Project Introduction

"Increasing the economic returns of agronomic management using Precision Agriculture"

Introduction

The project "Increasing economic returns of agronomic management using Precision Agriculture" aimed to apply Precision Agriculture (PA) as both a decision support tool and management tool that reduces risks and increases returns for SA grain growers.

To try and achieve this, 5 sites were investigated across South Australia. A consistent approach was used from data collection to ground truthing through to understanding the effects of the growing environment on production and the economic consequences.

Data Collection:

1. Quantifying the growing environment. Soil sensors combined with RTK GPS were used to measure, map and quantify changes in growing environment of each site. Two soil sensors were used – Multi Depth EM and Gamma Radiometrics. All data was collected in the single pass with an equipped vehicle as shown below in Figure 1:

Figure 1: *Collection of Dual EM, Gamma Radiometrics and Elevation Data*

2. Ground truthing: extensive sampling was used to determine the agronomic nature of the variation in growing environments including soil coring and analysis and tissue testing. A hydraulic soil probe was utilised, coring up to 1.1m as shown in Figure 2.

Figure 2: *Hydraulic soil probe and resulting soil core*

3. Analyse the relationship between the growing environment and production using yield maps.

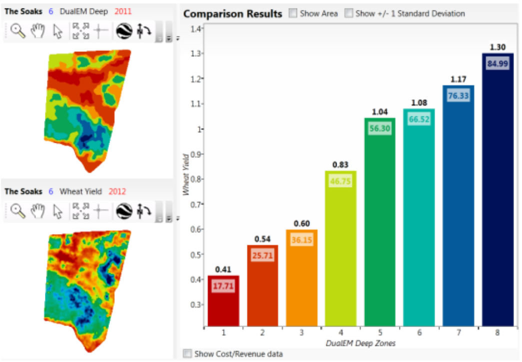

Figure 3: *Relationship between EM and Yield at Kimba*

Once the economic impact of variations in growing environment on production were established, site specific issues were identified and investigated further.

Identifying Issues:

1. Focus on an issue specific to or identified by co-operators or farmers/agronomists in the region
2. Low yielding areas – identify and correct limiting factor to increase productivity or reduce the annual cropping inputs in line with yield capacity
3. High yielding areas – no apparent limiting factor therefore assess productivity gains by increasing inputs to these regions

Site Locations:

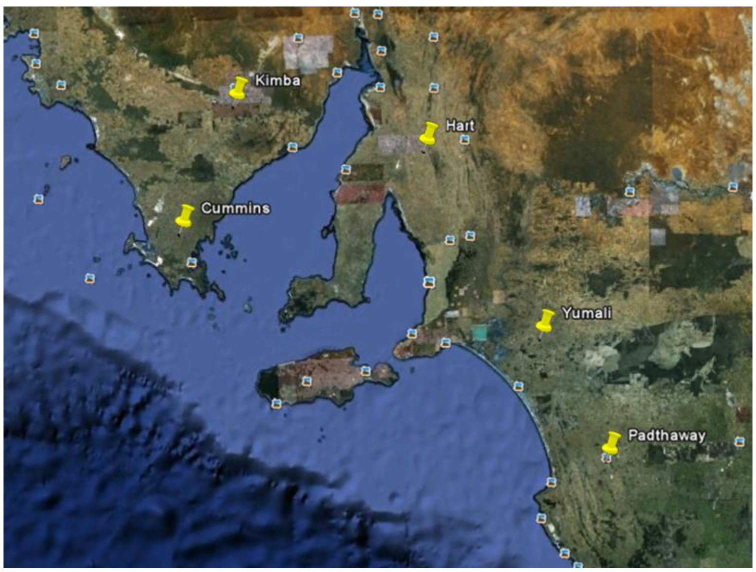

Figure 4: *SAGIT funded project site locations*

5 Focus Farm project sites were selected at quite diverse cropping districts of South Australia. The spread of locations is shown in Figure 4 above.

- Trevor and Craig Gameau – Edillilie
- Dion Woolford – Kimba
- Robbie Wandel – Hart
- Hansen Farms – Yumali
- Tony Mackereth – Padthaway

At each site trials were established or further investigations carried out to determine potential benefits to management changes in response to spatial variability in the growing environment. Harvest data was used to analyse responses to treatments and establish economic outcomes.

For more information about activities, site reports and results please click on the below links.

Site Reports

- **Edillilie**
- **Kimba**
- **Hart**
- **Yumali**
- **Padthaway**

Using Soil Surveys Decision Support

- **Soil Sensors**
- **Ground-Truthing**
- **Soil Amelioration**
- **Soil Water**

Case Studies

- **Soil Amelioration - Deep Ripping**
- **Variable Rate Seeding Fertiliser - Hart**
- **Increasing Fertiliser to High Yielding Soils - Edillilie**
- **Segregating Fields for Optimum Land Use - Edillilie**
- **Isolating Limestone - Yumali**

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Yumali and Padthaway

Acknowledgements: Precision Agronomics Australia, Esperance, WA – photo of soil sensing vehicle and equipment.

Edillilie Site

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Trevor and Craig Gameau “Shadow Brook”

Introduction

The site at Edillilie is a mixed farm, with a history of cropping and grazing. It is rolling terrain, broken by intermittent creeks, and the soils vary greatly from deep sands, through to sandy loams over gravel to “crabholey” red brown earths. An example of the terrain is shown in Figure 1. The annual average rainfall is 500mm.

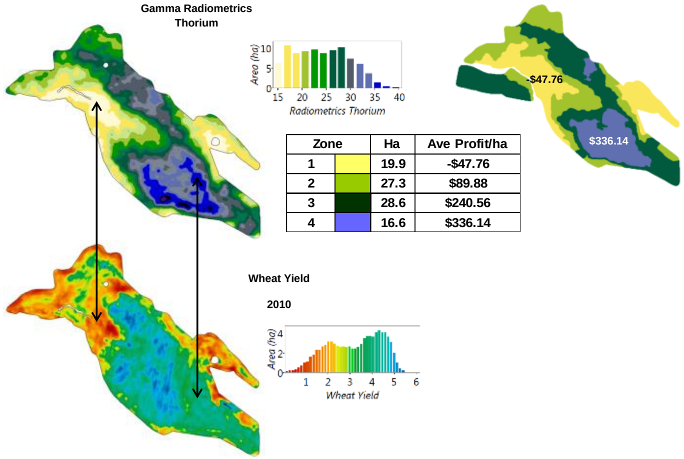
Figure 1: Terrain at “Shadow Brook”

Survey and Groundtruthing Results:

Soil types were highly variable and complex over the project area and within individual fields. In certain fields, investigations into the soil variability revealed that both gypsum and lime could be applied in different areas of the same field to ameliorate sodicity and acidity respectively.

Both the EM and Gamma Radiometrics sensors combined were found to be the most effective way to define and understand the soil variability. The Gamma Radiometrics proved valuable for its ability to detect certain soil changes the EM could not and in selected fields soil zones delineated alone related best with historical yield maps.

Figure 2 below shows the strong link between the Gamma Radiometrics Thorium layer and the 2010 wheat yield. The influence of soil variability shown in the thorium layer was replicated over multiple seasons. The economic data in Figure 2 is the cumulative gross margin impact between the different soil type zone for 6 cropping seasons.



Zone		Ha	Ave Profit/ha
1		19.9	-$47.76
2		27.3	$89.88
3		28.6	$240.56
4		16.6	$336.14

Figure 2: 2010 Yield Data x Thorium Data, with the economic analysis x zone over a 6 year period

The Dual EM showed strong correlations with various soil chemical factors including exchangeable sodium, pH, exchangeable aluiminium and the cation exchange capacity (CEC).

Issues Identified:

Key issues identified by growers and agronomists in the region included:

- Post Seeding nitrogen
- Planting phosphorus
- Liming
- Gypsum
- Pre Plant Potassium
- Soil modification – delving

The soil surveys and soil coring analysis results from ground-truthing revealed opportunities for liming, gypsum, soil modification (delving / deep ripping) and pre-plant potassium. Figure 3 shows how this knowledge can be used to segregate the farm for soil management decisions. Soil variability and correlations with yield indicated potential for variable rate inputs based on soil type.

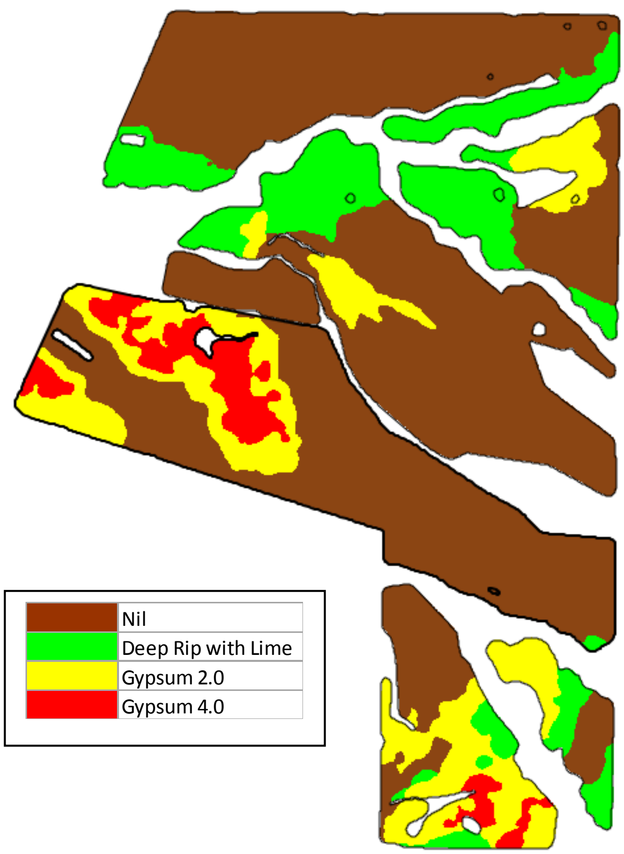


Figure 3: Map of "Shadow Brook" showing the identified management options for each area of the farm.

Key Activities Implemented:

- Deep ripping of sand over sodic clay in typically low yielding soil profiles
- Amelioration of low yield zones with profiles of high sub surface acidity and aluminium toxicity with the incorporation of lime and potassium fertiliser.
- Varying post seeding nitrogen applications according to variations in potential yield driven by soil type and water use efficiency.
- Varying seeding fertiliser rates according to changes in soil type and potential yield.
- Long term lime trial on soils identified with low pH, low potassium and aluminium toxicity established

Key Outcomes:

- Profitable responses to increased nitrogen rates on high producing soils. Benefit $51.01/ha
- Creation of VRT gypsum plan (see Figure 3).
- Significant yield response to deep ripping of long term problem soil type with subsurface acidity and aluminium toxicity. Increased wheat yield of 1.49 t/ha for lime and deep ripping treatment over no treatment.
- Profitable response to VRT seeding fertiliser in particular improved profit by increasing rates in typically high producing soils. Benefit $41.41/ha for variable planting fertiliser.
- Changed land use based on soil sensing maps, historical yield performance and soil test results. Re-fenced to reflect cropping paddocks vs. those more suitable for grazing.
- Drain implementation using terrain mapping and historical yield data

Kimba Site

[BACK TO START]

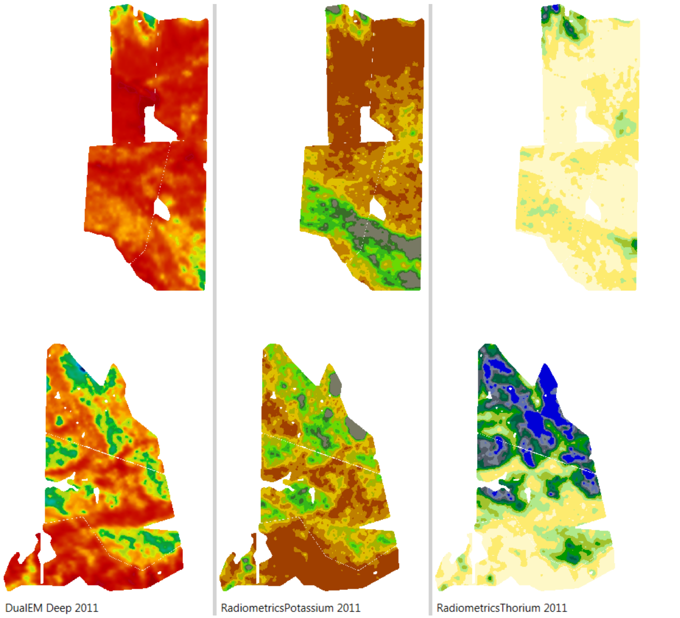
Dion Woolford “The Soaks”

Introduction

__Figure 1.__ Soil Cores lined from low (left) to high (right) EM38, showing the increasing clay content.

The site located south of Kimba is predominantly Dune-Swale and is a mixed enterprise of cropping and sheep. The soils are predominantly sandy soils, ranging from deep sands to loam heavy ground, some stone is found on the southern half of the site. Average annual rainfall is 340mm.

Overall none of the Gamma Radiometrics layers displayed significantly different patterns then the DualEM.



Survey and Groundtruthing Results:

The EM38 proved to be the dominant Soil Sensor due to most of the variation been driven by soil texture, with some areas of transient salinity.

Correlations between EM38 and estimated bucket size were found using 'Soil Water Express'. Initial soil coring highlighted a visual relationship between EM38 and depth to clay.

Issues Identified:

As with most low rainfall sites managing risk while maintaining yield potential is a key issue at this site.

- Variable Rate seeding fertiliser - reduce risk on heavier soils and lift yields on light soils
- Soil amelioration of sandy soils

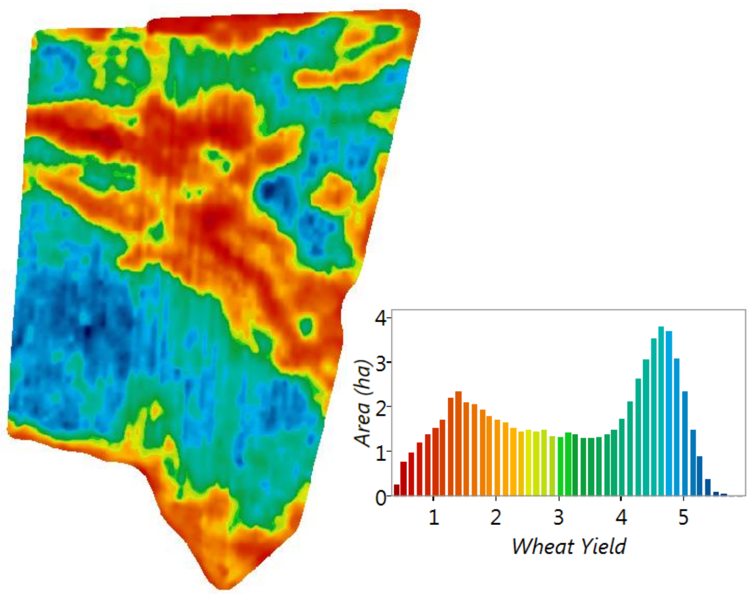
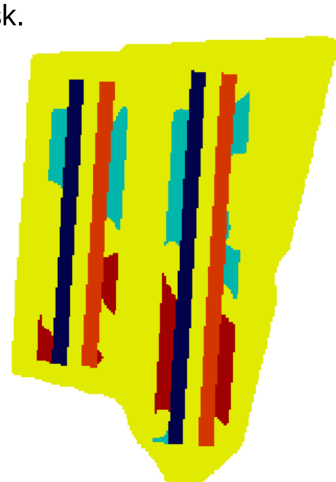


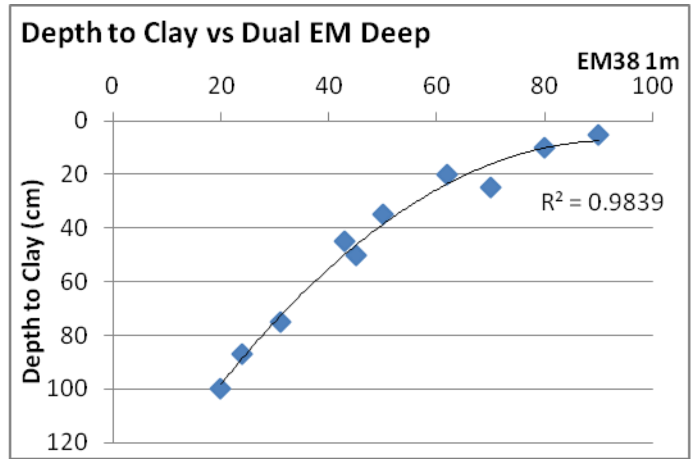
Figure 3. *2009 Wheat Yield map highlighting huge variation in Yield Potential, mostly due to underperforming sands.*

Key Activities Implemented:

- Two Year trial investigating increasing fertiliser inputs on light soils to lift production, while reducing inputs on the heaviest soils to reduce risk.



- Targeted soil testing highlighted relationship between EM38 1m and Depth to Clay.



Key Outcomes:

- Light soils do not respond to increased fertiliser or seeding rate, further evidence for the need to ameliorate soils.

- No yield penalty to reducing inputs on the heaviest soil types with the highest subsoil constraints. Implementation of a Phosphorus replacement strategy recommended to avoid running down of soils.

