SPAA Precision Agriculture Australia

Precision Agriculture Laboratory
monitoring | mapping | management

17TH Symposium on Precision Agriculture in Australasia

Tuesday 2nd and Wednesday 3rd September 2014
Magarey Room, AAMI Stadium, West Lakes, South Australia

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INCREASING THE ADOPTION OF PRECISION AGRICULTURE IN AUSTRALIA

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WELCOME!

This Symposium marks a dozen years of collaboration between SPAA and the University of Sydney. It is also a return to the city where, in 2003, the two groups first joined forces to run the 7th Symposium on PA in Australasia. Since then, the aim of this cooperation has been to promote the development of PA and profit agricultural production around the Region.

This year's event reflects the extent of that development, with the breadth of topics, technologies and tools on display providing evidence that PA is now a mature management philosophy which widely impacts on crop and animal production. We are seeing improvements in the quality and number of production decisions per area/time/animal through the application of PA which are providing a wide range of benefits – economic, environmental and social.

These benefits are being achieved at the production level because the research and application of PA in Australasia has been largely successful at focusing on the initial aim of applying technologies and information gathered at the site-specific level, together with grower/farmer knowledge, to:

- optimise production efficiency;
- optimise production quality;
- minimise environmental impact; and
- minimise risk.

As the PA industry continues to mature, these goals obviously remain relevant but now the PA philosophy should be extended further up and down the value chain. From the large amount of production data being gathered, relevant data streams/layers need to be identified and fused (locally, regionally and nationally) and used in more diagnostic ways to optimise management across all aspects of the pre-production (selection and preparations for crops and animals), production and delivery systems.

This will require thinking, research and linkages not only across multidisciplinary themes, but production and non-production industries. The outcome though should be the application of the PA philosophy leading more agricultural industries as well as the associated support/distribution/consumption chains towards incorporating practical, sustainable (commercially and environmentally) management techniques.

This would signify a large leap towards PA fully realising its potential influence on the security of food, fibre and natural resource systems.

So please enjoy the interaction and inspiration that the Symposium offers to participants. You will share in the revelation of developments in sensors, application equipment and delivery platforms, software, management techniques, knowledge and understanding that are leading the way forward.

The PA Lab and SPAA teams.

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RECENT ADVANCEMENTS IN GNSS POSITIONING FOR PRECISION AGRICULTURE.

Rod MacLeod
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SUMMARY

The Global Positioning System has provided agriculture with opportunities to develop innovative solutions where position is the core to their successful implementation. In most agricultural applications the position is relative to features on the ground or more recently to other moving machines when in autonomous and semi-autonomous operations. Each application has its accuracy requirements where in general the more accurate the requirement, the more expensive the solution.

NovAtel is the world's leading precision OEM GNSS manufacturer and provides GNSS technology across many vertical markets and customers. In agriculture it supplies most of the world's largest after-market precision system vendors. To do this it has developed a unique "CORRECT" algorithm that can provide various accuracies depending on the inputs provided without the need to change hardware, saving costs to both the supplier and the end user.

This includes:

- Using Multiple Satellite constellations including Beidou
- GLIDE only (no external corrections) <0.2m P2P
- PPP <0.1m absolute
- RTK <0.02m
- Heading and relative positioning on 2 or more moving objects to <0.02cm
- Optional IMU data input for specific autonomous applications

The presentation outlines these advances as used in the Precision Agriculture sector and some discussion on what may be seen in the future, particularly in machinery use in broad acre farming.

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SOIL PH MAPPING IN SOUTH AUSTRALIA.

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3 I'Anson Farms, Marrabel, SA.

SUMMARY

- Soil pH mapping machines are enabling pH zones to be identified and mapped with some confidence in cropping paddocks but the results are variable in long-term pasture paddocks.
- Under controlled environment conditions, the data from the machines is highly correlated with laboratory data.

INTRODUCTION

Throughout South Australia there are more than 1.9 million hectares of agricultural land susceptible to soil acidification (Soil and Land Program, 2007) that degrades the soil and reduces crop and pasture growth. Many of the soils in acid prone areas have a pH less than 5.0 ($CaCl2$) in the 0-10 cm layer, and sub-surface (10-20 cm) soil acidity is also becoming an issue. Lime is the most effective and economical method for the treatment and prevention of acid soils. Previously, the amount of lime required for a paddock has generally been based on a single soil test and the lime applied at a uniform rate across the whole paddock. In some cases soil sampling for laboratory analysis has been carried out in a grid system across the paddock but this is time consuming and expensive. In recent years, the cost of lime and its freight to the farm has increased. A more accurate determination of soil pH across the paddock is warranted so that money is not wasted applying lime to areas where it is not required.

As part of the Australian Government funded Advisory Board of Agriculture SA's project 'Innovative and cost effective solutions to the treatment of acid soils in SA', the use of soil pH measuring machines are being tried in SA to map the spatial variability of soil pH across paddocks. Using this information pH zones can be determined showing where and at what rate lime should be applied or those areas that do not require lime.

MATERIALS AND METHODS

Soil pH machines

The project has been testing two soil pH mapping machines for South Australian soils and conditions.

Veris pH detector

The Veris pH detector (Figure 1a) is a commercially operated machine that was purchased by PrecisionAgriculture.com.au from the USA in 2010. The pH detector is mounted on the back of a Can-am ATV and approximately 200 to 300 hectares can be mapped per day. The operator pushes the probe chamber into the soil with a foot lever that creates an opening for the pH electrode holder. With a hand lever, the pH electrode holder with the antimony electrode is then pushed into the soil cavity. The electrode makes contact with the soil at the bottom of the hole at about 7-8cm. The pH is read in 7 to 10 seconds and is then logged with geographic position data. The electrode is automatically washed and then ready for sampling at the next point. For this trial, pH readings were taken on 1 hectare grid sampling points. When sampling was completed, a pH map was generated (Figure 3).

Veris pH ManagerTM

The Veris pH ManagerTM (Figure 1b) 'on-the-go' pH machine is on loan from the Precision Agriculture Laboratory, University of Sydney and is the only machine of this type in Australia. It is mounted on the back of a tractor and automatically collects a soil sample, measures the soil pH from direct soil contact and records its geographic position while travelling across the paddock.

As the machine is driven across the paddock, a sampling shoe is pushed into the soil to a depth of about 8-10 cm. The front of the shoe cuts the soil material with a cone and produces a soil core that flows through the sampling shoe. The soil core in the sampling unit is then raised up against two antimony electrodes and held in place for 7-25 seconds (depending on the electrode response). If the difference between the readings of the two electrodes is less than 0.5 of a pH unit then the average value is stored with the geographic position reference. If the difference between the two readings is greater than 0.5 then that sampling point is discarded.

Once the measurement is finished, the shoe is lowered back into the soil, and the previous soil is pushed out as the new soil material flows through the cone. As this is happening, the electrodes are automatically washed. The average time for the cycle is approximately 10 seconds but can vary according to the electrode performance.

The number of samples taken can be adjusted by varying the speed. With this trial, travelling at 10 km per hour (a sample at every 25 m) and on controlled traffic tracks at 36 metres wide provided 11 to 12 samples per hectare. When sampling was completed a pH map (Figure 4) was generated using PAM FarmStar software.

*Figure 1:
Veris pH detector (a)
and Veris pH ManagerTM (b).*

The electrodes of both machines were calibrated before and after field mapping using standard buffer solutions of pH 4 and 7.

Validation (controlled environment conditions)

Soil pH data from the two machines was compared to laboratory pH CaCl2 analysis. pH (CaCl2) was used in preference to pH (water) as it is a more stable method and it is the parameter used in the calculation of lime requirements. Twenty four soil sites in the Mid North of SA were selected that had a range of soil textures from sandy loams to light clays and a range of pH levels from pH 4.5 to 7.5 (CaCl2). At each site, soil was taken from a 0.5m2 area at 10 cm deep. Each of the soil samples were thoroughly mixed and then placed into pots. A sample of each soil was sent to CSBP laboratories (WA) for analysis. The soils in the pots were wetted and allowed to drain.

The electrodes of both of the machines were washed and calibrated as outlined above. With the Veris pH ManagerTM, a sample of soil was pressed against the two antimony electrodes for 20 seconds or until the readings had stabilized recording the data on the Veris data logger. The process was carried out for all the soil samples. As the readings of the two electrodes were within 0.5 of each other for every sample no readings were discarded. The average of the two electrodes was recorded. With the Veris pH detector, the probe chamber and the electrode holder were placed into each soil sample. Three readings from each sample were taken and then averaged. The electrodes of both machines were thoroughly washed after each sample.

Both of the machines will be validated in the field. At each sampling point a soil sample will be taken from the same point and at the same depth and sent to the laboratory for analysis. The pH results of the machines and the laboratory data will then be compared.

Results and discussion

Soil pH maps

Figure 2 shows the maps generated by the Veris pH detector and the Veris pH ManagerTM over the same 200 hectare cropping paddock. The white areas in the maps are non-arable stony ridges. The maps show a large spatial variability of soil pH and definite pH zones across the paddock. There is also a rough line across the centre of the maps which is an indication of an old fence line and the zones north and south of the line show that the two paddocks have been managed differently in the past. Due to the more intense sampling of the Veris pH ManagerTM (11-12 points per hectare ~2,220 points per paddock) its map shows more detail and picks up smaller areas of lower and higher pH soils than the Veris pH detector's map (1 point per hectare – 200 points per paddock) but the zones are similar.

One of the significant constraints in using the mapping machines is that the soil must be wet. In cropping paddocks this is often just before or after seeding. The Veris pH ManagerTM on-the-go machine can cover a slightly larger area in a day compared to Veris pH detector but the soil sampling shoe can block up on heavy soils and with stubbles or pasture residues. A camera mounted on the back of the pH machine connected to a monitor in the cabin of the tractor allows the operator to see how the machine is performing.

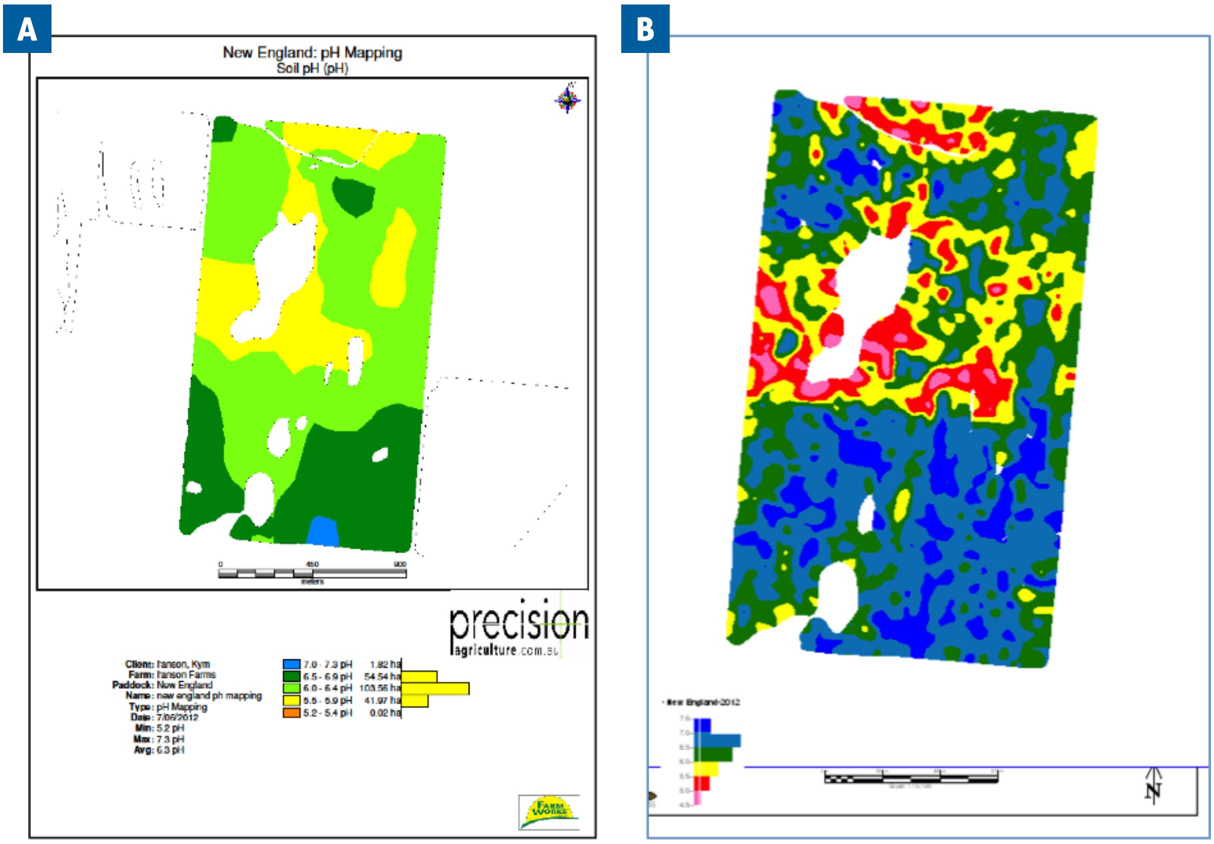

Figure 2.
Soil pH map by the Veris pH detector (a) and soil pH map by the Veris pH ManagerTM (b)
(Blue and dark green– high soil pH; yellow, red and pink – low soil pH)

Soil pH mapping of long-term pasture paddocks has presented a number of problems. Pasture paddocks are often compacted making it difficult for the Veris pH detector to push the electrode into the full 7-8 cm soil depth. In addition, the decomposition of leaf litter and organic matter can form a small alkaline layer (1 -2 cm) on top of the acid surface soil that can interfere with the test results. Removing the thatch layer before testing has provided better results.

Validation (controlled environment conditions)

Under controlled environmental conditions, pH readings of both machines were highly correlated with the laboratory results (pH CaCl2). The Veris pH detector and the Veris pH ManagerTM had a linear regression (R2) of 0.93 and 0.94 respectively (Figures 5 & 6). This is consistent to the findings of Adamchuk et al. (1999) and Schirrmann et al. (2011). It can be clearly seen that the Veris pH Manager TM is giving much higher pH readings than the Veris pH detector. Both of the machines are providing pH results that are slightly higher than laboratory pH (CaCl2) in the lower range of pH readings indicating that any machine reading below a pH 5.0 should be lowered by about 0.3 to 0.4 to bring it in line with pH (CaCl2) values. Field validation is being carried out with both machines although, as expected the results are more variable than the controlled environment trial.

Lime

The soil pH maps have shown that rather than applying a uniform rate of lime across the paddock, lime can be applied at appropriate variable rates to match the variability in soil pH.

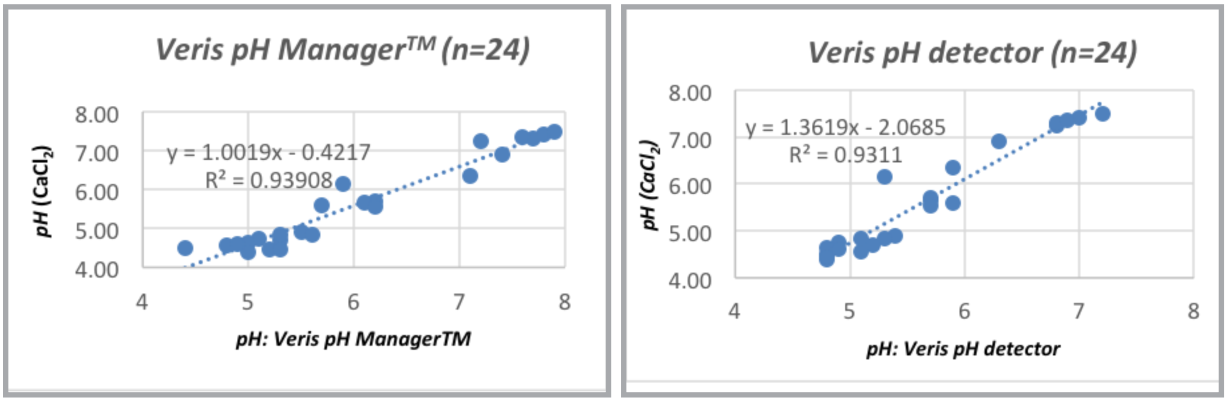

Figure 3. Correlation between the pH machine readings and laboratory pH (CaCl2).

The area of lime and appropriate liming rate for each pH zone can be calculated more accurately. Figure 2 shows that only the pink, red and yellow areas in the top half of the paddock require lime.

Case studies by PrecisionAgriculture.com.au have shown that applying the appropriate amount of lime for different areas of the paddock compared to applying a uniform rate to the whole paddock can reduce the total amount of lime applied and that the cost savings can be in the order of 25 - 30%. In some cases more lime may be required in more acidic areas but the cost will be out-weighed by the improvement in productivity.

CONCLUSION

The use of pH testing machines in cropping paddocks is showing promising results for soils in SA. More testing and validation is required to build confidence in the performance of these machines, especially in long-term pasture paddocks. Soil pH mapping and the identification of pH zones will enable more accurate targeting of lime applications. This will not only help to save costs but also will result in more homogeneous soil pH conditions over the paddock that will result in an overall improvement of crop and pasture productivity.

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MONITORING GRAZING BEHAVIOUR OF DAIRY COWS IN PASTURE-BASED SYSTEMS.

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INTRODUCTION

In Australia, dairy farms are categorised into five varying farming systems (Dairy Australia 2011) and according to national farm survey results, 50% of Australian dairy farms are classified as system 2 (grazed pasture and other forages with > 1.0 tonne grain/concentrates fed in bail). Developing management strategies that optimise profit from concentrate feeding is a key requirement for the Australian dairy industry and furthermore, understanding how dairy cows adjust their grazing behaviour and associated pasture intakes in response to concentrate feeding will be vital to developing such strategies (Sheahan et al. 2011).

Influences of herbage allowance and concentrate feeding level on grazing behaviour and associated herbage intake have been widely researched; clear reductions in herbage intake were reported as the level of concentrate feeding increases (Bargo et al. 2003) and higher pasture intake observed with greater pasture allowances (Dalley et al. 1999). Substitution rate and the marginal milk response (Stockdale 2000) for a given situation are usually defined at a whole of herd level.

With increasing rates of adoption of dairy parlour infrastructure allowing for individual bail feeding of dairy cows, development of technologies allowing the capture of individual cow grazing behaviour will assist in the development of individual cow bail feeding decisions, potentially leading to enhanced profitability. The aim of this study was to offer different levels of concentrates and by using GPS collars and motion sensors, capture and record grazing behaviour of individual cows.

METHODS

This study was conducted on 24 Holstein-Friesian multiparous cows selected from the Tasmanian Institute of Agriculture Dairy Research Facility at Elliott, 41o5'S, 145o46'E. Two groups consisting of 12 cows each were established and balanced for means and variances (± SD) of milk production (25.0 ± 3.9 litres per day), days in milk (71± 9 days), body weight (480 ± 34 kg), and age (4.6 ± 1.9 yr).

Each group of cows was allocated to one of two concentrate feeding levels. Cows received 50% of their concentrate feed allocation of 6.0 or 0.0 kg DM/day of Coprice® Dairy Pellets (CP = 14% of DM; ME = 12 MJ ME/kg of DM) twice daily during milking via automatic feeders (ALPRO System, Alfa Laval Agri, Sweden). Cows were milked twice daily through a herringbone parlour at approximately 0630 and 1530 hr. Milk yield for each cow at each milking was recorded using Delavals Alpro Herd management System (DeLaval International, Tumba, Sweden). Feeding treatments commenced on 25th of October 2012 and ceased on 31st December 2012.

Pastures grazed were predominantly perennial ryegrass and cows were rotationally grazed as one herd, with daily forage allocation allowance of approximately 30kg DM/cow/day of feed on offer above ground. For a period between 27th November and 13th December each of the 24 cows were fitted with a collar which consisted of a FleckTM (Sikka et al., 2004) with wireless networking. The collar had a number of sensors including GPS, 3-axis accelerometer, 3-axis magnetometer and data storage capacity. The collar number, time (seconds), latitude and longitude were collected and saved in the dataset. The dataset generated from the cow collars combined with observed visual behaviours was used to establish algorithms that allow for the generation of a model that can capture the behaviour of the animal (Bishop-Hurley et al. 2014).

RESULTS

There was significant ($P < 0.05$) difference in the proportion of time spent grazing between the two grain feeding groups. Cows receiving 0kg of concentrate were found to spend a larger proportion of time grazing than cows receiving 6kg. Similarly, cows receiving 6kg of concentrate were found to spend significantly ($P < 0.05$) more time ruminating than cows receiving 0kg. With both behaviours (grazing and ruminating), there was significant ($P < 0.05$) interaction between time of day (hour of day) and concentrate feeding group. Only between the hours of 0700 and 1200 was there significant difference in the proportion of time spent grazing between the two grain feeding groups (Figure 1). Between the hours of 1900 and 0200 and also between the hours of 0900 and 1200 there was a significant ($P < 0.056$) difference in the proportion of time spent ruminating between the grain feeding groups (Figure 2).

DISCUSSION

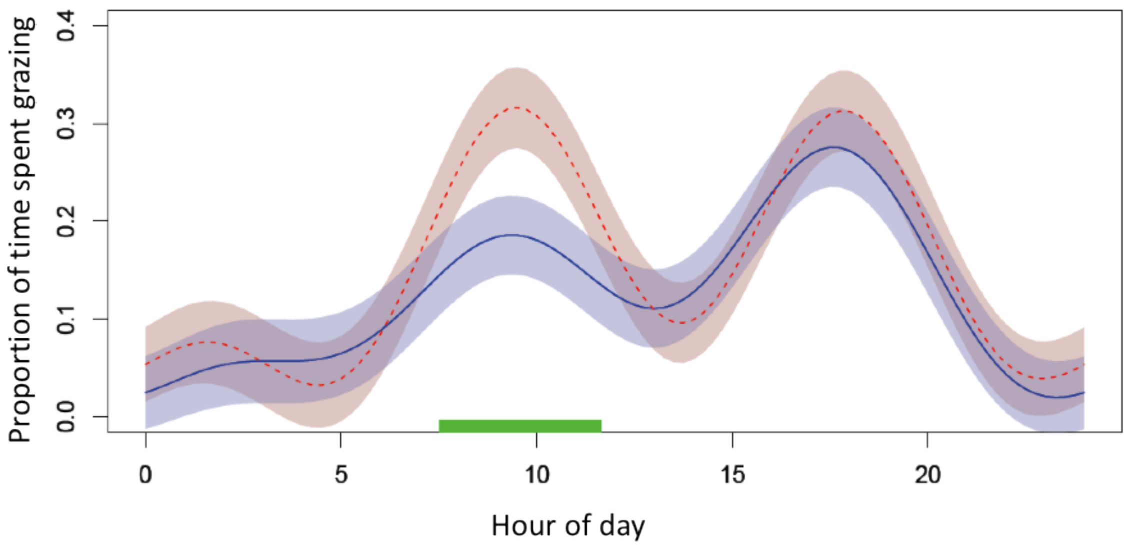

Figure 1. Proportion of time spent grazing by the two grain groups (Solid line = 6kg, dashed line= Zero) over a 24 hour period. Shaded area represents the 95% confidence interval for each of the two grazing groups. Heavy line along axis shows the time of day where the grazing differs significantly (P < 0.05) between the two grain groups.

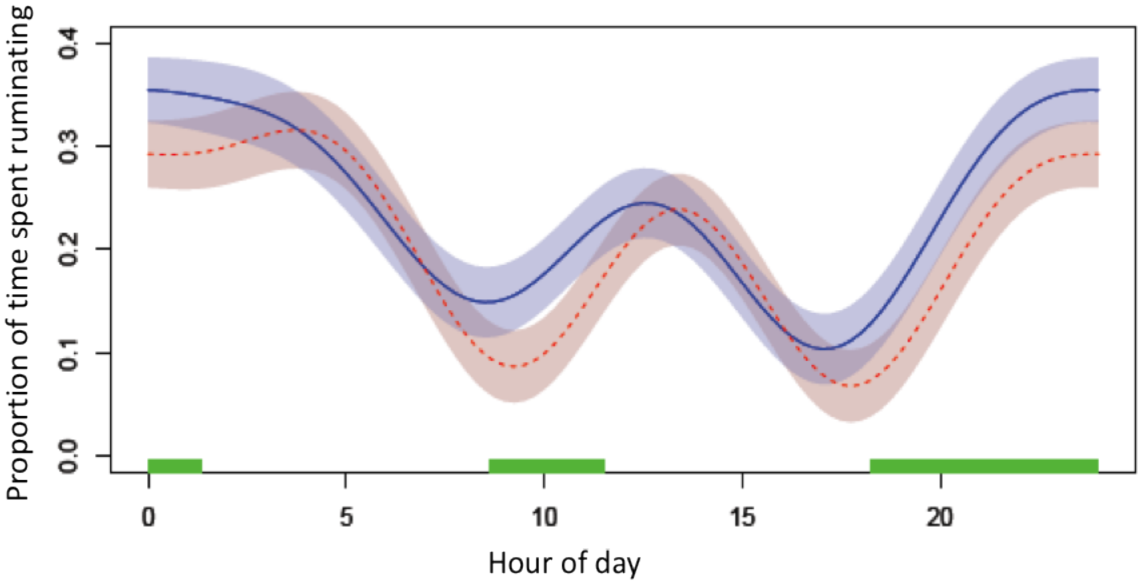

Figure 2. Proportion of time spent ruminating by the two grain groups (Solid line = 6kg, dashed line= Zero) over a 24 hour period. Shaded area represents the 95% confidence interval for each of the two grazing groups. Heavy line along axis shows the time of day where the grazing differs significantly (P < 0.05) between the two grain groups.

