Increasing the Adoption of Precision Agriculture

Precision Ag and Vit expo

Friday 13th February 2009

At the Keith Institute, Heritage Street, Keith, South Australia

Increasing the Adoption of Precision Agriculture
At Landmark, our farm services team is constantly developing new technologies and innovative systems to help farmers increase their productivity. Our highly trained agronomists have the expertise and experience to advise you on everything from implementing sustainable cropping and pasture programs, to maximising returns from precision farming. We’ll give you the smart solutions you need to ensure you always maximise the profitability of your business, now and in the future. That’s why more Australian farmers look to us.
09:00 Registration

09:30 Welcome

09:40 Ian Yule ~ Massey University, Palmerston North, New Zealand
Variable Rate Irrigation

10:10 Andrew Weidemann ~ Grain Grower, Rupanyup, Victoria
Practical PA Experiences to Improve Farm Management

Premium Sponsor Presentations ~ New Developments in PA

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<th>Topcon</th>
<th>The latest in technology from Topcon Precision Agriculture</th>
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<td>10:50</td>
<td>Leica Geosystems</td>
<td>The role of infield data communications for precision farming</td>
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11:00 Morning Tea & View Sponsor Trade Exhibitions

11:30 Felicity Turner ~ PA Specialist, Meningie, South Australia
MacKillop Farm Management Group Precision Ag Project

Premium Sponsor Presentations ~ New Developments in PA

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<td>12:00</td>
<td>Gps Ag</td>
<td>gps-Ag adds real-time crop sensing to its PA solution</td>
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<td>12:10</td>
<td>Omnistar</td>
<td>A look at the current and future uses of CORS-HP, and its potential ability to deliver machine robotics to farmers</td>
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<td>Post Harvest Crop Insurance</td>
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12:30 Lunch & View Sponsor Trade Exhibitions
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| 13:55 | **Wade Nickolls**, Grain Grower  
Using PA in a Mallee Environment | **David Lamb**, University of New England  
EM38 in All-Steel Vineyards - a Cautionary Tale  
20 |
| 14:20 | **Rick Llewellyn**, CSIRO  
Making use of EM38 in the Mallee | **Suzanne McLoughlin**, Fosters Group  
PV to Improve Vineyard Management  
20 |
| 14:45 | **Ryan Milgate**, Grain Grower  
Experiences and Opportunities for PA in the South East / Western Victoria | **Hans Loder**, Wingara Wine Group  
Pruning to Vine Potential An Unforeseen Benefit of Applying Precision Viticulture Technologies  
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Variable Rate Irrigation

Ian Yule(1), Carolyn Hedley(2)

(1) New Zealand Centre for Precision Agriculture, Institute of Natural Resources, Massey University, Palmerston North, New Zealand
(2) Landcare Research, Palmerston North, New Zealand

Phone +64 6350 4340 Email i.j.yule@massey.ac.nz www.nzcpa.com

Take Home Messages

• Soil mapping techniques can be used to better estimate and map the soil water holding capacity under a centre pivot irrigator. This information can then be used to more accurately prescribe irrigation under a precision (spatially variable) management system.

• Significant savings in water of 20 to 25% have been predicted from test sites, these are based on the assumption that irrigation would normally be based on the driest zone within the paddock.

• It is possible to control an irrigator to deliver in a spatially variable pattern but much more sophisticated planning and operational software is required to control it.

• Initial estimates of cost effectiveness have been based on rather simplistic estimates of water saving. Further work is required to calculate optimum operating strategies according to environmental and financial constraints.

• Using variable rate irrigation allows complete freedom of what is grown under the irrigator allowing much greater flexibility within the farming system.

Background

Variable rate irrigation is introduced as a possible method of improving irrigation water use efficiency, where the specific demands of a crop can be met at any point under the irrigator. Centre pivot irrigators are now the most popular system type being installed on New Zealand farms, a trend similar to the rest of the world. It is a method that has the advantage of very low labour demand and a high level of automation. One of the main problems is that it is a relatively inflexible system which has a major impact on the farming system under it.

Traditionally, irrigation uniformity has been a desirable goal, as farmers could have some assurance regarding the level of irrigation water applied at any point under the irrigator. While having reliable application is clearly important the concept of uniform application is challenged. Having total control of the irrigator and its application performance at any point under it will allow farmers and growers to optimise land use. In New Zealand for example where soil variation does not necessarily follow sectors of an irrigator it may be possible to opportunistically grow high value crops under parts of the irrigator where soils allow. Dairy farmers want to exclude farm infrastructure such as races and yards as well irrigate according to soil water holding capacity.

While these farm management goals are desirable the main focus of this paper is to illustrate practical methods that can used to improve water use efficiency. This can be achieved through using rigorous soil mapping techniques to map the calculation of soil water availability. This is used to calculate soil moisture status and schedule irrigation to specific points under the irrigator on a daily basis. Improved water use efficiency is seen as a key issue that needs to be faced by the agricultural industry.
Irrigation consumes around 70% of allocated freshwaters globally (Jury & Vaux, 2007) and in New Zealand the figure is 80%. The starting point to mapping daily soil water status is to use apparent soil electrical conductivity (EC). In New Zealand where salinity is not an issue EC mapping is seen as a surrogate measurement for soil texture. The EC map is used as the basis for further investigations of the soil in order to thoroughly characterise the soils within the site. A site from the property of Mr Hew Dalrymple, near Bulls Manawatu is used as an example to show how the water use efficiency could be improved.

A soil EC map was developed from a survey using a high resolution on-the-go RTK-DGPS linked to a Geonics EM38. For the purposes of this example the topographic information and soil water movements were not used as a dynamic element in the calculation of irrigation water requirement. It did however have a major influence of the soil formation processes on the site which is reflected in the EM map.

Three soil zones, as described by Hedley (2008), were selected on the basis of soil EC within the site. The selected zones were used to collect further samples for laboratory analysis of moisture release characteristics and particle size distribution. Three replicate sites were selected in each zone and soils were sampled at four depths (0-150, 150-300, 300-450, 450-600 mm) to obtain one mean value for each zone.

The relationship between available water holding capacity (AWC) and soil EC (Figure 1) was used to derive an AWC map (Figure 2), Hedley et al (2008). Zone C had the highest percent sand (94.5%) and the lowest soil EC compared to the other two soil zones (87.3%, 88.3%). Also soil EC increased with plant available water storage capacity (Figure 2).

A site specific daily water balance was used to predict the drying rate of these soils, so that each soil AWC point value was adjusted on a daily basis from a starting point when the soils were at field capacity (17 November 2007). The trigger for irrigation was set for 55% of AWC, so that the calculated date for irrigation commencement was 28 December (Zone C), 15 January (Zone B) and 16 January (Zone A). The soil water status map derived for 4 January 2008 (Figure 3) identifies that Zone C requires irrigation (marked black). This information can be uploaded as a shapefile to a variable rate irrigator, to programme operation of individual sprinklers on a daily basis.