- Creation of soil amelioration plan by segmenting paddock into management zones. Using the relationship between EM38 and depth to clay, deep sands can be targeted for clay spreading, clay less then 50cm can be delved and clay close to the surface can be targeted for clay pits.

Future Opportunities:

- Improve agronomy of sandy soils to increase returns from Variable Rate.

Hart Site

BACK TO START

Robbie Wandel "Firgrave"

Introduction

The site located south east of the Hart Field Site, between Blyth and Brinkworth. Soil types vary between Sandy Loams to Clay Loams. The average annual rainfall is 400mm. The property is intensively cropped with hay and sheep in the system.

Survey and Groundtruthing Results:

Due to the major variation in soil types been driven by soil texture and the major chemical constraints been transient salinity and sodicity, EM38 has proved to be the dominant soil sensor.

There was a strong correlation between EM38 and sodicity, both in the topsoil and subsoil.

With reasonable correlations to Texture, Salinity and Sodicity, there were likely to be strong correlations to Crop Lower Limit.

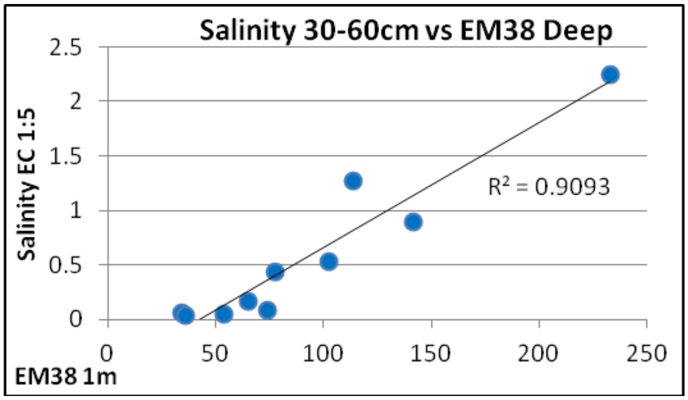
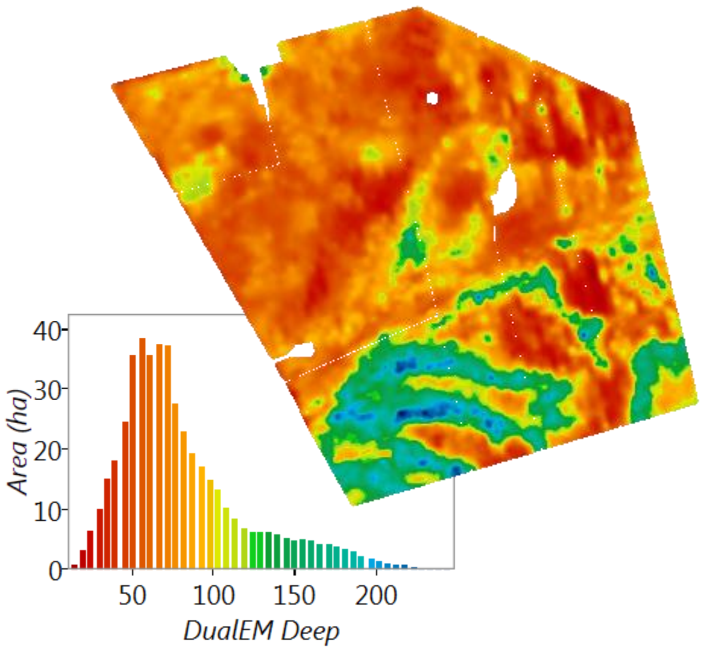


Figure 1. *Relationship between EM38 and Subsoil Salinity*

This was most evident in yield data from dry years where yield declined in as EM38 increased. Conversely in wet years yield was independent of soil type as the effect of subsoil constraints was masked.



Issues Identified:

Key issues identified for the site involved fertiliser management, focused on increasing seeding fertiliser to reduce pressure during the season.

Issues identified from the Ground Truthing included

- Variable Rate Gypsum
- Spatial understanding of Soil Water

Targeted soil sampling illustrated a strong relationship between EM38 and Soil Water properties.

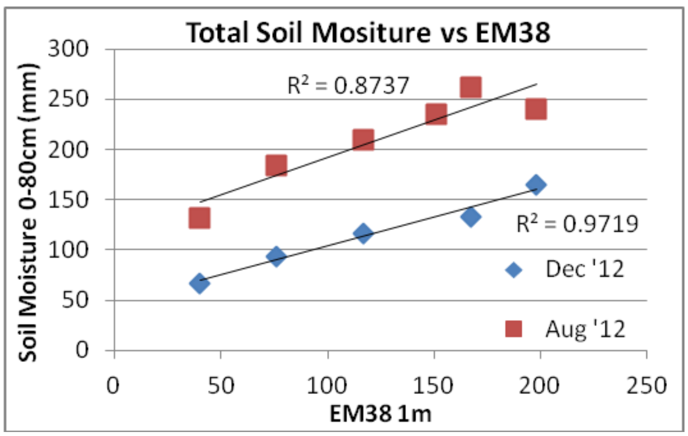


Figure 3. *Relationship between EM38 1m and Total Soil Water sampled in August (DUL) and December (CLL)*

Key Activities Implemented:

- Two Year fertiliser trial comparing 3 rates across 3 soil zones established.
- Variable Rate Gypsum zones created from strong correlation between sodicity and EM38.

	Low EM38	140kg
	Med EM38	140kg
	High EM38	140kg
	Trial 1	70kg
	Trial 2	200kg

Key Outcomes:

- Very little response to increased fertiliser following beans. Increased yield on low CLL soils not enough to justify extra fertiliser.
- No penalty to reducing rates on medium and high CLL soils after legumes.
- Response in all zones to increased fertiliser in wheat on wheat rotation. Highest gains on low CLL soils.
- If full VR was used of increased inputs on Low CLL soils and reduced inputs on High CLL soils, gross margin would of improved $27/ha across the field.

Future Work:

- Improve understanding of Nitrogen status as each stage of the rotation.
- Implement full Variable Rate to match all the variation in the field.
- Link understanding of spatial variability in soil water to production calculators such as Yield Prophet

Yumali Site

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Hansen Farms “Herberts”

Introduction

The site at Yumali is predominantly continuously cropped but livestock are a part of the farming system. It is undulating terrain with rocky limestone outcrops being prevalent in the landscape. The soils vary from deep sands through to limestone rubble with very little soil through to loam soils. The annual average rainfall is 450mm.

Survey and Groundtruthing Results:

Figure 1 shows the EM survey results overlaid over the landscape. It can be seen that there is quite a bit of variability in the EM, however the EM alone has not been able to separate out the sand from the limestone areas that have similar apparent conductivities (ECa).

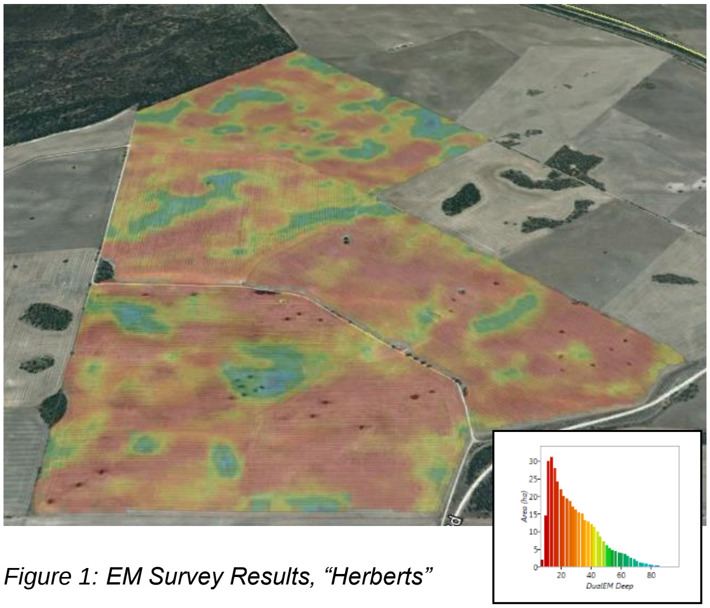

Figure 1: EM Survey Results, “Herberts”

Although there were some good correlations beteen Dual EM layers and key chemical soil properties, the correlations with soil texture were extremely poor. This is largely thought to be due to the limestone layer which varies in its depth below the soil surface. The DualEM sensor was not efficient in distinguishing between limestone and sand.

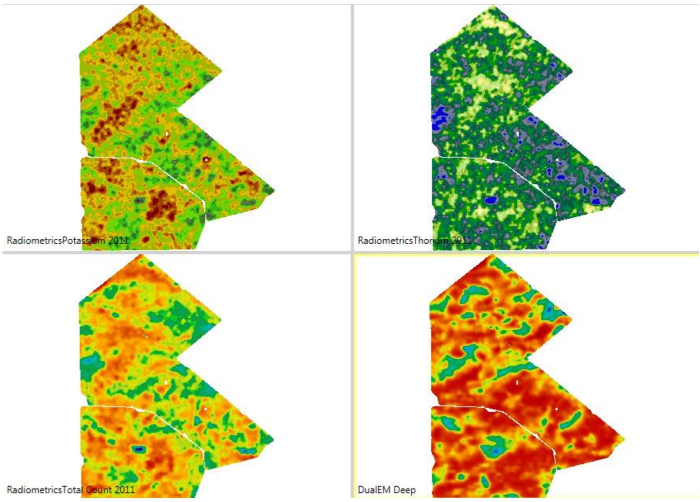

Figure 2: 2011 Survey Results showing some slight variations in patterns between EM and radiometrics.

Some of the Gamma Radiometrics layers appeared to be detecting soil changes that resulted in the maps having quite different structure to the maps created by the DualEM sensor. These different layers are shown in Figure 2. The potassium sensor had fairly good correlations with yield responses, however sampling results did not shed any light on what was “different or special” about the higher Gamma K soils that was driving the increases in production. The responses to the potassium sensor in particular will be monitored over continuing years.

The amount of variability and resulting gross margin across one field is shown below in Figure 3:

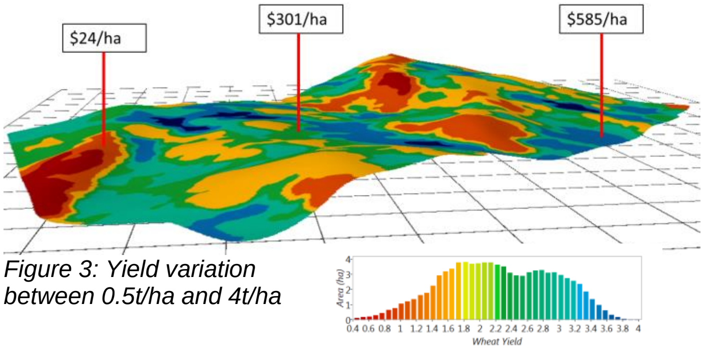

Figure 3: Yield variation between 0.5t/ha and 4t/ha

Issues Identified:

The main issue identified at this site was being able to Identify the presence of limestone in the landscape, and understanding where (at what depth) in the soil profile it existed.
This would then allow for improved spatial management through….

- soil modification (delving or spading clay-spread ground)
- targeted pre and post-seeding nutrition
- targeted trace-element nutrition
- targeted potassium requirements

Figure 3 shows the issues where 2 areas of the same DualEM apparent conductivity reading are very different soil types – this was recognised previously, and it was hoped that the Gamma Radiometrics could add value in the process of identifying rock in the landscape.

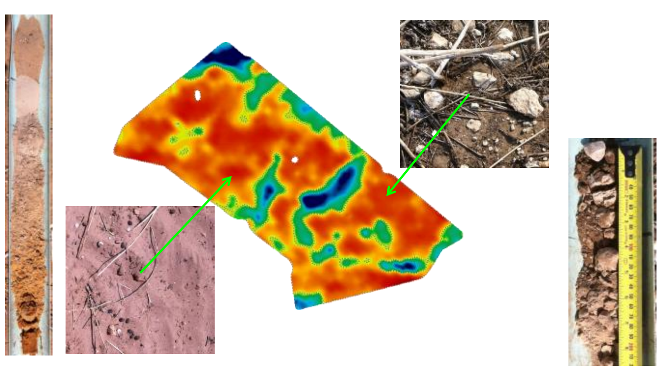

Figure 3: DualEM showing 2 areas of similar conductivity with very different soil properties

Key Activities Implemented:

- Intensive soil coring to model the presence of limestone across the field and within the landscape. Verification of the model on adjoining fields.
- Investigating the use of crop models and crop sensors to see if improved N-management could be achieved.
- Long term nutrition trials established to monitor use of high, medium and low nutrition regimes on varying production zones.

Key Outcomes:

- Combinations/ratio's of the Dual EM layers was effective in predicting the location and depth of soil over limestone.

- Gamma Radiometrics didn't appear to add any additional value over DualEM in this landscape

- CropSpec data showed the potential for zonal nitrogen management to increase yields

- Matching seeding inputs to potential yields resulted in over $10/ha increase in profit across the whole paddock.

NB/ All economic data has been generated using SAGIT Gross Margin guides for the relevant season.

Padthaway Site

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T.Mackereth “Browns”

Introduction

The site at Padthaway is cropped annually, but livestock are a part of the farming system, grazing paddocks over summer. The soils are predominantly brown clay soils with the strong presence of limestone. The landscape is extremely flat, with the elevation across the farm varying by only 1.5m across the whole area. This is shown below in Figure 1.

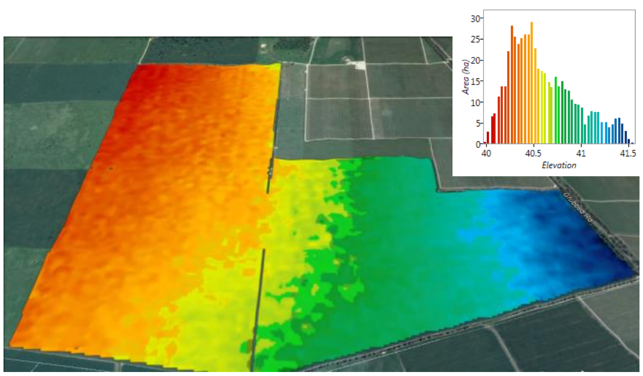


Figure 1: Elevation at “Browns”

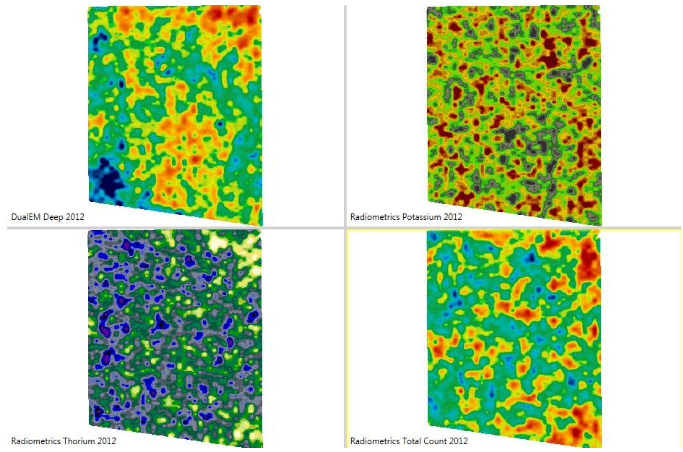


Figure 2: 2011 Survey Results showing highly variable pattern in field B6.

Survey and Groundtruthing Results:

There is extremely high variability in soil over a short distance in all paddocks at this site. This is shown in Figure 2 where all of the soil sensor results are shown for one of the surveyed paddocks.

Of both soil sensors used, investigations showed that the DualEM had the stronger link to major local soil profile variation.

The DualEM was highly correlated to the depth of soil over limestone. This had also been found in previous surveys in these districts. This relationship is shown in Figure 3 below, and the corresponding soil cores in Figure 4.

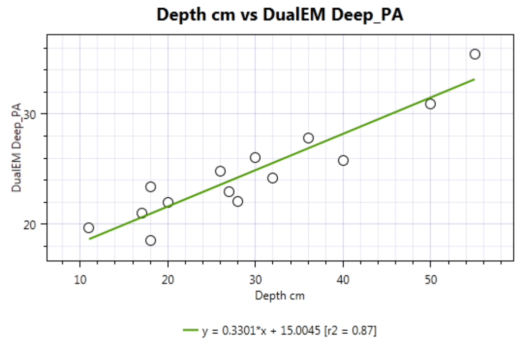


Figure 3: Relationship between Dual EM and depth to limestone

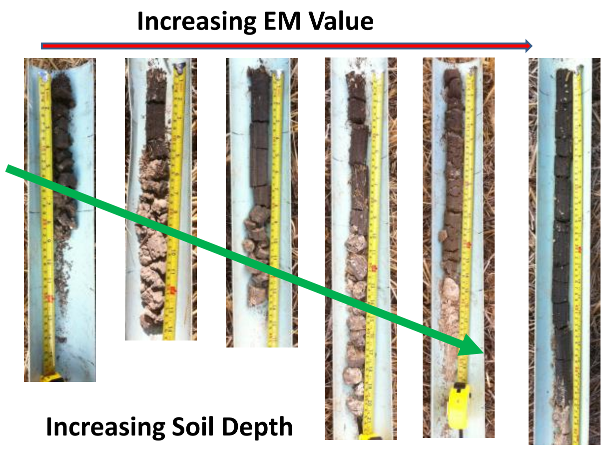


Figure 4: Relationship between EM and depth of soil as shown by the sampled soil cores

Issues Identified:

The issues identified as potential areas to pursue at this site included

- Managing fertiliser applications to variations in soil depth over limestone layer.
- Using soil sensor layers to identify variations in pH and managing this with targeted lime applications
- Using crop sensors to quantify variations in crop growth and nitrogen supply/demand across different soil depths and target strategic post-seeding nitrogen applications accordingly.
- Assess the potential impact of short term waterlogging on yield and the ability to manage this with changing of farming direction.

