strategy on a field a farmer must follow a series of steps. Firstly there needs to be some variation in yield (Robertson et al. 2008, Lawes et al. 2011) and the variation in yield needs to be captured and quantified. This is usually performed with a yield monitor attached to a grain harvester. Yields are routinely logged and positional information is recorded with a GPS. These data can be compiled with mapping software to produce a yield map and enable farmers to determine whether or not there is sufficient variation in yield to manage.

Farmers have been using this technology for at least 15 years, which now means the technology, or use of the technology should be approaching maturity and if useful would be widely adopted by farmers. However, recent surveys suggest that adoption rates of yield mapping have reach about 65%, while the use of variable rate technology and variable rate management has been adopted by about 20% of grain farmers in Australia (Robertson et al. 2012).

One of the major reasons behind an apparent plateau in adoption rates of precision agriculture has been the inability to cheaply and efficiently use the technology available to help manage in crop agronomy (Robertson et al. 2012). In the early 2000s, there was a substantial focus on variable rate controllers, in part because the technology was available and the industry was interested in using it. Variable rate controller boxes were developed and multiple fertiliser bins could be constructed on seeder boxes that allowed farms to apply a myriad of fertiliser combinations across the field. The array of possibilities is perplexing, and unless there is accompanying information on nutrients in the soil, then it is almost impossible to determine the value of such complex fertiliser management practices. To help farmers understand the economic merit in using variable rate technology, researchers focussed on developing economic calculators that adapted the standard fertiliser decision aids like NP decide so they could be used across the entire paddock with variable yields and variable quantities of nutrients in the soil. These calculators allow farmers to calculate the benefits of chasing a VRT approach to infield variability. However, one of the problems associated with adopting precision agriculture and variable rate technology in particular is the returns from implementing VRT are modest and range from $10 - $20/ha (for N and P on wheat, Lawes et al. 2011). This modest return means the farmer can only afford to spend a modest amount on implementing the technology. Nevertheless, when the yields in a particular field vary by more than 1 t/ha, and the soils in the different zones have different quantities of nutrients, VRT can pay. If these conditions, variable crop yields and variable quantities of nutrients, are met then VRT can generate returns greater than $30/ha (Lawes et al. 2011).

In one sense, the VRT component of precision agriculture undersells the value of the precision agriculture technology. The gains may be proportionally larger if a farmer is able to correct a crop stress or soil constraint and transform a zone from a low performing zone to a mid or even high performing zone. This is the economic Holy Grail for precision agriculture, and has many similarities with the yield gap analyses that highlight the difference between on farm yield and yield potential given the season (Hochman et al. 2009). Tellingly, Oliver et al. (2013), demonstrated that across an entire farm mean wheat yield was 50-60% of the water limited yield potential and the difference in between actual and potential yield varied from 0.6t/ha in a dry year to 1.5 t/ha in a wet year. Therefore there may be scope to generate substantial economic returns across the farm by improving yield in the middle zone.

It is when farmers pose the question “Where are the yield constraints on the farm?”, that the economic value of precision agriculture comes into its own. This question should be closely followed by “Where is there are large disparity between actual yield and potential yield”.

By asking these two questions, the farmer focuses on identifying where the problem soils are on the farm. Em38 and gamma radiometrics surveys (Wong and Lawes 2012) can help define the soil types on the farm and if the constraint is linked to a soil type, the em38 can provide a surrogate step to determining the boundary of a subsoil constraint. However, the em38 and gamma radiometrics surveys may not necessarily relate to yield variation, simply because subsoil constraints effectively reduce the soils plant available water holding capacity and do not affect yield in every season (Lawes et al. 2009).

Once a constraint has been diagnosed, it can then either be corrected to increase the yield of the zone, perhaps up to the level of another zone, or managed according to that reduced yield potential. Here we use the economic calculator to demonstrate the value of improving yield in the middle zone of a field and illustrate how the economic gains from adopting precision agriculture technologies can increase dramatically when yield constraints are corrected.

