How to use

PRECISION AG DATA LAYERS

to accurately and economically soil test

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WHY?

Soil testing can be an expensive and time-consuming process for the grower. Results can appear daunting and complicated to interpret if they're not collected with a specific focus or goal in mind.

It is common for farmers to have several years of yield data collected from their grain harvesters. It is less common for growers to be using these data layers to help determine soil zones in a field. Yield data is valuable when there are several seasons of data, in different crop rotations to compare trends. It is even more valuable when coupled with soil survey data and satellite imagery, as these layers can begin to reveal patterns about soil variability changes within a field and how they relate to final yield. Most fields will have inherent spatial soil variability.

This fact sheet is designed to demonstrate a process to use data layers to soil test strategically, then show how the results can help make variable management decisions.

SOIL TESTING

Whilst pre-season combined soil surface testing is valuable for determining nutrition input requirements for the upcoming season, deep core soil sampling (0-90cm), using a hydraulic soil corer, can measure more mobile nutrients such as available nitrogen or sulphur and assess subsoil constraints to root growth.

Soil coring at multiple depths down the profile in strategic locations can provide great insight into the soil attributes in each horizon; these influence the conditions the plant encounters at each stage of the growing season.

Data layers give clues about soil variability, which is important as it is a major influence on grain performance (yield and protein).

WHERE DO I START?

I want to use my data layers to select where to take soil cores

1. Pick a field where the cause of the variability is unknown
2. The degree of variability can be assessed using coefficient of variation (or CV%), or standard deviation/mean expressed as a percentage
    - <= 8% - not very interesting!!
    - >8% <= 16% worth investigating
    - >16% well worth exploring the cause and pursuing the opportunities

READILY AVAILABLE DATA LAYERS INCLUDE:

- Yield data
- Satellite imagery
- Elevation data
- Soil Survey (EM38/Gamma Radiometrics)
- Soil grid maps (pH, P, K)
- Protein data

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3. Compare yield maps with season rainfall (total and the distribution of the rainfall over the growing season) to remove environmental influence on yield. We are searching for factors within our control to change throughout this process

4. Collect and organise the data layers available to you and ensure they're accurate (processed)

WHAT IS DATA PROCESSING?

Processing precision ag map data involves looking at the raw data points to remove errors to ensure the finished map is a true reflection of what was collected in the field. Most raw data will contain outliers that need to be removed. Other factors like GPS drift can cause 'data delays' and these can also be corrected through processing. The raw data points will then be smoothed and given a colour scale with a representative legend.

5. Look at cereal rotations and compare the patterns over several different seasons. It is best to omit yield maps that have been heavily impacted by environmental factors such as frost or hail.

6. Compare yield maps with in-season imagery
   - Early season maps are good indicators of topsoil variability
   - Late season maps are good indicators of subsoil variability as plant roots venture into the sub soil resource

7. Use 'constant' map layers to compare with the yield and imagery to begin to find correlations – eg Elevation, EM38 or Gamma Radiometric data. Grid soil data may be useful too
   - Don't be concerned if you haven't got many layers to start with yet. The following steps will help to determine appropriate map layers to collect for localised soil type.

8. Develop 'zones' to test. This may require input and consultation from an agronomist

9. Choose a representative core site in each zone. The aim is to develop a deep and comprehensive understanding of the soil conditions within each zone. Record the latitude and longitude at the soil core site