Conclusions

The ability to irrigate soils on a basis of individual AWC introduces efficiencies of water use, including better use of stored water and less use of water overall; as well as maintaining optimum yield because each soil is irrigated to its irrigation trigger point and readily available water is maintained to the plant root zone. An analysis was completed for the growing seasons 04-05, 05-06, 06-07, as
detailed in Table 1, a 20 to 25% water saving could have been achieved, for this 22 ha site, other sites on the farm have offered similar savings. The impact of variable rate irrigation on water saving will clearly be site specific and it important that adequate soil mapping work is completed before investment decisions are made. There will also be differences between seasons, temporal variation, depending on weather conditions.

The Foundation for Arable Research FAR (2008) estimate irrigator operating costs as being NZ$1.30 per mm ha-1, this site would produce a saving in operating costs of between $77 - $113 per ha. Where water charges are in place then clearly there would be a much larger saving. This is based on the rather simplistic assumption that the farmer would irrigate according to the driest zone. This may not be the case, further information such as previous yield maps, could be used to calculate the potential financial return. This is seen as a rather subjective assessment at this stage and further work is required in the optimisation of irrigation at each point under the irrigator, where all environmental and economic factors can be taken into account. In order to achieve Variable Rate Irrigation (VRI) control systems have to be added and more sophisticated software within the overall framework of a GIS system is required. The estimated additional costs is approximately NZ$100 per linear (November 2008) meter of the irrigator.

### Table 1. Water savings on field site.

<table>
<thead>
<tr>
<th>Site</th>
<th>Area ha</th>
<th>AWC mm/m</th>
<th>Year</th>
<th>Irrigation mm</th>
<th>Total irrigation / season ML</th>
<th>VRI Water Saving</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ML % mm/ha</td>
<td></td>
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<tr>
<td><strong>Uniform Rate Irrigation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize field</td>
<td>22</td>
<td>85</td>
<td>04-05</td>
<td>380</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>05-06</td>
<td>430</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>06-07</td>
<td>230</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td><strong>Variable Rate Irrigation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone A</td>
<td>3.5</td>
<td>329</td>
<td>04-05</td>
<td>210</td>
<td>19</td>
<td>23</td>
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<tr>
<td>Zone B</td>
<td>11.9</td>
<td>214</td>
<td></td>
<td>270</td>
<td>20</td>
<td>87</td>
</tr>
<tr>
<td>Zone C</td>
<td>6.6</td>
<td>85</td>
<td></td>
<td>380</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Zone A</td>
<td>&quot;</td>
<td>&quot;</td>
<td>05-06</td>
<td>260</td>
<td>19</td>
<td>20</td>
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<tr>
<td>Zone B</td>
<td>&quot;</td>
<td>&quot;</td>
<td></td>
<td>320</td>
<td>35</td>
<td>87</td>
</tr>
<tr>
<td>Zone C</td>
<td>&quot;</td>
<td>&quot;</td>
<td></td>
<td>430</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Zone A</td>
<td>&quot;</td>
<td>&quot;</td>
<td>06-07</td>
<td>100</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Zone B</td>
<td>&quot;</td>
<td>&quot;</td>
<td></td>
<td>160</td>
<td>19</td>
<td>25</td>
</tr>
<tr>
<td>Zone C</td>
<td>&quot;</td>
<td>&quot;</td>
<td></td>
<td>230</td>
<td>15</td>
<td>59</td>
</tr>
</tbody>
</table>

**References**


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iTEC Pro™ (intelligent Total Equipment Control) is a revolutionary control system, that takes precision guidance to a whole new level. iTEC Pro™ automatically steers the tractor and makes headland turns a hands free operation. As you approach your headland turn, it slows down your ground speed, lifts the implement, steers the tractor into the next row and re-engages your implement without you ever touching the wheel.

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Since leaving school in 1981 and returning home to the family farm many changes have taken place. We farm approx 2700 ha in the Wimmera our soils are 95% self-mulching grey clays with Ph ranging from 7.6 to 8.4. The other 5% of our farm is made up of small timber belts of natural and man-made shelter paddocks and pasture areas. These soils are made up of Self-mulching grey clays and sandy loam. New products and ideas have been tested over the past 20 years and some things have remained and others replaced with newer and more up to date systems. The modern farmer has a number of issues to contend with and there are plenty of choices for them to make.

The adoption of new ideas and techniques on our farm has been ongoing. My parents had a philosophy of keeping up to date with not only the latest information but also the latest technology, which has made our farm operate on a profitable basis.

In 1990 we ventured into direct drilling and stubble retention to help the soils capacity to retain moisture and to improve the general soil health on our farm. During this time paddock recording and soil testing has been an integral part of this system. Currently paddock and soil test data are stored on Pivot Pam QA®, which is complemented with the Pocket Pam® recording system that has become our notebook recording system.

In 1995 we moved into yield mapping and more intensive soil testing with the help of Pivot Fertilizer agronomists. This work has opened up many questions and trying to find all of the answers have made it extremely challenging and interesting. Making profit from this technology has been hard to quantify but we place a lot of emphasis on the information gained.

EM38 soil surveying, trialing the HYDRO N Sensor measuring biomass on the move through the use of NDVI sensors, and more recently the introduction of satellite photo imagery, has given us more opportunity to evaluate yield data and soil types in the one paddock & make decisions on nitrogen applications in crop. Used in combination with the climate based APSIM yield prediction model, the probability of achieving productivity gain is enhanced. Trialing new varieties and using Variable Rate Technology has also been an integral part of this approach.

With the adoption of this technology and the use of satellites for site-specific work the use of machinery guidance has evolved. Through the use of guidance systems, we have found a way of making measurable savings on input costs. With average savings of around 5% on input costs this has made the option of Auto steer Guidance more affordable for the average farmer and more importantly improving efficiency and returning more profit. Auto steer guidance has also allowed us to try different crop management techniques such as wider spacing Beans & Chickpeas and inter-row spraying with a shielded sprayer. Cutting input costs in some cases by as much as 40%.

Oaten hay is now a part of the rotation in cropping as we look to other methods of weed control on ryegrass and wild oats.

Now, a major challenge is to use the information we are gathering to improve the natural resource management on our farm without compromising profitability. Although this will not be easy, we believe the business is well positioned to achieve this.
Controlled Traffic System
Our farming system combines the use of a controlled traffic system based around the wheel centre of conventional tractors using a wheel centre of 2.1 meters.