The observation that cows spend less time grazing when offered concentrates compared to cows receiving no supplementation is consistent with other studies (e.g. Hernandez-Mendo and Leaver 2006; Rook et al. 1994), and that the bouts of grazing occurring after the morning and afternoon milking are also consistent with other studies (e.g. Sheahan et al. 2011; Soriano et al. 2000). The greatest limitation to milk production in grazing dairy cows is intake (Roche et al 2007). Supplementing the diets of grazing dairy cows with bail fed concentrates can alleviate limitation of intake in pasture based dairy systems.

However, substitution of pasture as a result of supplementation results in a reduction of time spent grazing (12 min/kg of concentrate DM; Bargo et al., 2003). According to Roche et al. 2007, the physiological basis for substitution is poorly understood. Sheahan et al. (2011) reported the reduction in grazing time and associated pasture substitution varies depending on the time of day. Both reduction in grazing time and variation in the time of day of the reduction are consistent with grazing behaviours reported in this study.

The results of this study suggest grazing time, as an indicator of pasture substitution, is reduced following the morning milking but not in the period following afternoon milking. As suggested by Sheehan et al. (2013) this indicates different factors may regulate grazing behaviour at differing times of the day. Sheahan et al. (2013) showed during the morning grazing period the “hunger hormone” ghrelin and nonesterified fatty acids decrease and insulin increases in the cow. In comparison during the pre-dusk gazing period ghrelin concentration continues to increase until sunset (Sheahan et al. 2013).

Technology, such as the cow collar sensors deployed in this study, in combination with individual bail feeding technologies and a greater understanding of the factors known to affect hunger and satiety in dairy cows, could potentially result in development of new feeding approaches. Such knowledge, data and technologies will be required to develop and research new approaches to optimise individual bail feeding and economically optimise individual cow performance in pasture based systems.

ACKNOWLEDGMENTS

This work was undertaken as part of the Sense-T dairy and beef optimisation project. Sense-T is a partnership program between the University of Tasmania, CSIRO (through the Australian Centre for Broadband Innovation), and the Tasmanian Government. It is also funded by the Australian Government.

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BALLISTIC MODELLING SPREAD PATTERNS OF COMMON FERTILISERS FROM TWIN DISC SPREADERS, WITH REGARD TO THE SEPARATION OF BLENDS AND IN-FIELD STRIPING.

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ABSTRACT

Manufacturers of fertiliser spreaders claim that their large twin disc centrifugal spreaders are able to spread fertiliser products as far as sixty metres. Farmers and contractors have increased the bout width of their spreaders and reduced the number of tramlines to take economic advantage of these spreaders. Arable farmers have found increased striping and lodging of their crops when spreading fertiliser blends at these increased bout widths, generally greater than 30 metres. This is due to centrifugal and longitudinal separation of particles with dissimilar ballistic properties.

Representative samples were taken from fertiliser stores and measurements of particle, size, particle density and shape were taken, to compare with product specification and for ballistic modelling. This was done to establish the distance individual fertiliser particles should travel at various velocities. Fertiliser particle velocities were measured by high speed photometry using both common fertilisers and common spreaders found in New Zealand. High speed photometry was used to confirm the velocity and trajectory of the fertiliser particles.

Spreading equipment was pattern tested using the New Zealand Spreadmark method. Spreading bout widths which achieved a transverse CV of 15% are required to meet the Spreadmark standard with nitrogenous fertilisers and a CV of 25% for fertilisers with no nitrogen content. Measured spreading distances and bout widths were compared to modelled distances from the ballistic model which showed a good fit. A ballistic model shows promise in preventing the mixing of blends with incompatible ballistic properties which could prevent striping at increased bout widths.

INTRODUCTION

Manufacturers of centrifugal twin disc fertiliser spreaders have been improving delivery systems and features, including offering larger models which can spread fertilisers considerably further than previous generations of twin disc spreaders. Farmers and their consultant farm advisors, use and often recommend product blends to reduce the number of fertiliser applications and proprietary nutrient mixes or blends.

Most contractors and farmers using the new larger spreaders have increased bout widths or widened tram lines. Many of these have experienced striping or lodging of crops after having spread fertiliser blends or mixes, which they didn't experience when spreading from their old equipment at narrower bout widths.

Striping and lodging of crops is an indicator of uneven distribution of fertiliser from spreading machinery, resulting in a mixture of under and over-application of fertiliser producing uneven crop growth. Consideration should be given to the particle characteristics of size, density and shape that are required to achieve increased spread widths, greater particle exit speeds off the disc may be responsible for blends separating, meaning the striping is a result of less even lateral distribution of blends from the spreader due to increased speed off the discs causing centrifugal separation (Miller, 1996) and (Miserque et al, 2008). If blends of fertiliser are mixed in the same bin longitudinal separation may also occur, where smaller particles percolate through larger ones and accumulate in the bottom of the bin, whilst larger particles at the top of the bin. Longitudinal separation results in uneven distribution of fertiliser nutrient in the direction of travel (Miller, 1996) and (Miserque and Pirard, 2004).

A ballistic model is a means of predicting individual fertiliser spreading distance based upon the particle's physical characteristics. In conjunction with the spreader's specifications such as disc diameter, spinner speeds and trajectory the particles landing point can be predicted. It is with the use of modelling that different fertilisers may be evaluated before application, allowing for an accurate indication of achievable spread widths based upon the specification of the spreader used to apply them. Lodging and striping may, therefore, be prevented through increased awareness of product compatibility for blending in terms of lateral spread distance (Grafton et al, 2014).

MATERIALS

Two representative samples of common fertilisers spread by arable farmers using up market twin disc spreaders; Nitrophoska 12-10-10 (12.0%,N 8.8%,P 10.0%,K 0.4%,S 1.2%,Mg 4.6%,Ca) by weight and DAP (17.6%,N 20.0%,P 1.0%,S) were sieve tested as per (BS-410-2, 2000), see Figures 1 and 2. The samples were taken from 500kg bags of each product which was then pattern spread tested to the New Zealand Spreadmark standard using version 16 of their software (New Zealand Fertiliser Quality Council, 2013).

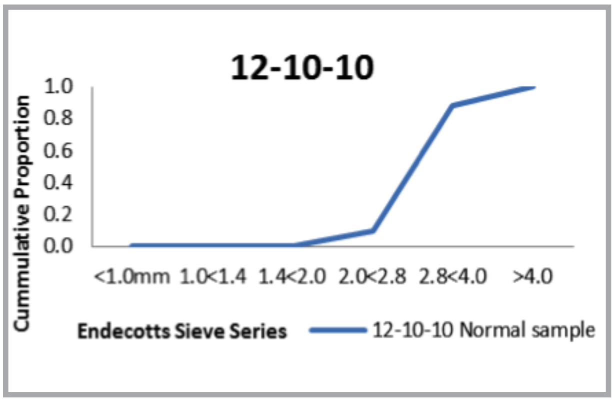

Figure 1: Cumulative sieve test Nitrophoska 12-10-10

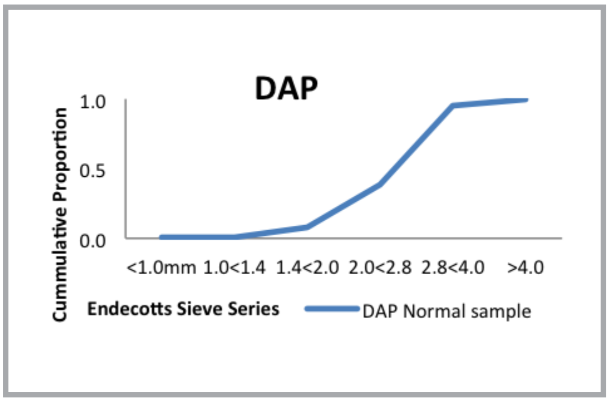

Figure 2: Cumulative sieve test DAP

The spread pattern tests were undertaken using a Kuhn Axis spreader, which was mounted on a New Holland tractor. Disc rotation speed and angle of trajectory were confirmed using high speed photometry (800 and 1,000 frames per second from vertical and horizontal angles to the discs) and disc and vanes measured so that the ballistic properties imparted to the particles from the spreader were known.

METHOD

To predict the disposition of fertiliser particles from a spreader using ballistic modelling and then compare the predicted disposition with the actual disposition as measured in the spread tests.

This information is required for ballistic modelling. The drag force on a particle is:

$$Fd = \frac{1}{2}\rho v^2 cdA \tag{1}$$

where:

$\rho = 1.2kgm^{-3}$ The density of air still air at standard temperature and pressure.

v is the velocity of the particle

cd is the drag coefficient of the particle around 0.6 for spherical fertiliser particles

A is the cross sectional area of the particle

v_f is the final velocity

v_i is the initial velocity

By dividing force by the particle mass which was calculated by the mean particle volume divided by the specific or particle density, determined by immersion testing in methanol, the acceleration a of the particle is determined. By use of calculus D distance a particle will travel can be determined.

$$a = \frac{1}{2} \rho v^2 cdAm^{-1} \quad (2)$$

$$K = \frac{1}{2} \rho cdAm^{-1} \quad (3)$$

$$\Delta a = 2vKt \quad (4)$$

$$v_f = (v_i - Kv_i^2)dt \quad (5)$$

Taking small increments of time, the distance travelled in each increment is given by:

$$D \approx v_i - (Kv_i^2 \Delta t)dt \ \ \lim_{0-t} v_i > 0 \quad (6)$$

The distance fertilizer particles would travel from an initial velocity is calculated by integrating and accumulating the distance travelled through twenty iterations. The time for the particles to travel before landing is a little over half a second. Many twin disk spreaders deliver fertilizers in a parabolic flight path, which contains a vertical as well as a horizontal component. The vertical component is Sin 15° of the exit velocity, which is a little over 25% of the horizontal component. Although, the vertical component is also subject to a drag force, the drag in the upwards direction is opposite and almost equal to the drag in the downwards component of flight, at the speeds and time period of fertiliser exiting the spreader a vertical drag force of 0 is assumed.

Thus the time to the parabolic apex is the exit velocity in the vertical plane divided by acceleration of g:

$$t \approx \Delta v / g \quad (7)$$

The distance to the apex is the area under the velocity time graph and total time of flight includes the time of descent which requires the apex height to be known.

$$d \approx \frac{\Delta v}{2} t \quad (8)$$

$$t \approx \sqrt{\frac{2h}{g}} \quad (9)$$

RESULTS

The spreading distances for fertiliser particles at the lower 10%, mean and 90% level from the cumulative distribution if spread by the Kuhn axis spreader were modelled and are shown in Tables 1 and 2. The actual spread achieved in the spread test which was conducted over three rows of 80, 0.5 m^2 trays, where trays were removed to allow the tractor to pass, and the missing tray weights were calculated by interpolation, the test results are shown in figures 3 and 4. The spread test for DAP was undertaken in a 6 ms^{-1} cross wind so this was also modelled and is shown in Table 3.

TABLE 1. BALLISTIC MODELING FORMULA-06A

PROPERTIES	CONSTANTS
Vane long (m)	0.285
Vane short (m)	0.215
ω rotational velocity ($rads^{-1}$)	18.05
Exit velocity large vane (ms^{-1})	32.5
Exit velocity short vane (ms^{-1})	24.5
Elevation angle of delivery (degrees)	15
Horizontal initial velocity long vane (ms^{-1})	31.4
Vertical initial velocity long vane (ms^{-1})	8.4
Horizontal initial velocity short vane (ms^{-1})	23.7
Vertical initial velocity short vane (ms^{-1})	6.3
Height of disks above ground level (m)	0.7
Apex long vane (m)	4.3
Apex short vane (m)	2.75
Height apex of parabolic flight long vane (m)	1.79
Height apex of parabolic flight short vane (m)	1.4

TABLE 2. PREDICTED SPREADING DISTANCES

	12-10-1-0	DAP
Distance long vane large particle size (m)	21.9	20.1
Distance short vane large particle size (m)	12.9	13.5
Distance long vane mean particle size (m)	18.7	19.2
Distance short vane mean particle size (m)	12.4	12.6
Distance long vane small particle size (m)	14.4	17.7
Distance short vane small particle size (m)	10.9	12.1

TABLE 3. MODELLED EFFECT OF 6 MS^{-1} CROSS WIND INTO 6MS^{-1} HEAD WIND		
	12-10-1-0	DAP
Distance long vane large particle size (m)	16.6	15.6
Distance short vane large particle size (m)	9.0	8.7
Distance long vane mean particle size (m)	14.7	15.0
Distance short vane mean particle size (m)	8.5	8.6
Distance long vane small particle size (m)	12.2	14.1
Distance short vane small particle size (m)	7.8	8.3
WITH 6MS^{-1} TAIL WIND		
Distance long vane large particle size (m)	22.8	24.4
Distance short vane large particle size (m)	18.1	17.1
Distance long vane mean particle size (m)	22.2	22.9
Distance short vane mean particle size (m)	16.2	16.5
Distance long vane small particle size (m)	15.6	20.6
Distance short vane small particle size (m)	13.7	15.6

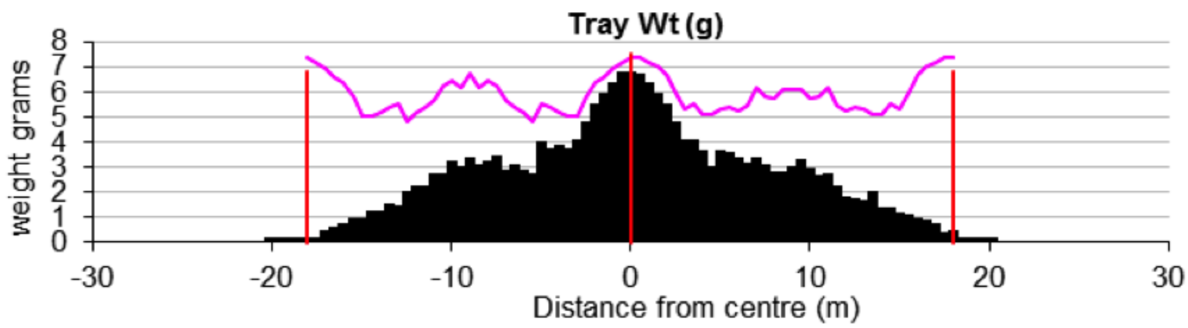

Figure 3: Spread pattern test of Nitrophoska 12 -10- 10 in still air

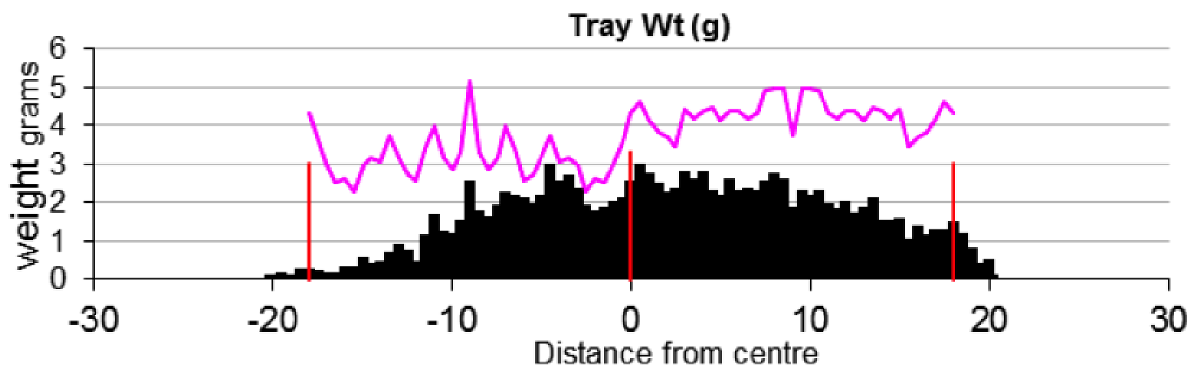

Figure 4: Spread pattern test DAP in 6ms-1 cross wind left to right

DISCUSSION

Although the spreaders are now capable of spreading to wider bout widths, part of the motivation from companies was to remain within conventional practice of say 24m but spread to a CV of below 10% rather than achieve 15 to 25% at a wider bout width. In the higher yielding situations such as New Zealand the evidence is that from an economic perspective farmers would be better off achieving lower CV's at a standard bout width. A number of studies have concluded that as in-field CV increases then the loss of productivity increases at an exponential rate. That is why there has been considerable effort to develop systems which use "Autosteer", headland control and boundary spreading, to improve in-field CV. The desire to spread wider with the dynamic risks that this poses seems inconsistent with the desire to more accurately control fertiliser application.

CONCLUSIONS

The ballistic model was a good means of predicting spreading distance. It could be used to compare and find incompatible mixes in respect of lateral separation and to provide driving offsets for spreading in windy conditions. In the future it could be used in conjunction with discrete element modelling to predict spread pattern for various materials in a range of conditions.

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NEXT-GEN TECHNOLOGIES FOR THE GRAZING INDUSTRIES – FROM YIELD MAPPING PASTURES TO VIRTUAL FENCING OF LIVESTOCK.

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ABSTRACT

There are numerous new technologies and systems being developed for the animal and grazing industries. This paper reports on some of the latest developments in autonomous livestock monitoring systems (ALMS). One of the key challenges is making the data from ALMS actually mean something to a producer. We report on several preliminary studies in this area that are using spatio-temporal data to model key behaviours such as lambing, oestrus and predation events. ALMS can also be integrated with other data sources such as live weight gain to produce animal product yield maps the equivalent of grain crop yield maps synonymous with traditional plant based precision agriculture. Virtual fencing has been under development for many years for cattle and we report on recent preliminary trials investigating its application in sheep systems.

INTRODUCTION

The grazing industries have traditionally been slower to adopt technologies compared to the cropping and horticultural sectors. However, there is an increasing interest amongst graziers in improving the efficiency of grazing systems and applying technological innovations. There are numerous technologies currently being developed and evaluated for the grazing industries. Some innovations are being adapted from the cropping and horticultural industries whilst others, particularly animal sensors, require specialist development. This paper describes some of the latest technologies being developed for these industries.

AUTONOMOUS LIVESTOCK MONITORING

Researchers have been using Global Navigation Satellite System (GNSS) collars to monitor the behaviour and landscape utilisation of livestock for over a decade. In recent years there has been a growing interest from producers in the potential of Autonomous Spatial Livestock Monitoring (ASLM) systems to enable improved animal management (Trotter 2013). However, GNSS units attached to collars and worn by livestock are largely considered an impractical solution for commercial grazing systems and the current costs associated with using these devices is likely to be prohibitive for most producers.

There are several technology developers attempting to solve this. One of these is the Taggle® system which provides an ear-tag form factor on-animal device at a much lower cost than currently available ASLM technologies (Figure 1). Unlike GNSS devices which receive radio signals from orbiting satellites the Taggle® ear-tag emits a radio signal which is recorded by a number of stationary receivers. In a similar way to GNSS the signal flight time is used to triangulate the position of the ear-tag.

In 2011 the University of New England Precision Agriculture Research Group and Taggle Pty Ltd established a research collaboration to investigate the potential for this system to provide useful information for graziers. Experiences to date with the system have highlighted many of the vagaries of time-of-flight triangulation that are associated with GNSS. Terrestrial multi-path effects and receiver geometry and spacing are two sources of positional uncertainty (currently producing of the order of tens of m in location error) and considerable work is required to understand the limitations and, where possible, mitigate such sources of error. While there is an enormous potential for the autonomous livestock monitoring systems in the grazing industry. However technological solutions need to be further developed to provide robust in-field sensing capabilities (Trotter 2013).

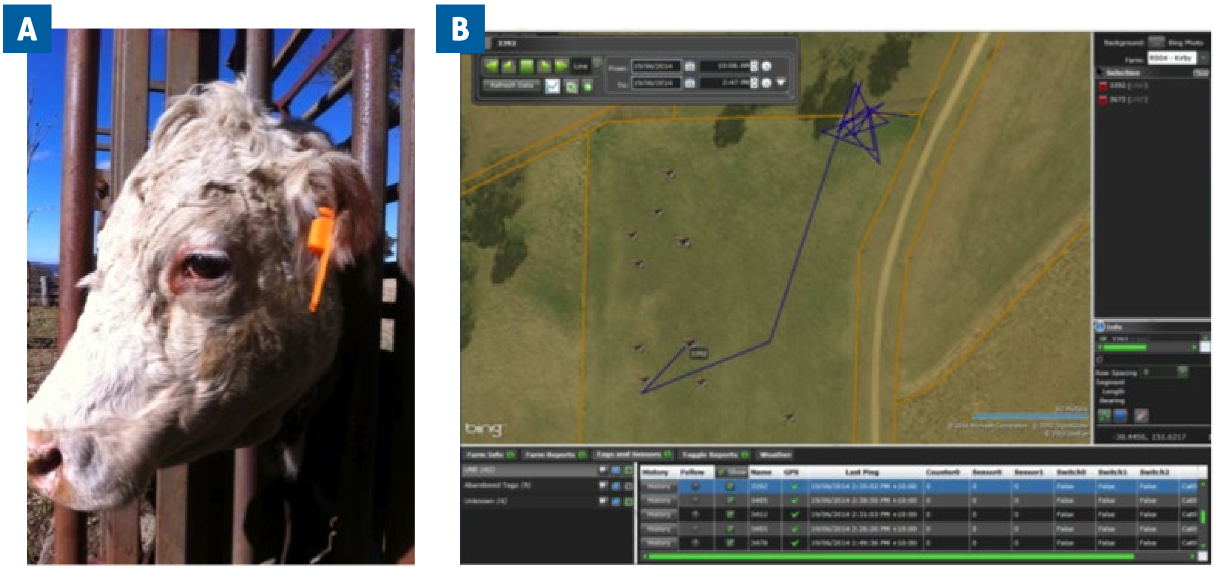

Figure 1. A cow fitted with a Taggle Systems ear tag allowing real time tracking of its location and behaviour (a). The Agtrix interface allows viewing and interrogation of Taggle data (b). In this case the blue line shows an animal moving from a camp (tangle of line segments at top of screen) to begin grazing (the three straight line segments moving south).

BEHAVIOURAL MODELLING OF LIVESTOCK

In addition to evaluating new sensing technologies and assuming that there will be convergence in the operability and user requirements for accuracy, there is a need to focus on the development of behavioural algorithms that provide key information required by graziers to enable better decision making. Producers are interested in having real-time information several key behaviours. These include: lambing and calving behaviour, oestrus detection in females and the occurrence of critical events such as stock theft and predation. Trials are currently underway which are investigating the potential for integrating inertia sensors such as accelerometers with spatial data to provide refinements to the behavioural modelling (Figure 2).

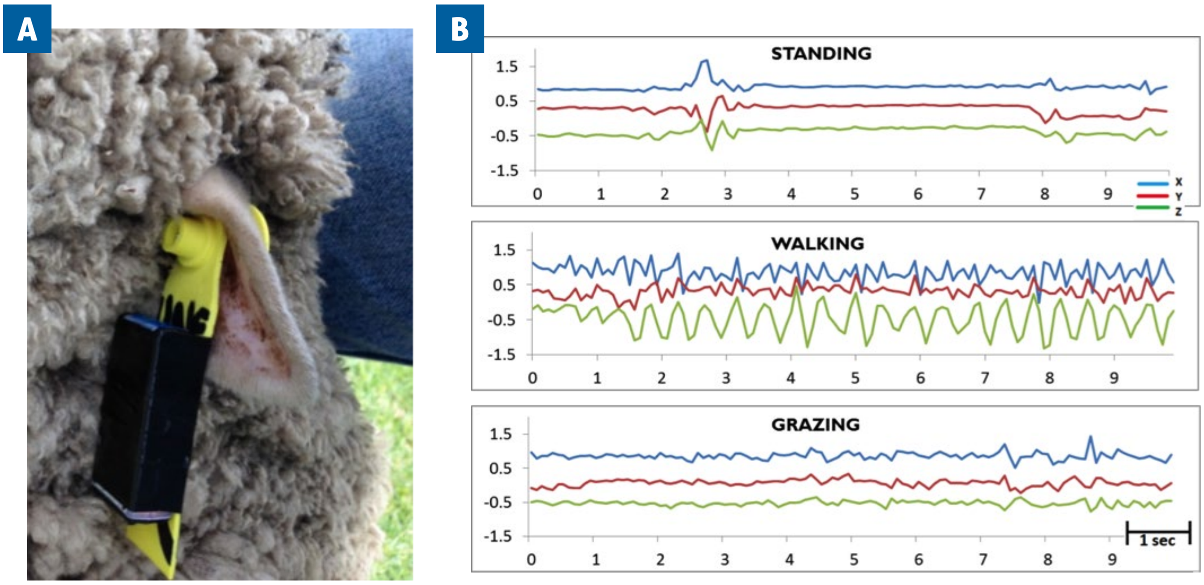

Figure 2. An accelerometer ear tag (a) and the data trace of the X,Y and Z axis demonstrating the different behaviours (b)

LAMBING BEHAVIOUR IN SHEEP

One study examined whether pre-lambing behavioural changes could be identified with the use of spatial data from Global Navigation Satellite System (GNSS) technology (Dobos et al. 2014 in press). GNSS devices were deployed on 20 pregnant Merino ewes grazing a 1.6ha paddock and their lambing activity was compared with the metrics derived from the spatial data. On a coarse temporal scale, mean daily speed (MDS) was faster ($P<0.01$) pre-lambing than post-lambing. At a finer temporal scale (hourly on the day of lambing) pre- and post-lambing mean hourly speed (MHS) was faster differed significantly ($P<0.05$), than post-lambing. An additional metric, mean distance to peers indicated that at the time of lambing, ewes were further ($P<0.01$) from their peers than at either pre- or post-lambing.

Despite MDS and MHS metrics indicating significant changes pre- and post-lambing, neither metric was able to conclusively identify the time of lambing. The MDP metric could not identify differences between pre- and post-lambing but was useful at predicting lambing. This study found that MDS and MHS metrics have the potential to determine a trigger point that could identify parturition and therefore could be used to remotely provide information to a producer regarding lambing events.