Methods

The PA economic calculator, which is based on NP decide, was employed to determine the economic advantage associated with correcting a low yielding zone in a field. The calculator is described in detail in Lawes and Robertson (2011).
For the purposes of illustration we use a hypothetical wheat field of 150ha that has three zones. The high zone has a potential yield of 3.5 t/ha in 50 ha of the field. The medium zone has a potential yield of 2.5 t/ha in 50 ha across the field. The low zone has a potential yield of 1.5 t/ha in 50 ha across the field. The fertiliser budget was not constrained. When fertiliser rates are varied across the field we refer to this as variable rate technology (VRT). When fertiliser rates are held constant across the entire field, we refer to this as uniform management.

Background soil N was 12, 20 and 25 kg/ha in the high, medium and low zones respectively. Background soil P was 4, 7 and 12 kg/ha. These starting levels are typical of situations where the better yielding portions of the field deplete the nutrient resource. In contrast, in the low performing regions, nutrients can accumulate, because insufficient grain is produced to use the nutrients supplied.

In the medium zone, we assumed yield could be increased, through an ameliorant from 2.5 t/ha to 3.5 t/ha on a sliding scale of 250 kg/ha increments. Therefore we evaluated the field return based on the capacity to increase the yield of the low region from 2.5 t/ha to 2.75, 3.0, 3.25 and 3.5 t/ha.

The economic calculation was conducted for two grain prices, $250/t, $300/t $350/t for wheat and two prices for nitrogen, $1.50/kg and $2.0/kg.

Results

In the standard field, with grain prices at $300/t and nitrogen prices at $1.50/kg, VRT generated a $15.32/ha advantage over a uniform management. High rates of fertiliser were applied to the high yielding (3.5t/ha) zone. Economically-optimal fertiliser rates progressively declined from 154 kg/N/ha, to 124 kg/N ha and 87 kg/N/ha as the potential yield of the zone declined and the amount of nutrients in the soil increased.

This advantage of VRT, is typical, where yields vary consistently from one year to the next across the field. However, the gains increase further if through the use of ameliorants, the potential yield of the middle zone is increased. A small 0.25 t/ha or 10% yield increase improved the partial gross margin for the zone from $465/ha to $531/ha (Figure 1) and the partial gross margin across the field increased by $21.31 from $469/ha to $491/ha (Figure 2).

The advantage of increasing the yield from 2.5 to 2.75 t/ha for the medium zone increased further as the grain price increased from $300/t to $350/t. The partial gross margin for the field increased by $26/ha from $560/ha to $586/ha (Figure 2).

To an extent, fertiliser prices did reduce the benefits of enhancing yield, partly because increasing fertiliser prices tends to decrease the amount of fertiliser applied, and hence generate a slightly lower yield. When nitrogen prices reach $2.0/ha and grain prices are at $300/t the 10% increase in potential yield increased the partial gross margin across the field by $14.04/ha. A further increase in grain prices to $350/t resulted in an increase across the field of $15.4/ha.

The economic gains from increasing yield in the medium zone by just 10% roughly equate to the gains generated from managing the field with VRT. If a constraint could be ameliorated entirely, the increases in the partial gross margin across the field also increase. Therefore, when grain prices are $350/t and nitrogen prices are $1.5/kg, improving yields in the medium zone from 2.5 to 3.5t/ha increases profit in the zone profit by $313/ha and profit across the field by $104/ha. This substantial increase in partial gross margin occurs across all grain and fertiliser price points in the medium zone (Figure 2). Even when grain prices are $300/t and nitrogen is $2.0/kg, the partial gross margin for the medium zone increased by $217/ha from $333/ha to $550/ha. The field partial gross margin increased by $59/ha from $348.33 to $407.35.