Our farm machinery equipment that we use are as follows:
JD 8410T, 8100 FWA, 7820 FWA, 7210 FWA. Working on 2.1m centers Auto steer compatible.
11.75m seeder on 250mm spacing.
36m Boom spray set to centre nozzle. We use a 40° 03 even nozzle over the rows early in the season and progress to an 80° 03 even nozzle mid spring.
JD 9760sts Header 11m front.
11-shield TPOS inter-row sprayer.
We sow Beans & Chic peas on meter centre paired rows. All other crops are sown on the normal 250mm spacing.
We currently use the John Deere Base RTK system as well as the SF1 system. Our repeatability is quite easy because our run lines are all setup on either 0° or 90° and by using the nudge button to compensate for the drift we are able to re enter the paddock at a later date and follow the same tracks.

Managing the Stubble
Up until 2003 we had mulched all of the standing stubbles to sow our pulse crops into since then Beans & now chic peas are all sown into standing stubbles on the Meter paired row system. Lentils and even cereals are sown inter row where possible and at this stage we have been able to manage 4t ha stubbles but the system will be tested should we return to larger stubbles or a more normal season.

Crop Insurance Post harvest Policy
One of the key issues we have faced during the last eleven years of uneven GSR and frost events is being able to predict accurately yield from paddocks pre harvest for Insurance purposes. We were either under insuring or over insuring crops and found this to be very expensive on our business. After a lot of discussion over a number of years with our insurance agent we were approached by our local Insurance representative to investigate the concept of a new insurance product called post harvest premium.

Requirements: November 15th to notify agent of prices and an approximate yield.
• Post harvest provide yield data summery for each paddock insured to agent by end of January then premium is struck.
• Yield monitor is calibrated to be within 10% of the actual yield.
• Has been an excellent policy and has the same cost as pre harvest premium.
• We believe it to be a fair product considering the seasonal finishes we have been experiencing and we have full confidence in it.
• Claims are managed as normal.
• We have been insuring crops this way since 2003.
As you can see the past few years has made life interesting on the land. We are excited about the future of agriculture, and the challenges it will bring.
SPAA has negotiated a crop insurance package on behalf of our members with MGA Insurance Brokers Pty Ltd. The package offers benefits to both SPAA members and to SPAA. SPAA members receive discounted rates on their insurance whilst the association also receives a sponsorship premium for each insurance package that is taken up.

The policy is arranged by Millennium General Insurance and Insurance Facilitators with MGA Insurance Brokers Pty Ltd.

The major feature of this policy for SPAA members is the ‘After Harvest Declaration’ where members can have their crop insurance premium based on the actual crop yield at harvest, as recorded by a yield monitor.

**Advantages of the After Harvest Declaration:**
- You only pay a premium on what you harvest from the paddock
- No requirement to fix final revision yields prior to harvest
- Claims are paid on the loss of potential harvestable yield
- Allows for yield loss due to unforeseen frost damage to the crop i.e. pay on harvested yield
- Pay the same rate as that of the Final Revision policy option
- Claims are paid on the proportion lost (%), paid against the potential yield x agreed value, less any excess that may apply.

**Other benefits include:**
- An agreed value per tonne
- Seed and grain in transit
- Seed and grain in storage
- Chemical overspray
- Straying livestock

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Chris Noonan
Phone 08 8632 5588  Email chris.noonan@mga.com
AFSL 244601
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Towards Better Vineyard (re)design

Rob Bramley¹, Colin Hinze² and David Gobbett³
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²Taylors Wines, PO Box 90, Auburn, SA 5451.
E-mail Rob.Bramley@csiro.au

Many people will be familiar with the sort of schematic description of Precision Agriculture/Viticulture (PA/PV) shown in the figure below – Observations of the production system (eg yield maps, remotely sensed imagery), supplemented by explanatory data layers (eg soil maps, elevation models) are used to identify zones for which differential management may be appropriate.

The most important feature of this description of PA/PV is that it is a continuous cyclical process in which the information collected is used to make future decisions. It is arguably a failure to understand the predictive value of PA/PV data that is constraining PA's wider adoption, with some growers failing to see that a yield map is much more than a measure of what happened this year.

We were interested to see whether the same philosophy could be brought to bear on the question of vineyard (re)design. To this end, we have been working on a small GWRDC-funded project which seeks to assess the value of high resolution spatial information about soils and previous system performance in informing the redesign and renovation of a Clare Valley vineyard. This presentation will outline progress to date.
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We farm 4000ha at Pinnaroo in the Southern Mallee. Wheat, barley, triticale, hay, canola, peas, lupins and vetch are the majority of our program with our livestock operation ceasing in 2008. Most of our country is generally flat with some gentle rising hills.

**Steady progression into Precision Agriculture**

**2004**  Guidance with Zynx X15 on boom spray, auto section control and spray controller  
Yield mapping setup on JD 9760 using JD Office mapping program

**2006**  JD auto steer with SF1  
Variable rate with Zynx X20, Horwood Bagshaw seeder

**2008**  Variable rate used over total farm

**2009**  JD base station and 2cm RTK accuracy for seeding

**Main focus is on variable rate over the past three years**

- Only using three zones to keep everything as simple as possible
- Zones defined using EM38, yield maps or paddock knowledge
- P replacement has been important with higher fertiliser prices
- Good for variety comparisons
- Ability to vary cultivars within a paddock has benefits
- Opportunities exist to vary seeding rate

Use plenty of technical support especially in the early days
VR and auto steer make the seeder simple enough for anyone to operate
Increase in paddock gross margins significant with VR, mainly with not using blanket rates for fertiliser

**Wish list in the future**

- Weed seeker
- Full controlled traffic system
THE COMPLETE SEEDING SOLUTION

**X20 Seeder Control**
Control up to 5 tanks, granular, liquid or gas. Change the application rate at any time.

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Warns of head blockages while seeding.

**X20 Variable Rate Control**
Variable rates of seed and fertilizer precisely where you need it.

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EM38 in All-Steel Vineyards - a Cautionary Tale

David Lamb
Associate Professor, Precision Agriculture Research Group
University of New England, Armidale, New South Wales Phone 0428 886088
Email dlamb@une.edu.au www.une.edu.au/study/physics-electronics/precagric.php

Take Home Messages

1. Distortion strong in all-steel systems
   • Unlikely with all-wooden posts due to poor loop paths
2. Keep to centre of row spacing (within 20 cm of track)
   • Dnote that deviation > 20 cm results in deviation >10% ECa
3. Trellis loops CAUSE offset in ECa
4. Do not survey row spacings < 3.0 m as loop currents cause further modulation in ECa
5. Do not include regions of different trellis-types in a single area for processing (eg surface fitting)
6. Evidence suggests distortion is an additive effect
   • Soil detail superimposed on trellis effect
7. Possibility of correction protocol (Clark et al) based on ‘handful’ of adjacent post measures
8. If in doubt- dig a hole !