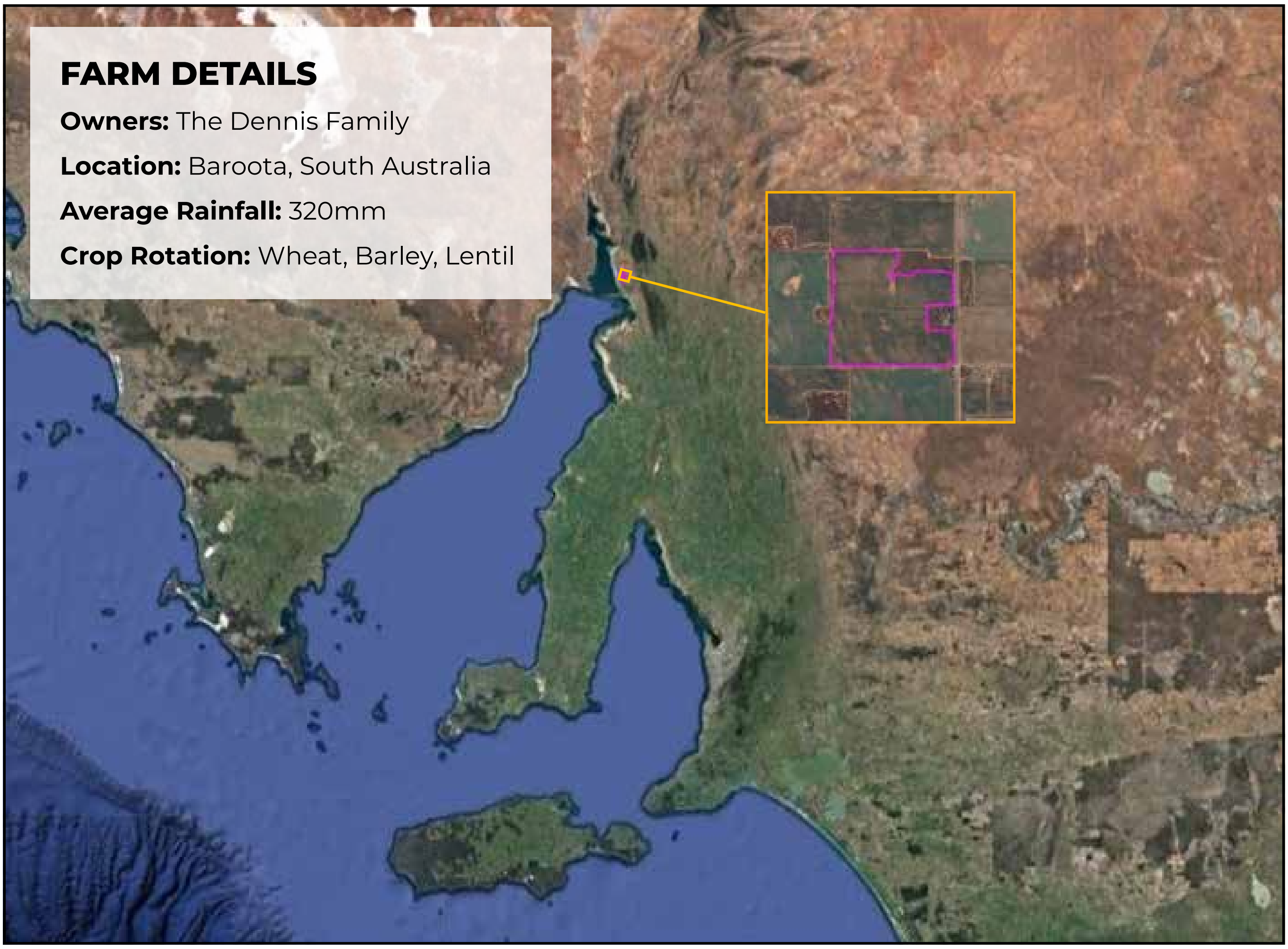
10. When the cores are taken, (usually up to a depth of 90cm), it is best to split the cores by horizons for testing. Take photographs of the cores to help with analysis and track root growth. It is best to take cores throughout spring in a cereal rotation. We are considering factors that do not fluctuate quickly here including soil texture, organic carbon, phosphorous, salt content and pH.

11. Use the results to determine overarching soil type for each zone, consider the soil properties at each location, as each zone may require different agronomic management. Also consider the differences down the profile as the crop may experience different growing conditions throughout the season, which will influence early and late season decisions differently.

12. Using the above soil core results, make an educated decision on which soil survey data will add value to your farming enterprise. These layers will provide special data across the paddock to help create variable rate management maps. This can be grid sampling or zoned aggregated sampling. Again, consult your agronomist for your individual situation.