Key Activities Implemented:

1. VR Nitrogen trials in wheat utilising EM data and cropspec data with an aim to maximise yield potential while taking into account variability in soil depth.
2. Soil coring to try and understand if Gamma Radiometrics adds any value in these situations (particular with regards to detecting areas of low pH within the limestone fields)
3. Collection of elevation data on smaller transects to assess the impact of water movement across fields.

Key Outcomes:

- Although the soil varied greatly in depth, the soil depth did not appear to be the key determinant in driving yield. The collection of yield data on this farm was largely unsuccessful. The monitor has had sporadic collection throughout the life of the project and this made analysis of data quite difficult.
- The movement of water across the field was also a factor that appeared to be driving some of the yield response. Figure 5 shows the depressions (areas where water ponds) on a Nth-Sth spraying line, vs the depressions on an East-West spraying line. The depression areas had a 0.2-0.25t/ha yield reduction in wheat* across each soil zone. Simulating a change in the direction of sowing reduced this area by 12ha. A change in the direction of sowing may also improve traffic ability and allow for more timely application of other farming operations.

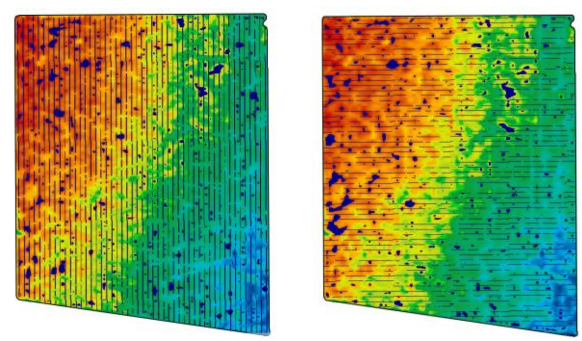


Figure 5: Wheel tracks across the elevation and depressions in the field where water ponds

- Using NDVI data in combination with soil zones resulted in greater economic responses than using soil zones alone when applying post-seeding N.

** Only limited yield data was available, so figures should be treated with caution*

Soil Sensors

BACK TO START

Using Technology to Map Soil Variation

Introduction

There is one constant in crop production, and that is the soil. Yield responses may vary greatly according to climatic changes, changes in management practices or agronomy, but generally soil and the soil properties largely remain the same (unless large scale soil amelioration occurs).

Soil sensors detect the changes in soil variability across the surveyed area. There are various types of sensors and in this project, 2 key sensors were investigated; EM38 (Electro Magnetic Induction), a sensor that has been typically used for mapping spatial soil variability, and a Gamma Radiometrics sensor which is widely used in Western Australia, but had not previously been investigated as a soil sensor in broad-acre cropping situations in South Australia

Ground Sensors Investigated

EM38

EM38 is the most commonly used sensor in detecting changes in soil variability in South Australia.

EM38 technology relies on an electro-magnetic pulse being sent from one end of the machine through the ground and the stimulating electrical currents through the soil as it feedbacks into the other end of the machine. What is measured by the machine is the apparent electrical conductivity (EC_a). The ECa can be influenced by several factors, some of these include the relationship between clay content, clay type or depth to clay. It may also be influenced by soil water content or soil salinity. Changes in EM relative to soil clay content are shown below in Figure 2.

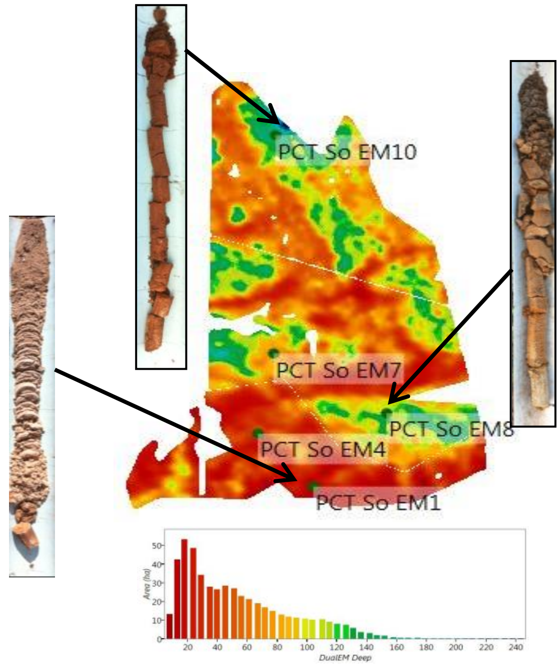


Figure 2: *Soil showing an increase in clay content with increasing EM value increasing.*

An EM survey is site specific and provides a snapshot of the apparent conductivity at that particular point in time. Targeted Ground truthing is an essential step to understanding the nature of the soil variability the EM38 is detecting.

GAMMA RADIOMETRICS

Gamma Radiometrics is a measure of the natural radiation emissions in the earth's surface. These emissions are given off by the decay of elements within the soil and rocks, and provide information about the parent material of the soil, which can then be related to soil types across the paddock. The primary elements measured are radioactive isotopes of potassium (K), thorium (Th) and uranium (U).

A radiometrics survey measures the spatial distribution of these radioactive elements as well as the total count in the top 30-40 cms of the earth's crust.

Figure 3: *Gamma Radiometrics Machine*

Gamma emissions travel through the atmosphere, so the machine was mounted on the front of a vehicle as shown in Fig.3, and the data collected through a computer in the cabin. In this project, the Gamma Radiometrics data was collected simultaneously with the EM data on 35m transects driving up and down the paddock. Broad scale gamma surveys can also be collected through aerial surveys.

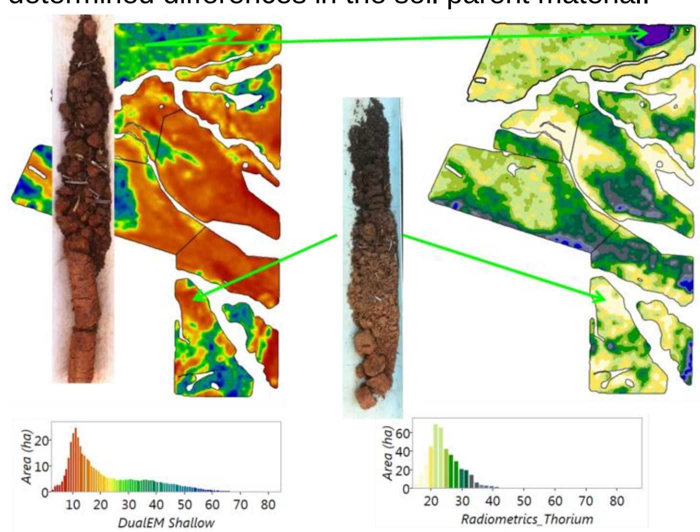
Gamma Radiometrics is a technology utilised in broadacre areas of Western Australia. In these situations it has proven very effective in discerning profiles of high gravel content from those of deep sand. Previously, this technology had not been investigated on a large scale in South Australia, so assessment of the technology was part of the SAGIT funded project.

EM AND GAMMA RADIOMETRICS…. Working together

While the use of the Gamma Radiometrics technology is relatively new compared to the EM, there are already some identified situations where they have been found to complement each other. These include

- Where soil conductivity levels are very low the Gamma Radiometrics can distinguish between deep sand and ironstone gravel profiles
- Where the soil profiles are higher clay with areas of gravel, the EM will tend to distinguish between these better.
- Gamma Radiometrics can assist in separating the clay profiles from those that are saline in areas of high conductivity with the EM instrument.

Figure 4 below shows a farm where the EM reading is similar, but the Gamma Radiometrics has determined differences in the soil parent material.



Key Project Observations

Edillilie Site – Combination of both sensors was the most effective in defining the soil variability

Yumali Site - EM data alone and analysis of data depths appeared be the most effective tool in landscapes where limestone soils were present.

Acknowledgements: Precision Agronomics Australia, Esperance, WA – photo of vehicle and sensing equipment.

Crop sensors

BACK TO START

Using Sensors for In-Crop Variation

Introduction

Active crop sensors (those that have their own light source) are becoming more commonly used in broadacre situations to measure the variability in reflectance of crops during the growing season. These sensors are starting to be used more for "on-the-go" nutrient application (particularly post-emergent nitrogen applications). The aim was to explore opportunities for "on-the-go" nitrogen applications using sensors or to see if the Normalized Difference Vegetation Index (NDVI) map generated was best utilised against a soil zone map to determine optimum nitrogen rates.

Fig 1: CropSpec mounted on vehicle

Crop Sensors

Crop sensors are mounted on ground-based vehicles and are being used to try and manage inputs/crop nutrition under varying seasonal conditions. These sensors are responsive to both crop biomass (amount of vegetation) and the crop colour (greenness of the crop). A darker green crop gives higher values than a paler green crop for the same amount of biomass present.

The sensors work on the assumption that the level of the biomass also represents the yield potential (ie. The higher the biomass, the higher the yield potential in a particular season).

As part of the SAGIT project, a cropspec was utilised. This was mounted on a vehicle and the data collected across the field. Recording occurred in the cabin. The crop-specs mounted on the vehicle are shown in Figure 1.

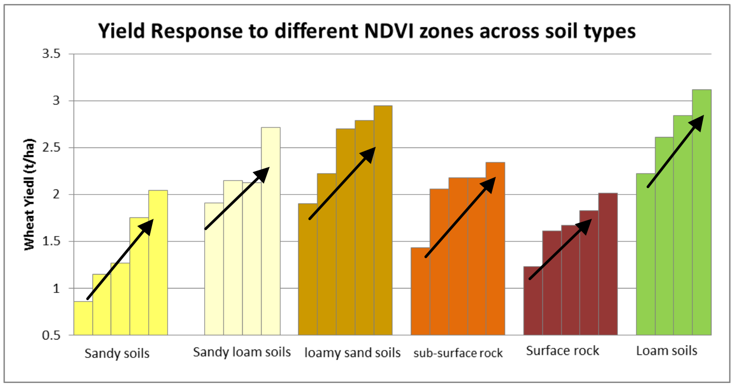
The collection of NDVI data is specific to the crop in which it is collected, and should be ground-truthed to make sure that the differences in reflectance and resulting NDVI are nutrient related. (Disease, pest infestations, waterlogging and other management issues can also result in low NDVI values).

Results

Initial work at the Padthaway site suggested that there may be the opportunity for "on-the-go" sensor application in some seasons. Where increased nitrogen rates were applied to areas of the same soil depth (but with a lower NDVI), the yield response was greater than when compared with the standard application rate. However this increase was not significant. The test strips applied to monitor responsiveness also suggested that the site was not responsive (across all soil zones), with the 30, 70 and 110L/ha UAN rates all resulting in similar yields across the trial area.

At the Yumali site, there was a significant response in yield to changing NDVI. There was up to 1 tonne/ha yield response across various soil types based on differences in the NDVI, suggesting that the potential for both zonal management (over 1t/ha in maximum yields across zones), and also the management within zones (over 1 tonne/ha within soil zones) exists.

Graph 1: Yield response to NDVI detected across soil zones



Shows the increase in NDVI values across the soil type

Soil cores to determine initial N-levels across zones were also taken, however due to the limestone fraction and the lack of soil characterization across the region, attempts at using models to understand total available nitrogen and the maximum yield potential were largely unsuccessful.

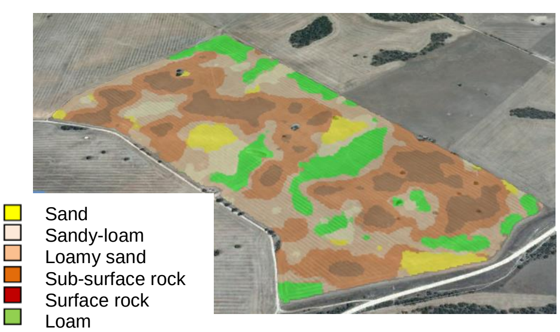


Figure 2: Soil zones at H2.

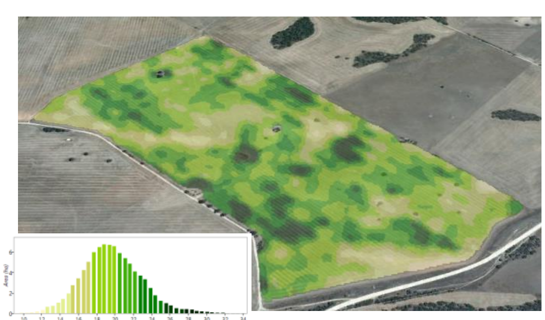


Figure 3: NDVI as collected by a cropspec at H2.

and 3 show the base data used for analysis in the above Graph 1. The low NDVI on the sandy areas identified in Figure 2 can be visually seen in Figure 3.

Conclusions

Crop sensors are becoming more commonly used for real time applications.

- In certain environments (particularly those with high soil variability with large differences in soil water holding capacity), the information is probably best used in combination with other sensor data (eg. Soil data).
- In environments where the variability in both soil and yield isn't as extreme, crop sensors may have applications for real time use, however need to be sure that the nutrient being applied is the limiting factor.
- Ground-truthing to see what the NDVI is telling you should always be carried out.

Ground Truthing

BACK TO START

The ESSENTIAL step to understanding Spatial Soil Surveys

Introduction

Ground Truthing is essential to understanding any spatial survey. It involves selective sampling and analysis across the range of the survey.

Compared to other Precision Ag surveys such as NDVI or Yield Maps, Soil Sensor surveys offer more time for sampling. Sampling can generally be revisited each year for temporal changes such as moisture content or to reassess any outliers.

How to Ground Truth - EM

The key to ground truthing EM38 Surveys is through soil coring. There are a range of considerations, with costs being the obvious, but it is important to consider that collection of the EM38 survey is only part of the whole process and without proper ground truthing it is easy to make mistakes interpreting the collected data.

Coring Considerations

How many cores?

As a general rule a minimum of 6 separate values should be cored. As the number of cores increases with larger surveys it is beneficial to repeat sample similar EM values in other areas of the survey.

Repeat sampling across the survey area increases confidence in both the EM and Lab results.

Left - Two cores taken from the same survey with different EM38 values

How Deep?

Sampling depth is driven both by the survey type, budget and the landscape, as physical barriers such as rock need to be considered.

For Shallow EM38 surveys the machine is responding to changes over the first 50cm in the soil profile, so sampling within this zone is most appropriate.

For Deep EM38 surveys the reading is more driven by the 40-100cm readings, although it is still influenced by the top 40cm to some degree.

Most EM38 surveys now are conducted using machines that sample both depths in the one pass. Giving a much more detailed survey as layers can be investigated individually as well as together.

Segments?

All soil coring should be segmented into different depths, to allow independent analysis. A minimum number of 3 segments should be separated - the Topsoil, Shallow Subsoil and Deep Subsoil.

For ease of analysis and use in calculators such as 'Soil Water Express' it is easier to have set segment depths for all cores, ie 0-10cm, 10-30cm, 40-60cm, 60-80cm etc.

Chemical Analysis?

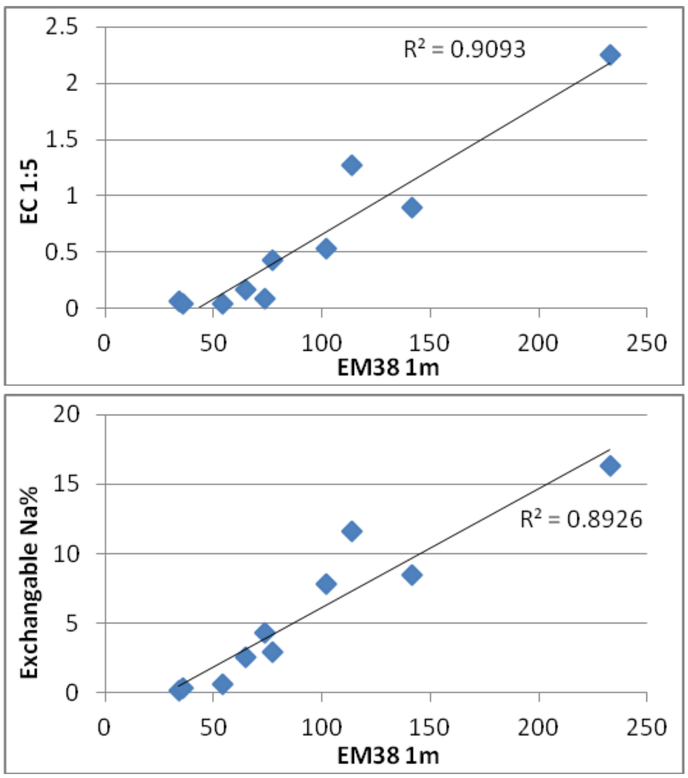
The major drivers of EM38 are Moisture, Texture and Salinity (EC), therefore these are priority tests. Other tests should include Boron, Exchangeable Cations for Sodicity and Chloride. Since Moisture is very temporal it is not essential, but it can be very informative depending on the time of sampling during the season.