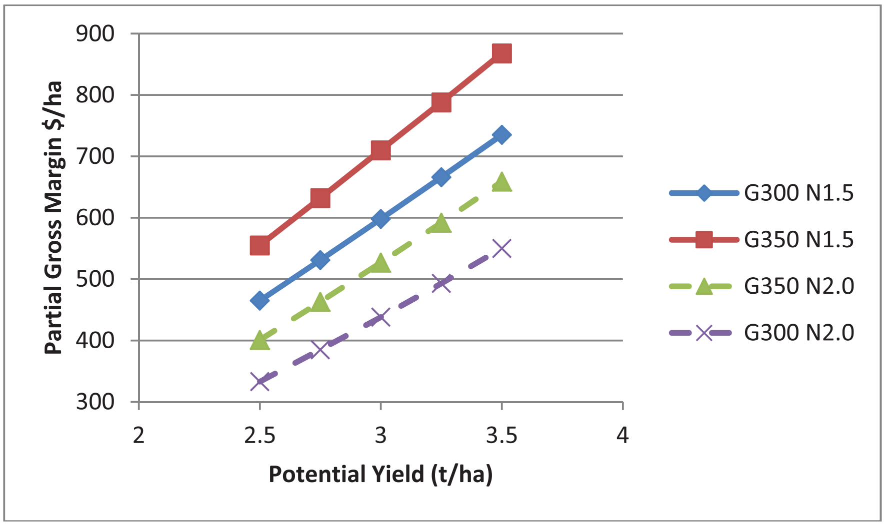

Figure 1. The change in the partial gross margin for the medium zone as wheat yields for the medium zone increase from 2.5t/ha to 3.5 t/ha when grain prices range from $300/t to $350/t and nitrogen prices range from $1.50/kg to $2.0/kg and managed with VRT.

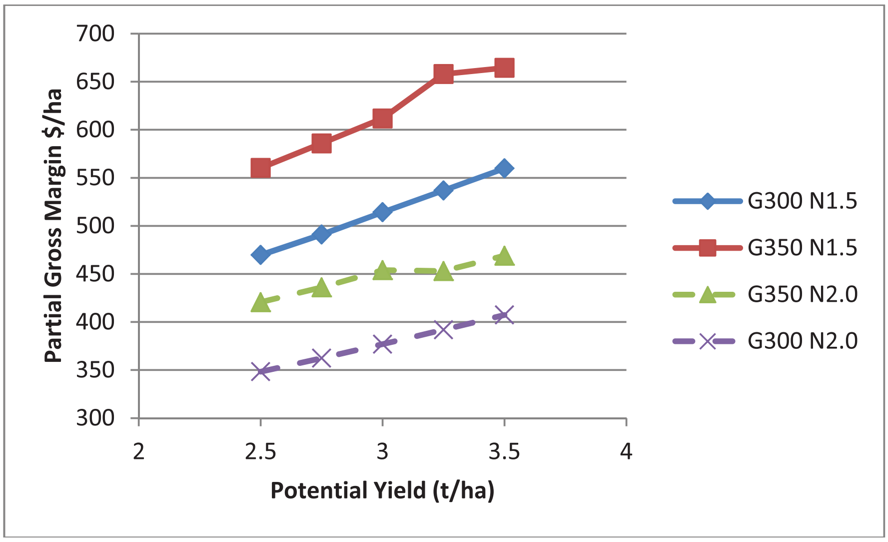

Figure 2. The change in the partial gross margin for the entire field as yields for the medium zone increase from 2.5t/ha to 3.5 t/ha when grain prices range from $300/t to $350/t and nitrogen prices range from $1.50/kg to $2.0/kg and managed with VRT.

Discussion

The PA calculator demonstrates that VRT can deliver economic gains for farmers and the analysis also demonstrates that these gains increase considerably, up to $100/ha, if a yield constraint can be overcome in the medium performing zone. Therefore the analysis demonstrates the advantages associated with targeting medium performing zone and trying to correct a possible problem, like a subsoil constraint, with the field. The analysis conducted here largely ignores the additional costs of correcting the constraint. However, the economics of applying lime have been covered by Sands et al. (2013) and a lime calculator can be used to determine if pH should be corrected. When some constraints are corrected, the yield improvement can be immense. For example, the spading of a non wetting soil with herbicide resistant weeds can more than double yields (Davies et al 2012). Since these techniques are expensive, it may be worth applying these costly techniques to part of the field and PA technology can help identify where a constraint occurs.

One of the issues farmers will have when trying to fix a constraint in the medium zone is deducing whether or not it can be fixed. For many constraints an operation like applying lime, applying gypsum or deep ripping will need to be conducted. It will be important to identify where the medium zone is in the field and then determine what the constraint is through soil sampling and careful observation of crop diseases and weeds. Once this process has been followed, the farmer can then determine whether the constraint can be overcome with management. If there is any doubt, a strip trial should be set up following the approaches suggested by Lawes and Bramley (2012) to give the farmer confidence that the constraint can be overcome.