Background

The need to measure and map spatial variations in soil characteristics, including texture, water content and salinity within agricultural fields has driven the development and application of electromagnetic (EM) induction soil survey instruments such as EM-38 and EM-31. EM soil survey technologies work on the principle that a small transmitter coil in contact with the soil, energised with a sinusoidal current of low frequency, typically ~10 kHz, produces a time-varying primary magnetic field (H_p) in the sub soil. Where the primary field lines pass through an electrically conductive medium, in this case the soil, local electromotive forces (EMFs) are induced, and depending on local soil conductivity, eddy currents are induced to flow. These eddy currents in turn generate their own secondary magnetic fields (H_s), in much the same as the way the primary magnetic field was originally generated in the EM unit. The individual current loops are not influenced by others nearby. Consequently, the net secondary magnetic field at the receiver is the sum of the independent secondary magnetic fields from each of the individual current loops.

This process of electromagnetic induction results in a secondary magnetic field that is 90° out of phase with the primary field. The sensor coil is designed to measure this out-of-phase component, hence the notion of quadrature. At low induction numbers (that is, the ratio of the distance between transmitter and receiver coils, to conductor skin-depth), the apparent conductivity in the vicinity of the transmitter coil is determined by the ratio of the magnitudes of the out-of-phase secondary to primary magnetic fields. When operated in both vertical and horizontal dipole mode, the axis of symmetry of the primary field lines are, respectively vertical and horizontal. In both modes it can be shown that the primary field lines extend out to the sides of the EM unit along the horizontal plane of the ground. When used in an established vineyard for an EM survey, the EM sensors are moved along transects in the inter-row spacing. Unlike ‘open’ agricultural fields, vineyards offer highly conductive
loops (placed in a vertical plane) which comprise steel trellis posts, wires and a portion of the ground (between the posts) in the vicinity of these sensors. It is likely that the secondary magnetic fields induced by current flowing in these highly-conductive loops may add to secondary magnetic fields generated by the conductive earth beneath the sensor, and therefore modify the overall conductivity estimates returned by the sensor. Noting that EM surveying technologies are being increasingly deployed in established vineyards, an investigation of the possible artefactual effects from steel vineyard trellising on ECa values from EM devices is warranted.

This presentation describes the results of a detailed investigation into the effects of VSP trellising with varying row spacing on apparent conductivity as measured using an EM-38 unit in vertical dipole mode. Implications for ongoing application of this technology in established vineyards are discussed, and key issues for further investigation are identified.

Test site and ancillary field measurements

- The investigation was undertaken in the centre of a 12 ha field (Paddock 15A), located at Kirby Farm (University of New England Rural Property) in the New England Region of Eastern Australia.
- The test site, measuring 85 m x 70 m (approx. 0.6 ha) was selected within this field on the basis of being flat and of uniform soil type, predominantly Chromosol/Ferrosol with a clay loamy A horizon (0-20 cm) and clayey B horizon, and exhibiting low ECa variability.
- This test-site incorporated the region to be occupied by the trellises and a 20 m wide buffer around the extent of the posts/wires. Within this test site, sixteen rows of VSP trellising, each row 30 m in length, were progressively erected, and then progressively dismantled.
- Each row of completed trellising comprised 150 x 2700 mm (6” x 8’) treated pine end-posts, four 2.7 m steel “gripfast” posts, a dripper guide-wire, cordon wire, grab wire and four foliage wires (2 pairs). The wire used was 2.5 mm high-tensile “flexabel”. The steel posts were driven 70 cm into the soil.
- Soil temperature readings at a depth of 60 cm and air temperature were recorded at 30-minute intervals throughout the course of the experiment.

Electromagnetic (EM-38) surveys

- Measurements of apparent soil electrical conductivity were completed using a Geonics® EM-38RT unit (Geonics Ontario, Canada) operated in vertical dipole mode. Prior to conducting each set of measurements throughout the course of the experiment, the instrument was switched on and warmed up for a period of 15 minutes, and zeroed following the standard Geonics protocol. Immediately following the zeroing procedure, the unit was placed on the ground at a pre-designated calibration point and the ECa measured and checked to ensure it was repeatable to within 5%.
- Two-dimensional surveys were completed by towing the EM-38 unit behind an all-terrain vehicle (ATV) on a rubber sled at a speed of 10 km hr⁻¹. The EM-38 unit itself was placed in a thermoplastic case (with styrofoam insulation on either side and a cover over the top to reduce case temperature fluctuations). The distance between the unit and the surface of the ground, as dictated by the bottom of the case and thickness of the rubber sled was approximately 15 mm.
- The continuous output data stream from the EM-38 unit was fed into a Trimble TSCe® datalogger along with the DGPS location information, every second, from a Trimble differential global positioning system (DGPS) (Trimble, Sunnyvale California, USA). With each survey, the ATV was driven between, and around the trellis rows (to cover the entire buffer and trial region) by following previously defined lines (marked in paint) on the ground. This particular requirement was considered crucial as it was the only way to guarantee that post-processing of the point-ECa data into surfaces would not be influenced by the varying locations of point data that would have occurred in each survey.

Sequence of trellis manipulation and ECa measurements

- Two-dimensional ECa surveys were conducted in sequence, corresponding to the following trellis manipulations; the bare field prior to trellis erection, after erection of the steel and wooden posts (ie no wires), following installation of all wires, following removal of all but the dripper wires (ie only dripper wires remaining), following removal of dripper wires (no wires- only posts remaining) and following removal of posts (return
Figure 1.
Two-dimensional ECa maps generated for (a) bare field, (b) wooden end posts and steel posts only, (c) posts and dripper wire, (d) posts and all wires. (•) = steel posts, (+) = wooden end posts. Treatments, outlined by the grey squares within each map are, from left to right; 2.5 m 3.0 and 3.5 m row spacings respectively.

Figure 2.
Re-scaled 2-D ECa map for full trellising in place. (•) = steel posts, (+) = wooden end posts. In this grey-scale coding the bare field ECa values range from 20-40 mS/m. The bare field map would thus appear uniform and coloured black, the same as the buffer region in this figure. Treatments, outlined by the grey squares are, from left to right; 2.5 m 3.0 and 3.5 m row spacings respectively.
The first ECa survey was conducted in the bare field at 0830 (AEST) and the final survey conducted in the bare field at 1630 (AEST). Within the measurement limit of the sensor, the 60 cm soil temperature did not vary throughout the entire experiment and the air temperature varied by a maximum of 2.7 °C. After zeroing the instrument prior to each survey, the ECa value recorded at the designated calibration point varied by only 2 mS/m (approximately 4.2%) between the first two sets of measurements, and remained fixed at 48 mS/m for subsequent measurements.

The effect of trellis manipulation on the 2-D ECa maps

- The ECa maps created from each 2-D survey are shown in Figure 1. Comparison between the ECa maps of bare field and that of steel posts (Figures 1(a) and (b)) indicate that there is little influence of the steel trellis posts on the resulting 2-D maps. Comparison of these figures with Figures 1(c) and (d), however, indicates a significant influence of the dripper guide-wire and subsequent addition of cordon, grip and foliage wires on the 2-D maps. Here, due to the ECa scaling used, the high-end portion of the grey-scale values are saturated.