Assessing Results

The first step in assessing coring results is through visual observations of the cores as they are collected and in comparison photographs.

Issues such as 'bleached' layers or rock are key factors easily identified, while trends such as depth to clay for soil amelioration can be observed also.

When assessing lab results it is easiest to look for correlations with individual factors such as Salinity.



Graph 1. *Two graphs comparing individual results to EM38 1m.*

Strong correlations with some factors can lead to immediate outcomes such as [Variable Rate Gypsum]() in response to strong correlations with Sodicity.

The next step is to look to each profile as a whole, this is easiest done using a calculator such as 'Soil Water Express'. This is an important step to understanding relationships with [plant available soil water]().

How to Ground Truth - Gamma Radiometric Layers

Sampling Gamma Radiometric (GR) Layers is slightly different to EM38. Whilst point sampling and regression analysis with soil attributes can provide useful knowledge, a zonal sampling approach has shown to provide useful and interpretable outcomes.

Creation of these zones is not a simple matter of zoning up each individual layer of GR. It needs to take into consideration the EM38 layers as well.

As EM38 is driven strongly by soil texture and EC it has been found that soils with a high EM value are of a very reliable type, ie high salinity and heavy textures. But soils with Low EM values can be for diverse reasons such as stone, gravel or sand.

By first isolating the Low EM soils and then zoning the GR layers, a clearer picture of the overall field variation can be seen.

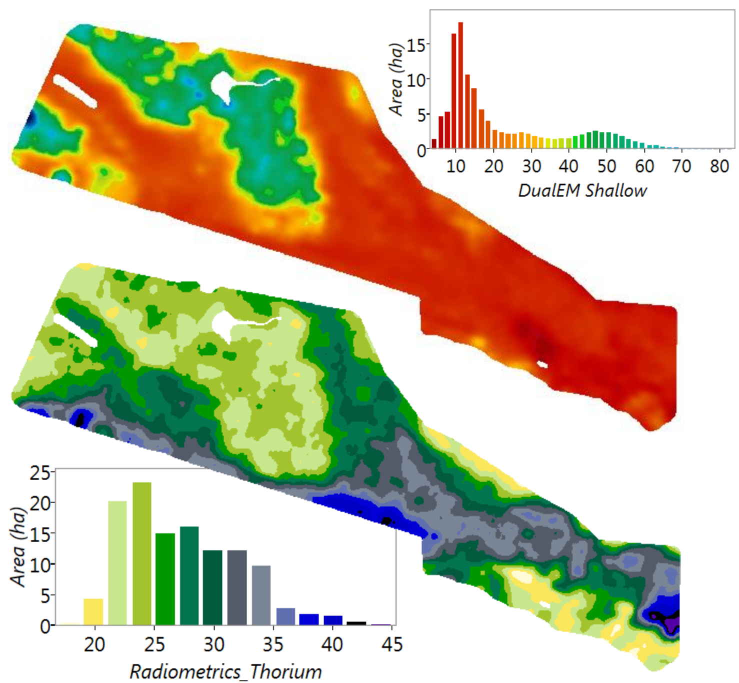


Figure 1. The Radiometrics Thorium map highlights variation not picked up by the DualEM shallow, particularly in the low readings.

Soil Amelioration

[BACK TO START]

Identifying Issues and Management Opportunities

Introduction

Soil Amelioration can dramatically improve poor producing areas, ranging from adding gypsum to sodic soils or deep ripping and delving.

Initial ground truthing has shown a range of opportunities for soil amelioration through this project. In sand over clay soils at Kimba site there was a relationship between depth to clay and EM38, while at Hart there was a strong relationship between sodicity and EM38.

Ground Truthing - Results

DEPTH TO CLAY

During ground truthing of the EM there was a visual relationship between EM and depth to clay at the Kimba site. This was further investigated with targeted soil testing which produced a very strong relationship.

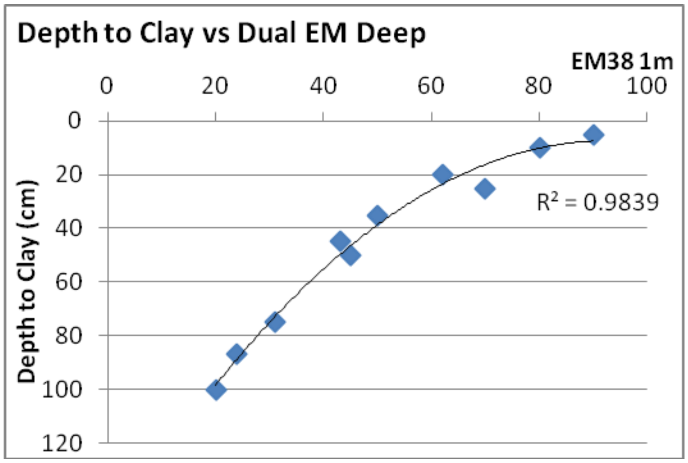


Figure 3. *Depth to Clay (cm) vs Dual EM Deep.*

The targeted soil profile investigations were done with a shovel to accurately measure depth to clay. This method was chosen over using hydraulic soil coring to measure depth of horizons which has the risk of the soil becoming compacted or not hold together to get an accurate measure.

Using this relationship management zones can be created to suit the amelioration options available. In this example areas with clay deeper than 60cm would require clay spreading. The other two zones were created to help the delving operation. The red zone with clay 40-60cm and the green zone 15-40cm below the surface respectively. Finally sites for clay pits to supply the spreading were also selected using this data.

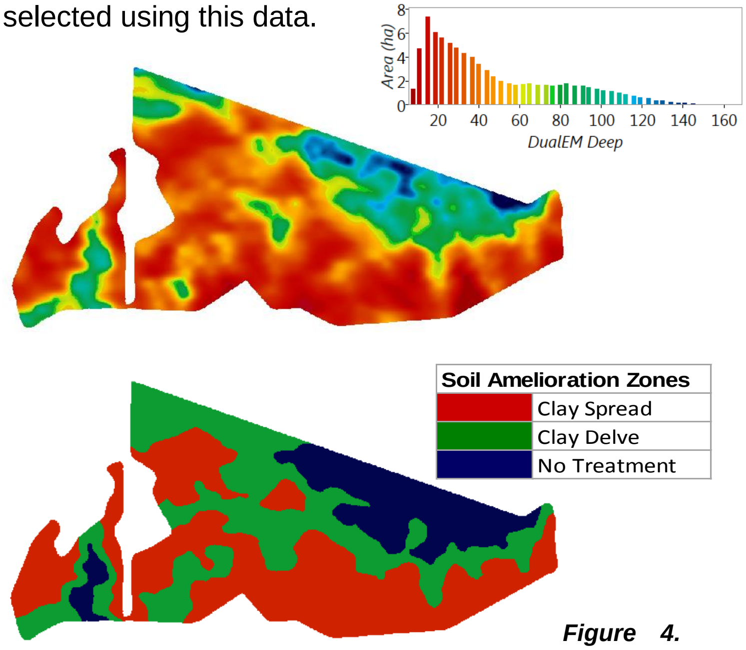


Figure 4. *EM Deep (Top) with resulting Management Zone Map (Bottom).*

SODICITY

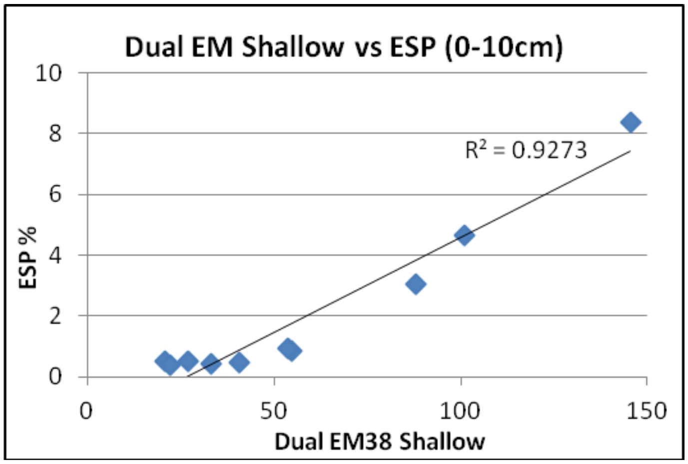


Figure 1. *Relationship between Dual EM Shallow and 0-10cm Exchangeable Sodium Percentage (ESP).*

Using the relationship between EM38 and Sodicity a varaible rate Gypsum map can be created that targets higher rates to areas of the highest sodicity. Thereby improving the result by adequately addressing the major issue.

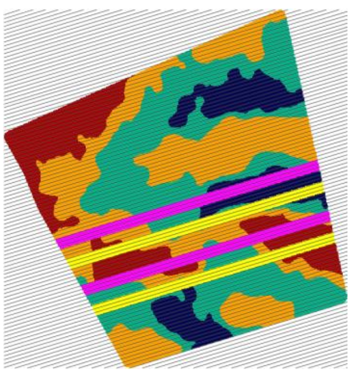
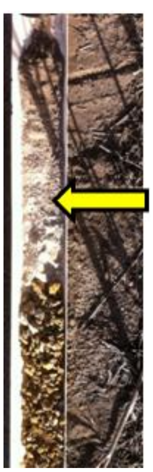


Figure 2. *Gypsum Management Zones with monitoring strips passing through all zones. (AB Lines are also shown)*

DEEP RIPPING



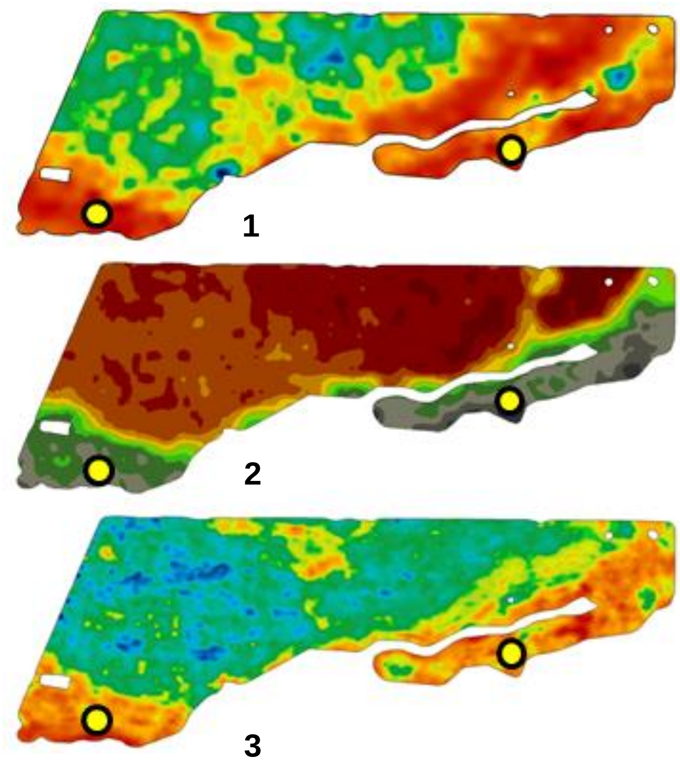
On lower EP site one soil issue identified in consistently low yielding areas was a 'bleached' layer in the soil profile.

Deep ripping can be considered as an option to disrupt this 'bleached' layer and improve root growth through this region

While the Medium to High EM38 readings clearly mapped out the higher yielding soils, the low EM38 had both high yielding and poor yielding areas. Ground truthing revealed different soils driving the low EM38 values.

By using the Gamma Radiometric Potassium in conjunction with the EM38 it is possible to isolate the soils with this 'bleached' layer.

Below are the EM38 1m Survey (1), Gamma Radiometrics Potassium (2) and 2010 Yield Map (3).



The yellow dots highlight areas of low EM38 and low Potassium and the problem soil area.

Trial work illustrated a positive response to deep ripping. The soil survey layers could then be used to identify other areas on the farm where similar responses could be expected.

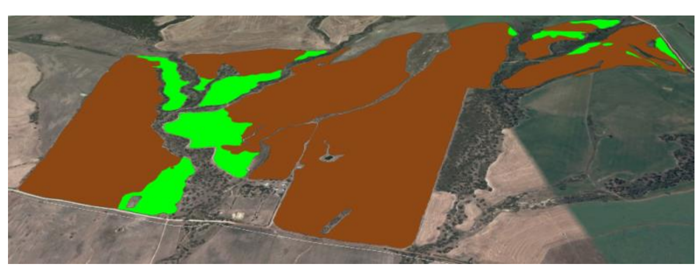


Figure 5. *Whole farm map highlighting areas of 'bleached' soil layer and therefore likely responsive to deep ripping treatment*.

Soil Water

BACK TO START

Identifying 'The Bucket' and Managing Risk

Introduction

Understanding Soil Water properties is an important component in Risk Management. It has been shown previously that EM38 correlates well to subsoil constraints and also to yield in drier years, especially in low rainfall districts.

Ground Truthing - Results

CHEMICAL ANALYSIS

Effective Ground Truthing will deliver soil data covering the range of survey data. The first steps is to look for the most obvious and simple correlations, examples are sodicity or salinity.

There are several soil water calculators available that after inputting lab results estimates of soil water properties such as Crop Lower Limit (CLL) and Drained Upper limit (DUL).

If there are a number of reasonable correlations between EM38 and major characteristics such as soil texture, salinity and moisture, another option is take more timely samples.

Timely Soil Testing involves collecting samples at relevant time in the growing season. For example taking samples in the middle of a reasonable winter is a good way of collecting accurate DUL for different soil types. Collecting samples once crops have dried off (provided no rain occurs) is a very efficient and accurate method of assessing CLL.

End of season sampling is also a very good way of understanding different crop types and their rooting depths.

USING A CALCULATOR

There are several calculators available which generate soil profiles from laboratory test results. While not as accurate as full soil classification, they do provide a snap shot of variation in soil water properties anytime during the season.

One example is 'Soil Water Express', which was developed by CSIRO. (www.apsim.info/swe/Default.aspx)

Calculators are an effective method for analyzing lab data results because they combine multiple chemical factors over multiple depths to build the profile.

Often these 'whole of profile' approaches give much stronger correlations to soil sensors, especially EM38 which reads down the soil profile.

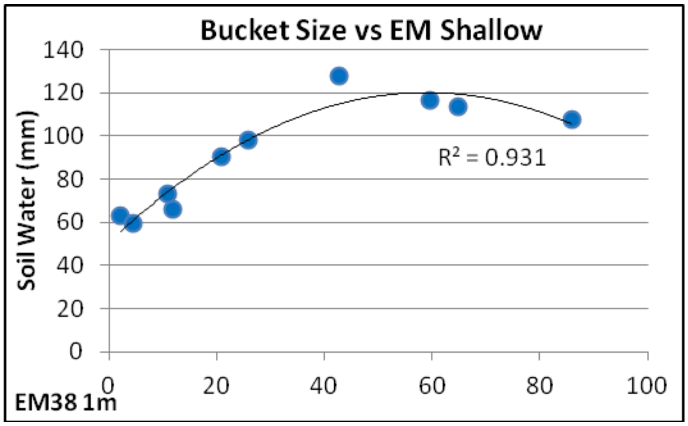


Figure 1. Relationship between EM38 1m and Estimated 'Bucket Size' using Soil Water Express.

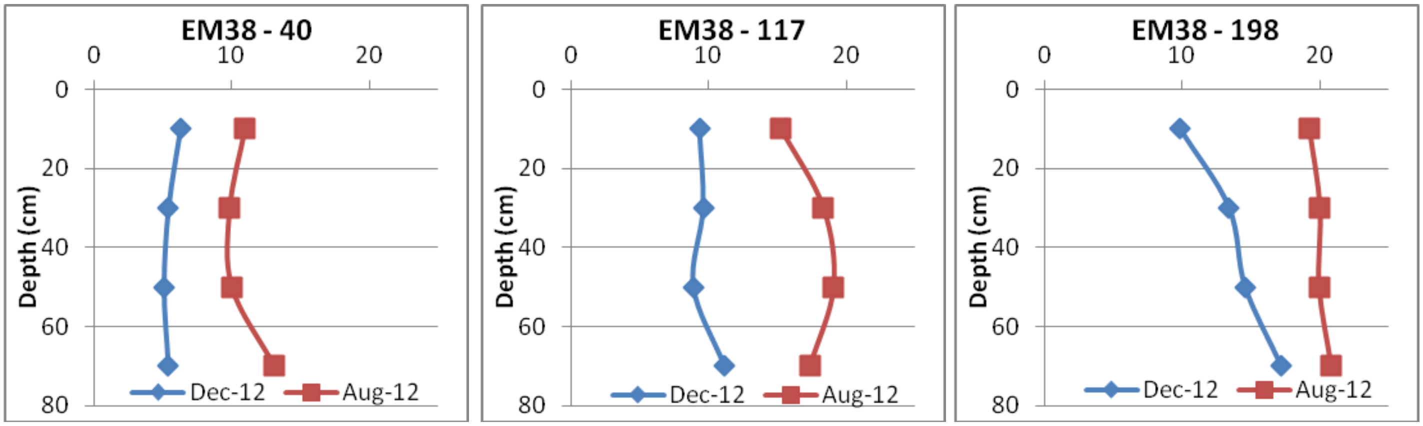


Figure 2. Differences in Soil Moisture Profiles across a range of EM38 values in season (DUL) and end of season (CLL).