Ultimately the farmer will need to identify where the constraint is in the field. Since the technology exists, or can be created, to measure almost anything, the questions that scientists and farmers need to ask is: What are the most useful attributes to measure in the field to diagnose a constraint? For a farmer, this question should be closely followed by: How will this information change the way I manage the paddock, and how can this help me generate a return. The PA calculator can at least help the farmer and consultant understand what the value is in correcting a constraint, and with this information can decide how much to invest in addressing the issue at hand.

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A global view of PA research and opportunities for Australia

Emma Leonard

AgriKnowHow, Urania, Via Maitland, South Australia 5573.

Contact: emma.leonard@bigpond.com

Key findings

- Precision agriculture is relevant to large and small scale farmers and is about improving efficiency and profitability with and without technology.
- Drivers for the development of precision management systems vary across the globe.
- New tools are in development, many are looking for a problem to solve, others need proving in Australian conditions.
- Take the opportunity to attend overseas conferences

Introduction

With about 80 per cent of grain growers in developed countries already using some form of satellite driven machine guidance, many may consider that spatial technology in farming has come of age. The reality is that guidance and autosteer are technologies at the vanguard of a new approach to farming.

Spatial tools and systems for agriculture are still in their infancy and it will take several decades before this latest agricultural revolution reaches maturity. This was my recurring point of view at the conclusion of the three international precision agriculture conferences I attended in June/July.

Two events were targeted at the scientific community - 5th Asian Conference on Precision Agriculture (ACPA) and 9th European Conference on Precision Agriculture (ECPA) – while the third – InfoAg in the USA - was designed for farmers and agronomists.

I attended these events with the support of an Industry Development Award (IDA) from the GRDC. The objective of my IDA was to gain a global perspective on the development and application of spatial technologies and information and communication technologies (ICT) and to share these with Australian farmers, agronomists and researchers.

Presentation Content

Relevance of precision management

The development of spatially based, precision management systems for agriculture is relevant to large and small scale farmers in the developed and developing worlds. In his key note address at the ACPA, held in South Korea, Dr Raj Kholsla of the Colorado State University illustrated that patterns of variation on large and small scale farms are very similar. Thus precision farming can be relevant irrespective of scale; however, the management system used may differ in its level of sophistication.

For example, precision management in a broadacre agriculture system in the USA might include nitrogen prescriptions based on soil and crop data collected using sensors and satellite, with applications controlled via computers. In a developing country precision could be a dose of fertiliser measured using a bottle cap and placed at the base of each maize plant, rather than being broadcast haphazardly by hand.

This example illustrates that precision does not necessarily require expensive and complex technology but is about improving efficiency and productivity, which in turn should support increased profitability and sustainability.

A global perspective

The speed at which precision management systems are adopted will be driven by their ability to deliver on-farm benefits. However, the development and adoption is also influenced by regional priorities and presentations at the three conferences showed these to differ across the regions.

China –Labour saving techniques and tools are a key focus for agricultural development in China. Improving yield per unit of inputs supported by cheap sensors and input controllers suited to smaller scale producers is also important.

Dr Chunjiang Zhao, director of the National Engineering Research Centre for Information Technology in Agriculture reported that the annual investment in China in precision agriculture research is about US$66 million.

South Korea –Extremely high levels of land productivity are already achieved in South Korea. The 2006 figures presented at the ACPA reported production of US$17,327/ha compared to US$984 for the USA. This is partly because production is focused on intensive, small scale production of relatively high value vegetable and fruit crops.

In his address Dr Sun-Ok Chung, Professor at Chungnam National University, proposed that precision technologies offer South Korea with the opportunity to combine food with medicine and focus on what he termed 'human specific crop production. Such food products could be tailored to meet physical and mental health requirements. Such crops could be produced in plant factories. These warehouse based multistorey farms have water, light and nutrient inputs controlled by sensors. A fully automated, robotic plant factory produces ginseng is already established in Korea.