OESTRUS DETECTION IN EWES

The change in sheep behaviour between non-oestrus and oestrus in Merino ewes was examined using GNSS tracking (Fogarty et al. 2014 in press). Data were validated through direct observation of the animals. Ewe speed of movement as calculated from the GPS data was plotted against hours of the day to decipher any differences in diurnal movement patterns between non-oestrus and oestrus days. Ewes were more active in the early morning of the day of oestrus.

In addition, an increased speed of movement was positively related to the number of mounts ewes received. Ewes also moved faster in the period leading up to maximum sexual activity, defined as the hour in which each ewe received her maximum number of mounts, with activity decreasing following this period of mounting behaviour. This suggests oestrus can be remotely detected as an increase in speed of movement followed by a return to 'normal' activity through the use of GNSS monitoring.

MODELLING PREDATION EVENTS IN LIVESTOCK

The predation of sheep by wild and domestic dogs is a major issue in Australia, causing serious welfare issues to inflicted animals. In a recent study spatio-temporal data derived from GNSS devices were used to quantify the behavioural responses of two flocks of 15 Merino ewes during simulated dog predation events (Manning et al. 2014 in press). Derived metrics include the spatial distribution of flock members, speed of animal movement and specific behavioural changes including centripetal rotation (circling behaviour of the flock, with individual sheep seeking the centre).

While the spatial distribution data did not appear to be specific enough to enable identification of a predation event, the speed of sheep was higher ($P<0.001$) during, compared to before and after, a simulated dog predation event. Centripetal rotation occurred in 80% of the simulated predation events during this study, and may provide a means for identifying predation. While further research and mathematical modelling of predation events is clearly required, the application of remote sensing technology has the potential to improve future livestock monitoring.

YIELD MAPPING THE GRAZING INDUSTRY

Both the cropping and horticultural industries were revolutionised by the introduction of yield monitoring technologies which provide a spatial representation of the variation found in landscape productivity. To date the grazing industries have largely been unable to collect comparable data. So far, the best solution has been to map variation in pasture characteristics (biomass, growth rate and quality). This project seeks to directly link the actual animal productivity (live-weight gain) with the location within the landscape from which it has been generated. In this pilot study a mob of 20 ewes were monitored over a period of 43 days. Live weight was measured at the commencement and completion of the trial.

Sheep were fitted with GNSS collars to monitor the spatio-temporal behaviour of animals across the landscape. A speed and diurnal activity based behavioural model was used to determine the ewe locations during grazing. The average daily live weight gain achieved over the study period was then interpolated over the spatial variability in grazing pressure to produce an animal product yield map (Figure 2). This animal product yield map was subsequently zoned into three classes (high, medium and low). The High class accounted for over 20% of the total weight gain but comprised only 5% of the total paddock area, while the Low class comprised 80% of the total paddock area but accounted for less than 50% of the total weight gain. New research will integrate walk-over-weigh systems with real-time spatio-temporal data and calculate spatial patterns of animal productivity on a daily basis that can be reported to the grazier in a similar time frame.

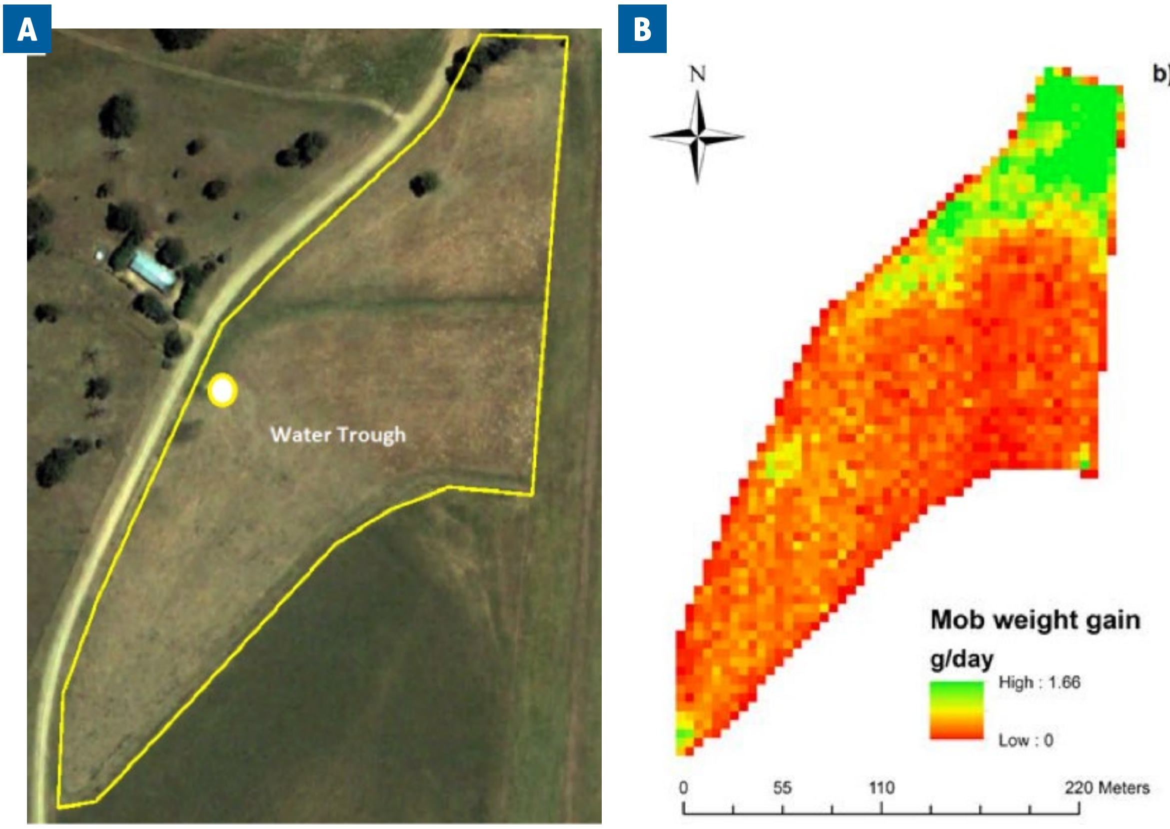

Figure 3. A typical pasture paddock on the New Engand Tablelands (a) and an animal product yield map developed using the integration of GPS tracking devices and a static weigh system.

VIRTUAL FENCING

Virtual fencing (VF) involves the use of technologies to restrict and direct the movement of animals without a physical barrier. It has numerous potential benefits, but one particular application, the management of grazing and camping behaviours is a particular interest to Australia livestock producers. A challenge to livestock farmers is the problem of animals overgrazing particular areas of a field and camping (resting) in areas which leads to high nutrient loads and potential environmental problems. VF would allow producers to regulate the use of overgrazed and camp areas.

In a preliminary, small scale experiment, we tested the viability of VF technology for managing the spatial movements of merino sheep. Merino ewes were fitted with electronic containment devices adapted from the domestic animal industry. Sheep learned rapidly with no animal breaching the VF boundaries despite several attempting to and receiving both audible warnings and electrical stimulation. No short-term detrimental effects were observed. Sheep returned to graze within 10-20sec following electrical stimulation and all animals crossed the VF after the system was removed.

Despite the positive results obtained in terms of animal response, numerous problems associated with the collar form factor were identified. The collar is not a suitable form factor for long term deployment of VF in Merino sheep. Contact of the electrical probes and interaction of the fleece may prove insurmountable problems if considering widespread commercial deployments. Virtual fencing does have potential for the management of the grazing and camping behaviour of Merino sheep. However new form factors (potentially ear tags) need to be developed before this technology has practical application in this industry. Research is currently being undertaken to evaluate how a simple radio frequency based VF system might be used to manage rotational grazing cattle systems.

CONCLUSIONS

There are numerous technologies and systems currently in development for the grazing livestock industries, however their success is not guaranteed. As with all new innovations the key will be overcoming the pitfalls that commonly plague the adoption process. The cropping and horticultural industries have learnt many hard lessons in this space and the researchers involved in these studies above are aware of some of these challenges and where possible are seeking to address these in the development process.

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AERIAL IMAGERY: ROBOFLIGHT'S INTEGRATED APPROACH TO PA SOLUTIONS.

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INTRODUCTION

Drones and Unmanned Aerial Vehicles (UAVs) are certainly the buzz word in the industry and media currently. Many growers and researchers alike are excited about the opportunities. Whilst cheap aerial platforms, sensors and software solutions are widely available there is a temptation to assemble solution components that produce seemingly good results. For example, the process and, nowadays, software to convert near-infrared imagery into NDVI images has been available for years, so it is easy to discard these deliverables as old school. The true power lies in the further processing of raw and NDVI images, giving us analysis and mapping capabilities unheard of in the past.

The challenge is to cut through the media hype and identify sound hardware and software components, integrated into one seamless system that produces consistently good results. Likewise, we require well trained UAV and image processing operators who understand the critical aspects of producing high quality deliverables. Last, such results, eg. field maps, need to be made available in a format which allows the end-user to integrate into their existing systems, eg. for variable rate applications, without second-guessing and in an efficient manner.

ROBOFLIGHT BACKGROUND

RoboFlight Australia draws on the expertise of RoboFlight US' team of scientists and researchers. They have been working on the science and application of remote sensing and agriculture for the last three decades, making them among the most sought after educators and speakers on these topics and receiving US national awards for service within the remote sensing community. The depth of research in remote sensing and agriculture is matched with over a decade of commercial aviation experience as professional pilots. The company has a symbiotic relationship with Kansas State University's world-renowned Unmanned Aerial Systems ("UAS") and Agriculture Colleges.

The head of the science team is Dr Kevin Price, previously a Professor in the Department of Agronomy at Kansas State University. Before his transfer he had spent 19 years on the faculty at the University of Kansas where he served as the Associate Director of the Kansas Applied Remote Sensing (KARS) Program. Dr Price has been working in the field of remote sensing and geographic information systems (GIS) for 33 years and is a true leader in this field.

AN INTEGRATED APPROACH TO AERIAL SURVEYING

The core functions within an (unmanned) aerial surveying system are the image capture platform, the remote sensor and the image processing software.

RoboFlight draws on modified commercially available unmanned as well as manned aerial vehicle platforms. However, this is not to say that aerial imagery from satellites could not equally be used. The reasons for giving priority to unmanned and manned aerial vehicles is the absolute control over the positioning of the sensor and the timing of the image capturing. If the operator has got no control over the sensor then the quality of the results cannot be guaranteed. As a matter of fact, if the operator has got no definite knowledge of these parameters then the quality of the imagery as such cannot even be assessed. For example, varying cloud conditions and sun angles across the seasons will affect the result, and need to be compensated for at the time of the flight. Hence, the reason why we apply UAVs in small areas (less than 3,000 acres in one day) and manned aircraft in larger areas (3,000 to over 30,000 acres in one day).

The sensor of choice are commercial cameras of varying complexity that have been software and optically modified depending on the application. There is a vast difference between camera conversion experts and so-called quick conversions. The team has spent a considerable amount of time sourcing and field-testing only the highest quality conversions from a couple of selected conversion specialists in the US. These cameras were then specifically matched with our aerial platforms. The critical step in producing high quality aerial imagery is to determine the correct camera settings for the environmental conditions and application on the day. Through extensive testing in the field we have established the appropriate camera settings for various types of crop.

Finally, the images need to be converted into usable and actionable results. At the core of our system is a proprietary software that converts near-infrared images into Normalized Difference Vegetation Index (NDVI) images. These are then further processed into specialised maps (see following paragraph). The typical turn-around time to produce these results is less than one day.

SOFTWARE CAPABILITIES

Once a survey has completed we process the many aerial images via commercially available software into georectified orthomosaics. In other words, the images are stitched together into one large image map where every point's geographical location is correct. Through RoboFlight's proprietary software these orthomosaics are then converted into NDVI images.

As a first step these images assess the in-field plant health / stress variability, ie. spatial variability. The true capability of the software lies in the interpretation and analysis of these images. Its statistical functions combined with visual tools allow the generation of specific field maps, as the following examples demonstrate:

VARIABLE RATE MANAGEMENT ZONES

The software through statistical analysis allows the clustering of areas with similar reflective values, hence identifying areas of similar biomass. The classification threshold can be varied to produce the desired number of management zones. The map can be exported into shapefile or other formats for uploading into machinery variable rate control systems.

WEED INFESTATION MAPS

The aerial images typically provide a very high (2-4cm) resolution, and therefore weeds can be zoomed in. The software reads the reflective value of the weeds as opposed to the crop and through a filtering process a weed map can be produced.

PEST AND DISEASE MAPS

These follow the same process as weed maps. Once an affected area is identified and therefore the specific reflective values of impacted crop is established, a filtered map can be produced showing the extent of the infestation / damage.

BIOMASS ASSESSMENT

Biomass is established via the means of ground control areas, typically 1x1 metre grids for which the actual biomass is established, e.g. dry weight. The biomass is then correlated with the reflective values (or sum of values) within the map. Once a crop specific model has been derived the software can use this model to calculate total biomass over very large areas.

EMERGENCE PATTERNS

Through very high resolution images (2cm), areas of poor early emergence can be filtered out, producing crop emergence maps and even allowing for seedling counts if desired.

MECHANICAL EQUIPMENT FAILURE

Areas where equipment failure occurred, e.g. by the planter or sprayer, can easily be visually identified and the combined total area can be calculated within the software. This may lead to equipment repairs or calibrations and rework in the field.

CROP DAMAGE

Areas affected by weather events (hail, frost, wind, etc.) can be accurately measured and quantified. The relative damage (or loss) in terms of biomass is calculated through statistical analysis – a valuable tool for insurance claims.

There are many more applications one might think of:

TEMPORAL VARIABILITY

Series of maps over time provide an understanding of crop growth over the course of the growing season. It is a very valuable tool to assess the effectiveness of prior applications and management decisions, and leads to better and more accurate decisions for the future.

However, care should be exercised as images taken of the same crop in different environmental conditions produce inconsistent results. For example, if an NDVI image of the same crop was produced in different weather conditions the results would not match up. The sheer fact that the sun angle changes over the seasons means images cannot be compared per se.

RoboFlight's software compensates for these inconsistencies and provides comparable images over the growing season and in fact over multiple growing seasons. Temporal variability can now be truly assessed.

Our software exports any of these types of maps into shapefile or other formats which in turn can be imported into third-party machinery auto-steering and variable rate systems.

CONCLUSION

It is easy to see why aerial surveying by UAVs is an exciting development. Cost efficiency, high resolution images, control over the exact timing of the survey and the short turn-around time to produce actionable information are now in the hands of the grower and service provider. As aerial platforms and sensors become commonly available the focus is shifting to software tools. These provide analysis capabilities producing results within hours rather than days. In combination with EM, elevation, yield and other maps, aerial imagery is a powerful addition to the grower's toolbox to advance precision agriculture.

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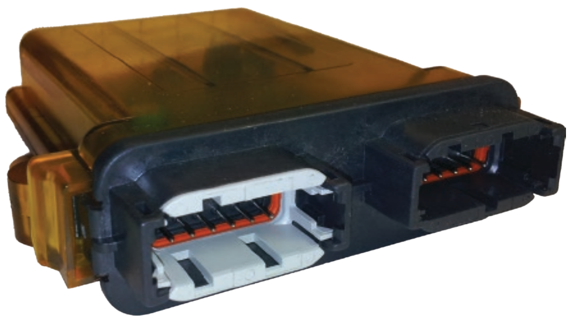

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SOIL SURVEYS FOR ON-FARM TRIALS: A PATHWAY TO UNDERSTANDING PRODUCTION VARIABILITY.

Simon Wallwork

Contact: swallwork@westnet.com.au

SUMMARY

Variability is everywhere in the production system; in the seasons, in the agronomy, in the techniques and in the soils. Soil surveys as a layer of information are a constant which is a good starting point to analyse and then manage production variability.

The two soil surveys I have had conducted are EM38 and Radiometrics. Both surveys are needed to differentiate between the different soil types on the farm; the two surveys of the same paddock in Figure 1 are EM38 on the left and Radiometrics Thorium on the right. EM38 can differentiate between clay and sand but not between sand and gravelly soils. The Thorium survey can indicate the gravelly soils.

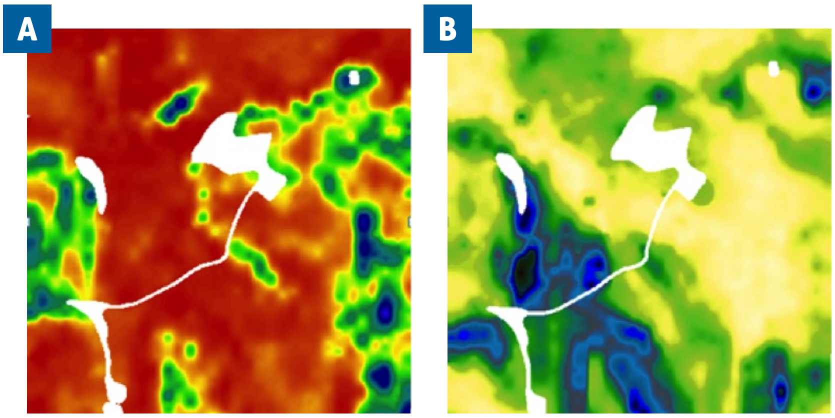

Figure 1:
Paddock J22; EM38 soil survey(a) and radiometric soil survey (b).

Ground-truthing is an important part in the process to match soil surveys with the different soil types in the paddock. Ground-truthing includes deep soil testing and digging lots of holes in the paddock with the map in hand.

I have used soil surveys to conduct on-farm trials and to analyse results by both treatment and soil type. By using soil surveys as a base, treatment yields in trials can be compared on like soils or unlike soils. One example of a trial I have conducted is a comparison between a DBS no-till tine seeding machine and a disc seeding machine on two key soil types, sand and gravelly sand as zoned by a Thorium Radiometrics Survey (Figure 2).

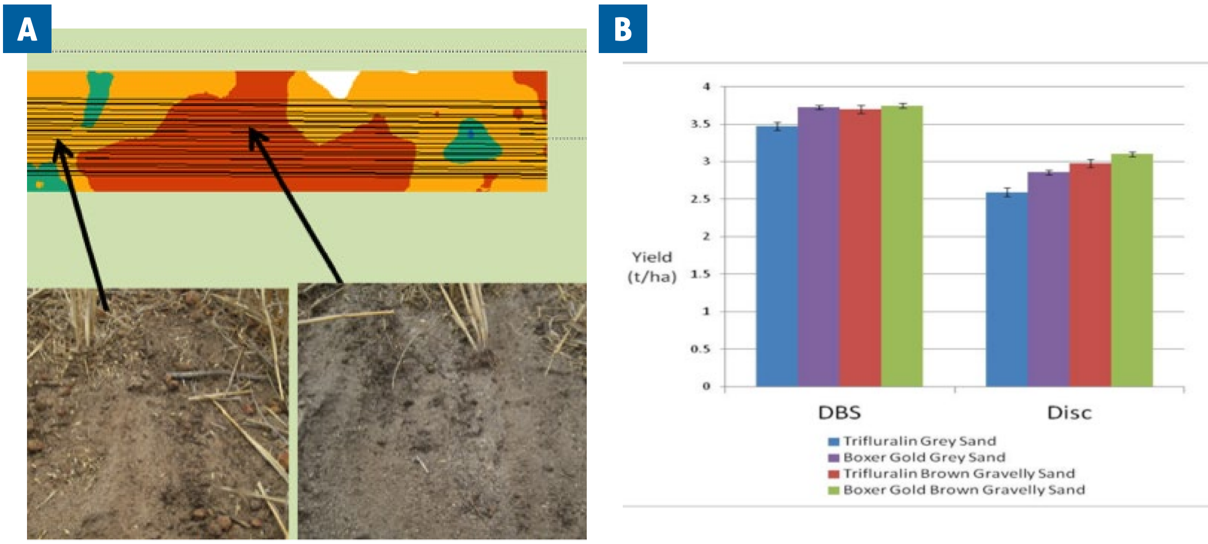

Figure 2. Key soils analysed in trial (a) and trial results of DBS (tine machine) versus Bullet (Disc Machine) (b).

Another example of a trial I conducted is a comparison of Mouldboarding, Deep Ripping and Untreated on white and brown sand as identified by an EM38 Soil Survey (Figure 3).

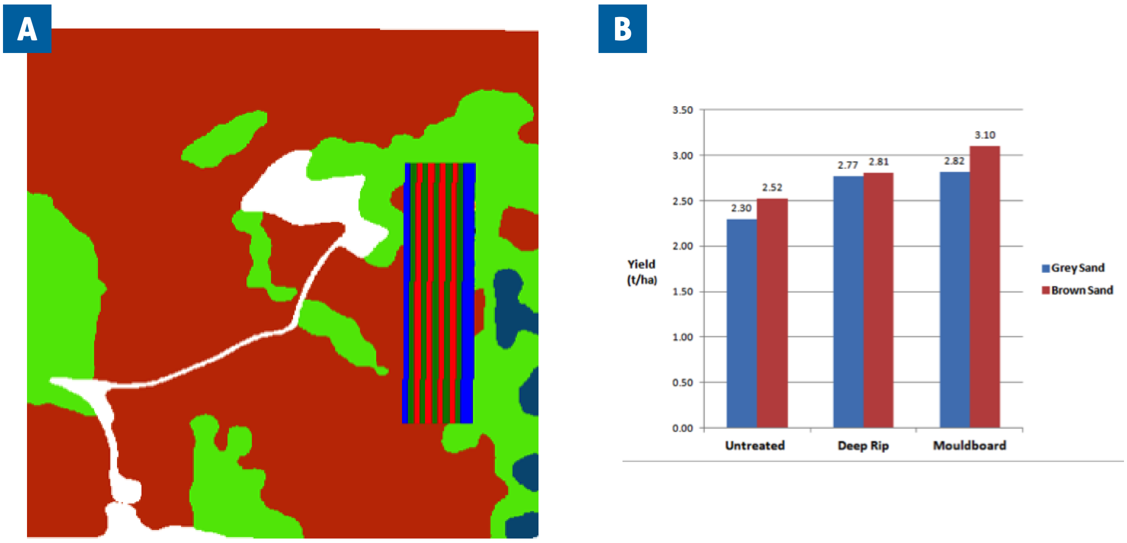

Figure 3. Trial treatment running through EM soil zones (a). Yield results for trial treatments for 2 key soils (b).

MULTI-BIN BUNKER SYSTEMS TO CONTROL DELIVERY OF SUPPLEMENTS TO INDIVIDUAL GRAZING ANIMALS.

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SUMMARY

An automated multi-feed bin system has been developed to enable the daily feeding of controlled amounts of supplement to individual grazing animals. Some potential applications of this technology, including some that may help reduce greenhouse gas emissions from livestock, are described.

INTRODUCTION

An automated multi-feed bin system has been developed to enable the daily feeding of controlled amounts of supplement to individual grazing animals. There are a number of applications for this technology, including some that may be used to reduce greenhouse gas emissions from livestock systems. For example, the feeding of wax-labelled supplement enables the daily pasture intake (and dietary components) of individual herbivores to be estimated from analyses of indigestible marker concentrations in the faeces (Cottle 2013; Cottle and Romero 2013). Feed intake and methane production are highly correlated (Cottle et al. 2011; Cottle and Pitchford 2014). Use of the bins enables pasture intake estimations of individual animals without the need for humans to dose animals with indigestible markers, e.g. by using controlled-release delivery devices.

BIN OPERATIONS

The bins incorporate an electronic ear tag reader, load cells to record bin weight changes, controlled ram-driven bin doors, purpose built electronics, solar panels and remote data input/output capacity (Figure 1). The electronic design caters for up to 4 bins fabricated into one bunker. Up to 4 bunkers can reside in the one paddock which enables 16 feeding bins to simultaneously feed animals in a paddock. A 4 bunker system can service up to 400 head of cattle in the one area.

Field trials in Victoria have helped identify and solve technology 'teething' problems and identify areas that require further development. Sapien has updated the firmware of the bins to provide a training mode that has the bin tray doors fully open to encourage stock to eat from the bins. The solid lead-up races (Figure 1) have been replaced with lighter weight gate panels to encourage animals into the bins. The diagnostic functions on the bins (Figure 2a) have been improved so that more information is sent from the bins to the 'cloud' so animal feeding activity can be better monitored.

Figure 1. Twin feed bin bunker with control electronics including RFID multiplexing and multi-bunk data sharing. Trial participants (left to right): Tom Gubbins (Te Mania), Robert Wyld (Sapien), David Cottle (UNE) and Fiona Conroy (Knewleave).

There were concerns that in training mode the bins were not sending all relevant data. However, observations of the animals identified that they were rarely visiting the bins due to the ample green feed present. Weighing of the feed bins has also been improved by necessity due to windy conditions encountered on site. An additional wind plate has been incorporated into the multi-bin design to prevent wind tunnelling effects and modifications made to prevent rain entry to the feeding trays. Improvements were made to the load cell mountings and these have worked very well with set up and calibration of the bins made simpler and quicker.