STRATEGIC SAMPLING

Testing Moisture at strategic times during the year can highlight the differences in soil water characteristics more accurately then modeling but is dependent on the weather and seasonal conditions.

Strategic sampling is a very cost effective method of understanding soil water, with only moisture needing to be tested.

Two areas to consider are firstly the topsoil, this is the most variable of soil readings and often is drier than CLL due to evaporation. Secondly the end of season sampling does not give an indication of why moisture is left behind, so if higher than expected levels of moisture are left behind other factor may be affecting root growth such as compaction. This is commonly seen in deep sands.

Once the soil profiles are generated correlations can be made with EM38 to help [create management zones](#).

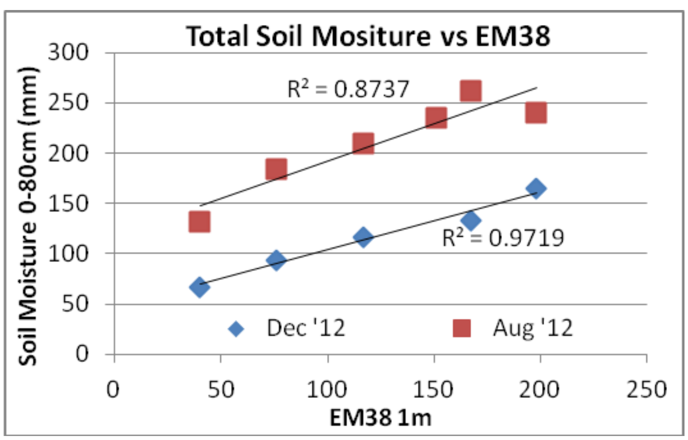


Figure 3. Relationship between EM38 1m and Total Soil Water sampled in August (DUL) and December (CLL)

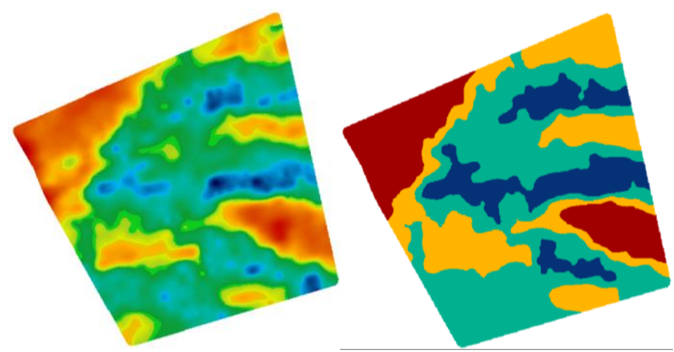


Figure 4. EM38 1m (Left) and Zone Map (Right).

The above Zone Map was created using the relationship illustrated in Figure 3. A difference in 25mm in December samples was used to differentiate the zones, meaning the Blue Zone has 75mm higher Crop Lower Limit then the Red Zone.

Establishing Zones based on Soil Water Characteristics is a crucial part of risk management, particularly in Low to Medium Rainfall environments. In Higher Rainfall environments spring conditions are more likely milder, which can reduce the impact of subsoil constraints on yield.

Agronomic Management Strategy

BACK TO START

Ameliorating problem soil types to improve productive capacity.

Steps

1. **Quantifying the gross margin impact.**
2. **Establishing the causes.**
3. **Collect supporting information including soil tests.**
4. **Decision on amelioration method.**
5. **Design and implement a trial.**
6. **Use yield data at end of the season to assess economic outcomes.**

Overview

Yield maps from field B2 for several seasons revealed significant variability in production output and subsequent profit. Wheat yield from the 2010 season (fig 1) ranged from a low of 0.51 t/ha to the highest yielding areas producing >6.0 t/ha. Of concern to the grower were the areas along the southern edge of the field which is fringed by a creek line that had performed poorly over multiple seasons and crop types.

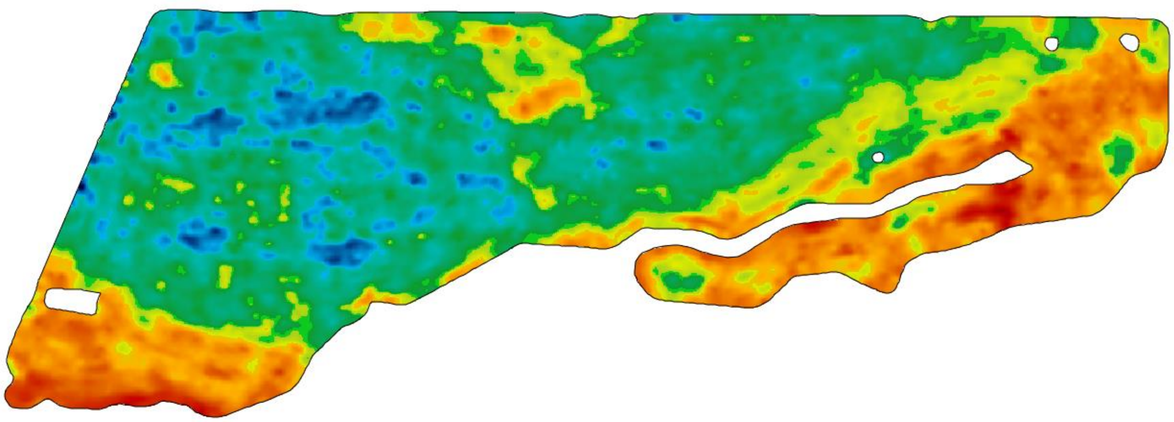
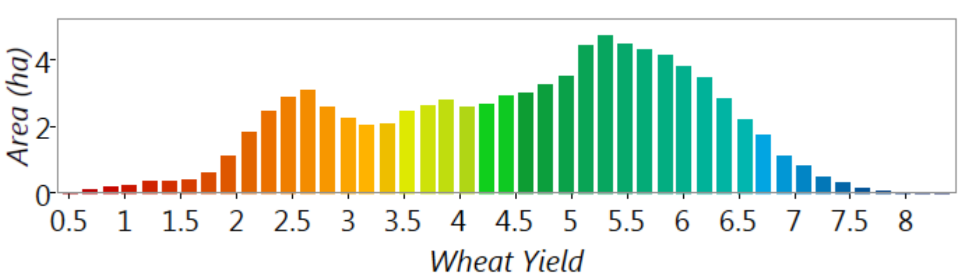


Fig 1. Wheat yield 2010 season



Min	0.51 t/ha
Mean	4.64 t/ha
Max	8.5 t/ha
SD	1.48
CV%	31.78

1. **Quantifying the gross margin impact.**

In figure 2 the wheat yield map from the 2010 season has been divided into 1.0 t/ha increments and used to generate a gross margin map. Figures used for wheat grain price and variable input cost were sourced from the Farm Gross Margin and Enterprise Planning Guide 2013. Gross margin figures are displayed below each bar representing that zone in the map.

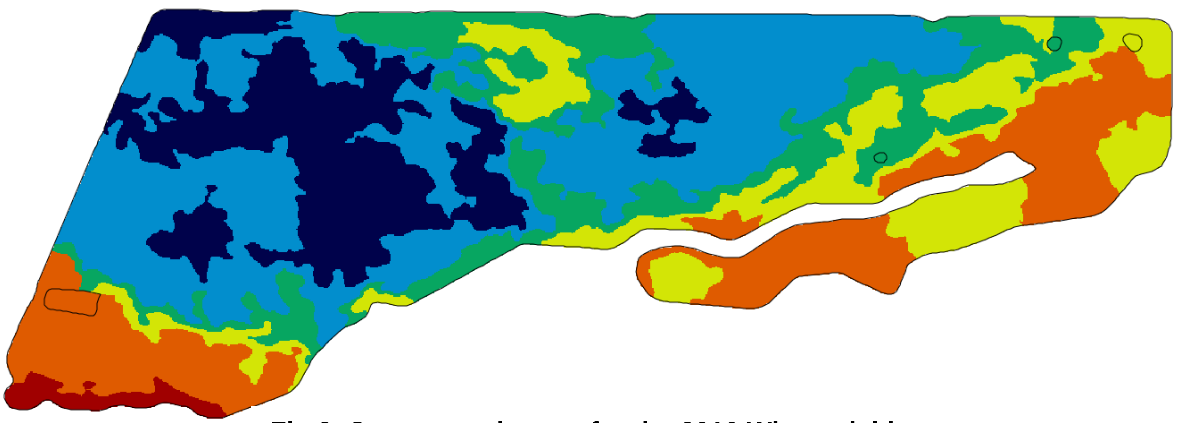


Fig 2. Gross margin map for the 2010 Wheat yield.

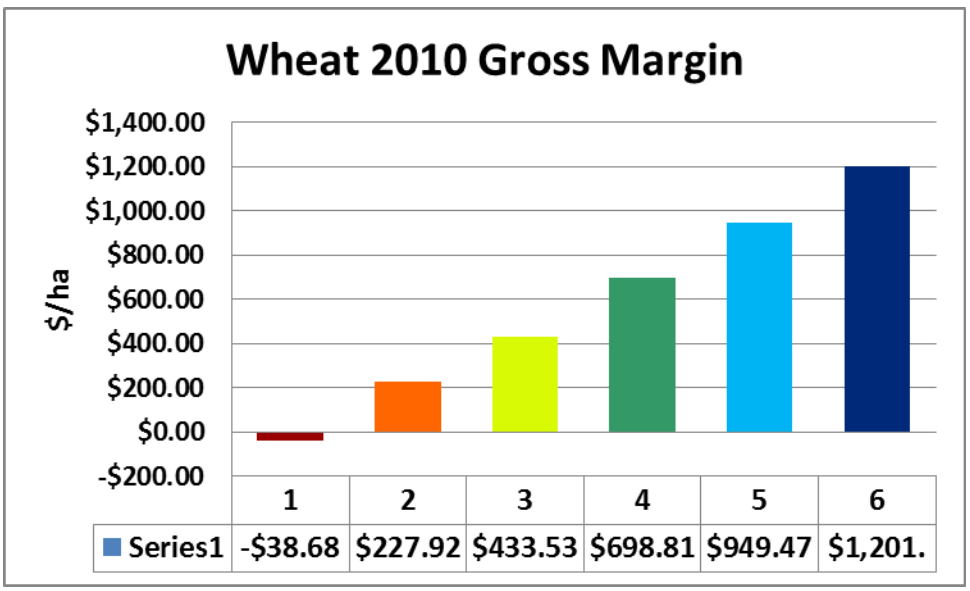
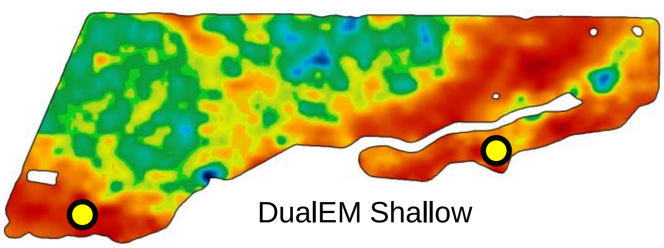


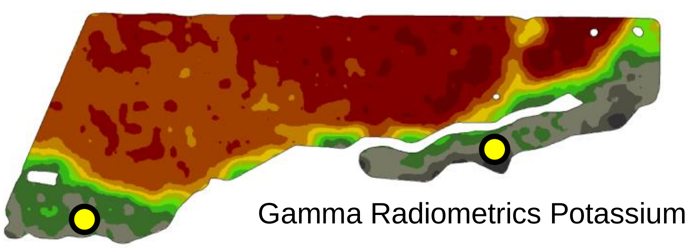
Figure 3.

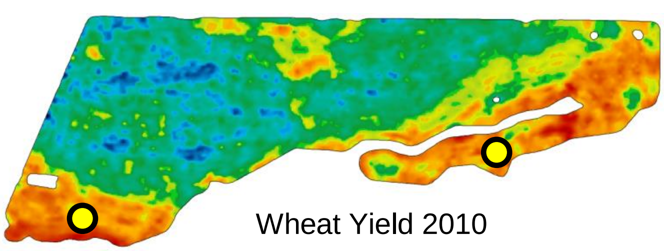
The low profit zones along the creek, red and orange, have a combined area of almost 20% of the whole field. This region of the field was similarly the lowest producing in 2012 canola with some areas having negative returns.

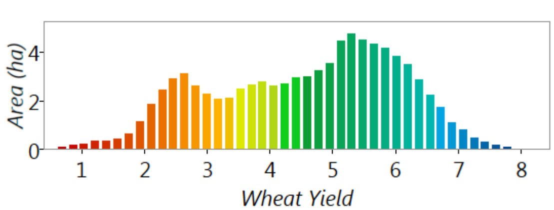
2. Establishing the causes.

The low yielding area was visited in the field and a cut away of the profile revealed canola plant roots extending to approximately 10cm into the profile before growing sideways. This coincided with the start of a ‘bleached’ layer in the profile indicating soil attributes were creating a hostile environment restricting the root development of young plants.



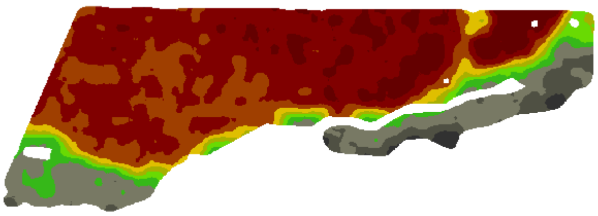


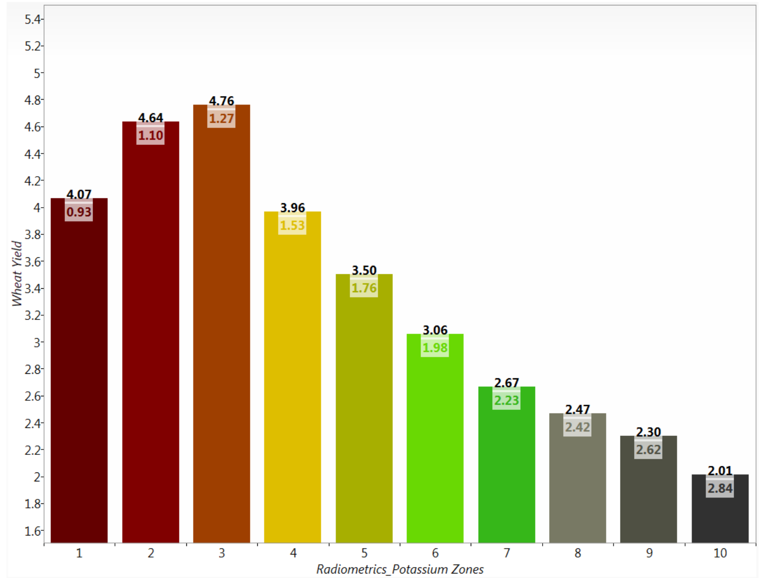




With knowledge from observations of soil profile and canola root depth effects the various soil sensing layers were analysed against previous yield maps. This commenced with simple visual assessment of the soil maps with low yield areas
.

Low wheat and canola yield areas corresponded with low EM areas and high Gamma Radiometrics Potassium areas. Further statistical comparisons determined that the GR Potassium soil sensing map correlated best with yield map variations over different seasons and various crop types.





Analysis showing the low GR Potassium soils having yields in the range >4.0t/ha and the higher GR Potassium soils yielding <2.5t/ha.

Soiltesting the Gamma Radiometrics Potassium region that corresponded with the low wheat and canola yield was conducted to determine actual soil attributes causing the restricted yield outcomes. Key soil properties creating the hostile soil conditions are highlighted with these being more severe in the 10 to 20cm profile aligning with the observed 'bleached' layer.

Depth	0 to 10cm	10 to 20cm
P Colwell	27	
PBI	11	
DGT P	194	
K Colwell	51	20
pHcl	4.8	4.7
EC	0.058	0.012
Total CEC	1.99	0.83
Ex Acidity	0.060	0.250
% Al H	3.02	30.12

- Very low Total CEC
- High Acidity
- Potassium Deficiency
- Aluminium Toxicity

3. Decision on amelioration method.

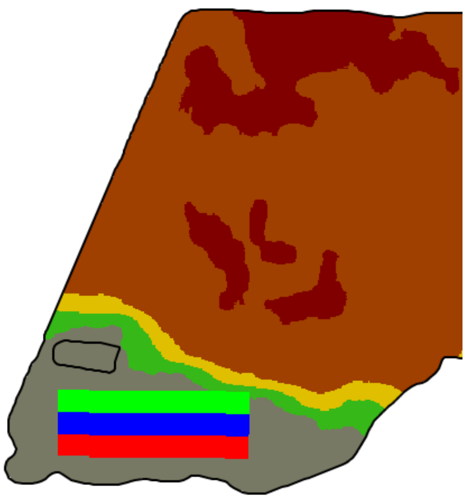
Decision was made to use deep ripping to an area of the problem soil defined by the changes in the GR Potassium map. This method would endeavor to disrupt the 'bleached' layer and dilute the effects of some of the concentrated negative soil properties in the topsoil but importantly work down into the 10 to 20cm depth where conditions were more severe.