Case Study

CYRILL'S PADDOCK



FARM DETAILS

Owners: The Dennis Family

Location: Baroota, South Australia

Average Rainfall: 320mm

Crop Rotation: Wheat, Barley, Lentil

The case study site selected to demonstrate the strategic coring process was at Baroota, in the Upper North Agricultural Zone of South Australia. The Dennis Family had recently taken over management of the field and wanted to gain a better understanding of the soil constituents. The yield maps were showing variable patterns and the Dennis' (landowners) suspected soil variability as the driver.

Brad, Robbie, and Matt Dennis on their Baroota, South Australia, property (Source: GRDC)

Map layers collected and analysed to create temporary zones and select soil coring sites.

These data layers were processed and presented in PCT AgCloud for the case study site.

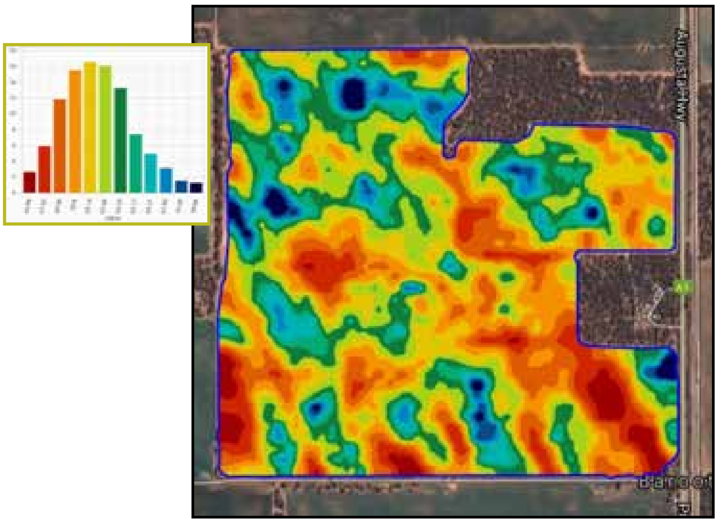


***Figure 1** - EM38 50cm Depth Map surveyed by AgTech Services on 2nd August 2021*

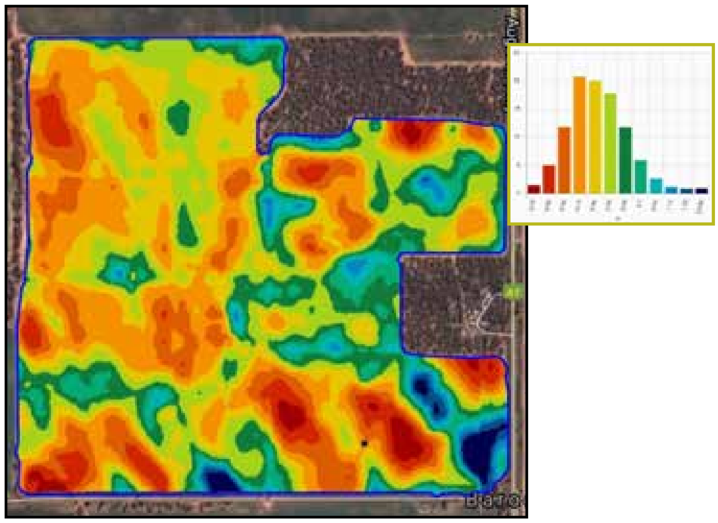


***Figure 2** - Landscape Change Map derived from elevation data. The elevation data was processed using 'as applied data' from the Dennis' seeding system*