- The influence of the final full trellis structure on the ECa maps is further highlighted in Figure 2, where ECa grey-scale have been re-scaled to enhance the high-end values. The map of Figure 4 suggests an along-row edge effect whereby the ECa values increase from the buffer region values (or that of the bare field) to a maximum in the centre of the trellising. In the case of longer rows, we speculate that the ECa values would then level out to what would amount to an offset to the bare field values.

- In Figure 2, however, it can also be seen that when all trellis wires are erected, the ECa values along the 2.5 m row spacing are modulated, with local maxima coinciding with the EM unit located midway between steel posts along each row. There is also a suggestion in the data of an along-row modulation for the 3 m row spacing map but no such modulation for the 3.5 m row spacing.

- The mechanism of the along-row modulation observed in the 2.5 m row spacing segment of Figure 2 may be explained as follows. As the EM sensor is moved along the rows, more of the magnetic flux either side of the sensor is intercepted by the conducting loop comprising the ground, steel posts and above-ground wires because the sensor is midway between the posts (a greater loop area presented to the primary magnetic field). The necessity of a closed conducting loop is particularly illustrated given the ECa map for the steel posts only (without wires) is the same as that of the bare field. (Figures 1 (a) versus (b)).

Conclusions

- Electromagnetic induction soil survey techniques (eg EM31/38), measure apparent electrical conductivity (ECa) and work on the principle that electric current is induced below the ground surface by a low-frequency oscillating magnetic field. The return magnetic signal produced by the underground current is detected.

- All-steel vineyard trellising act as large antennae and distort the electromagnetic response of these sensors.

- An artificial vineyard was ‘built’ and then dismantled in a single day and the EM38 surveys compared.

- The ECa profile of the bare site (ie without vineyard) was found to be modified by the trellising, with the least modification from steel posts only, and the degree of modification progressively increasing with the addition of wires up to to the final trellis assembly.

- The ECa values were found to increase from a range of 20-50 mS/m for the bare field to a range of 100-130 mS/m for the assembled trellising, with the amount of increase greatest for the smaller row spacing.

- The results indicate that extreme care must be exercised by an operator to ensure that the EM-38 antenna/sensor unit remains mid-row throughout any transects and that changes in trellising structure/row spacing may introduce artefacts in EM-38 maps.

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NOTE: use of commercial product trade names, for example EM38, does constitute an endorsement of these particular products.
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Making use of EM38 in the Mallee

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Take Home Messages

• An EM survey conducted on a typical Mallee paddock has a high probability of effectively mapping soil characteristics that are important in determining yield potential and useful in developing zones for variable rate applications.

• The variation mapped at the time of the survey is likely to be based on relatively stable soil characteristics affecting plant available water across Mallee soils.

• Results from farmer field trials and longer-term modeling have shown fertiliser inputs and risk can be reduced and average paddock gross margins increased by zoning Mallee paddocks according to the potential yield responses of different soil types.

• With relative reliability and stability allowing for practical application on Mallee soils, the number of agronomists and service providers delivering EM-based variable rate agronomy services has increased; the costs of EM surveying has declined; and the area of cropping land EM surveyed is now over 150,000ha in the Victorian Mallee alone.

Background

Increasing cropping intensity, rising fertiliser costs and greater recognition of the importance of salt-related chemical constraints in determining crop water use efficiency on Mallee soils has led to increased interest in variable rate fertiliser applications. Over the past three seasons, Mallee Sustainable Farming, in partnership with CSIRO and Mallee Focus, have conducted field testing of EM38 and run a number of farmer trial paddocks aimed at developing cost-effective ways to define zones for profitable variable rate applications. A main aim was to develop the practical application of EM38 as a tool to assist more cost-effective and lower-risk input use on Mallee soils. The GRDC-funded project has also used modeling to test the performance of variable rate N applications on the EM-based zones under a long-term range of season-types.

Electromagnetic (EM) mapping measures the apparent electrical conductivity of soil. It responds to a combination of soil water, salinity and texture in varying proportions. While it is always necessary to take soil cores to calibrate and validate EM38 measurements, EM38 mapping is particularly useful in the Mallee as it usually correlates well with important soil characteristics that are associated with crop yield potential such as common salt-related subsoil constraints that reduce plant available water. Knowledge of variable crop yield potential can then be used to inform decisions about variable rate fertilizer application.
Conclusions

EM maps on typical Mallee soils reliably map important and relatively ‘fixed’ soil characteristics related to potential yield and fertiliser response. Field results in the dry 2006 and 2007, together with simulated results over a longer-term range of season types show that zonal-based management can reduce fertilizer inputs, increase the probability of an economic return on fertilizer applications and increase paddock gross margins. This reliability and stability means that on Mallee soils, EM-based maps are now being widely used as a relatively low cost stable base layer for developing paddock zones.

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Background
The tools of Precision Viticulture have been used on Foster’s Vineyards for well over 10 years as an aid to management decisions relating to meeting target yield and quality specifications. Plant Cell Density (PCD) images created using the ratio of infra-red to red reflectance have been the most commonly used form in Foster’s vineyards to date. These PCD images highlight areas of differential vigour in the vineyard, attributed to many underlying factors, some of which include changes in soil type, soil depth, salinity, vine health, water table depth (waterlogging) and past site use. Once these differentially vigorous areas are ground-truthed, Vineyard Managers can choose to zonally manage economically viable areas. That is, they apply specific management techniques to these zones within a larger block boundary, in order to maximize the grape quality of these zones and therefore the overall block. It is important to note that the expected quality (vine performance) of identified management zones relative to the remainder of the block is likely to vary on an annual basis due to seasonal influences on the underlying factors creating this variation in vine vigour.

Use of Precision Viticulture for General Vineyard Management
Penfold’s Robe Vineyard has successfully applied precision viticulture for at least 6 years to aid production of its premium quality grapes. Management of the vineyard is tailored to each variety and quality grade, with many blocks zonally managed. This vineyard is located approximately 15km south-east of the township of Robe, South Australia. It has a cool, maritime climate, influenced by its proximity to the Southern Ocean and nearby large salt lakes – Lake Eliza and Lake Hawdon. The western side of the vineyard on foothills of the Woakwine Range is gently undulating, whilst the land on the eastern side of the property is quite flat. The soil profile is generally very shallow (5cm – 45cm) loamy sand over limestone, with smaller areas of Terra Rossa over limestone and deep sandy loam. This variation in soil type and depth, often occurring down the vine rows, adds complexity to managing the vineyard.

To handle the existing variability in soil type and depth and the resulting effects on vine vigour and grape quality, Plant Cell Density images are utilised to facilitate zonal management for the following functions:

- **Irrigation** – taps have been installed to shut off water to sections of dripper lines down rows for vines growing in deep soils where elevated vine vigour is negatively impacting grape quality.