4. Designing and Implementing the Trial.

A **strip trial** was designed to compare the effectiveness of three treatment decisions.

- Deep ripping with Lime 3t/ha
- Lime 3t/ha only
- No treatment

The trial was placed entirely within the soil type of interest whilst allowing for normal passes of the harvester to collect quality yield data to be recorded for trial analysis.



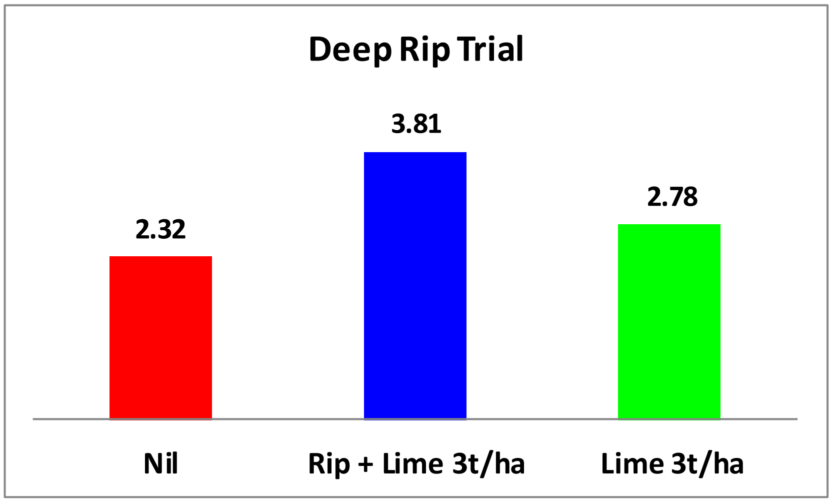
Treatment	
	Nil
	Deep Rip + Lime
	Lime

Figure 4

5. Analysing the trial outcomes.

Inspections of trial site showed distinct early differences between the deep rip and lime treatment (**A** in figure 4) against the nil treatment.

Wheat yield data from the harvest yield monitor was combined with trial treatments to assess economic outcome.



Treatment		Yield	Profit
	Lime 3t/ha	2.78t/ha	$40.00/ha
	Lime 3t/ha + ripping	3.81t/ha	**$47.50/ha**
	No Treatment	2.32t/ha	NA

- Significant yield increases resulted from both the lime only treatment and lime plus ripping treatments.
- Additional 1.03t/ha wheat yield gained from ripping treatment over lime only realised slightly greater than cost recovery in the first year. This treatment is expected to have enduring benefits due to the physical disruption to the sub surface 'bleached layer'.

The soil sensing layers for DualEM and Gamma Radiometrics Potassium can be combined to identify other areas on the farm that can be investigated for similar soil conditions and therefore potential positive responses to amelioration with deep ripping and lime.

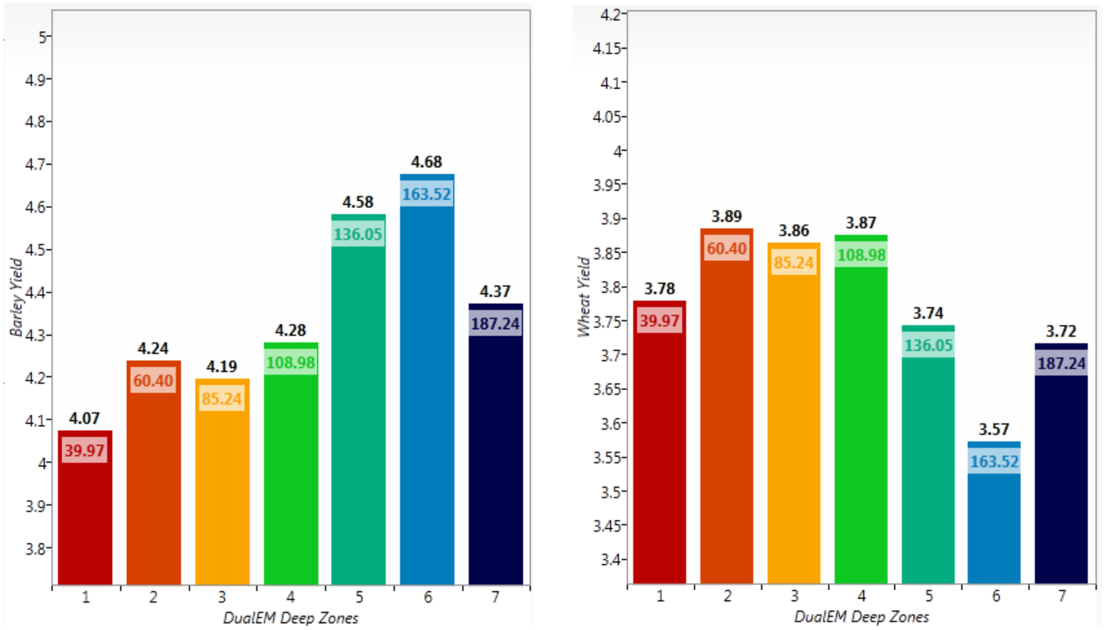
Increasing fertiliser rates at planting to reduce in season demands.

Steps

1. **Analyse yield – Compare with Soil Surveys**
2. **Design and implement a trial – Covering range of soil types**
3. **Use yield data at end of the season to assess economic outcomes and adjust zones and/or rates for next season.**

Overview

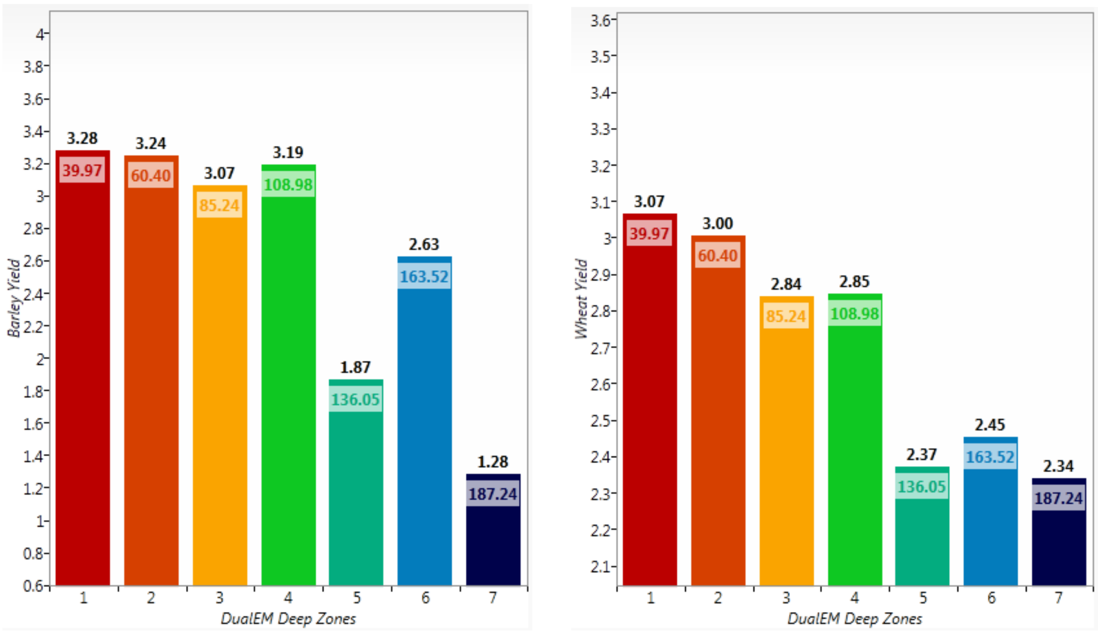
With in-season operations increasing the aim is to remove one in-season application of nitrogen by increasing seeding fertiliser. Due to a lot of prior work across the industry suggested this would increase risk, the first step was to investigate variation in prior yield, especially across different seasonal conditions.



Graph 1. 2003 Barley (left) and 2005 Wheat (right) yield data against EM38 1m

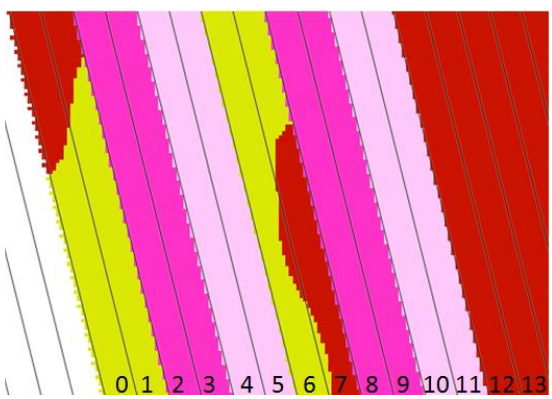
In above average rainfall years there is no correlation between yield and EM38, as seen in the two seasons shown in Graph 1.

In below average years, particularly those with poor springs, there is and inverse relationship between yield and EM38 1m. This can be seen in Graph 2. where yield declines as EM38 1m increases.



Graph 2. 2006 Barley (left) and 2008 Wheat (right) yield data against EM38 1m

As there was some seasonal risk on the higher EM38 soils and trial was designed that also included reduced fertiliser rates at seeding. As there was no automatic variable rate available and to keep the trial as simple as possible, 3 rates were compared over 3 zones.

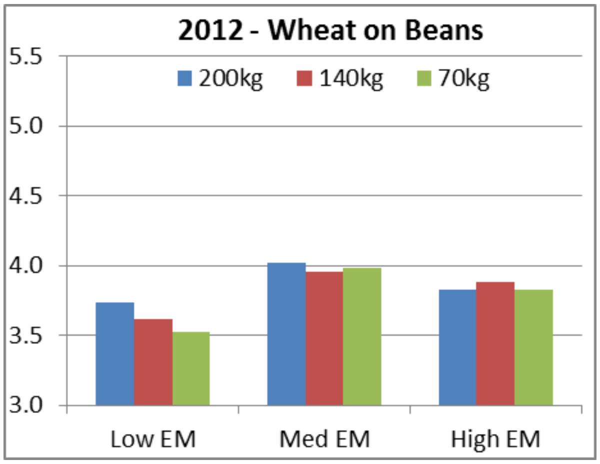


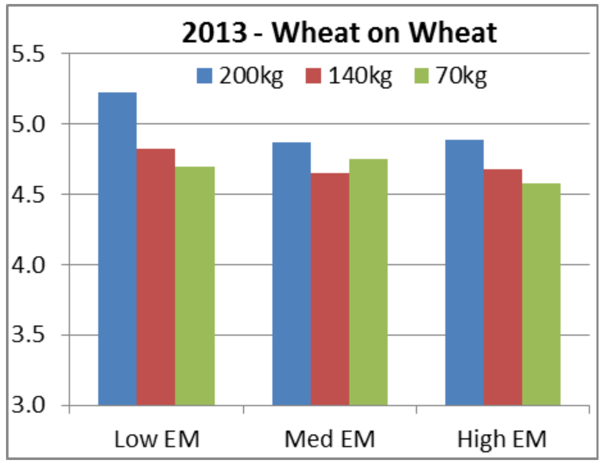
(red)	Low EM38	140kg
(yellow)	Med EM38	140kg
(blue)	High EM38	140kg
(light pink)	Trial 1	70kg
(pink)	Trial 2	200kg

Trial Design

- Each run is two passes of the seeder and numbered to match run lines on the John Deere Autosteer.
- The runs are spaced to guarantee at least 1 full header width is taken from each trial strip without contamination from another.
- Trial is replicated twice to improve accuracy.

Results



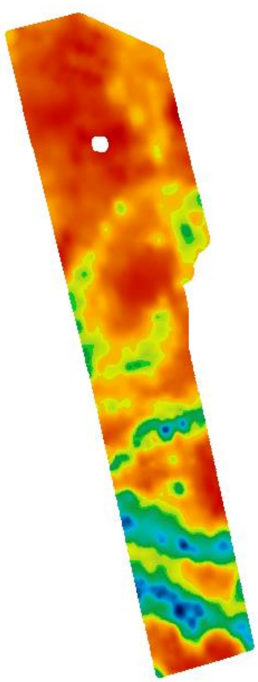


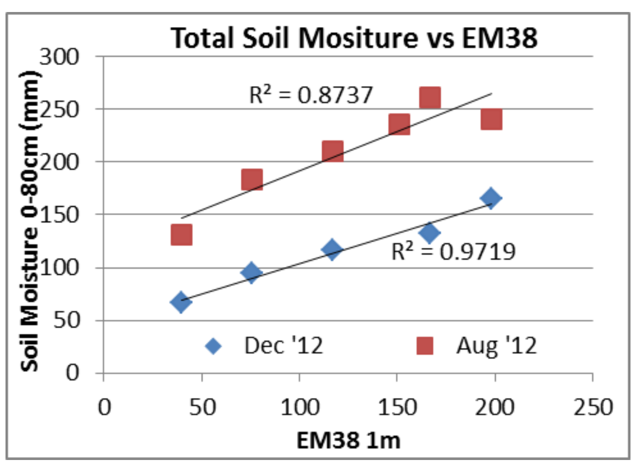
In 2012 there was very little effect of seeding fertiliser on yield, only the low EM zone should a trending response. This proved to not be economic as the increased yield did not cover the cost of the increased fertiliser.

In 2013 there was an across the board response to higher fertiliser in all zones, as expected with wheat on wheat. The largest increase was again seen on the low EM zone, all zones were an economic response.

If the farmer had applied a VR approach of higher inputs on the Low EM soils and reduced inputs on High EM, 2012 would breakeven compared to a flat rate. While in 2013 the return would be over $27/ha averaged over the whole paddock, with the low EM zone increasing returns by almost $60/ha and the high EM zone saving $16/ha from reduced inputs.

These numbers could be further improved by using automated variable rate to match the full variability present in the paddock, and target those inputs to match the stage of the rotation.





EM38 1m (left) and Management Zones (right) using the relationship between EM38 and actual soil water. Each Zone has a difference of 25mm in December Soil Water (CLL).

Agronomic Management Strategy

BACK TO START

Increasing fertiliser inputs to high producing soil zones.

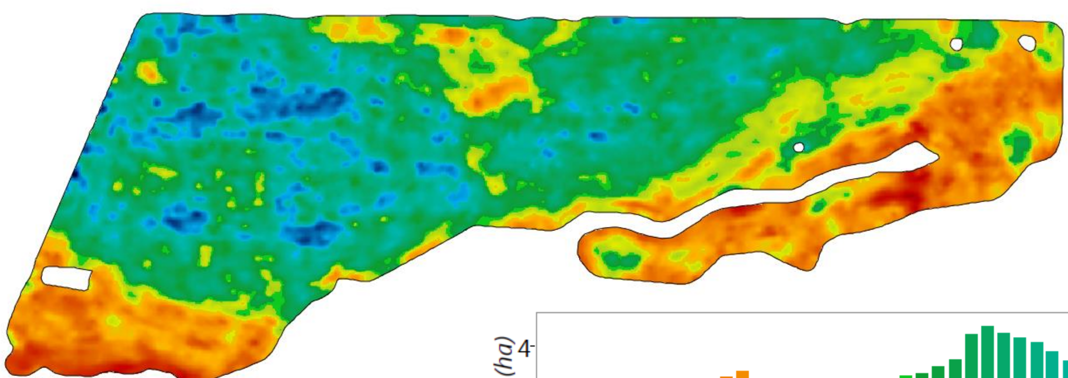
Steps

1. **Analyse yield – Define the high producing zone.**
2. **Create Zones from knowledge gained in step 1.**
3. **Collect supporting information including soil tests for DGTP and other attributes.**
4. **Design and implement a trial.**
5. **Use yield data at end of the season to assess economic outcomes and adjust zones and/or rates for next season.**

Overview

Traditionally planting fertiliser inputs have been a uniform application over a field with decisions on product type and rate being based on crop type, target yield and previous field usage. With the support of topsoil soiltest results, rates can be fine-tuned in accordance with the current fertility status, the potential for fertiliser response and consideration to applying additional fertiliser over and above predicted crop removal to allow for build-up of the soil fertility. Typically though, the main driver for the decision on rate was based on a target average yield for that season. Yield maps have shown how production varies across a given field and therefore nutrients, particularly phosphorus, are likely to vary in the amount used by the crop and removed from the field in the grain. Ultimately this can result in areas of different fertility levels and the risk that nutrient availability in the best producing soils will decline and potentially become a yield limiting factor.

Yield maps from Field B2 on the Edillilie project have indicated a high level of variation. Fig 1 is the wheat yield from the 2010 season showing a wide range in yield and a high CV%.