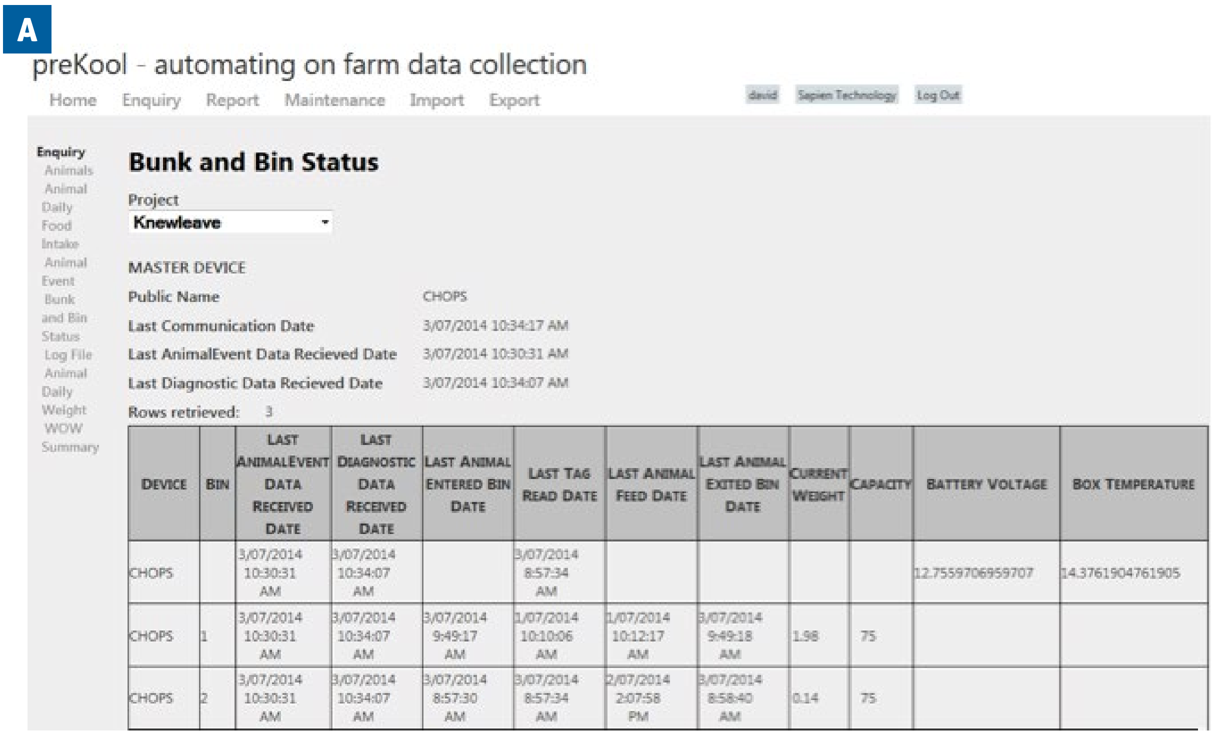
Sapien have also developed a browser screen available to anyone near the feed bunks. This enables checking that the feed bunker is operational without having to disturb feeding animals or animals near the feed bunks. The multi-bin feature of the bunkers has been proven to work with animals successfully eating from both bins in the bunker and having their feed events combined across bins. The bunkers will be re-engineered to be made more mobile via axle/wheels and trailer arrangement so that they can be more easily transported between and within properties.

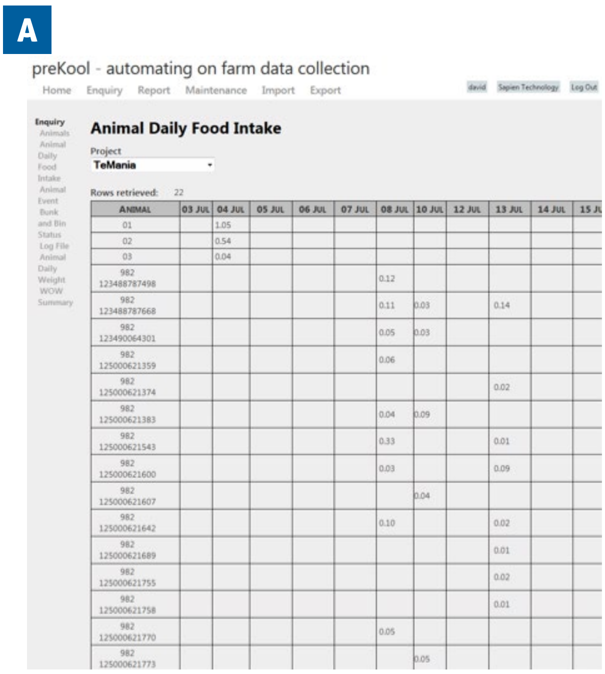
The parameters controlling feed access (e.g. ration allowance, timing of the bin door, training mode etc.) can be adjusted remotely over the web. The bunker data (e.g. supplement each animal has eaten (g/day)) is available through the purpose built website. For example, heifers grazing in southern Victoria have had their wax- labelled pellet intake monitored hourly in real time in an Armidale, NSW office via 3G wireless and the internet (Figures 2 and 3).

The advantages of the bunkers compared to other feed bins include:

1. the amount eaten by each animal is determined by bin weight difference (supplement disappearance), rather than calibrated discrete supplement drops, which may or may not be eaten;

2. up to 16 bins can share data via a central control board (Figure 3);
3. the bins' settings can be monitored and adjusted remotely;
4. the bin data can be accessed remotely;
5. the pasture intake estimation application is protected by an exclusive licence/full patent, and
6. the electronics are efficient and can be scaled up, so the cost of the bunkers will be competitive.





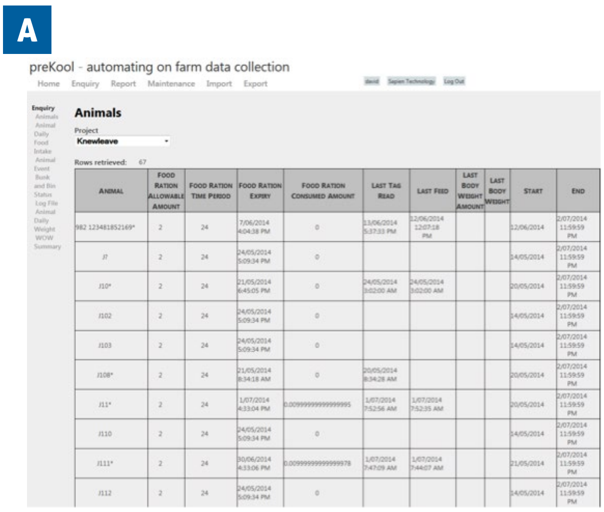


Figure 2. Remote data access and preKool webpages:
(a) bunker and bin status diagnostics,
(b) daily feed intake data,
(c) individual animal supplement input/output data.

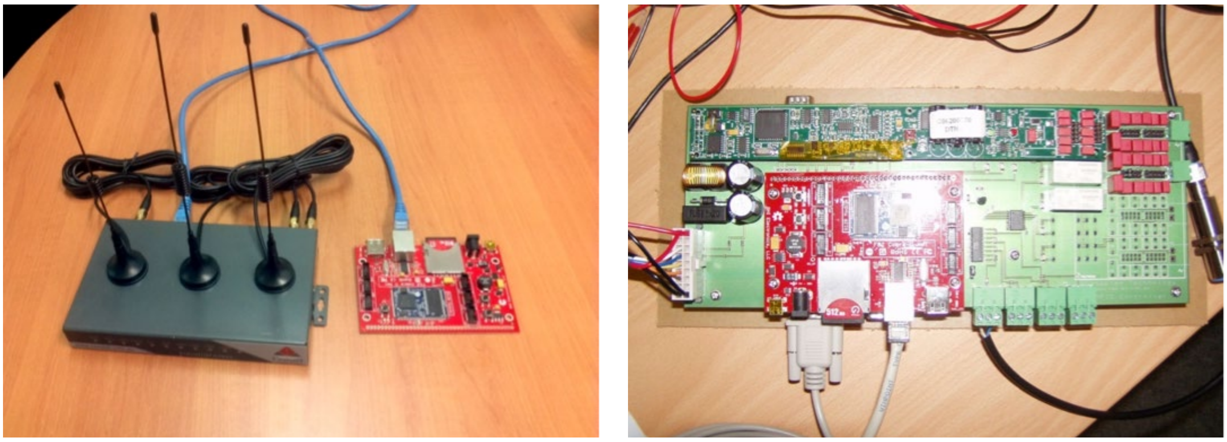


Figure 3. The 3G Wifi modem and a prototype controller board. Notable features of the board (current board shown on right) are that it incorporates all bin control, RFID multiplexing and multi-bunk/bin data sharing.

PASTURE INTAKE

One of the major advantages of estimates of pasture intake based on plant-wax components (e.g. alkanes, fatty alcohols) is that, like all estimates based on internal (indigestible plant) markers, differences in digestibility among individuals can be accounted for, especially if intake is estimated following an estimate of the diet composition in individuals (Cottle 2013). Least-squares procedures using more markers than dietary components are used to estimate diet composition (Cottle 2013; Cottle and Romero 2013). The bunker bins are used to deliver controlled and recorded amounts of wax-labelled supplement to individual animals. The wax (e.g. beeswax or paraffin wax) is used to give the supplement a unique marker profile. If the amount of daily supplement is recorded and internal markers are used to estimate diet composition, it is possible to calculate the total intake of each individual animal (Cottle 2013).

Pasture feed intake and methane production are highly correlated (Cottle 2011). Therefore animals which produce more liveweight gain (meat) per kg of pasture intake also produce more meat per kg of methane produced. Thus selecting for pasture feed use efficiency is an indirect way of selecting animals for lower greenhouse gas emissions intensity.

As feed (pasture) is the largest single cost item in most livestock enterprises, high feed use efficiency is an important breeding and nutritional objective. Residual feed intakes measured on ad lib grain-based diets in feedlots are expensive to obtain and poorly related to more restricted pasture intakes (Herd et al. 2011). The most cost effective way to select grazing animals for lower methane emissions intensity may be to select for improved pasture use efficiency (Cottle 2011) and it is necessary to be able to measure pasture intake to do this.

OTHER APPLICATIONS

As the bunkers can be used to control the individual daily intakes of any type of supplement they have the capacity to be multi-purpose and therefore more cost effective. There are a number of uses that have the potential to reduce greenhouse emissions by finishing stock for market in a shorter period. If livestock reach market weight at a younger age they will usually produce less methane during their shorter lifetimes (Cottle et al. 2011).

Controlled feeding options using the Sapien bunkers include:

- grain finishing of stock at pasture with less chance of lethal grain poisoning caused by grain gorging (Laurence 2014)
- backgrounding stock before feedlot entry or slaughter, e.g. beef supplied to Woolworths or Coles in Australia
- safely supplementing dairy calves and heifers with grain (Gardner et al. 1977; Wales et al. 2006)
- controlled feeding of lipids and nitrates to reduce methane production and obtain carbon credits (Cottle and Eckard 2014)
- differential supplementary feeding of different stock classes, (e.g. single versus twin bearing, weaners, lighter/thinner stock), without the need for separating the different mobs into different paddocks, to achieve final target liveweights
- supplements containing drench (e.g. fenbendazole) fed in controlled amounts for self-medication for parasite control (Fishpool et al. 2012)
- supplements containing medication for pain, such as anti-inflammatory drugs and anesthetics, could be fed following husbandry practices such as castration, tail docking and dehorning. This may provide graziers with an easier, stress free method of delivering pain relief to their animals by the animals self-medicating.

CONCLUSION

The multi-bin bunkers being developed with Sapien Technology allow the control and recording of daily supplement intakes of individual animals. This technology has the potential to reduce greenhouse gas emissions by both genetic selection and special purpose nutritional supplementation of grazing livestock. The most likely commercial applications are probably the feeding of high energy supplements, such as grain, to stock at pasture to either finish stock earlier or to achieve target liveweights at an earlier age, e.g. for mating.

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AGRICULTURAL ROBOTICS AN OUTLOOK INTO A NEW GENERATION OF TOOLS FOR SITE-SPECIFIC CROP AND WEED MANAGEMENT.

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ABSTRACT

Robotic technology is transforming current practices in industries such as mining and manufacturing. Following this trend and current R&D activities worldwide, we envisaged that this technology will also soon have a significant impact in agricultural practices. Robots can be used for tasks related to field and crop management enabling new management practices and data collection leading to further advances in Precision Agriculture. Like the internet and mobile phone technologies a decade ago, it is hard to envisage the full potential that having this technology deployed will bring.

MOTIVATION

With a world population currently over 7 billion and projections of almost 9 billion by 2050 (UN, 2004), sustainability and food security worldwide are significant challenges. In order to accommodate this demand, it is predicted that food sources may have to more than double capacity given our current food consumption habits and supply chain practices. Australia, in particular, faces a real challenge to ensure its participation in food production is both competitive and sustainable. With the development of very competitive markets, Australia can no longer be the supplier of the lowest-cost agricultural commodities.

There is also an increasingly reduced availability of land and water. About 3/4 of growers cannot sustain current operations, and there is an ageing workforce with a low replenishment rate. The low number of students taking interest in agricultural studies is also of concern. To address these issues, there is a need for an increased quality of produce and exploitation of premium and niche markets; an increased robustness of crops to deal with climate variability; the development and adoption of new technologies; the development and adoption of policies leading to sustainable practices; and an increase in investment in R&D and education in agriculture.

This article looks into the future of agricultural robotic systems as a tool that could enable a transformation of practices and the adoption of new technologies in field and crop management. In particular, we focus on capabilities that could enable new practices in Precision Agriculture (PA). With current developments in robot technology within ground and aerial vehicles, there is a potential for having access to crop and soil data at a faster rate than what is available with today's technology in PA. The availability of these data combined with specially-purposed mathematical models of crop development, and soil state combined with short term weather predictions can be used to determine an optimal time-space-wise application of inputs such as herbicides, pesticides, and fertiliser within the crop season. This can lead to the development of novel decision-support tools that optimise input application subject to soil and crop requirement constraints while optimising costs associated with energy and even market movements related to inputs and crop commodities. These tools can also lead to autonomous decision making strategies for robot site-specific crop management.

ROBOT TECHNOLOGY IN AGRICULTURE AND THE SECOND MACHINE REVOLUTION

Through the industrial revolution, agricultural practices were transformed by the use of machinery, which augmented the available human mechanical power used to conduct operations in field and crop management. This led to an increase in the size of fields as we see them used by growers today. The green revolution brought advances in biotechnology and agrochemicals that led to an outstanding increase in yield over the past 30 years. With the increase in the size of the fields, knowledge about crop, soil and weed population dynamics has also gone from being site specific to field average--both space wise as well as time wise.

In the 1980s, PA emerged as a whole-farm technology-enabled management concept to increase long-term productivity, profitability and sustainability while minimising environmental impact (Whelan & Taylor, 2013). For grain production systems, in particular, advances in global navigation satellite system (GNSS) technology and control systems have enabled the use of controlled traffic farming (CTF) to confine heavy machinery to the least possible area of permanent traffic lanes, which reduces soil compaction and minimises the use of inputs by reducing application overlap. The use of remote sensing based on satellite and aircraft imagery has led to site-specific crop and weed management (SSCWM) strategies in terms of variable-rate technology (VRT) and decision support systems, which in addition make use of field data and yield data from sensors fitted to harvesters (Whelan & Taylor, 2013).

Robotic technology has transformed the manufacturing industry and is currently rapidly finding its way into mining. The evolving use of robots and other intelligent machines is described as the second machine revolution, in which machines augment the brain capability of humans in terms of data analysis and rational decision making (Brynjolfsson & McAfee, 2014). Following these trends, it is believed that the use of multiple cooperative highly-autonomous farm vehicles in combination with unmanned aerial vehicles (UAV) could lead to the next step in agricultural automation and a key potential tool for PA.

Figure 1 shows the AgBot, which is short for Agricultural Robot. This platform is currently being manufactured from a design by the Queensland University of Technology (QUT). The AgBot is 2m long, 3m wide (this can be adjusted), and 1.4 m height. Such a platform can operate cooperatively and autonomously in a multi-vehicle operation concept in applications of weed management, fertilising, and seeding. The robots may also have the capability to communicate with UAVs to combine different kinds of environment and field information.

Figure 1. AgBot - QUT's Agricultural Robot.

A key transformation in the conduct of operations consists of replacing a single large machinery by several AgBots that can conduct the same operation co-operatively. The main advantages that AgBots can bring are as follows:

- Lower soil compaction,
- Lower environmental footprint,
- No single point of failure (multi-robot operations),
- Variable-rate application of inputs for SSWCM,
- Multi-purpose platform: weed, fertiliser, sensing,
- Multi-mode weed management (chemical, mechanical, electrical-thermal),
- Long endurance and safe operation (day/night),
- Avoid casual workforce,

The AgBot has been designed with a total mass in the range 300kg to 600kg, which aims at minimising soil compaction. A lower environmental footprint arises from energy efficiency of the robot power train and also from the smart co-operative conduct of the particular operation. Different options for drive train systems are being tested (fully electrical and electro-hydraulic) to optimise energy efficiency including the options to harvest solar energy to power some of the on-board equipment. In weed management, for example, the AgBots can be augmented with information from a UAV about location and distribution of weeds in the paddock, which in turn can be used for mission planning taking into account energy expenditure. Figure 2 shows an example of how automatic classification areas with weeds or plant disease can be achieved based on imagery collected from a hexacopter UAV equipped with advanced sensors such as multispectral, thermal camera, a LIDAR sensor, a modified NIR camera and advanced onboard image-processing capabilities.

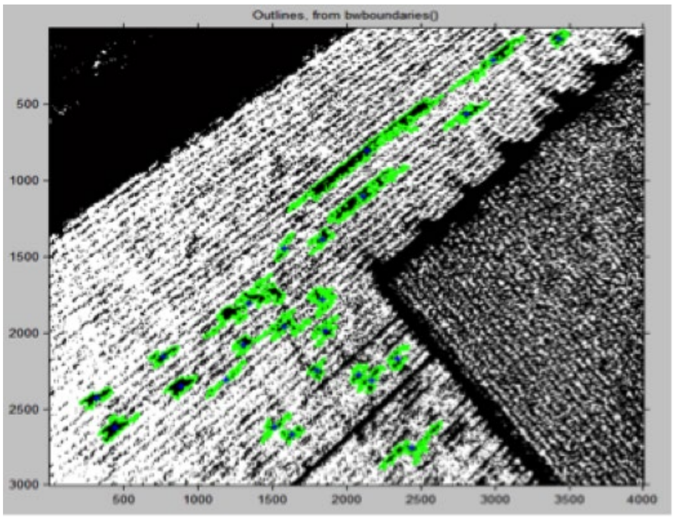

Figure 2. UAV image processing and automatic classification areas for the AgBot to direct its effort.

The use of computer vision on the AgBot not only for weed detection--which is where current commercial technology based on reflectance sensors is at--but also for weed identification can be used to improve weed management operations. For example, with weed identification and local environment information, the appropriate chemical mixture and delivery method can be selected on the spot in the case of chemically managed weeds. This is enabled by the multi-vehicle operation, which aims to cover the same amount of ground in a given time interval but moving at lower speeds with a number of robots rather than adhering to traditional single machine operations. The AgBot is being optimised for operational speeds of 5km/h and they have the option to stop to manage weeds appropriately, whether it is chemically with adaptive application means, mechanically (Cloutier et al., 2007) or thermal (Ascard et al., 2007). That is, the AgBot can enable multi-mode weed management strategies.

AgBots can operate day and night and conduct autonomous replenishment of energy and inputs such as agro-chemicals. This can lead to safer operations, since these do not depend on the alertness of a human operator; which is a key factor in accidents for agriculture operations. The potential benefits of the AgBots can extend beyond grain production systems and into horticulture. Specific to this industry there are benefits that could be brought by automated harvesting. Today, most of the harvesting of horticultural produce is done by human labour. This creates some challenges for growers. There is stress associated with finding a capable sessional workforce to take of advantage of the optimal time windows for harvesting. Often times, there is a significant produce losses due to re-growth, which is not financially viable to harvest with a human workforce---this can be addressed with AgBots. The benefits for using agricultural robots designed not only for weed management but also for harvesting can be significant (Rankin, 2010).

IMPLICATIONS FOR PA

With the AgBot navigation and motion control capabilities, CTF can be implemented. Indeed, the AgBots are equipped with sensors for navigation: GNSS receiver, inertial measurement units (IMU) (which measure accelerations and rate of turn), cameras, and encoders. Sophisticated algorithms for data-fusion are used to extract information from the variety of sensors. This also allows the use of cheap sensors to obtain high accuracy in robot localisation and navigation. For example, in recent experiments, the combination of a low resolution webcamera information was used to track heading angle and robot cross track by processing image information of crop rows combined with a low cost IMU (Au$200), which lead to an accuracy of 10% of the inter-row spacing in cross-track error without the use of GNSS (English et al., 2014). These results can be aided with a cheap GNSS receiver (Au$200) to increase robustness to visual characteristics of crop rows (English et al., 2013). The same cameras used for navigation can also be used to conduct image processing for detection and avoidance of obstacles during both day and night operations (Ross et al., 2014). This may potentially result in the suppression of expensive radar and laser ranger sensors as computer-vision-based detect and avoid technology improves in the future.

The use of dedicated cameras for weed detection and classification can be used to control VRT in herbicide application. The weed-classification information together with the location of the different weed species through GNSS can be used for improving site-specific weed management strategies as well as studying weed population dynamics and weed-crop interactions. The development of models for population dynamics and crop-weed competition can enable novel weed-management strategies in the future (Maxwell & O'Donovan, 2007).

The most relevant feature of the AgBots for PA is their capabilities to carry a variety of sensors and their multi-vehicle operation. Having the AgBots roaming in the paddock, can be exploited to carry soil sensors for apparent electrical conductivity, electromagnetic induction, and Gamma radiation. When this information is combined with that from the cameras used for weed detection and classification, an estimation of crop vigour and soil state can be obtained.

The data collected by the AgBots can be also augmented with data from remote sensing collected from UAVs. The combined use of AgBots and UAVs bring the possibility of sampling at a faster rate than what is achievable with satellite or even piloted aircraft technology. The availability of these data combined with specially-purposed mathematical models of crop development, and soil state combined with short term weather predictions can be used to determine an optimal time-space-wise application of inputs such as herbicides, pesticides, water, and fertiliser. This can lead to the development of novel decision support-tools that optimise input application subject to soil and crop requirement constraints while optimising costs associates with energy and even market movements. These tools can also lead to autonomous decision making strategies for robot site-specific crop management.

THE CHALLENGES AHEAD

To date, the large majority of agricultural robots remain as proof of concept with relatively successful field demonstrations--except for countries like Japan where there has been a strong support for R&D over the past twenty years, which has led to commercial robots. Even though research in this area is growing worldwide with leaders in Europe and the US, 5 and small pockets of activity in Australia, the uptake of agricultural robot systems will not come without some challenges and barriers. We believe that there are four enabling factors that need to be addressed to a threshold of maturity for the successful technology uptake (Perez, 2013):

- Technology
- Regulation and certification
- Business
- Legal and socio-economical aspects

When it comes to technology, a lot of progress has been done in terms of proof of concepts. There are, however, aspects still in need of further research such as energy efficiency, robustness of the autonomous decision making by the robots, increased reliability for long endurance operations, development of energy take points at remote locations, development of better robot-human interfaces.

Operation of agricultural robotic systems will potentially have to be regulated to ensure safety. In order to do this, there is a need to develop a framework for assessment of autonomy and to develop regulations and procedures for certification. Some of these frameworks have already been proposed for unmanned aircraft, as in (Rankin, 2010), and can be adapted to agricultural robots. This will also have a bearing on insurance premiums.

In terms of business, there is a need to reduce the cost of equipment without sacrificing performance and safety. This is very much linked with the development and uptake of technology. The use of cheap sensors, for example, is enabled by sophisticated software and algorithms for data fusion and estimation. As in any other areas, the adoption of the technology will lead to a reduction in equipment costs. Since there are currently no robots conducting long-term operations, there is little data available for estimating reliability relative to other equipment. Agricultural robotic systems, however, fit in with VRT and CTF. Therefore, we could expect similar gains in terms of better management of inputs such as fertiliser and chemicals, which account for 16% of farm costs (Whelan & Taylor., 2013) plus further improvements in reduced fuel and energy consumption. However, at this stage we are still working on estimates of return benefits expressed in terms of Au$/ha. Also, it may be possible to have a roll-out of technology as a mix of farmer use and service industry and then transition more onto farmer operations only. These scenarios will lead to different economic benefits.

There are aspects to be considered in terms of legal issues such as, for example, liability in the application of herbicides and the potential damage to the environment. Recently there has been also a lot of activities in the area of intelligent agents (Chopra & White., 2011): ``As we increasingly interact with these artificial agents in unsupervised settings, with no human mediators, their seeming autonomy and increasingly sophisticated functionality and behaviour raise legal and philosophical questions." A legal framework for autonomous agents aims to answer questions such as:

- What is the standing of these entities in our socio-legal framework?
- What legal status should artificial agents have?
- Should they be mere things, tools, and instrumentalities?
- Do they have any rights, duties, obligations?
- What are the legal strategies to make room for these future residents of our policy and society?

Other developments in robotics like unmanned aircraft systems and drive-less cars are helping indeed in the answering of these questions and the development of legal frameworks.

Socio-economical aspects are of great importance for the uptake of this technology. Questions as to whether this technology can attract a younger generation to agricultural industry, the benefits to the economy in the creation of the agricultural robotics industry, the potential development of decision support systems and site-specific crop and weed management policies associates with PA are but a few of the socio-economical aspects that need to be understood better.

CLOSING REMARKS

Agricultural Robots or AgBots that conduct multi-agent co-operative operations of weed management as well as variable-rate application of fertiliser have the potential to transform some current practices in agriculture. The most relevant feature of the AgBots for PA is their capability to carry a variety of sensors and their multi-vehicle operation. This type of operation can enable data collection at a faster rate and in combination with remote-sensing data from UAV could lead to novel decision support systems and strategies for robot autonomous decision making in relation to site-specific crop and weed management strategies within seasons.

Given how robotic technology is transforming current practices in industries such as mining and manufacturing, and the current trends in R&D activities worldwide in agricultural robotics, it is envisaged that this technology will also soon have a significant impact in agricultural practices. Like the internet and mobile phone technologies a decade ago it is hard to envisage the full potential that having this technology deployed will bring.

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INCORPORATION OF PA INTO THE UPPER NORTH FARMING SYSTEMS 2013 PADDOCK-SCALE SEEDER DEMONSTRATION.

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2 Precision Cropping Technologies, Crystal Brook, SA

KEY POINTS

Precision Agriculture technologies can be a vital tool in gaining a better understanding of the underlying soil characteristics within which a crop is grown.