- **Pruning** – sacrificial canes have been employed as a devigourating technique for vines growing in deep soils. Without intervention, these vines traditionally have relatively dense canopies and large berries. For this technique, vines are spur pruned (as per traditional pruning method) but canes are also retained during pruning to vastly increase bud numbers per vine. These sacrificial canes are then removed later in the season (assuming fruit set has been successful) leaving remaining bunches with smaller berries, concentrating colour and flavour and a balance of fruit to canopy growth.

- **Covercrops** – Lucerne, a deep rooted perennial, has been planted in the midrows of deep sandy soils as another method of devigourating vine growth.
• Compost application – the shallowest soils commonly occurring on the rocky ridges show the lowest vine vigour and lightest crop loads. Compost has been strategically placed undervine in these areas in the vineyard to successfully increase vine vigour, overall vine health and crop load.

• Harvest – blocks are harvested according to zonal management to fully realise the potential of these zones differentially managed throughout the season. These zones are separately maturity sampled due to their often different ripening rates, expected qualities and yield. Winemakers taste the fruit from these zones separately in the vineyard and batch ‘like’ zones together to produce minimum 10T batches of fruit. These zones are ‘split picked’ out of the remainder of the block, either by using tractors towing two bins, one for each zone of fruit to be harvested, or by harvesting out one zone and then waiting for the remainder of the block to reach optimum ripeness and re-harvesting the block.

New Plant Cell Density images are obtained by the vineyard every few years in order to visualize changes in relative vine vigour, attributed to the above management techniques employed by the vineyard manager.

Use of Digital Elevation Modelling to position frost fans

Penfold’s Robe Vineyard utilized another Precision Agriculture technique, Digital Elevation Modelling, to assist in pinpointing the most suitable locations for installing frost fans in the vineyard. A series of three-dimensional images of the site were produced – a base map of the vineyard, a map indicating air movement through the vineyard and a map showing frost damaged areas from the previous season’s damaging frosts. The information from each of these images was overlaid and used together with the frost fan manufacturer’s specifications to identify the most suitable placement of the frost fans to protect the maximum area of high frost risk vineyard. In addition, sections of tree lines were also identified for removal, to enhance drainage of cold air away from the site during a frost event.

The successful placement of the frost fans was realized the following season after installation, with the four fans protecting the crop from frost, resulting in payback for this project at just over one year.

Conclusions

Zonal management aided by precision viticulture tools such as PCD imagery, facilitates detailed management of a vineyard, allowing small parcels of premium fruit that would otherwise be absorbed into a large batch to be isolated and harvested with ‘like’ batches to maximize the quality grade of the vineyard.

Plant cell density images often do not reveal variations in vine vigour that a good manager is not already aware of. However, these variations in vine vigour once ground-truthed, allow the manager to pinpoint with accuracy, the shape of a zone to be differentially managed within a block and the apparent differences in fruit quality between these variations in vine vigour. The manager is therefore provided with more confidence that the zone may be of a size to warrant zonal management.

Digital Elevation Modelling can be a useful tool for Vineyard Managers who require a detailed topographical model of their property in order to fully assess impacts of various installations such as frost fans on their site. Vines growing in cooler, lower elevations can produce enhanced quality with Chardonnay for example, and this can merit split picking in some circumstances. Other uses for this tool include mapping of water movement through a site pre-installation of drains or drainage bores, or to map movement of saline water through a property and its future impacts on vine health.
Take Home Messages

• Autosteer is only the start of PA.
• Gather and Measure variation across paddocks thorough yield maps, soil tests, elevation maps, EM38 and your knowledge.
• Understand what causes this variation.
• Use this information to maximize your returns from your inputs in each area of the paddock.

Background

Llanthro is a 4000ha property located at Apsley, Vic, about 10km from the SA border. It is owned by Tom and Susie Porter and I am the cropping manager. There is both cropping and sheep run on the farm with around 15000 sheep across three flocks (merino self replacing, merino to 1st X and 1st X ewes producing lamb). Cropping takes in 2000ha and crops grown are canola, wheat, barley, peas, chickpeas and some oats. All cropping is dryland except for 40ha under two centre pivots.

All crops are now grown on a 9m controlled traffic system, using no till and retaining all residue by inter row sowing. The basic rotation is canola, wheat, barley then peas of chickpeas and back to canola although there can be many variations due to specific issues in paddocks.

I have been managing the cropping operation at Llanthro since 2004. When I first came to the property there was around 800ha in crop which was managed in a very conventional way. From what I saw in my first few months on the property it became apparent that we would need to make many changes to address issues such as burning of stubble and soils that lacked structure and went from being boggy to rock hard in a few weeks.

One of the first things that we identified was a significant compaction layer in the soil from years of heavy stocking rates during wet times of the year. We also decided that the best way to attack this was to retain all of our organic matter and stubbles to improve soil health. With this in mind 2cm autosteer was purchased to enable us to inter row sow into heavy cereal stubbles and a new airseeder bar with 300mm spacings and the ability to deep rip to 150mm and sow the seed at a constant depth with press wheels. The width of this machine was 9.6m. Fertiliser rates were a blanket 100kg/ha DAP across the farm.

In September 2005 we purchased our own header with a 9m front and set it up to yield map so we could see the variation within our paddocks and in the future maybe use this information for variable rate applications. JD Office was the program used to view the yield maps. During harvest in 2005 we noticed that they spray tracks had cracked from the compaction and we were getting green unripe grains in these areas, which were an issue in some paddocks.

From what we saw in late 2005 the decision was made to go to a full controlled traffic system with 9m as the base unit and 3m wheel tracks. Tynes were rearranged on the bar and spacing was adjusted to 320mm with the wheel tracks being left unsown. Cotton reel spacers were put on the front of the tractor and the back wheels wound out on the axels. The boom axle was adjusted and wings extended to 27m. Although 2006 was an extremely poor year, yield mapping really showed the variations that we have in paddocks with cereal yields varying from 250kg/ha to 5t/ha within a few hundred meters. At this stage we were still just looking at yield maps because we perceived variable rate as being very time consuming and difficult to produce prescription maps.
2007 was much the same with improvements being seen in cropping paddocks through less compaction. Fertiliser rates were reduced to reflect the reduction in yields in 2006. After harvest in 2007 with rising fertilizer costs we decided to go down the variable rate path much more seriously and sought help from Felicity Turner who cleaned up our yield maps and we developed prescription maps for our fertilizer. We had been running the airseeder though our X15 for 3 years and it was just a matter of registering the maplink software for $1000 and loading the maps and away we went without any problems.

With Gypsum and Lime also being large costs in our system, EM38 surveys have been done over 500ha and will be used to generate lime and gypsum prescriptions and will be used along with yield maps to fine tune our Nitrogen strategies into the future.

The future for PA at Llanthro is endless, more EM38 surveys will be done and overlaid with yield and elevation data, remote sensing is on the wish list (Yarra N sensor?) and further fine tuning of our existing system.