Min	0.51 t/ha
Mean	4.64 t/ha
Max	8.5 t/ha
SD	1.48
CV%	31.78

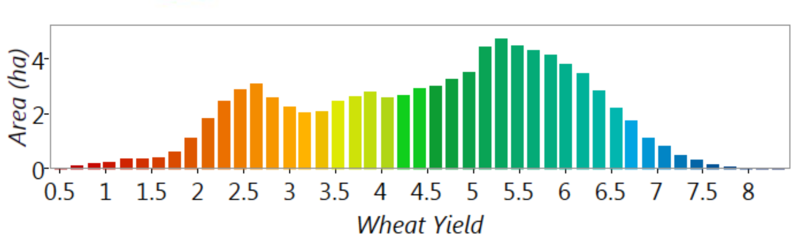


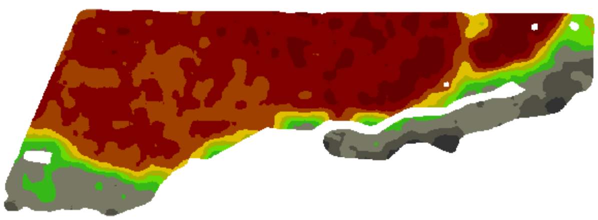
Figure 1. Wheat yield 2010

The Steps

6. Analysing yield with Soil.

Various soil sensing and topographic layers were analysed against yield maps. In field B2 the Gamma Radiometrics Potassium layer was well related to the changes in the yield maps for the 3 seasons available which included both canola and wheat crops (see fig 2).

- Changes in soil type were a dominant cause to yield variability
- The Gamma Radiometrics soil sensing was effective in mapping the important soil change.
- The performance of the soil types was relatively consistent over the three seasons.



Analysis showing the low GR Potassium soils having yields in the range >4.0t/ha and the higher GR Potassium soils yielding <2.5t/ha.

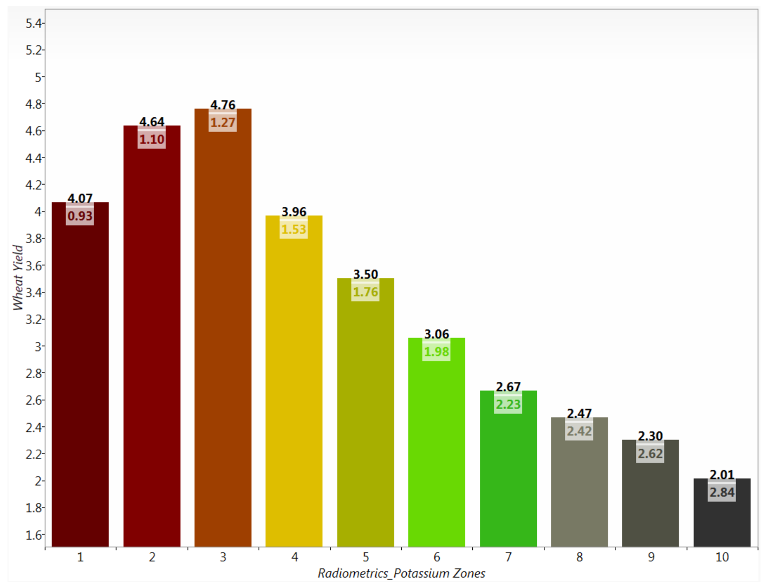


Figure 2.

7. Creating Zones

Zones were then created using the GR Potassium soil sensing layer. Three soiltype/yield zones (Figure 3) were used to allow analysing of strip trial trends at the end of season.

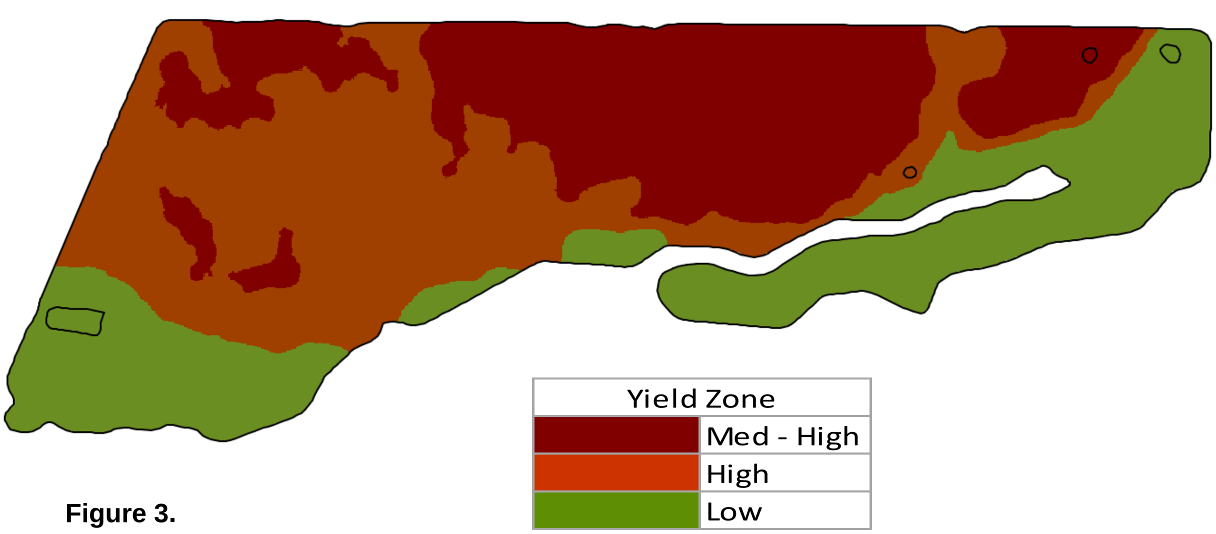


Figure 3.

8. Supporting Information

Soiltests for 0 to 10cm and 10 to 20cm were collected in the low and high yielding zones (Table 1).

Key Results

Yield	**P Colwell**	**PBI**	**DGT P**	**K Colwell**	**pHcl**	**Total CEC**
High Yield	32	130	12	293	7.2	44.94
High Yield	27	111	21	512	7.7	40.8
Med-High	68	77	61	270	4.8	9.12
Low	27	11	194	51	4.8	1.99

Yield	**K Colwell**	**pHw**	**pHcl**	**EC**	**Total CEC**	**Ex Acidity**
High	36	8.4	7.3	0.135	47.79	
High	198	8.7	7.7	0.14	28.11	
Med-High	227	7	6.2	0.111	18.66	
Low	20	5.2	4.7	0.012	0.83	0.250

Table 1

Higher Yield Zones characterised by:

- Lower DGT P – higher P fertiliser responsiveness
- Higher PBI
- Higher pH and CEC, K Colwell.

Lower Yield Zone characterised by:

- High DGTP
- Low pH, CEC, K Colwell
- Acidity also 10 to 20cm.

Soiltest results for low yielding zones indicated conditions that required amelioration prior to profitable responses to applied fertiliser could be expected. Amelioration to remove yield limiting factors could include lime and deep ripping.

9. Designing and Implementing the Trial.

A strip trial was designed to compare the effectiveness of changing fertiliser rates in each soil zone. The agronomic focus was to investigate if yield and profit could be further increased by raising planting fertiliser rates in the typically high yielding soil types. The trial was placed to also transect the low yielding problem soil type (see figure 4) and this would allow analysis of whether decreasing rates would be an appropriate strategy.

The field was sown to wheat with an intended whole field rate was 110kg/ha 24:16:0 with a strip at this rate separating a low rate of 70 kg/ha and a high rate of 150 kg/ha.

Treatment 28:13:0	
(red)	70 kg/ha
(green)	110 kg/ha
(blue)	150 kg/ha

Figure 4.

10. Analysing the trial outcomes.

Wheat yield data for 2013 from the harvest yield monitor was combined with trial treatments to assess economic outcome (Figure 5). The three treatments were assessed for yield performance in each of the yield zones, High, Medium High and Low respectively. Wheat grain was priced at $250/tonne and 28:13:0 fertiliser @ $600/tonne.

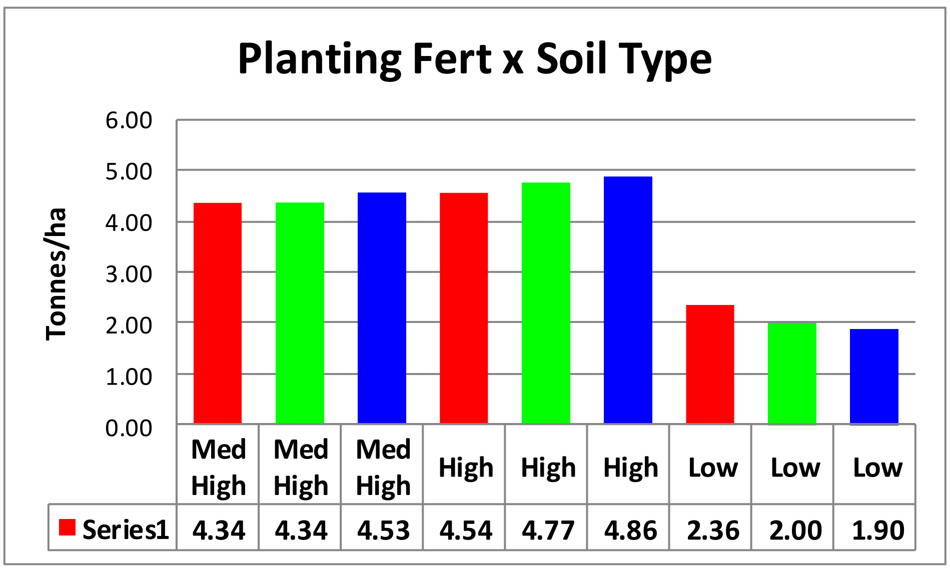


Figure 5.

- Medium to High Yielding soil – optimum rate was increasing to 150Kg/ha with benefit $25.00/ha.
- High Yield soil – whilst the high treatment of 150kg/ha produced a yield increase of 0.09t/ha over the traditional 110kg/ha this was approximately the cost of the additional fertiliser.
- Low Yield Zone – suppression of yield was evident for both the higher treatments. The low rate 70kg/ha was the highest yielding and greatest benefit. Due to the subsoil acidity and aluminium toxicity issues, it is possible that additional crop potential encouraged by the higher rates could not be supported due to reduced root growth and poor water use efficiency.
- The trial results indicate a whole field benefit from variable rate applications of planting fertiliser of $40.41/ha.

Increasing Post Seeding Nitrogen on High Producing Soil.

A second trial was implemented on this field to investigate if the production and profit could be increased by increasing post seeding applications of nitrogen over typical rates. This trial was placed in the soil zone which had previously been the most productive for wheat. In addition the soil test data for this soil zone had not revealed obvious crop limiting factors like acidity, aluminium toxicity and sodicity that were evident in other areas soil zones and adjacent fields.

Figure 6

Treatment Total Urea	
	90 kg/ha
	170 kg/ha
	290 kg/ha

Figure 6 shows the location of the trial and season totals of urea over two applications applied in the trial. The trial design was aligned with AB line passes of the broadcaster.

Two applications of post urea were applied. The first pass was 90kg/ha over the entire field. With the second application a further 80kg/ha was to be applied as the standard treatment with a trial treatment of no additional urea and a third treatment of 200kg/ha.

As with the planting fertiliser trial wheat yield data for 2013 from the harvest yield monitor was combined with trial treatments to assess economic outcomes.

Table 2 details the total urea applied over combined two applications with the resultant wheat yield and net profit/ha. The benefit to increasing urea in the second application by a further 120kg/ha over standard rate was $51.01/ha.

Treatment Total Urea		Wheat Yield	Net Pofit $/ha
	90 kg/ha	4.69	-$11.91
	170 kg/ha	4.93	$0.00
	290 kg/ah	5.43	$51.01

Table 2

Agronomic Management Strategy

BACK TO START

Segregation of fields for land use.

Steps

1. **Field observations.**
2. **Gross margin analysis using yield maps.**
3. **Using Soil Survey and Terrain maps and Supporting information.**
4. **Decision on fence line.**

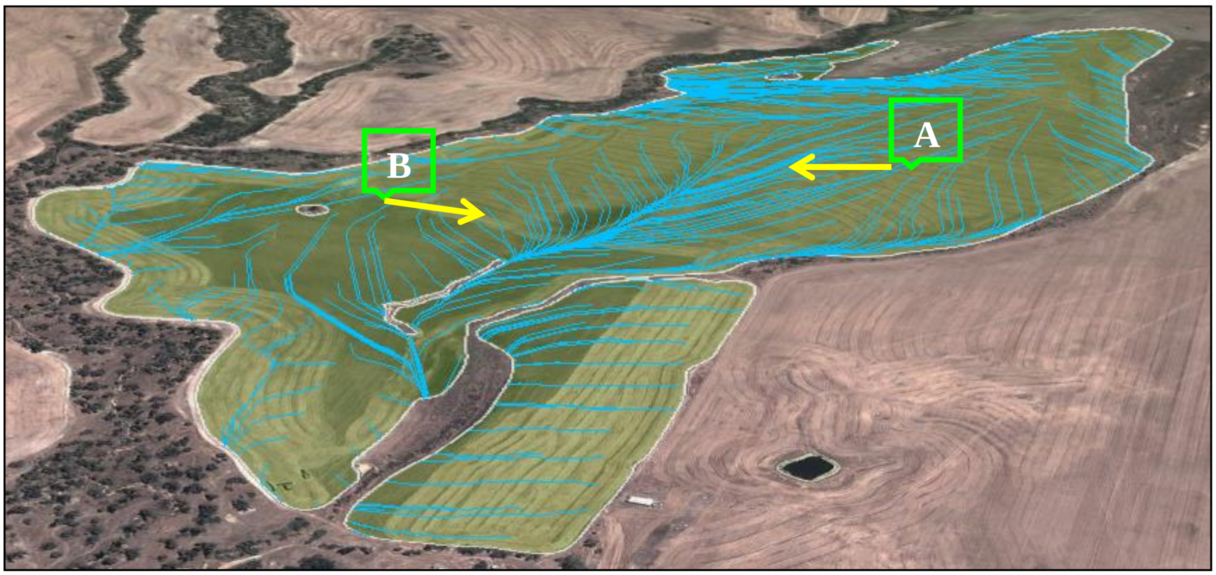
Overview

The project farm had recently been acquired. Due to the planned continuation of a cropping and grazing system for the new farm there was a need to segregate some areas to be dedicated to grazing. Major considerations were:

- Maintaining the best producing fields/regions for continued cropping.
- Designing new fields to a manageable size and for ease of access.
- Aligning new fences with AB Lines.

1. **Field Observations**

After farm inspections two fields were selected for potential to be segregated for cropping and grazing use. Fields B1 (119.18ha) and B3 (102.44ha) would be further investigated for best potential to split due to their size, current shape, observed dominant soil type and variability in soil type and terrain. The progress to the re-fencing stage is followed in this report for field B3.



Field B3 has a general fall from SE (slope >5%) to NW (slope <2%). The rolling terrain in this field results in drainage to the centre of the field and toward a creek at the western end where waterlogging can occur. Photo A is at the head of catchment effect of the terrain and photo B overlooks the low lying area at the western end where water congregation combined with soil profile conditions can cause waterlogging issues.

2. Gross Margin Analysis using yield maps.

Several seasons yield maps were available for wheat, canola and lupins (table 1) and these could be used to assess differences in production performance over the field. The field B3 has a high degree of variability in yield produced over the field with medium to high CV% each season across various crop types. The intention was to identify if certain areas produced consistently well to be maintained for continued cropping and conversely are there areas that often performed low rendering them more suitable for grazing under current plans. If this was established then the practical considerations could be applied for final decision on if and how the field could be segregated and fenced.

Crop Type	Season	Min	Mean	Max	CV	Total
Barley Yield	2005	0.2	2.4	4.11	28.50%	220.75
Canola Yield	2006	0	0.51	1.04	56.45%	47.26
Lupins Yield	2008	0.37	1.87	3.11	24.91%	171.91
Canola Yield	2009	0	1.32	2.68	47.21%	121.06
Wheat Yield	2010	0.12	3.26	6.21	37.23%	299.46
Canola Yield	2012	0	1.26	2.69	57.55%	115.55

Table 1

Using grain pricing and variable input costs sourced from the Farm Gross Margin and Enterprise Planning Guide 2013 a relative gross margin map was created for each season. These individual season gross margin maps were then combined to generate a 6 year average profit/ha map (figure 3).