BACKGROUND

The adoption of no-till farming systems has been significantly lower in the Upper North (UN) region with many farms still cultivating paddocks before sowing. The concept of the demonstration was to find how different seeder bar types and configurations would affect plant establishment and ultimately yield. 13 seeding systems (set up how the farmer would usually operate them) sowed a 12-24m x 800m plot using RTK steering guidance. A Primary Sales Precision Seeder Bar and Flexicoil Box was used as the control treatment. Treatment widths were determined by bar and header width with each plot needing to accommodate 1-2 passes of a 12m header front in order to gather yield mapping and quality data.

The Trial was sown on the 17th of April into a bone dry profile. Although this was not optimum time of sowing for barley in Booleroo Centre, the logistical challenges of getting farmers to donate their time and machines before their own seeding programs commenced meant that this timing was necessary. Each treatment was sown at 70kg/ha of Hindmarsh Barley with 70kg/ha of DAP (18:20). This was done to avoid fertiliser toxicity with the single shoot machines. A pre-emergent herbicide application of Boxer Gold at 2.5L/ha plus 1L/ha of Trifluralin 480 was applied prior to sowing.

A range of Precision Agriculture (PA) technologies were incorporated into the plans for the Seeder Demonstration in 2013. Through observing historical yield data, it was clear that there were underlying soil characteristics that were driving yield variation throughout the paddock. Analysis of the 2012 wheat yield map showed that along one of the proposed treatment runs the yield varied from 0.45t/ha to 2.45t/ha. Large scale demonstrations are by their nature exposed to greater variability than smaller plot trials, given the length of the treatments (800m) in this demonstration it was inevitable that they would traverse a range of soil types and that this would not be equal for all treatments. This soil variability then had the potential to bias performance comparisons between machines.

The use of PA was implemented to assist in removing this variability from the results. In addition, there was interest in whether there could be differences in the performance of each seeder according to soil type. This had the potential to be exacerbated due to the extremely dry soil conditions into which the demo was sown.

WHAT PRECISION TECHNOLOGIES WERE USED?

It was decided that an EM38 survey, crop biomass sensing and yield monitoring was conducted to assist with the assessment of the performance of each treatment, and to serve as a valuable knowledge building process for those interested in, and following, the Seeder Demo progress. A multi depth EM38 instrument used to conduct the survey was coupled with RTK GPS that collected survey grade elevation data (Figure 1). From the EM survey, maps for two depths were created to define differences in the soil environment. The elevation data was used to create a digital elevation map and derivative like slope to understand water behaviour.

CropSpec™ is a crop sensor for mapping variation in crop biomass (crop cover, colour and vigour). The CropSpec™ crop sensor was used to map the variation in crop growth at stage GS32. This was conducted to investigate if the changes in soil type were influencing crop establishment and early growth/vigour (Figure 2).

Yield monitoring compared past yield maps and the 2013 trial yield map to analyse air-seeder performance and the influences of soil type differences.

In June 2013 the CropSpec map and EM38 maps of soil change were used in conjunction to carry out field investigations. Sites of key differences and relationships in the maps were selected, then using the coordinates and GPS these sites were ground-truthed (Figure 3).

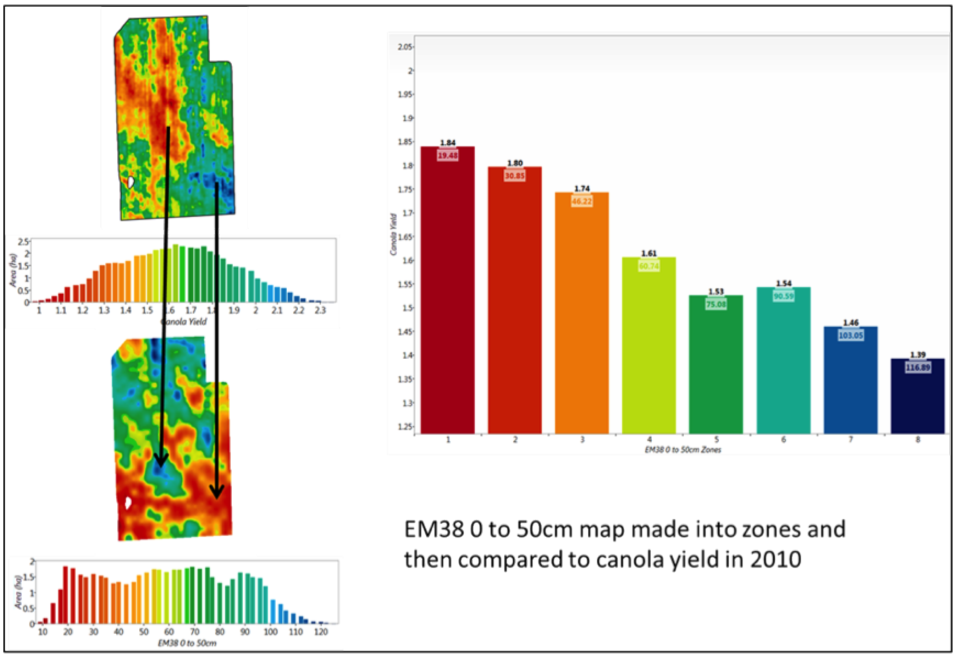

Figure 1. Relationship between yield and EM Values: The top left map shows the difference in canola yield, whilst the bottom left map is the EM values for the site. It clearly shows a relationship between low yield - high EM values and high yield - low EM values.

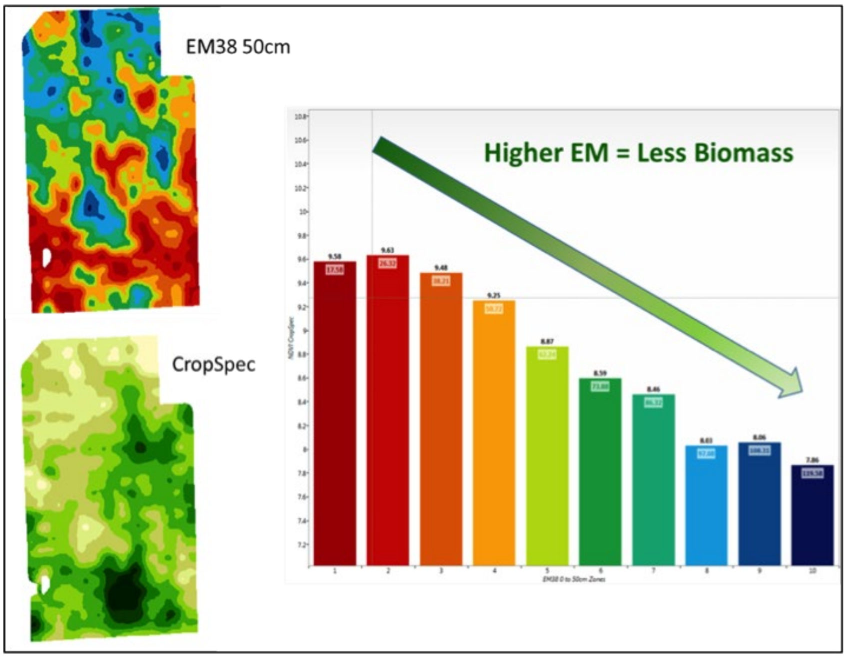

Figure 2. Relationship between Biomass and EM Values. On the left are the EM38 and CropSpec maps. On the right is a graph demonstrating the relationship between EM and biomass. The higher the EM value, to lower the biomass.

Sites were selected for low, medium and high EM38 values (2-3 of each). Low EM values are typically associated with lower clay content, low water and low salts (also stoney profiles) whilst highest EM likely indicates high clay content, higher salts and water in the profile. Three of these sites were selected along the control treatment that had large historical yield variability along it's transect.

At each site, a soil pit exposing approximately 40cm of the profile wall was dug. Photos were taken of the profile and localised crop cover. Low EM38 sites that had been historically high yielding had more friable open profiles (easier to dig) and had good plant densities and high early vigour and depth of colour (Figure 4). Higher EM38 sites visited had tighter more massive heavier clay profiles (which were difficult to dig to 40cm due to the plastic nature of soil), lower plant establishments, reduced tillering and vigour. High EM soils in this cropping district can be a good indicator of sodicity and this was apparent at these sites (Figure 5). Visual differences in crop growth were clearly evident between the soil types. Changes detected in the CropSpec map were verified in the field and showed that changes in soil type were having an important influence on yield potential at an early growth stage.

At the UNFS Annual Field Day in September the three ground truthing sites were re-visited. Holes were again dug to 40cm to demonstrate the differences in soil texture and profile between the soil types. Jar tests and soil cores were also taken to 60cm to demonstrate the soil profile physical characteristics and view the corresponding crop potential. Walking along the path between treatments it could be noted the differences in the hardness of the soil surface, differences in plant density/growth and how this varied along the treatment as displayed in the EM and Crop Spec maps. An EM classification map was loaded on a mobile device with GPS for people to view. This was a very valuable learning exercise for those who attended.

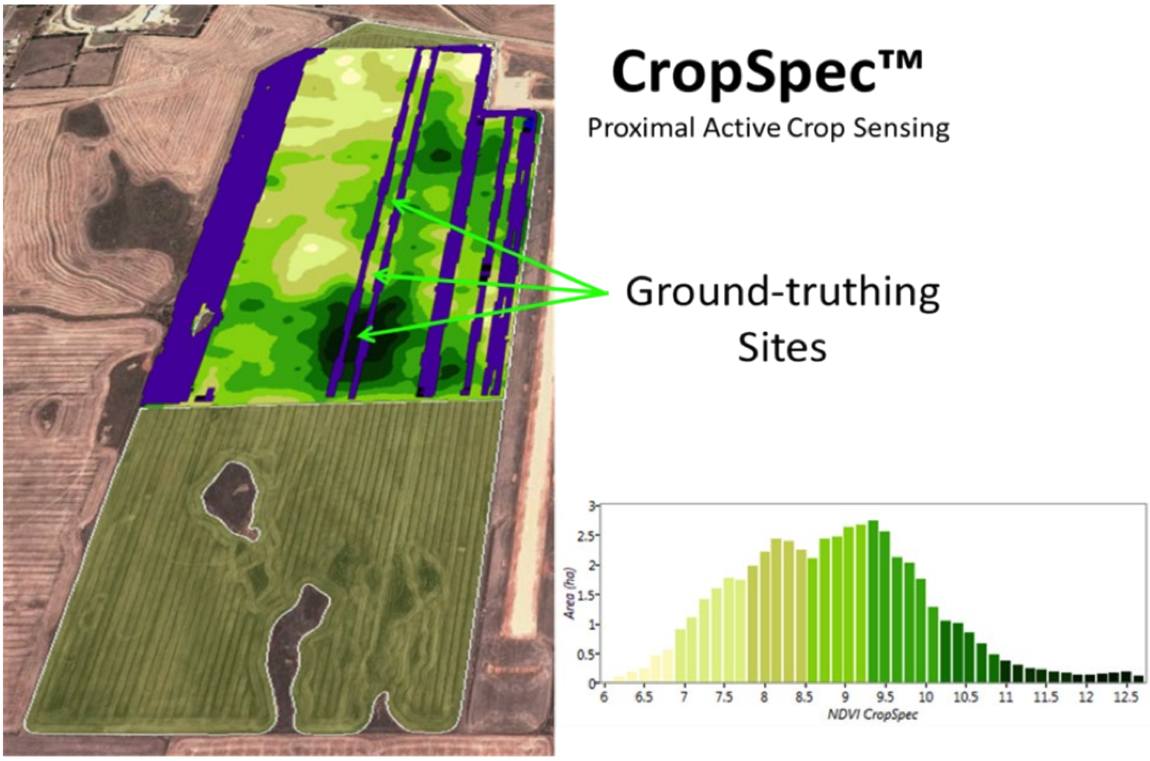

Figure 3. Ground-Truthing Site Selection: The arrows showing the Crop Spec ground truthing sites selected based on high, medium and low values.

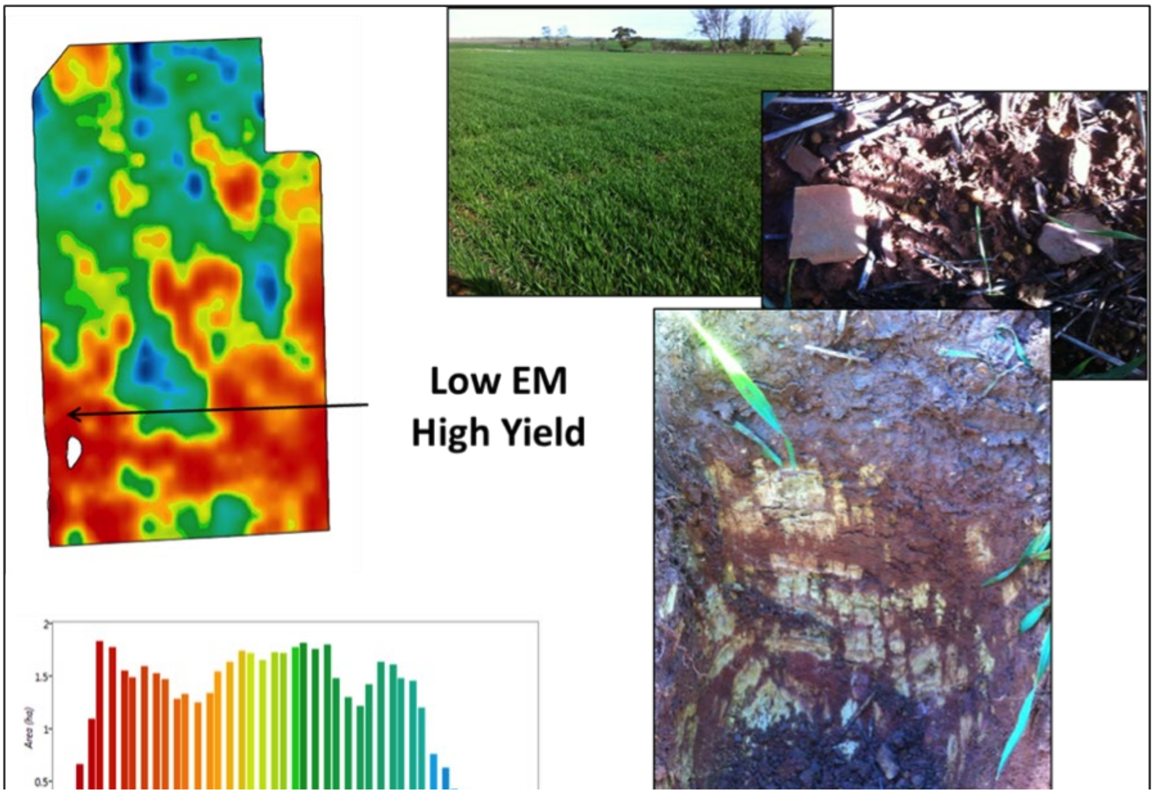

Figure 4. Ground-truthing – Low EM. The Low EM areas of the paddock are historically higher yielding. This is displayed in the crop vigour photo at the top. The soil was found to have friable open profiles and had good plant densities and high early vigour and depth of colour.

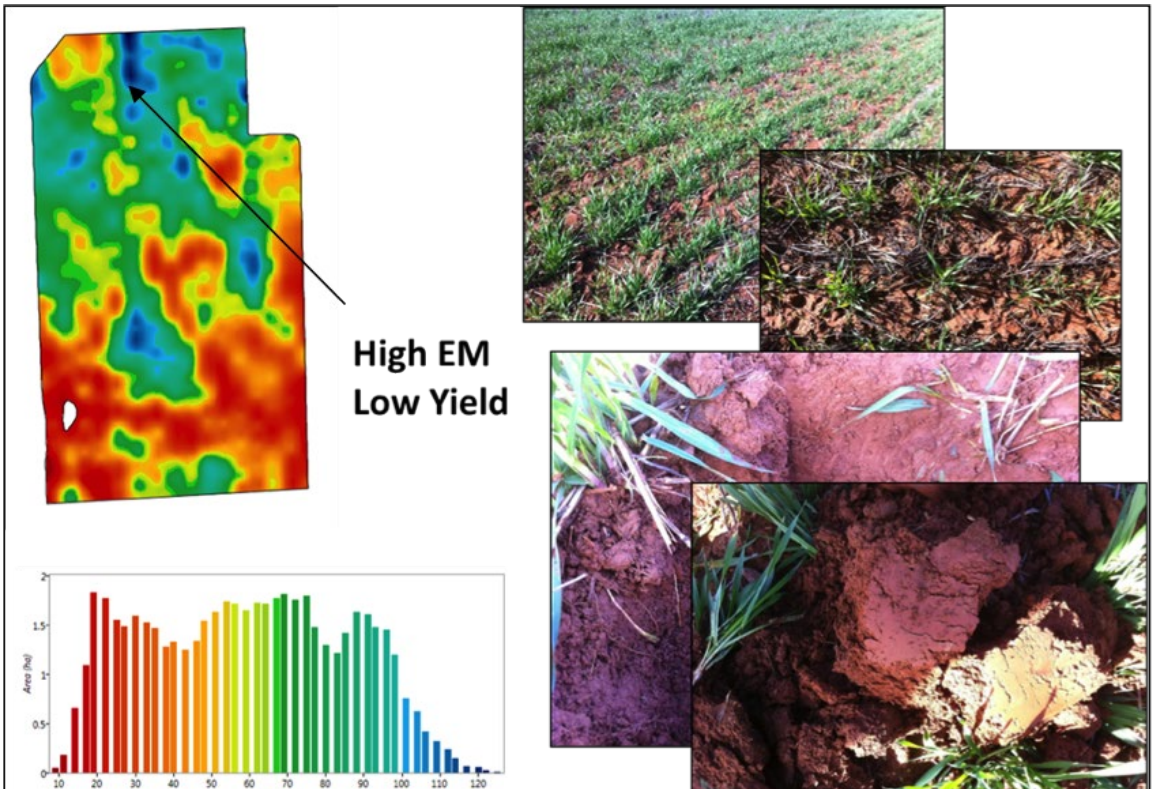

Figure 5. Ground-truthing: – High EM. The higher EM areas of the paddock are historically lower yielding. Higher EM38 sites visited had tighter more massive heavier clay profiles, lower plant establishments, reduced tillering and vigour.

DISCUSSION

Precision Agriculture technologies can be a vital tool in gaining a better understanding of the underlying soil characteristics within which a crop is grown. It can enable the source of yield differences to be investigated and can describe the variability within a paddock, farm or district.

The paddock in which the Upper North Farming Systems 2013 Seeder Demonstration was conducted displayed significant soil characteristic variability that translated into yield differences when the historic yield maps were overlayed with EM maps (Figure 6). In-crop monitoring using a CropSpec crop sensor for mapping variation in crop biomass also displayed a strong relationship between the variations in soil characteristics and the crop vigour and biomass.

A yield monitor was used on a CR9090 harvester to record strips of yield data for the length of each air-seeder treatment. These were used to create individual yield maps x treatment and can be used to compare total yield of adjacent treatments and also yield by soil type.

It is important to get out in the paddock with the shovel and investigate differences that are being displayed on a map to gain an understanding into why the crop establishment, vigour or yield changes. It is not always the expected soil characteristic that is creating the resulting variation in the maps. Subsoil constraints can create a hostile environment for seeds to germinate, establish roots and develop. They can limit the crops ability to extract water from deeper in the profile at critical stages in the season.

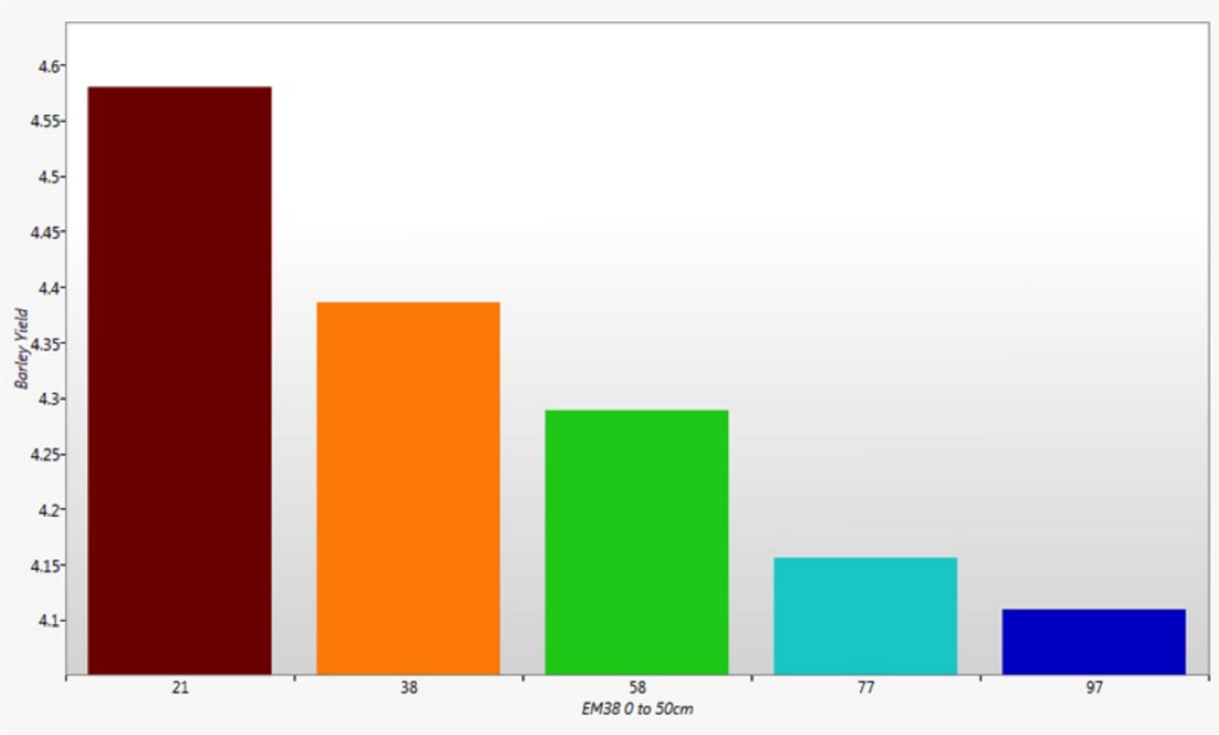

Figure 6. Yield Map and EM Map correlation - The historic relationship of yield declining as soil gets heavier (increased subsoil constraints) can still be observed over the entire site at the end of 2013 despite the application of 24 different treatments. This same trend could also be observed along the length of individual treatments. This clearly shows the importance of understanding soil conditions when undertaking broad scale demonstrations and when managing your farm. Small changes to management may not reach potential increases in production if soil constraints are not ameliorated.

With the variability within the paddock there are implications for improving management decisions. In this paddock there is potential for variable-rate applications of gypsum, seeding, fertiliser and importantly post-seeding nitrogen. By adjusting the rates of inputs applied it is possible to reduce soil constraints, improve productivity and help manage risk by maximising the outputs for every kilogram of input (Figure 7). The information gathered by collecting yield maps, crop sensing, EM38 surveys in conjunction with ground-truthing can help in making more timely decision's when it comes to post seeding N, and avoid or reduce rates in less reliable soils.

CONCLUSIONS

The use of Precision Agriculture can significantly increase the quality of information gained from a paddock and can help to improve the understanding of how and why an outcome has been achieved. Most farmers have a fair understanding of what parts of their farm perform better but with the information gained by combining yield data, soil surveys and biomass maps it helps draw the definitive line between good and bad performing areas. With the knowledge gained by then ground truthing these defined areas the farmer can ameliorate poor areas, or if that is not possible manage them accordingly. While there may not always be savings involved in varying inputs, shifting the inputs to areas of the paddock in most need, results in more profitable and efficient use of inputs.

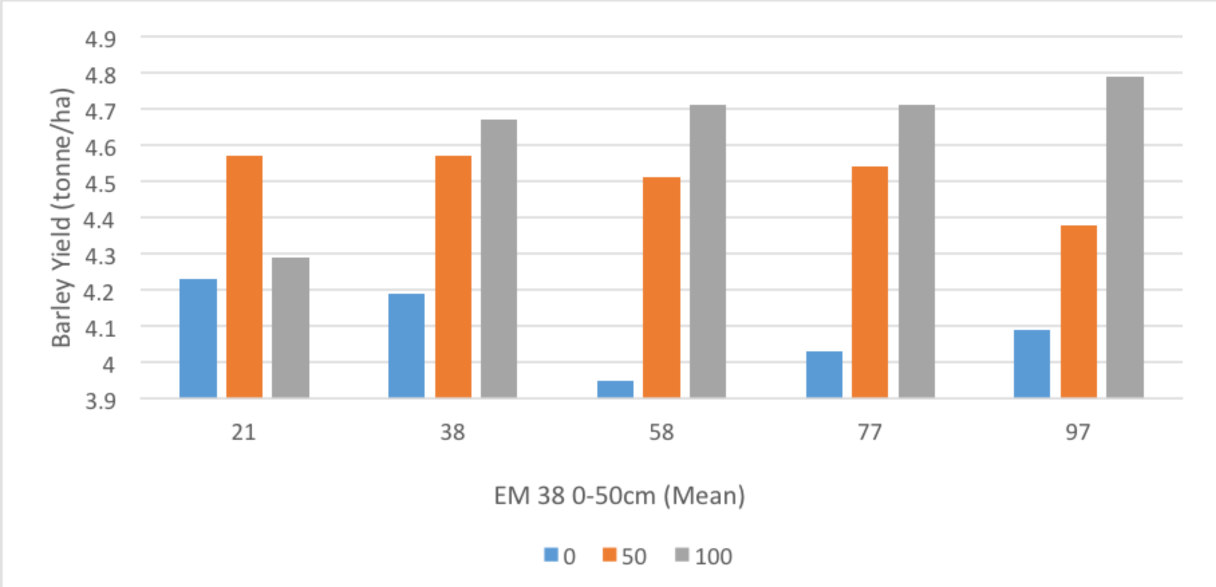

Figure 7. Overall the site was highly responsive to the addition of N in-crop in 2013, however different soil types respond differently.