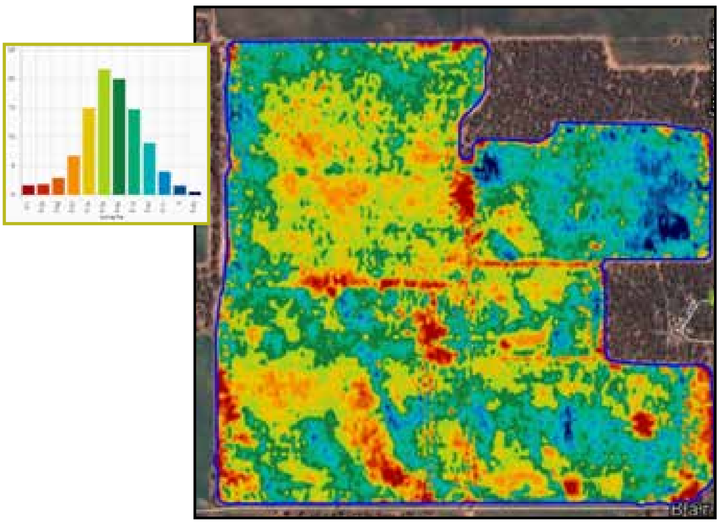


***Figure 3** - 2019 Barley Yield Map*

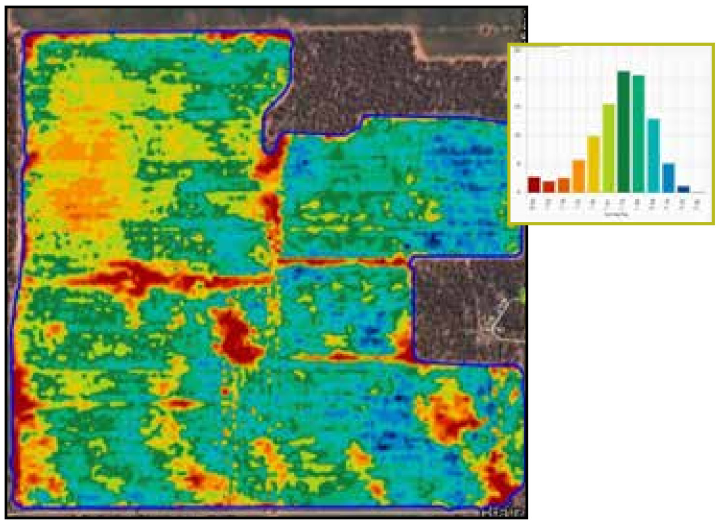


***Figure 4** - 2020 Lentil Yield Map*

Selecting sites to soil test in 'Cyril's' paddock

The 'where to start' guide above was used to work through the process of analysing the maps. An agronomist, precision ag consultant, and the farmers knowledge of the field all fed into the interpretation to eventually settle on the sites to take the cores. The goal is to find the most representative soil types in the field.

The Dennis family knew there was significant yield variability through their observations at harvest and by viewing their own yield maps. The coefficient of variation in their barley yield map is 13%– worth investigating for variable management. The raw data layers were processed and presented in PCT AgCloud. The seasonal rainfall was then compared with the yield maps and SVI satellite maps. The reason this process is important, is that patterns can be revealed about sub soil constraints and soil water holding capacity when comparing wet vs dry springs and the patterns that may cause in the yield maps. There were two yield maps available for Cyril's, one in a dry season, one in a wetter season and the patterns were quite similar between the two.

All maps clearly showed the old fence lines in this paddock, which have now been removed. These areas consistently showed up as poorer yielding areas, which was attributed to sand drift patterns. Another environmental influence identified in this paddock included the 'shelter belt' running around the north, east corner of the paddock. This vegetation acts to reduce sand drift, consistently boosting yield in this area. Upon comparing the EM38 and elevation maps, similar patterns were found, suggesting that we are working within a clear 'dune, swale' system. Areas showing higher elevation, showed lighter soil texture. These patterns are also weakly correlated to the yield maps we had available too. Therefore, we chose to base our soil sampling on the EM38 map, with the intuition that soil texture is a strong influence of yield potential at this site. A soil core was placed in each zone of the EM38 map, with landscape positioning when sampling also front of mind.

The 'constant' map layers we had available were EM38 and elevation (and derivatives such as landscape change, slope, aspect etc). These maps gave more insight into the soil type makeup of the field,

It was decided that taking 6 cores should give good representation, particularly when broken up by horizon and analysed separately.