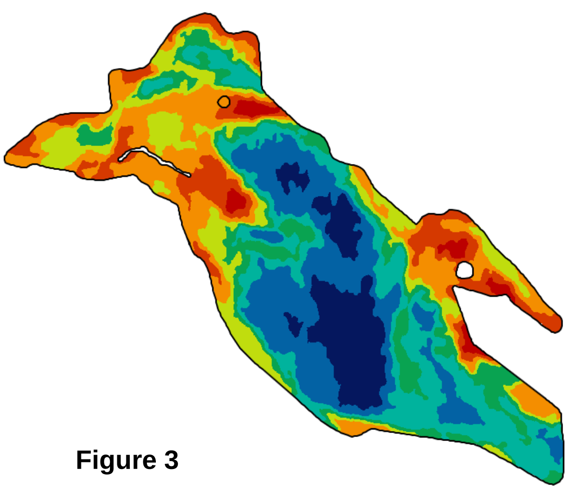
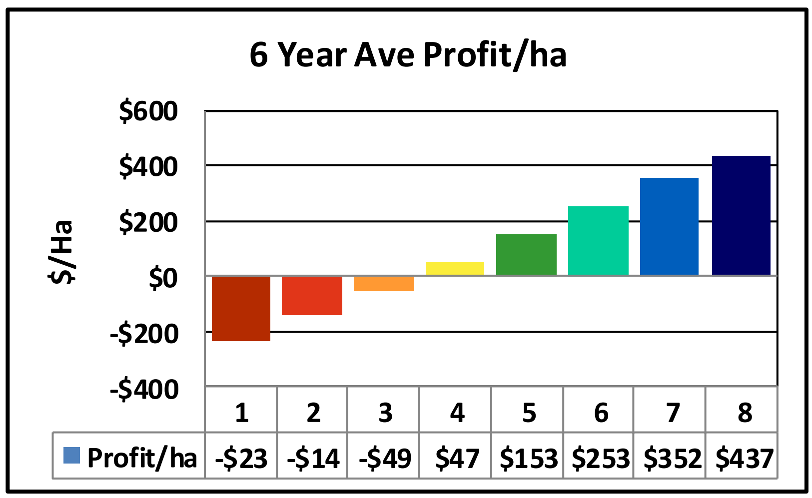


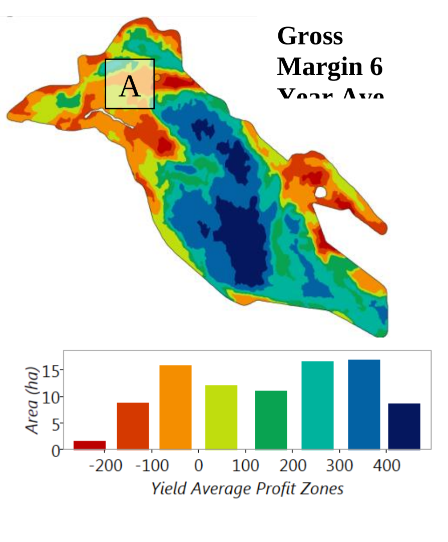
Figure 3

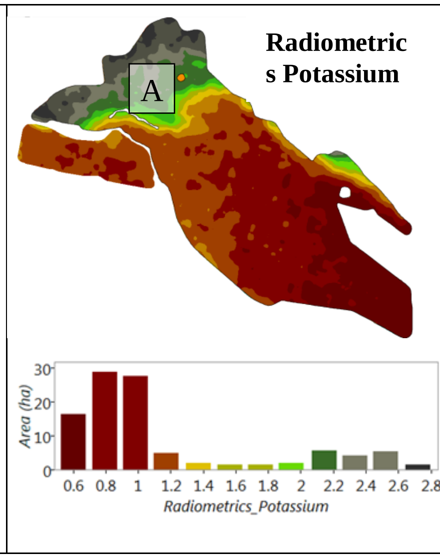


Yield data used to create maps showing profit variability over this 6 year period reveals areas toward the north-west end that are consistently negative gross margin whilst regions of the field toward the middle and east are consistently profitable across all crop types. A more precise decision can now be made as to the areas to retain for cropping.

3. Using Soil Survey and Terrain maps and Supporting information.

Having defined the areas of the field that had been consistently lower performing and had potential to be segregated for grazing other information could be used to verify causes to the low productivity. This process would add further knowledge and confidence to the decision to segregate for grazing but also a guide to align with soil types. Soil Survey layers for Multi Depth EM and Gamma Radiometrics with soiltest information were assessed.





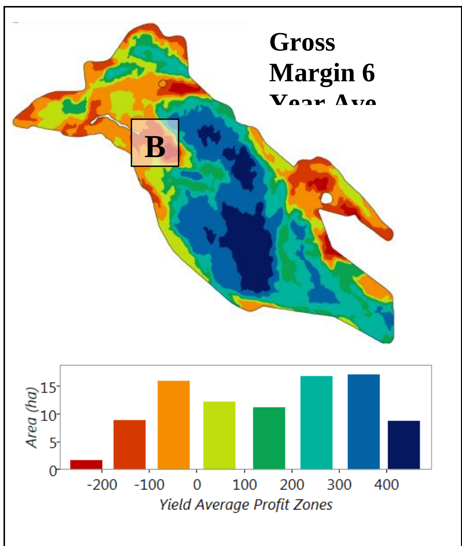
'A' Northwest end of field

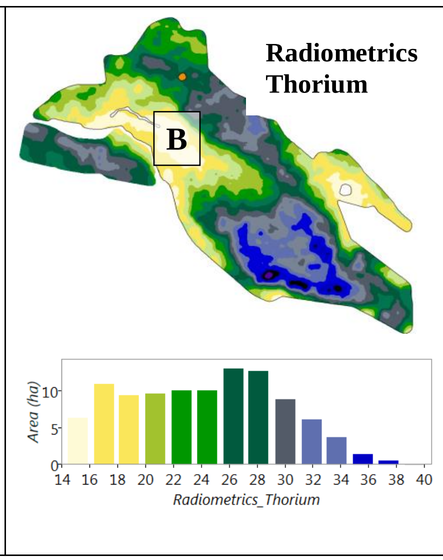
- Low gross margin
- High Radiometrics Potassium
- Soil type limiting
- High acidity
- Aluminium Toxicity
- Low CEC

Sub Surface restrictions

Figure 4

Low performing areas at the north - west end of the field corresponded to changes in soil environment as depicted by the Gamma Radiometrics soil sensing layers for Potassium (fig 4) and Thorium (fig 5). Soil cores collected and analysed from the region of the field revealed a series of soil characteristics that would continue to restrict crop growth unless they could be viably ameliorated.





'B'

- Low gross margin
- Low Radiometrics Thorium
- Subsurface acidity
- Alum toxicity
- Drainage point for field
- Sodic Subsoil 30cm
- Waterlogging

Figure 5

The field was fenced segregating to retain the western 66.9 hectares for continued cropping and the western portion (35.54 ha) for grazing. Deep ripping and lime were used to begin soil renovation of the grazing section to correct soil pH and mitigate water logging.

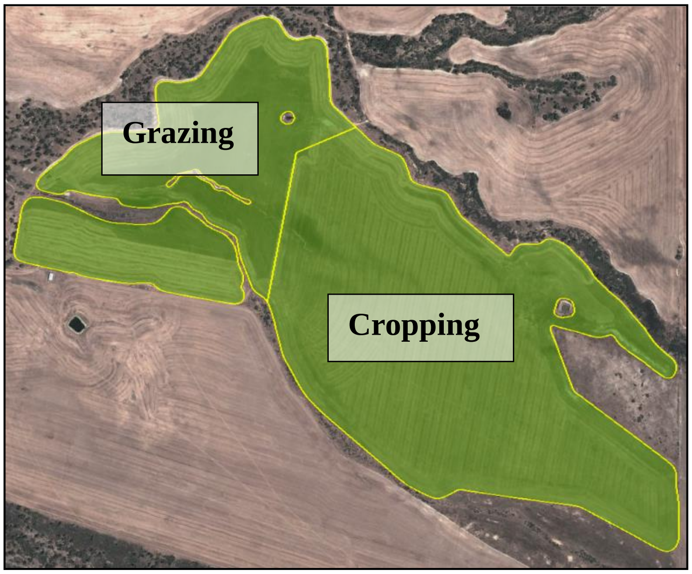


Figure 6

Agronomic Management Strategy

[BACK TO START]

Defining major soil zones and areas of limestone.

Steps

1. **Analyse multi depth EM Survey data**
2. **Field ground-truthing.**
3. **Assess soil zones with yield.**

An important focus for the Yumali site was investigating methods for identifying where limestone belts were present below the soil surface. Interest was in using delving and/or clay spreading to increase yield potential in low water holding capacity areas or non-wetting sand areas. The inability to confidently avoid sheet limestone just below the surface and within range of preferred delving depths currently prevents soil modification from proceeding. If sub surface limestone areas could be defined then other input management opportunities could be responded to.

Focus management issues and opportunities.

Defining soil zones – detecting sub surface limestone areas from deep sand profiles with subsequent benefits for

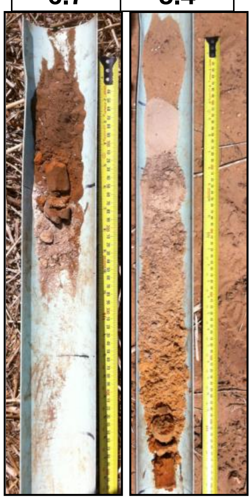
- Seeding fertiliser decisions– balancing to soil yield potential type and phosphorus status.
- Soil modification – targeting for clay spreading, but importantly potential for delving or spading those clay spread areas whilst avoiding limestone risk.
- Post seeding nitrogen decisions – increasing yield in high producing soils, minimising risk in limestone constrained areas.

The Steps

1. Analysing Multi depth EM Survey data.

The field H2 was the focus of this investigation. Over 65% of the field area has an EM value <14.5mS/m. Within this area soil profiles vary significantly. Sites A and B (figure 1) have similar EM values however site A has a depth of soil of ~200mm whilst site B is >650mm. These soil profile differences are not clearly distinguished in the EM map alone.

A	B
EM Value	
6.7	5.4



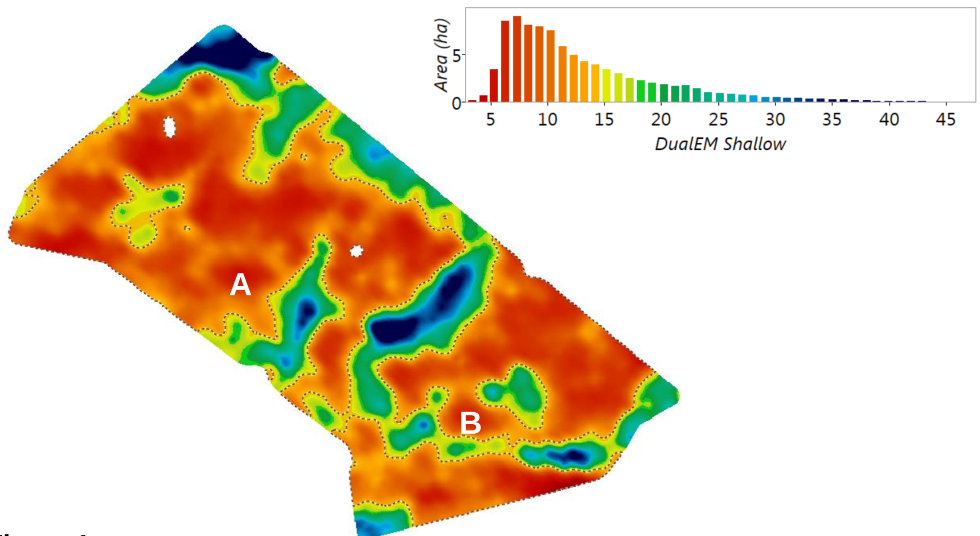


Figure 1.

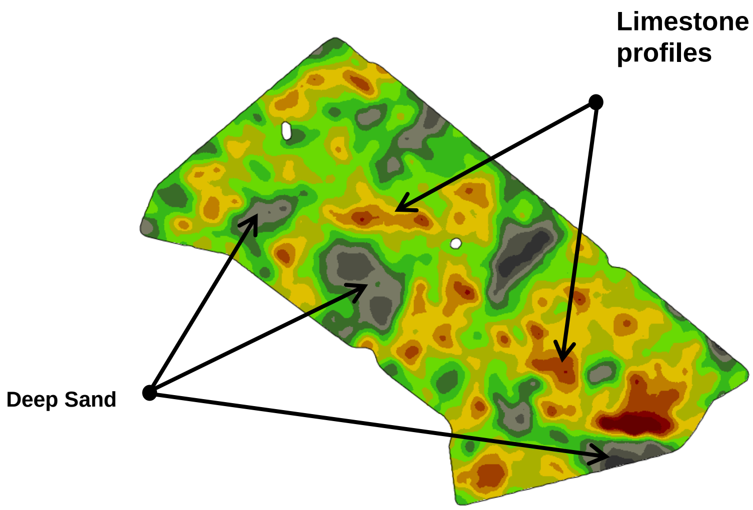
The EM maps were created from data logged using a DualEM 1S which senses two depths simultaneously. The values from the dual depths can be compared and the relationships used to create additional maps which can have a different spatial structure to the original EM map. These additional maps have shown potential as templates to use for ground truthing with soil coring for isolating the soil profiles of interest and to date the findings at this site have been encouraging. This has been a two stage process.

- Separating within low EM response areas the sub surface limestone profiles from deep sand for field ground truthing (see Figure 2).
- Estimating the depth to the limestone for managing risk with delving or spading.

2. Field Ground -Truthing.

Originally the sub surface limestone and deep sand profiles were of similar DualEM values. The relationship between the shallow and deep sensing values appeared to separate them them in the data distribution.

The maps were used for ground-truthing in the field. Firstly to assess if the deep sand rises and shallow soil over limestone regions aligned with the map. In addition 25 pre-determined sites at different map values were cored and a measurement taken for the depth of soil over limestone.



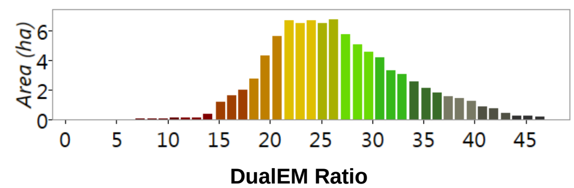


Figure 2

A good correlation was evident between the multi depth EM map and the depth of soil over limestone. Figure 3 shows selected sites with their respective depth to limestone measurement.

1 – 12cm	2 – 28cm	3 – 58cm	4 – 80cm
			

Figure 3

3. Creating Zones and assessing with yield.

Knowledge gained from field ground-truthing and GIS layer intersecting processes were used to create the soil zone map in figure 4 with corresponding wheat yields achieved in 2013. Table 1 details the wheat yield achieved for each soil zone.

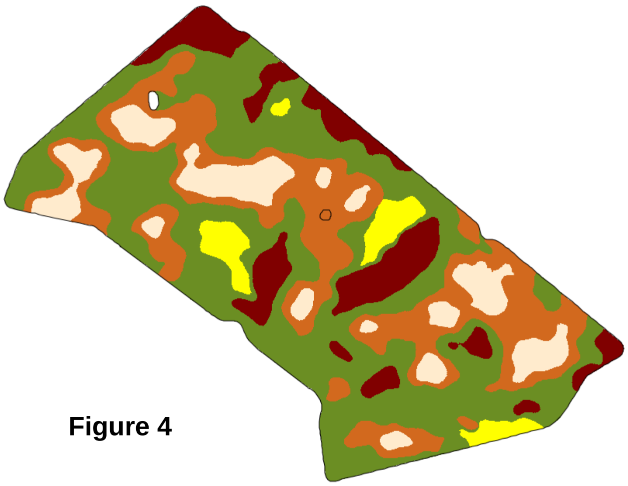


Figure 4

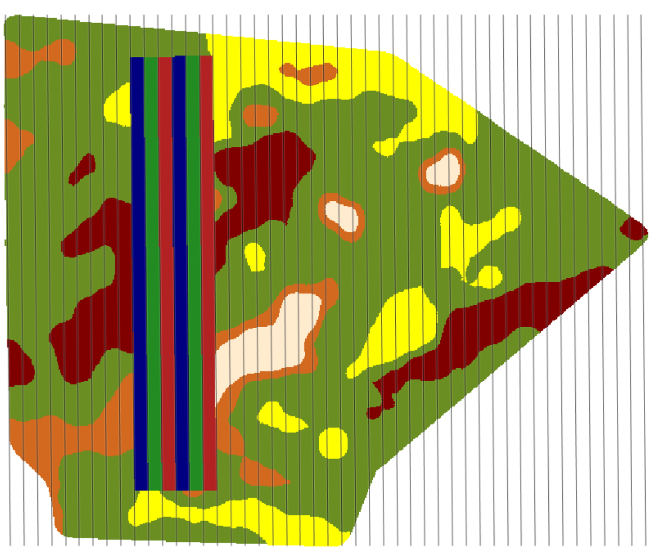
Soil Zone		Wheat Yield 2013
	Sand	1.14t/ha
	Stone to Surface	1.72t/ha
	Stone Sub Surface	2.02t/ha
	Sandy Loam	2.52t/ha
	Loam	2.86t/ha

Table 1

How this knowledge can be used

- Segregating soil zones and understanding productive capacity.
- Strategic use of inputs and managing risk particularly post nitrogen decisions.
- Assist decisions for soil modification with clay spreading/spading and delving potential.

The same soil zoning method was adopted on an adjoining field in the project area where a planting fertiliser trial was implemented. Figure 5 shows the trial designed to transect the major soil zones.



Zone	
Sand	
Stone Surface	
Stone Sub	
Sandy Loam	
Loam	

15:10:0:14 Planting	
	40 kg/ha
	70 kg/ha
	100 kg/ha

Figure 5

Yield monitor data from for the 2013 wheat harvest was used to analyse the yield response x fertiliser treatment x soil zone. Table 2 details the results for the most profitable treatment for each soil zone and determines varying the fertiliser at planting to match the soil zone productive capacity was profitable with an average benefit of $10.30/ha.

Soil		Area	Optimum Rate	Benefit/ ha	Total Benefit
Sand		10.37	40	$14.28	$148.10
Stone Surface		2.93	40	$21.38	$62.81
Stone Sub		7.39	75	$0.00	$0.00
Loamy Sand		42.9	100	$4.93	$211.88
Loam		10.09	100	$37.27	$376.27

Table 2