There are many farmers that have a yield monitor on their header yet don't collect yield data. Even if the data isn't used straight away, collecting it over different seasonal outcomes builds the picture on how parts of the paddock perform making the transition from blanket based management to zone based management clearer and easier.

ACKNOWLEDGEMENTS

This paper reports the results from a project titled: Maintaining profitable farming systems with retained stubbles in the Upper North of SA which is running from 2013 to 2018. The project is funded by GRDC, Precision Cropping Technologies and UNFS. Without the technical support and guidance from Michael Wells, Precision Cropping Technologies, the additional PA elements of the seeder demonstration would not have been possible.

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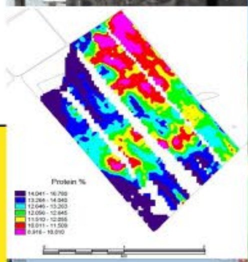

“Protein mapping is built as a real time in-field analysis tool for grain profit at harvest. We see the other major benefit of protein mapping as an historical analysis tool for future farm decision making.

We can use the protein maps, yield maps, soil spatial data maps to ground-truth paddocks to improve soil and plat performance. It has given us far greater insight into the variable that contribute to yield, quality and soil condition. It has permitted a more refined review system for planning for cropping profitability.

Protein mapping is very much a precision agriculture tool. It opens up as an insight into another dimension of cropping productivity previously not obtained with such resolution in field.”

Michael Eyres, GM, Injekta Field Systems

NextInstruments

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PA LESSONS LEARNED, DREAMS DREAMT, AND PLANS MADE: SOME PERSPECTIVES OF A U.S. HIGH PLAINS DRYLAND RESEARCHER AND FARMER.

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LESSONS LEARNED

The history of precision agriculture technologies has resulted in some advancements and adoption periods taking longer than expected, some shorter than expected, and the emergence of some technologies that were completely unforeseen surprises. The industry has evolved from a focus on collecting data for the purpose of site-specific management with an initial view that we were going to reduce variability in fields and make them more uniform in their productivity. It didn't take many years of that strategy to pass before we realised that making fields more uniform through site-specific management most often didn't make sense from an agronomic or economic standpoint. It became apparent that our efforts would be best spent by managing the variability that inherently exists.

The efforts revolving around the collection and use of data were quickly overshadowed by the emergence of machine control technologies. These technologies: guidance then replaced by auto-steer and automatic swath control for sprayers and planters were appropriately coined by K-State agricultural economists Dr. Terry Kastens and Dr. Kevin Dhuyvetter as "duh" technologies. These were technologies that provided an instant return on investment, were easy to deploy, and they required little to no technical background for the adopter to reap the benefits. All the producer needed to do was simply make the purchase and write the cheque.

These technologies changed the playing field in precision ag forever by bringing essentially every commercial producer into a period of rapid technology adoption, and in many cases, equipping them with hardware that was capable of much more sophisticated tasks than it was initially purchased for. With the hardware in place, many producers who were not early adopters of precision agriculture or started with site-specific management as a goal, are now searching for additional return on investment from this hardware.

The spectrum of mechanisms which a producer can use to develop site-specific management strategies ranges from developing their own in-house solutions with their own data to completely outsourcing the process whereby the producer doesn't even provide data but receives variable rate prescriptions from a "black box" solution using data the provider collects on-site or through remote sensing (Figure 1).

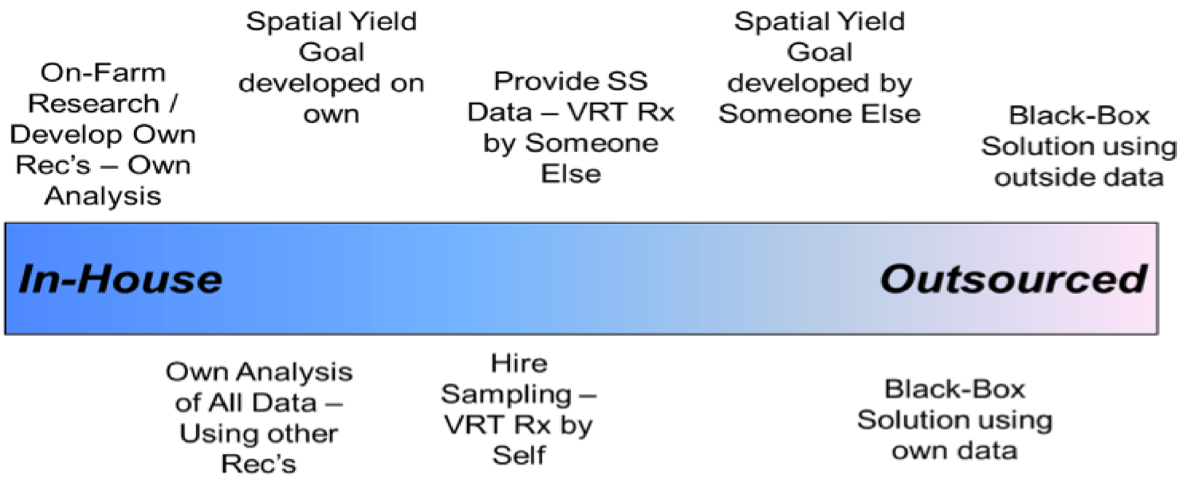

Figure 1. Spectrum of options for development of a site-specific management strategy.

The demand for services along any level of this spectrum has generally outpaced availability. Availability includes anything from having the knowledge and resources available for a producer wishing to implement a complete in-house solution to the availability of full-service providers who have a thorough understanding of what they are trying to manage. In general our ability to collect data and perform site-specific applications has outpaced our ability to adequately perform the steps in-between. As a producer moves more towards outsourcing his site-specific management efforts it becomes even more important that good questions are asked of those providing the service to ensure that what is being done is agronomically sound and matches the management philosophy of the producer. If your service provider can't explain to your satisfaction exactly what is happening behind the scenes to create what is being delivered to you, then buyer beware.

SITE-SPECIFIC MANAGEMENT OF CROP INPUTS

As we evaluate our crop input decisions it becomes apparent that they all have a common driving factor, yield goal or yield potential. For some input decisions the relationship is quite explicit. For example nitrogen rates are driven by yield goal and then adjusted for available N supply including factors such as organic matter, soil profile nitrate levels etc. Seeding rates for determinate, non-tillering crops (e.g. corn) are determined on the basis of the number of emerged plants necessary to obtain a given yield potential. For tillering and/or indeterminate crops (sorghum, wheat, peas, millet, cotton, etc.) assumptions regarding tillering, branching, etc. are included but yet the seeding rate is still selected based on a yield potential and the final number of heads/

acre or similar yield component needed to produce that potential. Phosphorus inputs, largely determined by threshold soil test levels, are less explicitly tied to yield potential however yield is a critical component in determining how much phosphorus is needed to attain or maintain a given soil test level.

Historically we have made these input decisions at the farm or field level typically using data that was collected or assumed at the farm or field level. With site-specific management the only thing we are changing is the spatial scale we are making those decisions at. This is a key concept to keep in mind as it's easy to become overloaded with information and choices in using that information.

I have been involved in site-specific management of a number of factors: nitrogen, phosphorus, seeding rate, planting geometry, and management of soil pH, and through these efforts have always tried to maintain the focus on matching these inputs to spatial yield goal. In my experience, the further we get away from that relationship the less successful we are both agronomically and economically. A common practice and first step for many in the U.S. is to variable rate corn seeding rates based on soil type, which in many scenarios is a logical step. However, the question that always should come before implementing that strategy is, "Do my yields vary by soil type?" For all of the aforementioned reasons, I strongly believe that any site-specific management approach should include historical yield monitor data as a key component.

As an extension agronomist I continually emphasize that producers answer these questions when implementing a site-specific management practice and use this to help guide site-specific management efforts on our family operation as well:

1. Does it make sense agronomically?
- are we addressing a factor that affects yield?
- do we adequately understand the input vs. yield response of what we are managing?
- are we addressing the issue in an environmentally sound way?
- do I have a way to evaluate the this method of management?

2. Does it make sense technically?
- can my method of application accurately apply my intentions?
- do I have a way to evaluate the results? (as-applied maps)

3. Does it make sense economically?
- what are the true costs of implementation? (don't forget to value your time)
- what is the probability distribution of years in which this will pay?
- is there an easier (cheaper) way to achieve most of the benefit with less cost?
- am I collecting enough data in my agronomic and technical evaluations that I can evaluate the economics of the practice?

USE OF PRECISION AG TECHNOLOGIES FOR BETTER "UNIFORM" WHOLE-FIELD OR WHOLE-FARM MANAGEMENT

While the focus for precision ag technologies (other than the "duh" technologies) has focused on site-specific management, it's important to keep in mind that precision ag technologies offer opportunities to improve our management at not only the site-specific scale but also allow us to make better uniformly applied management decisions at the whole-field and whole-farm levels. An early precision ag expert and mentor of mine, Dr. Randy Taylor, emphasized that precision ag technologies will at least get producers to consider "turning the big knob" between fields. Often the low-hanging fruit from the standpoint of implementation cost and return on investment involve using technologies to improve our field level and farm level decision making. As an example, a producer may not jump straight into site-specific variable rate applications of nitrogen in wheat using on-the-go sensors or intensive soil sampling, but with tools such as handheld NDVI sensors and applicators equipped with automatic rate controllers producers can make much better field level decisions that have the opportunity to generate large returns on investment. These opportunities exist in the traditional agronomic framework of making better crop production decisions, but also exist in the areas of machinery management and logistics. The conducting of on-farm research trials, made much easier with precision ag technology, is a key component making better farm and field level decisions.

On my family's farming operation, our largest returns on investment to date have come from using our precision ag tools to make better decisions at the farm and field level. Examples include agronomically relevant ones such as hybrid/variety selection, evaluation of GMO traits, evaluation of seed treatments and other specialty products. However machinery management decisions regarding wheat harvesting methods of conventional vs. stripper header harvesting, logistics of grain cart operation, the value of a dedicated tender truck to spraying operations, and determining machinery efficiency and costs. The use of precision ag technologies in this manner was not something I anticipated, but is certainly going to become more possible as telematics and machine monitoring become more mainstream in the agriculture industry and machinery costs remain a large driver to profitability.

DREAMS DREAMT – THOUGHTS FOR THE FUTURE SUAVS (A.K.A. DRONES)

Certainly the biggest story in precision ag to capture the attention of producers, industry, and the ag media since the advent of auto-steer is that of UAV's. Recently a producer commented to me that he feels sUAV's have the potential to actually set precision ag back, that they might be a distraction. The utility of drones to improve the efficiency of crop scouting is apparent to anyone who has looked at video or still frames acquired by a sUAV. I believe the producer's frustration was that for his fields the NDVI imagery he had collected correlated very well with soil EC data and historical yield data layers. His investment of time and resources had provided him a new data layer that contained no new information. While certainly this won't be the case for all who implement sUAV technology, it is a valid concern. A fair question that many are asking themselves is: We are already awash in data, what is the value in another layer?

I believe the potential for sUAV technology as a site-specific management data source stems from several unique characteristics of data collected with this platform.

1. Temporal resolution – The data are fresh, not from the last available cloud-free satellite pass
2. Spatial resolution – The user has control over flight height and pattern to obtain the resolution necessary for the intended use of the data
3. A separate step – This is a significant challenge to sUAV use but also an important benefit when compared to on-the-go sensing systems. It requires another trip to the field, but it allows the opportunity to add external knowledge to the process before inputs are applied. For example, sensor based N application on wheat with real-time sensors as compared to a prescription written with sUAV NDVI data and historical yield monitor data representing spatial yield potential. Which method would you prefer?

Current research efforts among a group of colleagues at K-State are placing an emphasis not only on NIR but rather on thermal imagery, which provides a much better characterization of water stress in our semi-arid environment. I'm currently part of a team that is looking at thermal imagery from sUAV's as the driving data layer for variable rate irrigation. The aforementioned attributes of sUAV technology make this approach feasible whereas the limitations of sensors located on satellite, general aviation, or other platforms (e.g. on the irrigation center-pivot itself) limit the usefulness of the system.

CONTINUED IMPLEMENTATION OF ON-FARM RESEARCH

Several factors in the U.S. (and I suspect many other places) have fuelled the interest and demand for on-farm research efforts. The operational capacity for land-grant universities has been significantly reduced in many states over the past decades. Meanwhile the introduction of products and technologies from industry has accelerated and producers are seeking answers that are more specific to their operation than what has been provided by pubic research institutions in the past. The advent of user-friendly precision ag technologies has empowered producers to conduct their own scientifically and statistically valid evaluations on their farm under their conditions. The key limiting factor to growth of this activity is getting the necessary training and support to producers and their industry associates. This is being addressed by many extension programs of the land-grant universities in the U.S. Another key limitation is not only training but having adequate functionality built into the common agriculture data management/GIS software packages to adequately and easily handle and analyse on-farm research trials. Once that software has simplified the process to a few clicks, I believe we will see adoption increase dramatically. At present, it is still a tedious process even for someone with experience in this area.

LOGISTICS/MACHINERY MANAGEMENT

Machinery cost are and will continue to be a large expenditure on commercial farming operations and how well a producer manages machinery will continue to be a driving factor in productivity. We are rapidly seeing telematics advance in the agriculture industry. I think almost everyone would agree there is value in being able to monitor the performance of a tractor, combine, or seeding tool when not physically present. That is however a tough value to quantify. While the initial wave is focused on the real-time monitoring of specific pieces of machinery, additional value lies for those producers who are able to aggregate the data from multiple moving pieces and truly manage the logistics of their farming operation. The importance of this issue is certainly a function of farm size, maximum travel distance, and the number of operating pieces of machinery, all of which have been trending upward for many years.

INTEGRATION OF PRECISION AG TECHNOLOGIES AND DATA WITH CROP MODELS

Computerized crop models have made significant progress over the last several decades and especially recently as computing power, our knowledge of plant physiology, and the availability of quality datasets for model building and evaluation all continue to grow. In my mind there are opportunities to merge dense datasets generated from our precision ag activates, i.e. yield data, RTK quality elevation, etc. with crop models and weather probability distributions to better improve our decision making capabilities. Australia is especially well positioned for such a system with the development efforts that have gone into models which have been shown to perform well (APSIM). We are seeing movement in industry with regard to this concept with offerings of online based services where weather data and user inputs are used in a model to provide nitrogen status, crop growth and development, and other factors, tracked on smaller spatial and temporal scales than ever before.

BETTER INTEGRATION OF DATA COLLECTED AT DIFFERENT SPATIAL SCALES

A lot of debate and research has gone into the argument of zones vs. grids (especially with respect to soil nutrient testing) for aggregating precision ag data and as a management unit for site-specific application of crop inputs. In the scientific literature there is difficulty in finding research results that consistently show advantage of one method over the other. This lack of clarity I believe is due to the fact that the proper spatial scale for data aggregation depends largely on the dataset, the spatial variability of the field in question, and the intended use of the aggregated data. This issue has been a source of indecision and a barrier to adoption of site specific management by producers while on the other end of the spectrum the strict adherence of one method or another by individual producers has allowed in some instances potential opportunities to go unrealised as all data and management decisions are forced to one spatial structure regardless if it is the optimal one. In my opinion, to make the best use of the data and tools available we must be flexible in what scale we collected data and at what scale we aggregate it.

For example, soil texture data in most fields is obviously best represented by zones due to its nature. However, should we be aggregating spatially dense data such as soil EC and crop yield to those same zones and forfeiting the information contained in that data about the spatial variability that exists within those soil type zones? We should also consider that the same dataset may be usefully aggregated at multiple spatial scales. For example, yield monitor data collected over many years could be analysed to determine areas of spatial-temporal yield stability, thus creating management zones representing areas that are stable high yielding, stable low yielding, stable average yielding, and unstable. These zones would be used as the basis of differing management strategies for site-specific management. That same yield data however could be aggregated at a much finer scale (perhaps 60 or 120 foot cells) for the purposes of creating phosphorus removal values, which could be used in phosphorus recommendation equations that differ based upon yield stability management zones (Figure 2).

This flexibility however can only exist with continued improvement in the software tools available to producers and a willingness to be flexible in our philosophies in data analysis and aggregation. The continued advancement of software is key to advancement in this area. As researchers we have tools available to use that can be quite useful in the analysis of data and building of relationships, tools such as kriging, co-kriging, spatial regression etc., however in practice producers and industry personnel are largely limited to inverse-distance weighting methods (often with only default values) simply because that is what is available to them through their software package. In order for an analytical method to be adopted, no matter how superior it might be, it needs to be accessible to the users, easy to understand and use, and easily peaceable within a workflow.

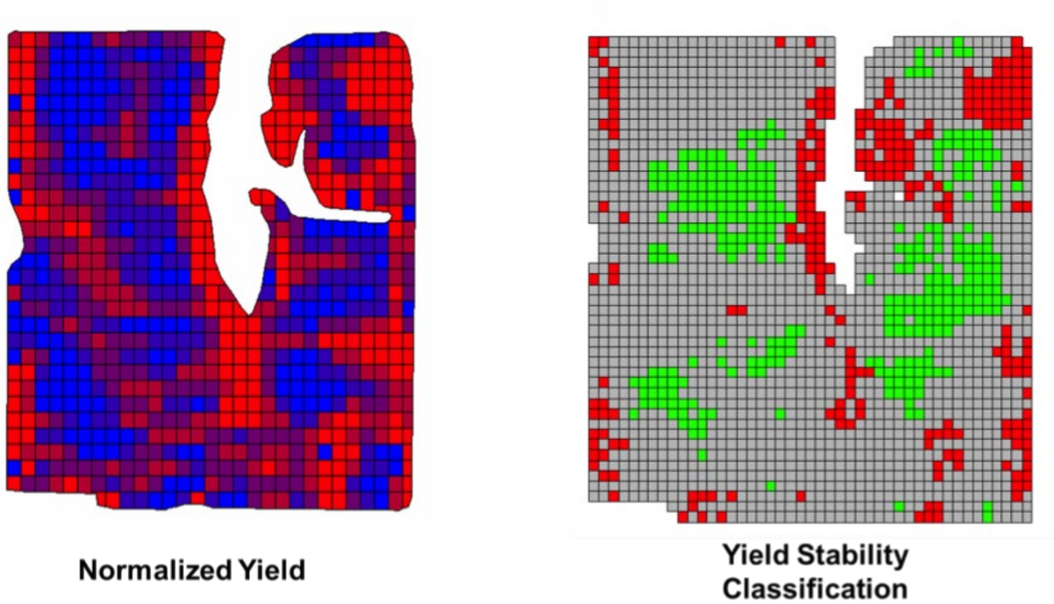

Figure 2. Illustration of how a spatially dense dataset, yield data, can be aggregated at two different spatial scales to produce useful layers. On the left is the multi-year normalized yield, or spatial yield potential. On the right are zones classified as stable high (green), stable low (red), and unstable (grey).

PLANS MADE – MAKING THE MOST OF WHERE WE ARE AT:

For producers who have not adopted precision ag technologies at all or perhaps only the "duh" technologies, the biggest issue in an action plan is to have a plan. The development of your philosophy on how you want to approach site-specific management isn't something to rush in its creation phase, nor should it be held as sacred in that you're never willing to change and adapt as new information and new ideas become available.

The proper targeting of precision agriculture efforts within a farming operation involves decisions that can benefit greatly from something largely unrelated to precision agriculture, enterprise analysis. Strong efforts by a producer in enterprise analysis provides the data necessary to understand what cost and revenue areas are driving the farms profitability (or lack thereof) and aid in identifying those areas where precision ag technologies can be used to reduce cost and/or increase revenue.

As precision ag adopters we are certainly people who enjoy the newest technology. The question and caution that goes with that is how frequently do we fail to fully exploit the features, capabilities, and opportunities of a technology before we are sinking our efforts into something new (amongst friends we refer to this as the "ooooh shiny" effect). The greatest returns on investment can sometimes come from the technology you have already made the payments on.

Amongst the producers I have worked with along with my own experiences I have seen the value of standardising how things are done, and most importantly documenting it. Developing workflows for each step in various processes (calibrating yield monitors, writing seeding prescriptions, reconciling fertilizer invoices with as-applied data). Some of these events only occur once a year, and so the standardization and documentation of these procedures can result in a huge gain in efficiency and data quality while reducing stress, workload, reliance on your memory, and errors.

At the end of the day there is no easy button, no magic black box. For myself its often a fine line to walk between realising that we will never have the level of data and understanding that we need to make a decision with 100% confidence, but yet at the same time we do need to scrutinize what we are doing and ensure it makes sense agronomically, technically, and economically. We must be willing to move forward and make the decisions we can with the data and tools that we have.

Disclaimer: This paper is not written as a research summary or technical paper but rather as a collection of experiences and thoughts of the author. It has not been subjected to peer review.

HOW PEPPERY IS YOUR VINEYARD?

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SUMMARY

Previous work has highlighted the importance of vineyard variability and the benefits which may accrue through targeting management in response to it. However, most zonal vineyard management has relied on understanding of variation in vine vigour and grape yield and an assumption that variation in fruit quality follows a similar pattern of variation; robust understanding of spatial variation in specific attributes of grape and wine quality has been somewhat elusive.

The Grampians region of Victoria is well known for producing Shiraz wines with a distinctive 'spicy' and 'peppery' aroma and flavour. This characteristic is considered desirable in many markets and has been suggested as evoking the terroir of some cooler climate Australian Shiraz. The 'pepper' aroma and flavour have been shown to be due to the presence of the chemical 'rotundone' (C15H22O) which is found in the skins of Shiraz berries. Despite the aroma detection threshold of rotundone in red wines being only 16 ng/L, it is considered an 'impact aroma compound' since many tasters will detect its 'peppery' character during sensory analysis, even at such low concentration. The objective of this study was to see whether the content of rotundone in Shiraz (Vitis vinifera L.) grapes was spatially structured and related to other aspects of vineyard variability so as to inform the possible selective harvesting of grapes destined for high value wines of 'peppery' character.

Immediately prior to harvest (2012 and 2013) of a 6.1 ha block in the Grampians region of Victoria, a region known for producing 'peppery' wines, fruit was sampled from 177 'target vines' and analysed for its rotundone content. The resulting data were mapped and overlain with other map layers describing variation in soils, topography and vine vigour (Figure 1).

Berry rotundone concentration was found to be markedly spatially variable and showed remarkably similar patterns of variation across the two years of the study in spite of a 100-fold difference in mean rotundone concentration between the two contrasting years. As with previous analyses of variability in indices of grape quality, spatial analysis strongly suggests that variation in berry rotundone concentration was associated with variation in vineyard soils and topography, with the influence of aspect on ambient temperature and/or incident solar radiation implicated as likely drivers of rotundone variation.

These results provide the first demonstration of within-vineyard spatial variability in a grape-derived wine flavour compound. They highlight the commercially significant possibility of using selective harvesting as a means of influencing wine style – in this case, the 'pepperiness' of Shiraz. Further details are provided by Scarlett et al. (2014).

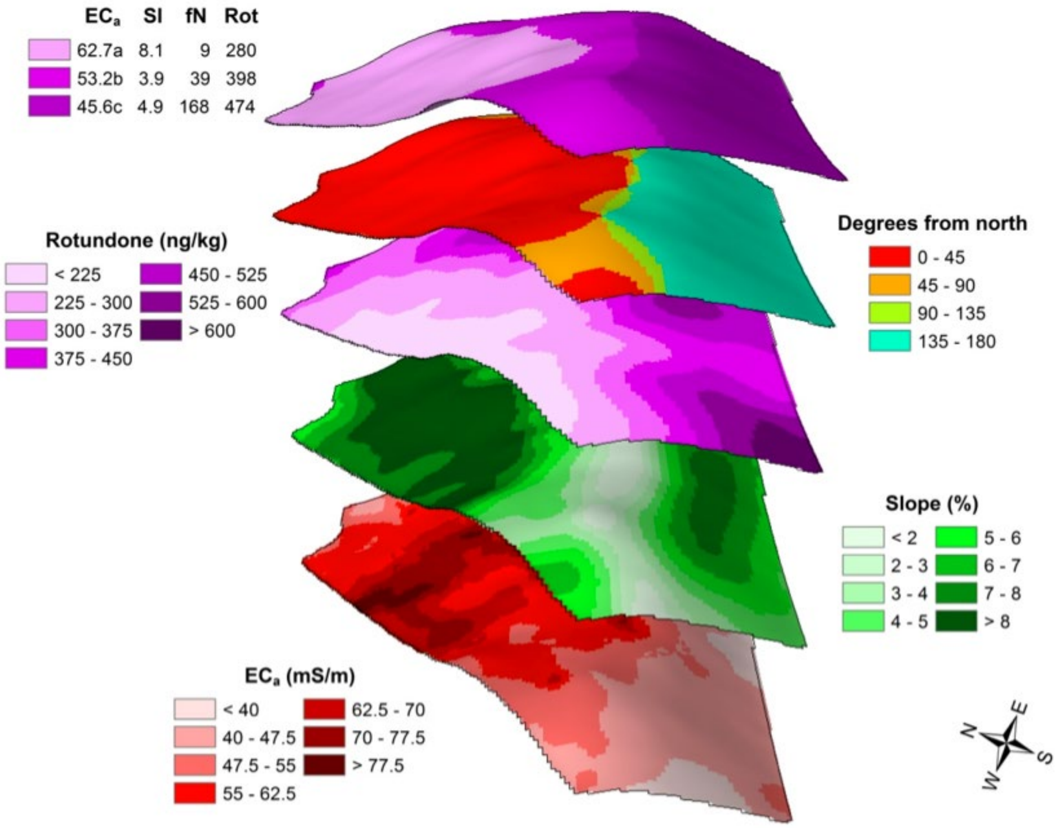

Figure 1. Variation in the 'pepper' compound rotundone (Rot) in a 6.1 ha Shiraz vineyard in the Grampians region, vintage 2012, and the possible influence of soil and topography on this. The bottom map was derived from EM38 soil survey and shows the bulk electrical conductivity (ECa) of the soil. The elevation model of the site (obtained using a survey-grade kinematic GPS whilst doing the EM38 survey) enabled maps of both slope (Sl) and aspect to be derived; here, aspect is expressed in terms of deviation from north (fN). When these map layers are clustered together (top map), three zones are identified with significantly different average values of ECa, and contrasting slopes, aspect and average berry rotundone concentration. The areas of greatest pepperiness are those with the lowest values of ECa, on medium slopes, and orientated furthest from north. Note that the direction of the north arrow is approximate only. Data of Scarlett et al. (2014).