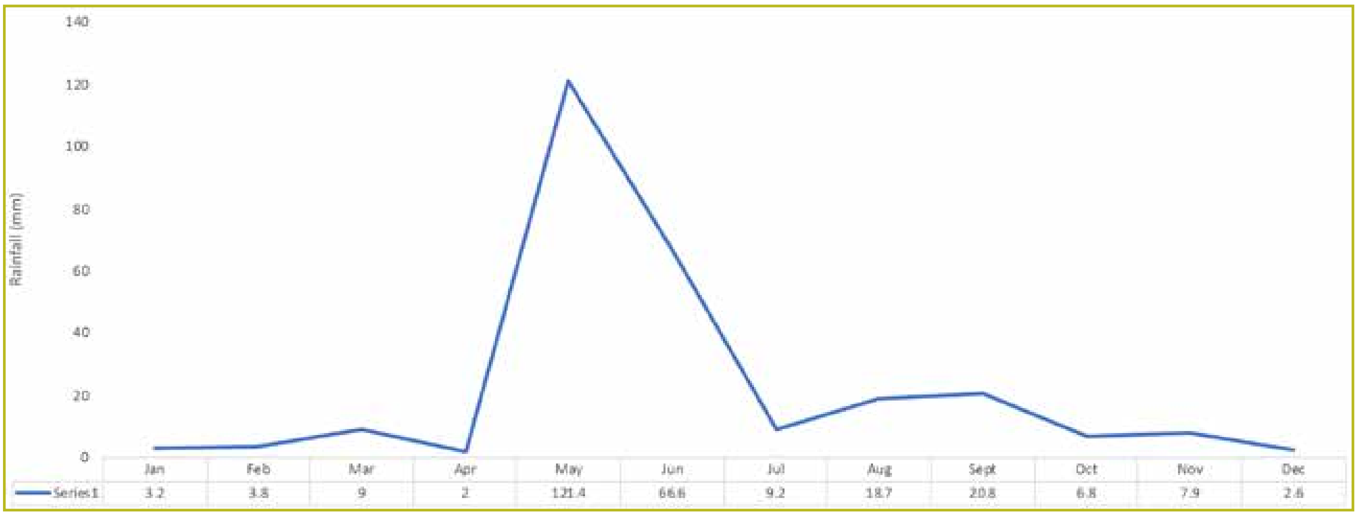
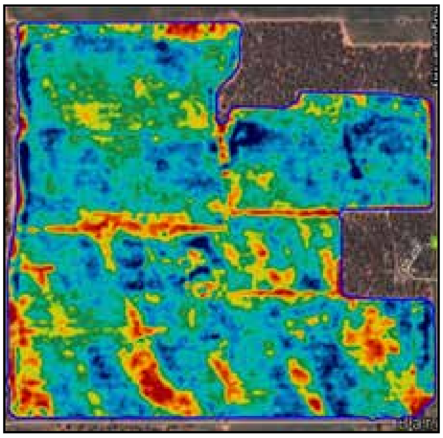
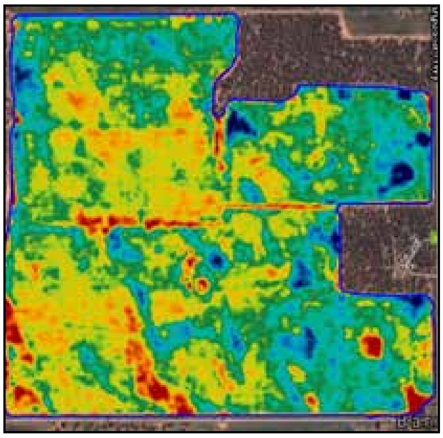


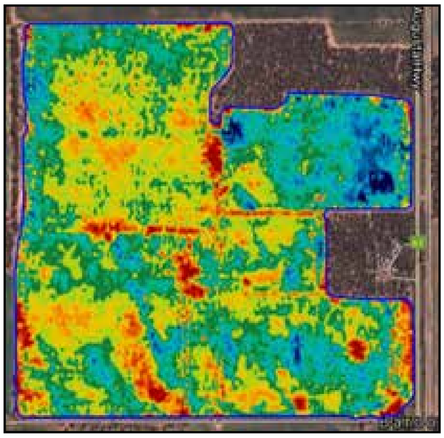
Figure 2 *- Annual rainfall by month for Baroota in 2019. This be compared with the NDVI/SVI imagery throughout the season and helps decipher how the crop behaves under different soil moisture situations*