Japan – While food security is important in Japan, it is food safety that is paramount. Technology to provide trace ability through the food chain as well as non-destructive sensors to measure product quality before going to market are areas of interest presented by Dr Sakae Shibusawa, Professor at Tokyo University of Agriculture and Technology. It is interesting to note that at Hokkaido University the Laboratory of Vehicle Robotics is already running a fully robotic farming operation.

Europe – High value crops and reducing environmental impacts are priority areas for precision management research in Europe. For example, orchard crops offer significant opportunities for the improved application of pesticides. Approximately 4.4% of the cropped area in the European Union 27 is under orchards, yet 14% of all pesticides used are applied in orchards.

At the field tour, organised as part of the ECPA, Dr Alexandre Escola and colleagues from the University Lleida, Spain, demonstrated the use of a light emitting laser (lidar) to measure canopy density in grape vines. This information was then used to moderate pesticide rates.

This research team has also produced a simple web based system (www.dosafrut.es) to determine the pesticide requirement for different sized fruit trees. Its use has resulted in up to a 50 per cent reduction in pesticide application.

Another important focus in Europe is improved integration between equipment. Dr Robbin Gebbers, Leibniz Institute for Agricultural Engineering Postdam-Bornim, Germany, reported on two initiatives aimed at improving equipment compatibility and integration of multiple platforms.

Agricultural Industry Electronics Foundation (AEF) is an international partnership between implement manufacturers and tractor manufacturers within the agricultural industry. With a worldwide membership of over 100 companies the objective of the AEF is to promote the electronic standardization and assure that ISOBUS-implements and tractors from different brands.

A near market system 'iGreen' provides connectivity between multiple machines, irrespective of brand, to achieve two way data flow.

USA – Unmanned aerial vehicles (UAVs) were of interest Asia and Europe but in the USA they were the platform of the moment. At InfoAg, at least six providers of fixed wing and rotary UAVs or UAV based services were exhibited. No doubt this flurry of excitement has been triggered by the announcement of that the USA laws on the commercial use of UAVs will change in 2015 but the details have yet to be presented.

The use of precision technology is seen to be relevant across all industry sectors in the US, however, there seems to be tailoring to industry sectors. For example, initial robotic investments are being focused on horticulture and industries where smaller vehicles are appropriate. John Deere presented details of a fully automated orchard sprayer and mowing systems being tested in a commercial citrus orchard.

In the US, broadacre application of spatial management is similar to Australia but new commercial platforms are being developed.
For example, FieldScripts™ is a variable rate seeding package for corn, delivered by Monsanto through agronomists. To be fully launched next year this system uses up to 20 layers of data to provide a farmer with variable rate seeding maps for different Monsanto corn cultivars. Monsanto also owns the company that supplies the variable rate seeding equipment.

Apparently, Cargill is working on a similar product that may include other parameters but these are currently top secret!

Examples of technologies and potential uses that will be presented will include:

- Soil sampling –near infra red- on the go soil sampling.
- Weed control – laser weeding, micro dot spraying

- Nutrition – biomass sensing for phosphorus nutrition, hyper-spectral and thermal sensors to measure crop stress and to separate nutrient and water stress.
- Disease – hyper-spectral, fluorescence, bionic nose, high definition imagery, lasers to measure canopy structure and to control variable pesticide application.
- Platforms – UAVs and robots
- Phenotyping – ultra-sonic sensor, multi-sensor platforms

Conclusions

Over 300 papers and posters were presented at these three events. Many of these can be found in the programs on the conference websites. I encourage you to take a look at these resources to gain a taste of the diversity of precision management tools and applications that are in the pipeline.

In addition to myself, only seven delegates from Australia attended one of these three events. I encourage you all to take the opportunity to apply for funding to attend these and similar international events. I believe that supporting a team of a famer and researcher would be valuable to gain a broader perspective on the research opportunities and outcomes presented.

Notes

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SPAA Precision Agriculture Australia
PO Box 3490 Mildura | Victoria 3502
P 0437 422 000 | F 1300 422 279

www.spaa.com.au

Precision Agriculture Laboratory
THE UNIVERSITY OF SYDNEY
1 Central Avenue, Australian Technology Park |Eveleigh | NSW | 2015
P 02 8627 1132 | F 02 8627 1099

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