**Conclusions**

With PA I have a much better understanding of many factors that influence crop production across a paddock, now I have this knowledge I can start to manage to reduce variation and maximize the return from inputs.
Take Home Messages

1.) What began as a water use efficiency trial, using EM38 to determine soil RAW and PCD images as one of the bench marks of irrigation effectiveness, ultimately provided information which improved the overall management of the vineyard.

2.) Shallow soils limit overall vine potential

3.) Segmented harvesting was not seen as viable or the best option. Instead, it was felt that vine balance in the vineyard could be improved by adjusting pruning rates.

4.) Initial findings suggest that the treatment has proven effective in delivering uniform shoot length and canopy architecture.

5.) Comparison with pruning trials conducted by Tony Profitt in Margaret River WA, underlines the point that there are broad applications for PV data once it is collected.

Background

Soil surveying prior to vineyard planning and establishment is desirable, if not mandatory as is the case for some parts of Australia. In Coonawarra, however, production of a detailed soil map prior to planting has not always been the norm.

Vineyard variability is the inevitable result of uniform management across soils of varying types and depth. In this trial, soil depth was determined as a primary limiting factor on vine “potential,” expressed primarily by vigour.

In the traditional sense, potential has been accounted for at pruning time, with each vine assessed in relation to its response to the previous seasons pruning. The ascendancy of mechanical pruning methods has seen the loss of much of this control and therefore increased variability. Precision viticulture (PV) technologies, however, are once again empowering vineyard managers to critically assess their vineyards and delineate zones of vine potential.

Trial Concept

Following several dry seasons and an increased reliance on irrigation, in 2006 an in – house PV trial was proposed for one of the Katnook Estate vineyards. The aim of this trial was to improve water use efficiency by undertaking an EM38 survey determining soil depth to limestone (Figure 1) and then using this information to calculate Readily Available Water (RAW), Plant Available Water (PAW) and plant water use.

Although an established vineyard, assessment followed a standard process for assessing any proposed irrigation development:
As the trial was planned to run for two seasons, benchmarking involved vineyard scoring by:

- Point Quadrat measurements
- PCD image
- yield mapping

Whilst the EM38 information (including elevation) enabled:

- Adjustment of Enviroscan probes (sensors)
- Installation of “Full Stop” probes and SoluSAMPLERS® in representative sites
- Calculation of soil RAW and incorporation of average gravel content
- Almost immediately, management of this vineyard changed as a result of the new information to hand. Primarily, an appreciation of the shallow average soil depth (of as little as 25cm!) meant a fundamental shift in irrigation management.

**PCD – The turning point**

It wasn’t until the PCD image was developed (Figure 2) that the full, limiting effect of soil depth and its expression on vine potential began to be realised. Up until that time, management changes had targeted irrigation alone to avert vine water stress resulting from the soils limited water storage capacity. What the PCD image displayed, however, was that overall vine potential was affected, presumably as a combination of factors including:

- restricted root zone
- increased soil temperature
- low soil RAW as a result of limited water storage capacity and increased gravel content
- Restricted nutrient storage

**Figure 1:** EM38 Map developed for the Katnook Estate trial vineyard. An r² value of 0.98 shows a strong relationship between conductance and depth to limestone in the areas represented (middle vineyard not displayed in this image).

The survey includes the location of:

- i. .Enviroscan probes,
- ii. Soil survey “ground truthing” sample points
Plant Physiology & Pruning – a simple overview

With the aim of pruning being to maintain a harmony between growth, yield and quality, management must take into account the vines physiological requirements in a given environment. In a shallow soil environment, a limited root zone below ground will only be able to support a proportionately limited canopy above ground. The vineyard manager can make decisions at pruning time to regulate the level of this canopy, with the desired goal being vines of moderate vigour (Smart & Robinson, 1991).

Trial Response – Pruning

In this trial, the economics of segmented harvesting were not seen as viable. Rather, it was felt that the aim should be to improve the quality of the fruit from the low potential zone by pruning vines in each of the management zones to different levels. Ultimately, zones identified as having high potential were pruned lightly, with more buds left and areas displaying low potential were pruned harder. The philosophy behind this being that fewer buds will result in less shoots of higher vigour. This has the overall effect of providing sufficient leaf area to ripen fruit in the low potential area, to the same quality as the remainder.

At the time of writing, only Point Quadrat sampling had been completed, with figures suggesting that the variable pruning rates have resulted in similar canopies and fruit exposure for each of the treatments.

Figure 2: PCD image developed for the Katnook Estate trial vineyard, displaying management units (insert). Soil effects were masked for a significant portion of this image, as a result of back-to-back frost events. Needless to say, PCD is a useful tool for mapping frost damage.
**Same Data – Different ends . . .**

It is of interest to note that another example of where PCD information has been used to assess pruning rates resulted in an entirely different application. In a trial example undertaken by Tony Profitt and Andrew Malcolm (Margaret River WA), a vineyard was segmented into three zones based on vine vigour: high, medium or low. Subsequently, “piece rates” paid to pruners were adjusted according to the difficulty of pruning vines in each zone and the time allocated to work on the vines. Furthermore, each pruner was allocated a set number of rows in each zone to ensure an equal allocation of work.

This policy had the effect of maintaining high morale and low truancy, whilst completing pruning on time and delivering an estimated saving in pruning cost of 11.6%.

For further detail, refer to: Proffitt et. al. 2006, *Precision Viticulture, A new era in vineyard management and wine production*, Winetitles, p.76

**Conclusions**

Using multiple PV tools enabled both the identification of distinct vineyard zones, along with the primary causal factor for vineyard variability (soil depth). With this identified, management of the vineyard could be adjusted to compensate for the effect of soil depth. In this case, changes were made to irrigation management and pruning rate.

The same information could similarly be used for other applications or changes to management practice. This emphasizes that there are broad applications for PV data once it is collected.

**References**


Take Home Messages

In pastures:

1. Active optical sensors (AOS) are sensors that contain their own light source; they can be used under any conditions (day, night, cloud etc). Note that water on the surface of leaves (eg heavy dew, rain) has been reported to influence sensor response. AOS are currently limited to a maximum sensor-target distance of < 5 m.

2. AOS can be an effective photosynthetically-active biomass (PAB) assessment tool in pastures: 0 - ~3000 kg DM/Ha.

3. Users are unlikely to get an absolute calibration applicable between sensor response and biomass for all times and all plants but AOS are good for day-by-day calibration and/or extending a few point measures to extensive surveys.

4. AOS as point-sensors can be used to calibrate remotely-sensed imagery allowing users to convert an NDVI (or PCD- simple ratio) image to a map of PAB.

5. AOS can be used with dGPS/dataloggers to conduct field surveys of PAB in pastures and crops. Recent tests have been completed with sensors mounted in a low-level aircraft.