NDVI June 2019



NDVI Sept 2019



Barley Yield 2019

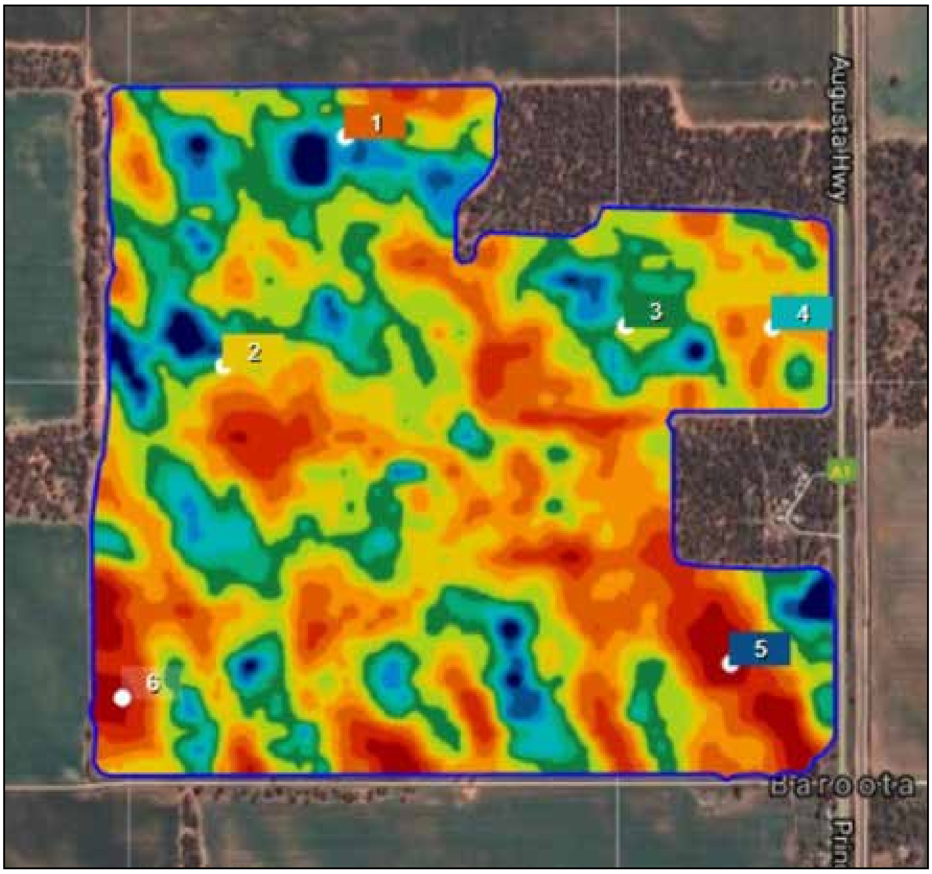
The EM38 map in focus

EM38 refers to electromagnetic soil mapping. Electrical conductivity is primarily influenced by soil texture, in particular clay content, soil salinity and moisture levels. EM38 data is used to generate a spatial layer that provides information about soil variability within a field. As further analysis was carried out in this field, it became

clear the EM38 would become a 'standout' layer to help describe soil type and would largely help in determine management zones.

WHY?

The patterns in the landscape change map, the two yield maps we had available, and the imagery throughout the season indicated that soil texture (often indicated in an EM38) was driving variability.



Interpreting the Soil Test Results

It is important to enlist the assistance of an agronomist and/or soil consultant to analyze the core results. Splitting the cores into topsoil and sub soil horizons is hugely valuable and the information from these results in isolation can lend themselves to different management decisions as the plant root system moves through the soil profile.