ACKNOWLEDGMENTS

This work was initiated by the late Nathan Scarlett (Rathbone Wine Group) and drew heavily on the analytical chemistry expertise of Tracey Siebert and colleagues at The Australian Wine Research Institute (AWRI). The work was jointly funded by the Rathbone Wine Group, CSIRO and AWRI, with the AWRI input supported by Australia's grape growers and winemakers through their investment body, the former Grape and Wine Research and Development Corporation (now the Australian Grape and Wine Authority), with matching funds from the Australian Government. The support of Damien Sheehan (Rathbone Wine Group – Mt Langi Ghiran) and of Drs Markus Herderich and Mark Krstic (AWRI) is also gratefully acknowledged.

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USE OF REMOTE SENSING FOR PASTURE MANAGEMENT.

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ABSTRACT

Remote sensing and especially the accessibility of UAV's have created a great deal of interest within agriculture. Massey University has invested heavily in this area with a range of multi-rotor and fixed wing UAV's, multispectral and hyperspectral sensors and imaging systems. A range of research has been undertaken mainly in the area of measuring pasture cover and quality. A number of technologies have been applied, including proximal hyperspectral and multispectral sensing, remote hyperspectral and multispectral sensing and remote hyperspectral imaging. Research with proximal hyperspectral sensing pointed to the potential of this approach, where pasture quality was able to be identified in-situ. This presents a considerable time saving in sampling and analysis and gives farmers a more realistic opportunity to inform their grazing decisions and pasture management to maximise farm productivity.

Keywords: UAV, RPAS, Drone, Remote sensing, pasture management.

INTRODUCTION.

The main advantage of going from proximal (ground based) sensing to remote is the ability to cover larger areas more quickly and to carryout significant recognisance in near real time. However this must be balanced against reduced spectral resolution which could lessen the value of the survey data. The options are then to use an aircraft borne sensor or use an RPAS (UAV or Drone). In New Zealand the Civil Aviation Authority (CAA) prefer the term RPAS, Remote Piloted Aerial System. They prefer this to UAV and certainly prefer it to Drone, which has negative connotations due to its military use. There is a useful website which sets out some of the proposed rules and regulations around using RPAS in New Zealand, http://airshare.co.nz

Australian authorities are working within a similar framework. The basic rules in New Zealand are that all RPAS must be flown within line of sight and their flight must not interfere with manned aircraft or the general public. The use of RPAS in National Parks in the US, for example, has been banned because of their misuse by some users.

There are three level of use of RPAS, first is a simple "eye in the sky" where the user puts the RPAS in the sky to observe stock or scout crops. At this level of use there is no attempt to correctly map results they are simply used to make observations. The second level of use is where repeated measurement (over time) is attempted and the results are placed in a geographically correct map. This requires considerably more work and is actually difficult to achieve with a multi-rotor RPAS. The main reason for this is stability of the vehicle. Modern GPS navigation systems can get a vehicle to the correct position but its pitch and yaw may be affected by wind. Thus what happens is the vehicle tries to hold position and the gimbal which holds the sensors attempts to get in the correct position. This can lead to prolonged hovering and reduced survey coverage. It is easier to achieve with fixed wing aircraft where stereo imaging is used to construct geographically correct image through photogrammetry.

Even in this instance known ground control points are required to register the image. The third level of use is where is a product is applied as a result of sensed data. For example in remote areas there is a potential to spot spray noxious weeds and creeper from bush areas. This requires an accurate map to be developed of the target species and the applying vehicle to have the navigational capability to reach the target and spray it. The operator will have to have an aerial rating to apply agricultural chemicals and it is unclear at this stage how much effect the propeller wash from the craft would have on the spray trajectory. It should be borne in mind however that these chemicals are either already applied from aircraft or helicopter where similar question marks exist. Here the RPAS would appear to offer a considerable operating cost advantage to full scale aerial systems and may have a niche role to play when smaller areas are required to be sprayed.

The International Conference on Precision Agriculture (ICPA) which took place in July 2014 in Sacramento California, held a total of 38 sessions, 12 which were dedicated to optical sensors including three which were entirely devoted to the use and application of RPAS, a demonstration of considerable international interest in these topics.

METHODS

A number of multi-rotor systems are being employed with a range of configurations. The size, number of rotors and configuration determines the lifting capacity and power requirements. At Massey, six and eight multi-rotor aircraft are being used along with quad rotor craft for training. The general quality of GPS and navigation is improving and newer models appear to offer improved stability and control. Care must be taken to ensure they are used within radio range, although some newer systems will automatically come back to base if radio contact is lost. Fail safe systems are becoming more of a feature of both multi-rotor and fixed wing systems, again making them more useable. If connection is lost the craft will hold position and try and re-establish contact, hold position until it does and then come back to the launch position if it cannot be re-established. The Trimble fixed wing UX5 will carry on with its survey for a time before returning to landing position if control contact is lost for more than 2 minutes.

Massey is currently using a Trimble UX5 fixed wing craft where a complete survey or digital elevation map (DEM) is required. Although a complete and very detailed survey of 80 ha can be conducted within 40 minutes, and the process is highly automated, considerable processing time is required in order to mosaic the images, (perhaps 1400 images, to cover 80 ha). Data processing is completed through Trimble Business Centre Software which comes with the unit; full operator training is also required. Ground control points need to be included in the survey. One of the issues potential users need to realise is that the push for very high spatial resolution, pixel size of 2.5cm on the ground for example, leads to very large data sets and complex processing. A survey completed at this resolution would have 16 million pixels per ha, a satellite survey with a 2.5 m spatial resolution would have 1,600. There is a considerable processing load which seems to be forgotten about.

A range of sensors have been used mainly in the eye in the sky category. True colour and infrared photography has been carried out using modified cameras., Cannon Power Shot SD 780 IS digital camera, both true colour and infrared, and Sony NX5, again both true colour and infrared, the latter is mounted on the Trimble UX5. A multiple camera array (MCA) six camera array has also been used. The Tetracam MCA was used where each camera has a user defined narrow band filter to collect spectral information. Each camera collects a separate image saved on a separate memory card from the factory aligned cameras. Again the level of automation within the surveying process is improving. Automation of firing the camera for example helps to create a better seamless process and more consistent results.

Sensors such as the Holland Scientific Raptor have been flown, the University of New England have done similar work in Australia. The Raptor is an active sensor which uses its own light source; this modulated light eliminates a lot of the inconsistency between serial surveys where different lighting conditions exist. Most other sensors do not have the sensor to target range and are passive sensor which means that if lighting condition change then results will reflect that, (no pun intended). All surveys need to have ground control and various correction procedures carried out to ensure consistent data is collected. The data must be in the correct geographical position and the lighting conditions must also be accounted for through atmospheric correction and ground control points. The active sensor also reduces the limitations on surveys using ambient light which are best done around noon.

Hyperspectral sensing has been demonstrated to be a much more robust technology in terms of describing the target. Pasture quality is one area the team at Massey have concentrated on, but this technology has a great number of other applications as demonstrated by the huge number of papers being written and presented around the world in this area of research. Within Hyperspectral sensing, information from many discrete wavebands is sensed, this level of spectral sensitivity and spectral range mean that information can be collected from other parts of the spectrum as well as the red edge. This means that information on plant characteristics and qualities can be sensed, pasture protein, ME and Digestibility are obvious examples. The actual composition of the sward can be in terms of nutrient concentrations can also be obtained. This opens up a whole new area to farmers with the potential for comprehensive information on pasture yield and composition within reach.

In order for this to happen the technology has to migrate from sensing (discrete points on the ground) to imaging or mapping of the whole farm. This is the basis of the Primary Growth Partnership Project (PGP) being conducted between Massey, Ravensdown Fertiliser Cooperative and Agresearch. The Project is called, Pioneering to Precision: Application of Fertiliser in Hill Country. In order to achieve the spectral sensing range and resolution an expensive airborne sensor has been purchased by Massey

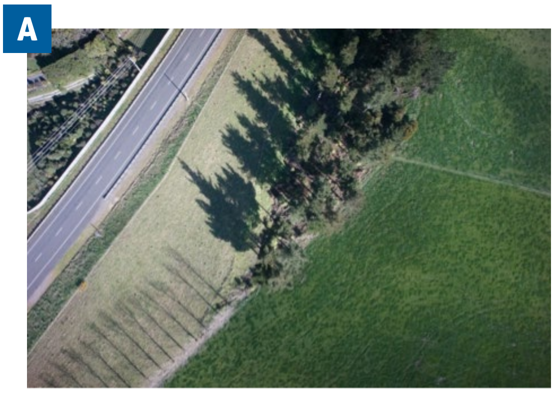
University. The system is called an AisaFenix from Specim, in Finland. This imager has the required range to take high spectral definition imagery from the air. It is flown usually at around 660m above ground and the push broom sensor senses around a 350m swath width with a spectral range between 380 and 2500 nm in a single continuous image and can use up to 620 spectral bands. This is being used as a research platform to identify spectral bands of importance over a large range of applications.

RESULTS.

Using an RPAS for "eye in the sky" types of operation should be looked upon as scouting operations and these are always going to be highly variable if lighting conditions change. It is therefore difficult to extract mathematical relationships between subsequent observations. However crop or farm scouting is a legitimate use for this technology and its simplicity and the ability to observe large areas in great spatial detail quickly should not be underestimated.

Mapping with sensed data from an RPAS platform should be treated with a little caution in terms of spatial resolution, in a dairy farm it is perfectly feasible to monitor individual paddocks and form an average measurement for a paddock. Even though the same route might be followed, wind conditions for example can alter the angle of the RPAS and therefore the position of the target. If photogrammetry is used then ground control points should be incorporated into the survey in order that the survey can be properly georeferenced. While the data gathering process may have been significantly simplified in terms of having a vehicle in the sky to collect information conducting vegetation mapping is extremely processor intensive and prone to interruption from environmental factors. Changes in cloud cover and lighting conditions for example makes the accurate measurement and calculation of pasture cover difficult to achieve.

A useful example may be the Trimble UX5, when used to collect very accurate topographic data, although it can be processor and time consuming to mosaic 1400 photographs into a survey DEM, it is a lot easier and more accessible than other methods available. Figures 1a and b, demonstrate both true colour and infrared imagery of the same part of the survey. When we try and quantify pasture cover we need to do a lot of image processing, to exclude parts of the scene that we don't want, include ground control points to ensure spatial reference within and between surveys.



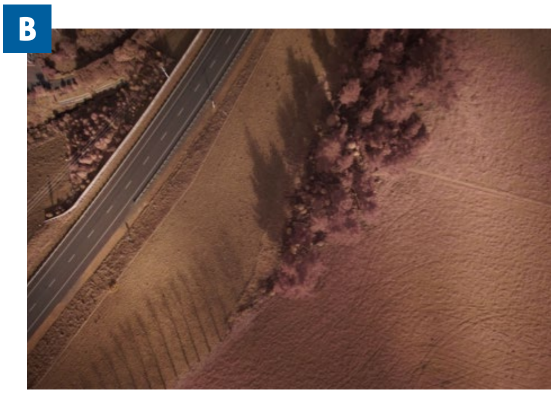


Figure 1. True colour image taken from Trimble UX5 using a Sony NX5 camera (a), and an infrared image taken form Trimble UX5 using modified Sony NX5 camera (b)

Environmental and lighting conditions also need to be accounted for but this is not always possible. The images used here are from a project called Optimum N where we want to identify urine spots from cows, locate them and also monitor their distribution and longevity on the pasture. The figures show the same paddock but there is a variation between areas of the paddock which creates problems in classifying out what is a urine spot and what is not. This is in winter with moderate cover, the problems change with season and cover, note the winter lighting conditions.

Use of an active sensor such as the Raptor from Holland Scientific is also a feasible option to gain vegetation surveys and maps, although similar caution needs to be exercised in terms of spatial resolution. The use of a modulated light source does get over the limitation of changing ambient lighting conditions. The Raptor appears to be the only sensor on the market with enough range (sensor to target distance) which would make the use of a RPAS feasible. We have used them on light aircraft flying at low altitude mainly. A paper (Lamb and Holland 2014) on this topic was presented at the recent International Conference on Precision Agriculture.

Other sensors such as the TetraCam could be used, care needs to be taken over exposure times and again ground control points are required if results are to be properly mapped.

In short the use of RPAS is a step in the right direction and it is likely that image processing will become more affordable, but the data processing associated with this is still a fairly specialised and time consuming activity.

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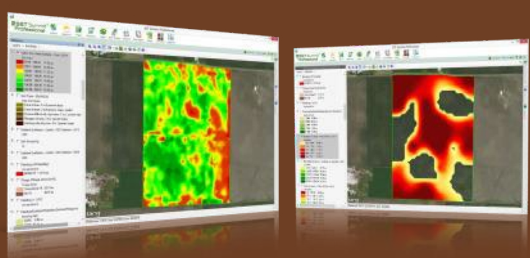

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REAL TIME MACHINE VISION APPLICATIONS FOR CROP SENSING.

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SUMMARY

Machine vision systems have been developed at NCEA for a range of applications in precision crop and field sensing. Colour and depth image analysis, along with GPS data, enables automated detection of spatially-varying crop information in real world conditions. Sensed attributes comprise crop growth and development, and crop and weed discrimination.

CROP GROWTH MONITORING AT REMOTE SITES

Camera-based systems have been developed to remotely monitor irrigation sites for site specific irrigation and grains trial plots in the National Variety Trials. Algorithms have been developed to identify flowers and extract plant growth (Figure 1). The systems enable spatial detection of crop condition and reduce the labour and travel of manual trial inspections.

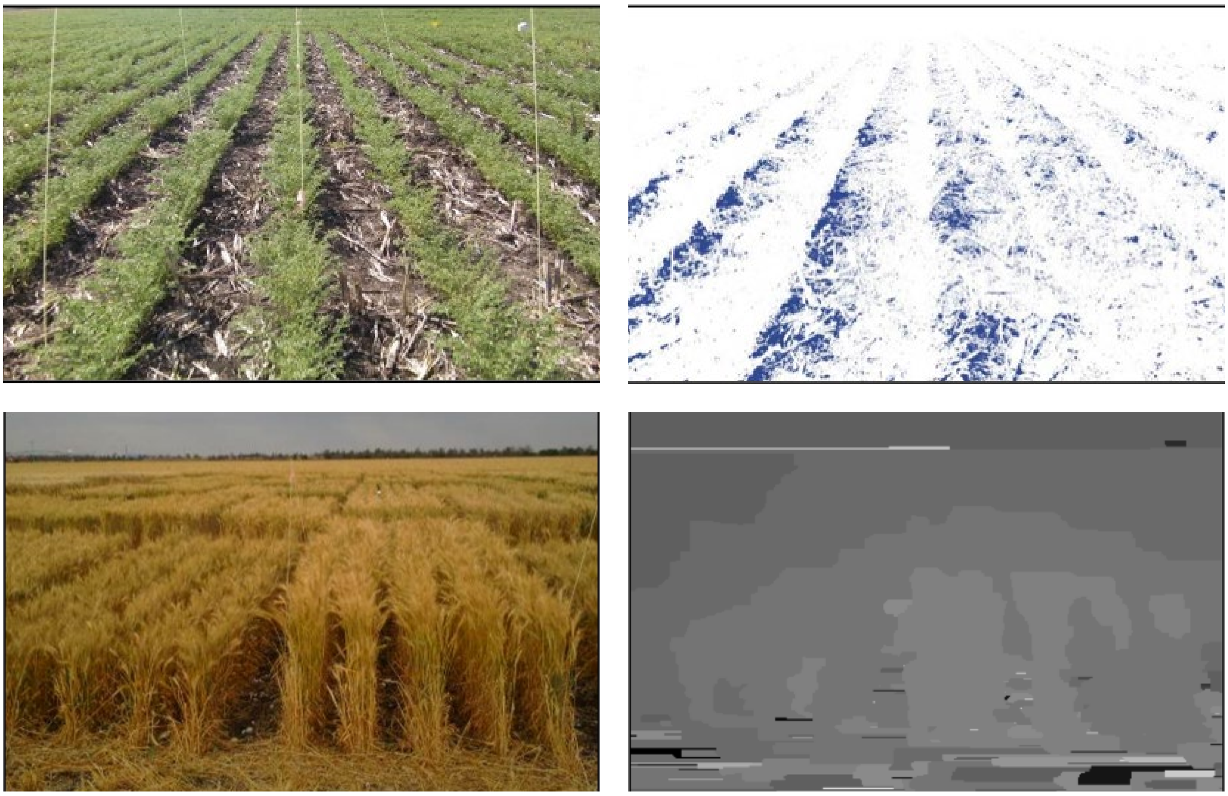

Figure 1. Height detection algorithms for grains crop monitoring using shadows (top) and stereovision (bottom). Left: Original image. Right: Analysed image.

WEED DETECTION FOR SPOT SPRAYING

Machine vision-based weed detection systems have been developed for the sugar, cotton and pyrethrum industries. A Depth and Colour Segmentation Algorithm (DCSA, Figure 2) enables occlusion-tolerant weed detection and a new processing technique enables the vision systems to operate at commercial groundspeeds of 10-15 km/h.

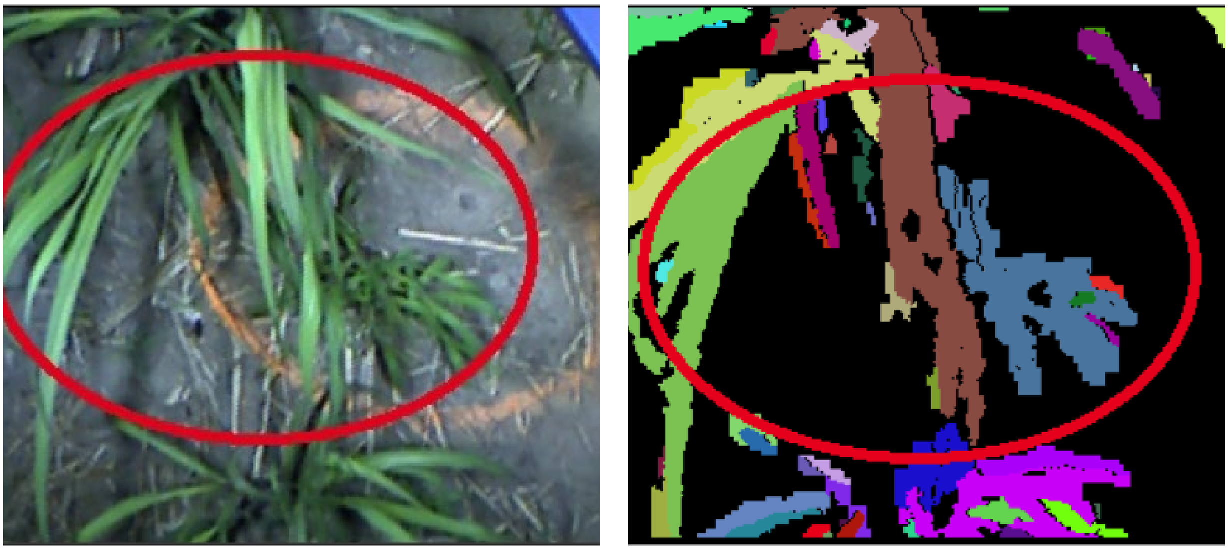

Figure 2. Occluded weed detection with the red circle highlighting: sugarcane plant occluding a grass weed in the original image (left); and the sugarcane and grass weed separated by the DCSA (right).

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3 Ag Logic, Meningie, SA

INTRODUCTION

Increasing the economic returns of agronomic management using Precision Agriculture is a 3 year SAGIT supported project which is nearing completion. The project has had an emphasis on practical applications of precision agriculture as a logical extension to agronomic management.

The project commenced with data collection in May 2011 on 5 Focus Farms in dryland cropping districts of South Australia (Figure 1)

Figure 1. Locations of the focus farms in SA.

A consistent and stepped approach to investigations was adopted at all 5 sites.

- Quantify changes in the crop growing environment using soil sensors and RTK GPS to measure and map variations in soil and terrain across the project area and within each field.
- Ground truth with geo referenced soil testing and other field measurements to determine the agronomic nature of the changes in growing environment.
- Build knowledge on how changes in growing environment impact crop production by analysing soil and terrain layers with yield data.

Having established the economic impact of variations in growing environment on production, discussions were held with co-operators and local agronomic support personnel to plan management responses and test these in the field using strip trials and end of season yield maps.

The following are a summary of selected activities and findings at some of the sites.

EDILLILIE SITE

The combination of both Multi Depth EM and Gamma radiometrics soil sensor layers with soil-testing and comparisons to yield revealed various opportunities to ameliorate localised crop limiting factors in areas where production had been historically low. Higher rainfall and subsequent greater yield potential provided scope to viably correct these issues as opposed to leaving uncorrected and simply reducing inputs.

In addition the identifying of higher producing soil zones that had apparently low constraint factors there was opportunity to target higher inputs, particularly higher nitrogen post seeding, in a canola/wheat rotation of high yield potential.

FOCUS MANAGEMENT ISSUES AND OPPORTUNITIES

- Post seeding nitrogen decisions – increasing yield in high producing soils.
- Seeding fertiliser – balancing to soil type and phosphorus status.
- Amelioration of soils to lift productive capacity – liming, ripping, gypsum and potassium.
- Segregation of selected fields for cropping and grazing balance.

CASE STUDY IN BRIEF
AMELIORATING PROBLEM SOILS

Visual assessment of the soil maps with low yield areas (Figure 2) supported field observations of very limited root growth (Figure 3) at these locations due to a 'bleached' layer at 10 – 20cm.

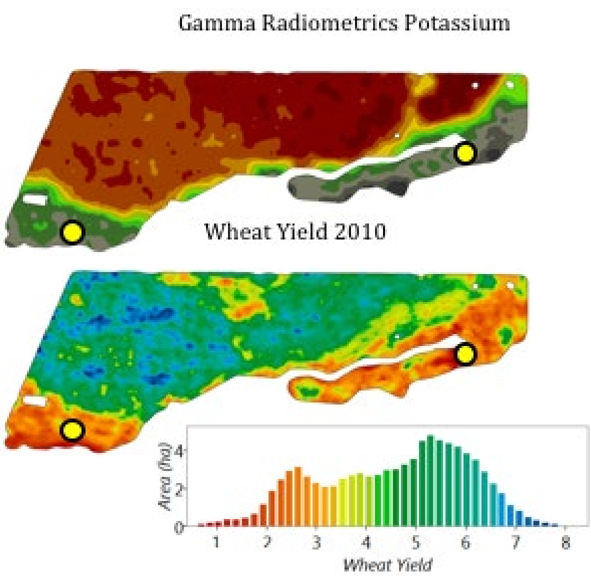

Figure 2. Soil gamma radiometrics and wheat yield map for 2010 at the Edillilie site.

Figure 3. Soil profile from sample site at the Edillilie site.

Soil testing in this zone revealed high acidity, very low total CEC, low available Colwell K and aluminium toxicity. These conditions were most severe at 10 – 20cm.

Statistical comparisons determined that the Gamma Radiometrics Potassium soil sensing map correlated best with yield map variations over different seasons and various crop types.

This knowledge was used to position a trial where the treatments were lime 3t/ha, lime 3t/ha with ripping and no lime application. Yield monitor data for wheat was used to assess outcomes as per Table 1.

TABLE 1. RESULTS OF THE LIME APPLICATION TRIAL.

TREATMENT	YIELD	PROFIT
No treatment	2.32t/ha	NA
Lime 3t/ha	2.78t/ha	$40.00/ha
Lime 3t/ha + ripping	3.81t/ha	$47.50/ha

The trial will continue to be monitored to assess if yield benefits are sustained. Soil sensing layers can be combined to identify other areas on the farm with good potential to respond to amelioration with deep ripping and lime.

KIMBA SITE

EM38 proved to be dominant soil sensor at the predominantly dune swale environment at Kimba. High EM values were in areas of heavier textures and higher subsoil constraints mostly salinity, while low EM values were deep sands.

Fertiliser inputs and risk management were the major issues, while soil amelioration to improve the low performing sands was also important. As is common for low rainfall environments the yield maps flip-flopped between wet and dry years.

FOCUS MANAGEMENT ISSUES AND OPPORTUNITIES.

- Soil amelioration of lighter soils.
- Seeding fertiliser – increase yields on lighter soils and reduce risk on heavier soils.

CASE STUDY IN BRIEF – USING DUALEM SOIL SENSING TO IMPROVE CLAY SPREADING AND SPADING DECISIONS.

Initial strategic soil testing illustrated a correlation between EM map (Figure 4) and depth to clay. Targeted soil testing followed which provided a stronger correlation. Using the relationship from the graph (Figure 5) management zones can be created for specific soil amelioration practices (Figure 6).

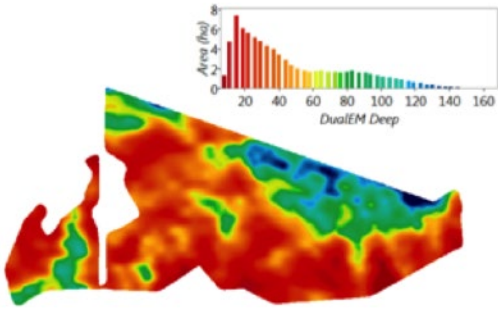

Figure 4. EMI map (1 m depth).