6. Pasture PAB maps can be augmented to get an insight into pasture quality by using 3rd-party indicators- eg GPS livestock tracking, EM38.

7. GPS cattle tracking in pastures shows a diurnal variation in grazing behaviour- with peak morning and afternoon grazing windows that can be linked to digestibility and be a valuable tool in understanding biomass and nutrient pathways during grazing.

Background

Airborne and satellite images offer a synoptic view of agricultural fields and can be readily converted into maps depicting indices (eg NDVI or PCD/simple ratio) that are related to PAB. However acquisition of satellite and airborne imagery is limited by cloud cover and/or availability of platform when suitable operational windows occur (eg crop stage, availability of ground staff to coordinate calibration, plant cuts etc). Moreover, the data are un-calibrated, and application of imagery to change detection is limited to qualitative assessment. AOS can, by their definition, be operated irrespective of illumination conditions (including day/night). They can be used as hand-held optical sensors for PAB assessment or collection of calibration data for remotely-sensed imagery, or can be integrated with other on-ground sensors (eg EM38) configured with GPS/dataloggers to measure and map PAB in their own right.

This presentation summarizes a number of applications of AOS, as well as other sensors currently being investigated by the Precision Agriculture Research Group at UNE.

General- AOS

- AOS are ‘active’ because they emit their own light and use detectors to sense the reflected radiation from this light
- AOS generally use pulsed light sources and ‘synchronous detection’ to allow them to select out the reflected light from their integrated source against the background light (Figure 1a). This enables them to be used under any (including varying) light conditions.
- The AOS’ radiation reflecting back off a plant will vary with distance to plant (inverse square law) hence the AOS rely on band ratios (eg NDVI) which (over a fixed range) will be invariant.
However, accessing the raw, single-band reflectance data provides an opportunity to employ AOS as a proximity, as well as PAB sensor.

- AOS’ can be used for manual sensing, or mounted on ATVs and even low-level aircraft (Figure 1b-d)

**Application to Pastures**

- AOS are being trialed to calibrate CSIRO’s Pastures From Space (PFS) pasture growth rate (PGR) algorithms for perennial pasture systems on the Northern Tablelands of New South Wales as well as for generating high definition biomass maps in their own right.

- The relationship between pasture biomass in kilograms of dry matter per hectare and CropCircle generated NDVI shows the NDVI ‘saturates’ for values greater than ~0.45, corresponding to dry matter values in excess of 3000 kg/ha- effectively setting an upper limit on biomass estimates. From 0-3000 kg/ha, the measured dry matter explains in excess of 70% of the variance observed in the optical response.

- We are also augmenting the basic AOS PAB data using the diurnal grazing behavior extracted from GPS cattle tracking collars to see if we can infer indicators of pasture quality. GPS tracking logs show a clear diurnal trend with peak morning and afternoon travel cycles (PMG, PAG- Figure 2). Other researchers have indicated (based on manual observational work) ‘unforced’ travel distances > 250 m/hour correlate with grazing behaviour.

![Figure 1.](image1.png)

(a) Photograph of the CropCircle (red) AOS showing pulsing LED’s located in the top of the detector head (note, only red radiation emitted by the LEDs is visible) and dual photodetectors below.

(b) Manual deployment of an AOS for estimating biomass

c) ATV-mounted AOS (with GPS and datalogger) for on-the-go surveying.

d) AOS deployed on low-level aircraft for mapping PAB

![Figure 2.](image2.png)

Figure 2. GPS position logs (10 minute sampling interval) converted to travel distance and distances traveled in each hour averaged over 6 collars and 14 consecutive days (error bars ± 1 SD).

- Work is now in progress to test an AOS on a low-flying fixed-wing aircraft (Figure 1d) to generate full-paddock maps of PAB.
Conclusions

• Active optical sensors offer an alternative means of assessing pastures (and crops) for biomass and may be used as stand-alone sensors (manual) or incorporated into on-the-go configurations, on the ground and even in the air.

• Animal grazing behaviour, and the connection between grazing and pasture quality can be inferred from data recorded using low-cost GPS collars and other sensor data.

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NOTE: use of commercial product trade names, for example CropCircle as an example of an AOS, does constitute an endorsement of these particular products.
Precision Agriculture (PA) can be regarded as a means of increasing the chance that the right crop management strategies are implemented in the right place at the right time.

Numerous examples exist of the successful application of PA to the production of various crops around the world including wheat, corn (maize), soybeans, potatoes, sugar beet, barley, sorghum, cotton, oats, rice, wine and juice grapes, citrus, bananas, tea, date palms, tomatoes, apples, kiwifruit, sugarcane, olives and tobacco, and PA has even been used to assist in the management of sporting venues and railway lines. More often than not, this use of PA has been shown to be profitable. In spite of this, the rate of adoption by growers of many crops remains low (both the grains and wine industries in Australia are good examples) and, in some industries adoption has been negligible. An Australian example of the latter is the sugar industry - despite its relatively high rate of adoption of controlled traffic and the ready access that growers have to supporting infrastructure such as local GPS base stations. One reason for this low rate of adoption is the lack of an informed basis from which to make decisions as to appropriate investment in PA – whether these be in terms of pragmatic application by growers, the level of involvement (if any) by processors, or with respect to research to facilitate such adoption. ‘Will this work on my farm?’ is a key question which many are uncertain about.

A part of acquiring an informed view of PA is to look at its application in other cropping systems. This is also a worthwhile activity for an organisation such as SPAA as it seeks to maximise the value that it can provide to its members, especially with respect to ensuring that individual growers and industries can learn and benefit from the actions of others. It is also valuable as an aid to identifying areas of hitherto untapped opportunity.

This talk, which derives from a more extensive review, will draw on PA research and application in a range of cropping systems from around the world and considers the key drivers of variability in these production systems. Constraints to the adoption of PA and its likely economic benefits are also considered. An important conclusion is that whilst the primary opportunity for PA in broadacre systems (e.g. wheat) may be to use it to target the management of inputs to production, whereas in more intensive higher value systems (e.g. winegrapes) it is to selectively harvest into different parcels according to the intended end use or market opportunity, there is good reason to suppose that the benefits being chased by winemakers are also available to maltsters, pasta makers and flour millers. Equally, benefits being sought by wheat farmers are also available to growers of winegrapes or vegetables, etc… Thus, PA should be considered as a tool for optimising management of the whole value chain. It can also play a useful role in natural resource management and the minimisation of the environmental impacts of agriculture.

In addition to R+D to support the broader implementation of PA outlined above, opportunities also exist for developing new sensors in support of soil management and the management of crop quality. We also need to recognise that in addition to inferring management that is ‘site-specific’, PA requires that interpretation of some of our commonly used agronomic tools (soil tests are a good example) also needs to be site specific. We must therefore be willing to challenge and recognise the limitations of existing agronomic norms, and recognise that experimentation is a key farm business management tool and not just something done by researchers.
The original review was published as:

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