Two soil tests were used for this case study:

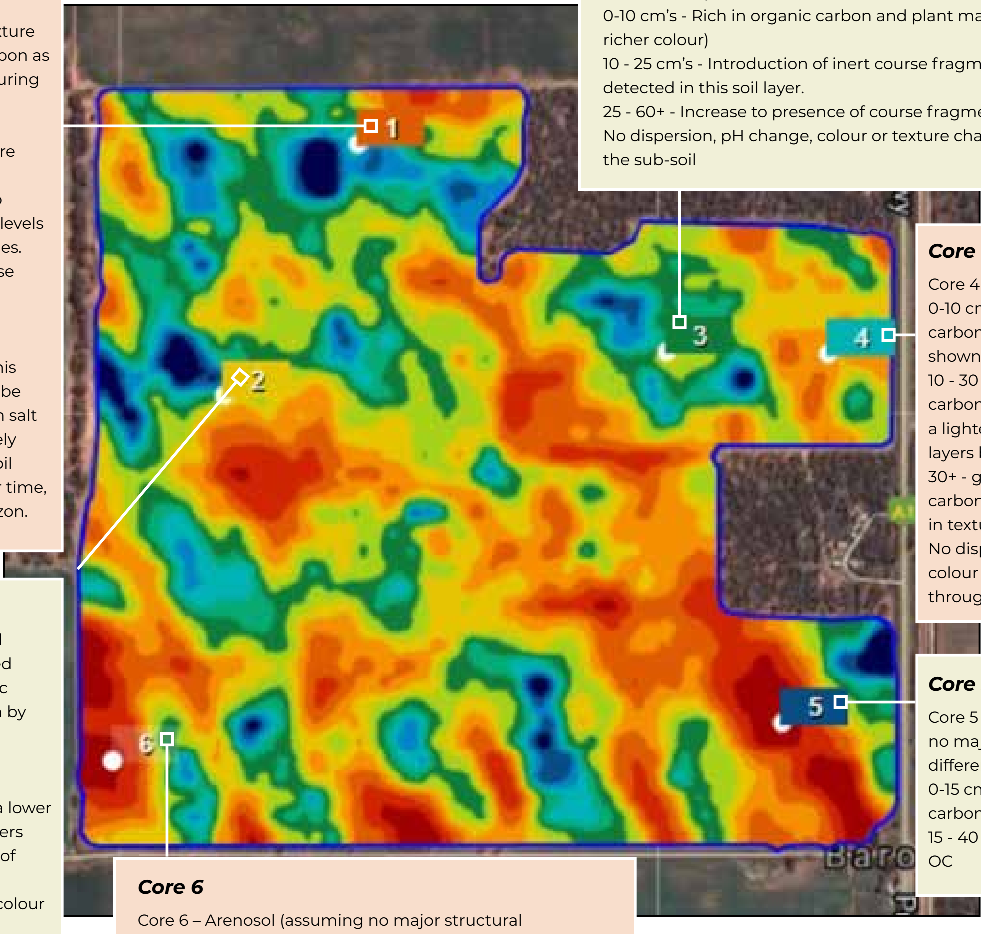
Topsoil	Comprehensive Analysis	Soil pH, pH CaCl, S-OC-WB.12, Soil P Colwell, Soil PBI, Soil DGTP, S, Ca, Mg, K, Na, Soil Ca:Mg, Soil Ca %, Soil Mg %, Soil K %, Soil Na %, Al, EC, CEC, Soil ECse, B, Soil Clay %, Soil Sand %, Soil Silt %
Subsoil	Health Check	Soil pH, pH CaCl, Ca, Mg, K, Na, Soil Ca:Mg, Soil Ca %, Soil Mg %, Soil K %, Soil Na %, Al, EC, CEC, Soil ECse, B, Soil Clay %, Soil Sand %, Soil Silt %

Why did we choose these tests?

- Budgeting, keep the cost of the testing affordable, and ensure 'bang for buck'
- Matching information to potential variable management possibilities. There are differing management possibilities between the topsoil and subsoil. For example: DGT P, Colwell P and PBI have relevance to phosphorus management – an element managed in the topsoil. Phosphorus is an immobile element compared to an element like Nitrogen. Therefore, the phosphorus-based tests were taken in topsoil only. Alternatively, salts were measured in the subsoil health check, as they are typically soluble and therefore readily move into the subsoil.