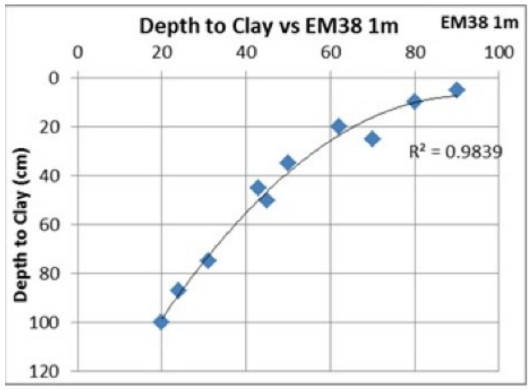

Figure 5. Depth to clay across EMI values.

Figure 6. Soil management zones.

For example any clay beyond 60cm is too deep to reach efficiently by a delver and so this zone is set aside for clay spreading. Then depending on the delver available, potentially two more zones can be created, one for deep clay (40-60cm) and one for shallow clay (15-40cm). Lastly sites for clay pits can also be identified, to source clay for spreading. This can help reduce clay spreading costs by sourcing clay as close to spreading zones as possible.

HART SITE

This site was south east of the Hart Field Site, so had very similar soil types. Initial soil testing indicated EM38 having strong correlations with a range of soil properties, particularly sodicity which was used to create a variable gypsum map. Correlations were also found with soil texture and salinity, further testing found strong correlations with soil water characteristics such as crop lower limit and drained upper limit.

FOCUS MANAGEMENT ISSUES AND OPPORTUNITIES

- Soil Amelioration through gypsum on sodic areas.
- Seeding fertiliser – managing seeding applications without increasing risk.

CASE STUDY IN BRIEF
MANAGING FERTILISER INPUTS TO SOIL WHC.

Soils with increasing EM values had higher water holding capacity but also had higher subsoil constraints reducing the 'bucket size' or potential plant available water (Figure 7).

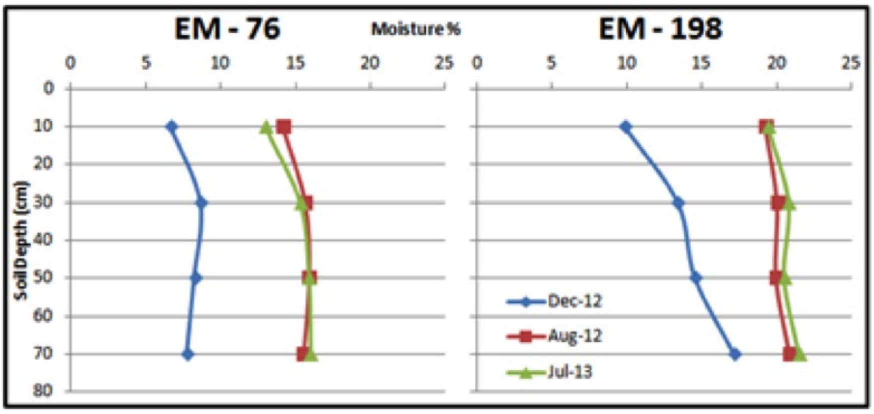

Figure 7. Differences in soil water profiles between EMI deep values.

To reduce workload during the season higher levels of seeding fertiliser where applied. Along with the standard rate of 140kg/ha of 28:13, trial strips of 70kg/ha and 120kg/ha were also applied as per Figure 8.

In 2012 following Beans, the only significant yield increase occurred on the lowest EM zone (Figure 8). Using 2012 prices this was only a break even return for the increased fertiliser. Conversely over $40/ha could of been saved on the other two zones by applying only 70kg/ha.

Wheat was again sown in 2013, meaning there was a higher requirement for added Nitrogen. Yield increases from high fertiliser were seen in all zones. The low EM zone was the most economic with $98/ha return, while the Medium and High zone were $22/ha and $17/ha better off.

HOW THIS KNOWLEDGE CAN BE USED

- Match inputs to soil water properties (bucket size and crop lower limit).
- Understand influence of rotation on Nitrogen requirements.
- Higher inputs targeted to lower EM soils with low constraints as these soils have the least risk.

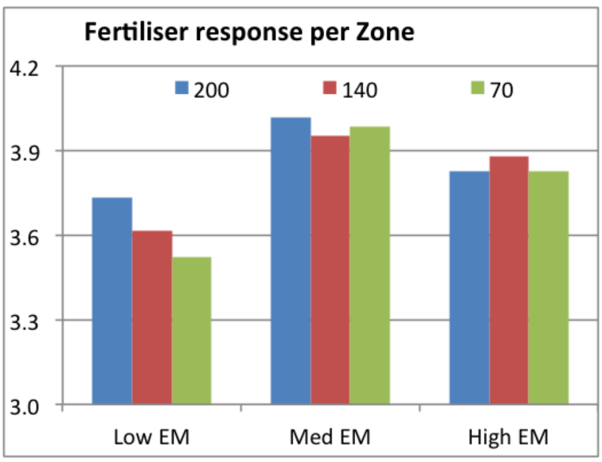

Figure 7. Differences in soil water profiles between EMI deep values.

THE ROLE OF PRECISION AGRICULTURE ON AN EXPANDING FARM.

Robin Schaefer

Bulla Burra Collaborative Farming Australia

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TAKE HOME MESSAGES

- PA is not only about gadgets it is about farming precisely.
- Simplify systems: we use one electronic PA platform only.
- Canbus is ok but ease of connecting varies between systems.
- Some PA gadgets are cool and improve the bottom line, other stuff is only cool.

BACKGROUND

Bulla Burra is a collaborative farming venture between my family farming business 'Schaefer Enterprises' and John & Bronny Gladigau. It was established in 2009 and is situated in South Australia's Northern Mallee. Cropping 9000ha and managing 13000 ha our properties are spread from the township of Loxton to 50km by road SW at the furthest point and about 20km across. The land class is typically dune swale, red sandy loam soils. The sandy rises have rooting depths of up to 2m the swales tend to have their rooting depth constrained to 60cm by transient salinity or sodicity. We also have areas constrained by stone at much shallower depths. Annual rainfall is 275 to 290mm and growing season 180 to 200mm.

Our business specialises in dry land cropping, growing mainly wheat, barley, and canola. Small areas of lentils, chickpeas and peas are also included. We use conservation farming practices, with 97% of our crop sown using No-Till and the remainder minimum till. We do not run any livestock, though some of the businesses we share-farm for do have a livestock component.

PA TOOLS

- JD 2630 Screens in all machines.
- JD 1870 Conservapak precision seeder.
- JD 1910 triple bin air cart.
- JD 4940 SP sprayer, canopy height sensing, section control, variable rate, JD Link, Mobile weather station.
- Croplands Weed It, weed sensing sprayer with dual line for blanket and selective spraying.
- JD Link on S670 Harvesters and 8335 RT tractors.

- JD 940D harvester front height sensing.
- Kverneland Accord variable rate spreader with weigh cells and section control.
- JD Apex software for managing data.

KEY POINTS

Where we use PA

- fallow spraying: the Weed It sprayer uses infra-red technology to spray only green weeds
- sowing: we run an application map for each of the three bins. Seed and urea are applied according to productivity zones, Phosphorus fertiliser is applied at replacement rates.
- monitoring: N-rich strips were used this year to show zone responsiveness.
- spreading: zone maps to apply SOA only to deep sands and target urea at soils likely to give the highest return per dollar spent.
- in-crop spraying: variable-rate is used to target higher rates on skeleton weed areas.
- harvest: yield maps are used to produce Phosphorus removal and replacement maps and monitor paddock-scale trials.

Making and or saving money using PA

- JD 2630 screens on all machines makes operator training, and managing data easy.
- Weedit: since its arrival in December last year it has saved us $55 to $60k; dual boom works well with a mix of small & large weeds
- precision seeders: precise seed placement by the conservapacs has given us excellent establishment of all crops even in difficult soils and under difficult conditions
- variable-rate: huge savings in fertiliser, and better return on investment of Nitrogen
- N-rich strips??: showing potential to refine zones and rates for spreading nitrogen.
- VR spreading: allows better targeting of fertiliser to the most responsive zone, load cells improve accuracy of SOA spread. Section control reduces overlap and out of zone spread.
- post emergence VR spraying: saving money on high blanket rates, section control with increasing number of sections keeps making paddocks smaller
- paddock-scale trials: show which zones are most responsive.

Stuff that is just cool (at the moment)

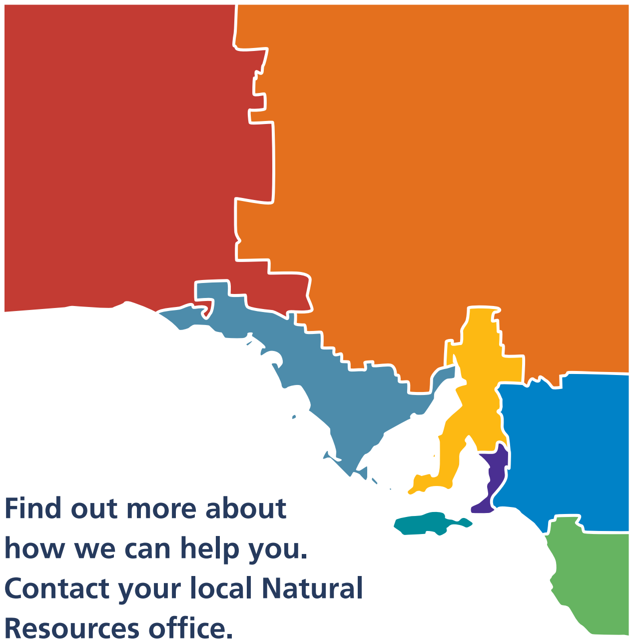
- weather station on the sprayer: works well for most weather readings but lacks accuracy for wind speed
- JD link: interesting data but currently too expensive for what you get.

Frustrations

- some canbus systems are just plug and go others are plug and play around a lot before you go.
- seeder, harvester and sprayer coverage maps can't communicate real time with each other yet.
- maintaining accuracy of S670 yield monitors, (a lot to do with our highly variable in paddock yields)
- current harvester front height sensing is ineffective when operating over 12 kph

SA's natural resources management boards

supporting sustainable primary production



SA's eight Natural Resources regions provide advice and services to primary producers and land managers statewide.

Pest plant and animal control

We work with landholders to reduce pest numbers and losses to agriculture while helping restore native biodiversity.

Soil and pasture management

We provide ideas, training and information to increase productive capacity and reduce land degradation.

Water planning and management

We work with local communities to plan for sustainable, fair access to water for all users including the environment.

Assistance and incentives

We provide advice on sources of external funding and any NRM levy-funded incentives.

Find out more about how we can help you. Contact your local Natural Resources office.

Natural Resources
Adelaide and Mt Lofty Ranges

Gawler
8523 7700
Lobethal
8389 5900
Willunga
8550 3400

Natural Resources
Alinytjara Wilurara

Ceduna
8625 3706

Natural Resources
Eyre Peninsula

Port Lincoln
8688 3111

Natural Resources
Kangaroo Island

Kingscote
8553 4444

Natural Resources
Northern and Yorke

Clare
8841 3400

Natural Resources
SA Arid Lands

Port Augusta
8648 5300

Natural Resources
SA Murray-Darling Basin

Berri
88580 1800
Murray Bridge
8532 9100

Natural Resources
South East

Mount Gambier
8735 1177

PRECISION AGRICULTURE EDUCATION RESOURCES.

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SUMMARY

Education plays a large part in developing and integrating PA within agricultural industries and across supply, delivery and consumption systems. In Australia and New Zealand there has been a substantial investment in education resources to help achieve the goals of PA. The resources listed here have been developed for the region (except the on-line forums) and all have local relevance for PA practitioners.

BOOKS, BOOKLETS AND MAGAZINES

- Advanced field-scale experimentation for grain growers, GRDC.
- A Guide to Smart Farming, LandWISE.
- Applying PA: A reference guide for the modern practitioner. GRDC.
- Designing your own on-farm experiments – how PA can help, GRDC.
- PA in Practice. SPAA and GRDC.
- Precision Ag News. SPAA.
- Precision Agriculture for Grain Production Systems. CSIRO Publishing.
- Precision Viticulture, Winetitles, .
- Proximal crop reflectance sensors, GRDC.

DIGITAL RESOURCES

- Agronomyjigsaw (video)
  youtube.com/user/agronomyjigsaw
- PA Manual (CD) available from GRDC
- Precisionagriculture.com.au (video)
  youtube.com/user/precisionagriculture/videos
- Precision Agriculture: Education and training modules for the Australian grains industry (CD) available from PA Lab, USYD
- Precision Agriculture for Grain production Systems: Tertiary education course resources (CD) available from PA Lab, USYD

WEB SITES

- CSIRO csiro.au/Outcomes/Food-and-Agriculture/PrecisionAgriculture.aspx
- LandWISE landwise.org.nz
- NZCPA nzcpa.com
- PA Help Desk pahelpdesk.com
- Precision Agriculture Laboratory sydney.edu.au/agriculture/pal
- SPAA Precision Agriculture Australia spaa.com.au
- UNE PARG une.edu.au/parg

INDUSTRY AND TERTIARY PA EDUCATORS

- SPAA workshops and forums spaa.com.au
- Charles Sturt University: Precision Agriculture undergraduate unit of study csu.edu.au
- UNE: Precision Agriculture undergraduate unit of study; Graduate Certificate in Precision Agriculture une.edu.au/parg
- Universities incorporating PA into coursework Curtin, Lincoln, Massey, QUT, UCQ, UniAdel, UniMelb, USQ, USYD, UTAS

ON-LINE FORUMS

- [A] Agriculture .com – Precision Agriculture Forum
  community.agriculture.com/t5/Precision-Agriculture/bd-p/precision-agriculture
- AgTalk – Precision Talk
  talk.newagtalk.com/forums/forum-view.asp?fid=6
- Farm Journal – Precision Agriculture
  agweb.com/farmjournal/precision_agriculture.aspx
- PrecisionAg
  precisionag.com
- PrecisionAgwired
  precision.agwired.com

PA MEETS LOT - INTEGRATING IN-SITU SENSOR DATA AND BIOMASS PREDICTION TOOLS FOR CROPS AND PASTURES.

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ABSTRACT

Monitoring pasture growth rate is an important component of managing grazing livestock production systems. In this study we demonstrate a pasture growth rate (PGR) model, initially designed for very large scale satellite imagery, can be operated at a scale of metres when incorporating in-situ sensor data. A light use efficiency (LUE)-based PGR model was combined with in-situ measurements from proximal weather (temperature), plant (fAPAR) and soil (relative moisture) sensors to calculate the growth rate of a tall fescue pasture. When incorporating in-situ measurements of temperature and moisture index, the model provided an accuracy (RMSE) of 1.68 kg/ha.day (R^2 = 0.96, p-value ≈ 0).

INTRODUCTION

Recent advances in wireless sensor networks (WSNs), and the availability of cheap ‘plug and play’ devices capable of sensing soil moisture, in-situ plant biomass and local climate conditions is redefining the meaning of precision agriculture (Vinayak and Apte 2013). Agricultural landscapes themselves are set to become sources of high quality, local, yet synoptic, contemporaneous, biophysical data and will exemplify the so-called ‘internet of things’ (Taylor et al. 2013). There are opportunities now to integrate live environmental data with well-established plant growth models in order to quantify the growth and development of crops and pastures in real time and on-location.

In this paper, we illustrate this concept by combining the light use efficiency (LUE)-based pasture growth rate (PGR) model of Hill et al. (2004) with in-situ measurements from proximal weather (temperature), plant (fAPAR) and soil (relative moisture) sensors to calculate the growth rate (PGR) of a tall fescue pasture in real time.

MATERIALS AND METHODS

The study site was located at the University of New England’s ‘SMART Farm’ (30°288'51" S, 151°388'46" E), 5 km north-west of Armidale, NSW Australia. The experiment was conducted in a 0.6 ha field of Tall fescue (Festuca arundinacea var. Fletcher) pasture over a three week period in January 2013 (mid-summer) when the pasture was at the vegetative-leaf development stage (E6 – E10) according to Moore et al. (1991).

The 0.6 ha trial site consisted of 3 blocks, each measuring 17 m × 12 m. Each block contained 5 experimental plots measuring 10 m × 2 m, and these were given a different treatment of regular irrigation in order to develop differing soil moisture level and hence pasture growth rates. The end result of this design was three replicates of 5 different levels of soil moisture (and hence pastures re-growth).

The above-ground PGR was measured from each plot at 1-week intervals during this experiment. At the commencement of the experiment, the pasture was first 'harvested' from every plot to a residual height of 6 cm above ground level using a plot mower. From then on, at weekly intervals the accumulating biomass in each plot was harvested back to the same residual height and the removed pasture bagged, oven dried at 70° C for 48 hours, weighed and the values converted to growth rate in kg dry matter (kg DM) per hectare per day. The procedure was repeated for 3 consecutive weeks in January 2013.

The pasture growth rate (PGR) model used in this work is based on Hill et al. (2004) and is given by

$$\mathrm{PGR(kg\ DM/Ha/day)} = \mathrm{LUE_{max}} \times 4\ \mathrm{day\ average\ (fA} \tag{1}$$

where LUE is the light use efficiency of plant growth (kg DM/MJ), fAPAR is the fraction of absorbed photosynthetically active radiation by the plant canopy which can be inferred by the canopy NDVI, PAR is the photosynthetically active radiation (MJ) and MI and TI are dimensionless moisture and temperature indices, respectively, that 'condition' the plant growth rate according to the local soil moisture and temperature.

At the experimental site, photosynthetically active radiation (PAR) was monitored using an SQ-100 quantum sensor ('SQ-100 sensor', Apogee Instruments, Inc., Logan, USA), measuring the irradiance (400 – 700 nm) above the canopy. In order to subsequently monitor daily fAPAR during the experiment, daily NDVI data were acquired using a CropCircle™ ACS-210 and converted to fAPAR using a fAPAR-NDVI calibration equation (Rahman et al., 2014a). At each plot CropCircle™ ACS-210 was positioned at a height of about 90 cm above the ground level and moved steadily backwards and forwards along the length of the plot (four traverses required) to cover the whole area of each plot to produce a mean NDVI value.

The soil moisture content (% volume) of each plot to a depth of 10 cm was measured at approximately 2-day intervals using a time domain reflectometer ('TDR', Mini Trase Kit – Model 6050X3K1B; Soil Moisture Equipment Corp, Santa Barbara, CA, USA fitted with two 10 cm wave guides). For each set of plot measurements, the waveguides were randomly placed at 5 - 6 locations within each plot and the volumetric water content (VWC, %) determined following the protocol outlined by numerous workers (Topp et al. 1984; Zegelin et al. 1989; Brisco et al. 1992). Each probe site within the plots was carefully inspected to ensure cracks or rocks in the soil did not confound measurements. The average VWC for each plot was calculated from the 5 – 6 individual measurements within each plot.

From a visual observation of plant growth and the range of TDR -measured soil VWC, a quadratic polynomial curve was fitted to scale the moisture index (MI) from 0 to 1. A value of 0 was assigned to the lowest VWC where plant growth was observed to stall and 1.0 assigned to the value of VWC when the growth rate appeared highest. It was noted that there were VWC levels greater than this peak growth rate value where plant growth also stalled; attributed to minor water-logging and this was also assigned a MI value of 0. The polynomial curve, encapsulating these departures from the optimal growth rate, takes the form:

$$MI = (\alpha \times (mmc - omc)^2) + 1 \tag{2}$$

where, α is a value to adjust the curve with minimum and maximum VWC; mmc is the measured VWC at plots with zero growth, and omc is the VMC when plant growth is observed to be highest.

The local air temperature was monitored using Thermocron temperature loggers (DS1921G, Maxim Integrated Products, Inc., San Jose, USA) installed 2 m above the soil level and set to log every 10 minutes. In the previous work of Nix (1981), a series of different plants groups all depicted similar temperature-growth rate behaviour, each having the optimum, minimum and maximum temperature for their growth and from this a generalized Gaussian temperature response curve was formulated. In this work we applied the response curve, developed by Nix (1981), for the mesotherm group. Again, we assigned a TI ranging from 0 – 1 corresponding to the relative growth response between the minimum and maximum temperature. In this study, the minimum, optimum and maximum temperatures used to fit the model were 2, 19 and 35 °C, respectively.

To determine the maximum LUE value under ideal condition for our Tall fescue (Festuca arundinacea var. Fletcher) pasture, a back-calculation procedure was performed based on the actual accumulating pasture biomass observed within each of the plots. The plot with the highest actual growth rate in the study period was selected and the fAPAR, PAR, MI and TI in a 4 day period spanning the observation used to estimate the maximum LUE value according to:

$$LUE_{max} = \frac{\mathrm{PGR}}{\text{4 day average (fAPAR*PAR*MI*TI}} \tag{3}$$

On deriving a maximum value from the single-plot observations, and on completion of all field measurements, the model-predicted PGR values were compared to the actual values and a second, iterative adjustment made to LUE_{max} in order to minimize the RMS prediction error, following Hill et al. (2004).

RESULTS AND DISCUSSION

Based on observations of pasture growth in the plots, the coefficients for Equation 3 were determined to be α = 0.0035 and omc = 0.38 (Rahman et al., 2014b). The value of LUE_{max}, derived from the plot exhibiting the highest growth rate, an optimized following Hill et al. (2004) , was 1.59 g DM/MJ APAR (Rahman et al., 2014b). Based on this value, a scatter plot of predicted average daily growth rate against the actual growth rate for all the plots is given in Figure 1, with an RMSE of 1.68 kg DM/ha.day.

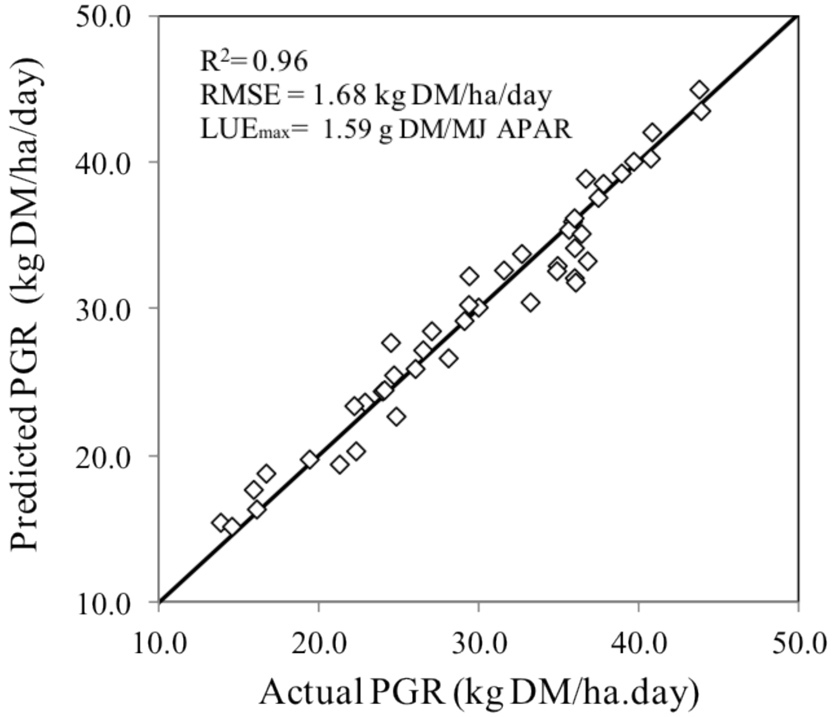

Figure 1. Scatter plot of predicted versus actual PGR for all plots at all measurement dates (n = 45). The solid line indicates 1:1 equivalence. Extracted from Rahman et al. (2014b).

CONCLUSION

An empirical light use efficiency model, originally designed for using large scale remote sensing tools to infer and map net primary production of vegetation, has been used to estimate pasture growth rate at the metre scale using a combination of in-situ soil moisture, ambient temperature and PAR sensors to derive model inputs.

ACKNOWLEDGMENTS

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TAGGLE TECHNOLOGY: ENABLING IMPROVED MANAGEMENT IN A VERY LOW STOCKING RATE ENVIRONMENT.

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SUMMARY

Our activities are motivated by the need to develop new systems for managing grazing animals in the Southern Rangelands of WA to deal with both the long term deterioration in the resource and climate change. The tremendous complexities in animal-ecosystem interactions mean that information and knowledge are vital components of a grazing management system. Cost effective information gathering is one essential component of the system. Being involved in field testing and de-bugging the Taggle Telemetry solution meets part of that need. Monitoring waters, electric fences and gates from the desk-top more than halves labour and fuel costs, and provides the confidence to take new management approaches. Being able to locate tagged cattle simplifies inspection, mustering and provides new information about animal behaviours as they interact with the environment.

BACKGROUND

The old saying; “If you keep on doing what you have always done, you will keep getting what you have always got”, should read for the Southern Rangelands of WA, “you will keep getting less and less until you have nothing”.

This is in fact the situation for most small stock producers over a large sweep of country from Carnarvon in the West to the border with SA in the East. In hindsight it is clear that with fixed fence paddocks and the ability to set stock, a grazing management system totally unsuited to the complex ecosystems and variable climate was largely adopted in this region. The exception has been on properties where wild harvesting of almost totally unmanaged cattle is practised. Here the animals choose where to be and in some areas range far out into the ‘desert’ when conditions allow.

As returns declined, profitability was maintained by reducing inputs and allowing infrastructure to run down at the expense of the basic resource. The most serious outcome from a productivity point of view has been the ineffectiveness of what rainfall we are getting as our climate changes. Two years after taking over Austin Downs in 2001 we totally de-stocked the property for 4 years, took on agisted stock in 2006 and again destocked till 2010. As a result of this rest, groundcover has more than doubled, perennial grasses have returned and effectiveness of intensive rainfall use has increased from 20% to better than 60% as measured by flood flows.

A NEW BEGINNING.

So far, so good. Now we needed to start to get some return from the place. Without taking it back to where we started from. Amongst others the concepts of Allan Savoury and Fred Provenza about the complexity of living systems and the need for flexibility, adaptiveness and responsiveness in managing them have informed the path we are taking.

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