Physical Properties

Having information about soil attributes in different EM38 sites, at different depths throughout the horizon gives a detailed insight into the overarching soil types. If the regressions between the EM38 value and attributes such as Soil Clay %, Cation Exchange Capacity (CEC) and Sodium (Na) are strong it validates that the EM38 is a good indicator of soil texture change, therefore soil type changes.



Core 1

0-15 cm - lighter in soil texture and higher in organic carbon as shown by the darker colouring of this soil fraction.
15-45 cm - There was an increase in both soil texture and pH when moving to this horizon. There was no dispersion indicating low levels of sodium and clay particles.
45-60 cm - a steep increase in pH was observed when moving to this horizon, driven by the presence of carbonate. Additionally, this soil fraction was found to be dispersive, indicating high salt concentrations. This is likely where salts from above soil layers have moved to over time, accumulating in this horizon.

Core 2

Core 2 - Likely a calcarosol
0-15 - split due to increased plant material and organic carbon content (as shown by richer colour of the soil)
15-35 - The presence of carbonate comes in from approx. 15 cm's. This is at a lower level of underlying soil layers
35 + - increased presence of carbonate in this fraction
No dispersion, texture or colour change from 15 cm +

Core 3

Core 3 - Likely a calcarosol
0-10 cm's - Rich in organic carbon and plant material (as shown by richer colour)
10 - 25 cm's - Introduction of inert course fragment. No carbonate detected in this soil layer.
25 - 60+ - Increase to presence of course fragments (?)
No dispersion, pH change, colour or texture change throughout the sub-soil

Core 4

Core 4 - Likely a calcarosol
0-10 cm's - Rich in organic carbon and plant material (as shown by richer colour)
10 - 30 cm's - Less than 20% carbonate in this fraction and a lighter texture compared to layers below
30+ - greater than 20% carbonate and slightly heavier in texture
No dispersion, pH change, colour or texture change throughout the sub-soil

Core 5

Core 5 - Arenosol (assuming no major structural differences)
0-15 cm's - higher in organic carbon then underlying layers
15 - 40 cm's - Slightly higher OC

Core 6

Core 6 – Arenosol (assuming no major structural differences)
0-15 cm's - higher in OC then underlying layers
15+ - no pH or dispersion change and colour texture same throughout

Chemical Properties

Below is a summary of findings from each core taken in the project paddock. The summary considers pH, salt content, texture, organic carbon, phosphorous and micro-nutrient deficiencies, and toxicities for each site at dual depths. The chemical driver of this paddock is carbonate (free lime), which influences pH and hence nutrient availability.The main physical constraint of this paddock is soil texture and hence water holding capacity.

Core 1	Core 2	Core 3	Core 4	Core 5	Core 6
pH is considered strongly alkaline throughout the whole core, increasing as you move down the profile. This will be a yield limiting constraint for commonly grown crops in this area. When considering EC(1:5), which looks at the salt content of the sample, levels are reasonable. However, when considering EC(se), which takes into consideration soil texture and salt content, concentrations will result in toxicity for legume crops in particular. The main salt present at this site was found to be sodium and magnesium. Therefore, applications of gypsum may be required in this area of the paddock long-term. Phosphorous levels are bordering on low, meaning replacement plus some should be applied in this area. The top soil of this site has a low phosphorous buffering index, meaning the tie up of P at this site is low. Potassium levels are good with sulphur being low.	The pH of this site is strongly alkaline, driven strongly by the presence of carbonate, with a low organic carbon content. The texture of this site ranged from a loam to a clay loam, meaning water holding capacity is reasonable at this site. The alkalinity of this site will likely reduce yield potential. When considering EC(1:5) the salt concentration at this site is not of concern, however when taking into account soil texture (ECse), the sub soil of this site has a salinity issue that will limit legume production. Calcium levels are elevated in the top soil fraction. Throughout the sub soil, magnesium and sodium are elevated, likely causing dispersion issues and driving toxicity issues at depth. Applications of gypsum should be considered at this site. Phosphorous levels are low, with a moderate PBI in this zone. Phosphorous should be built on in this area moving forward. Potassium levels are good and sulphur is low.	pH at this site was found to be strongly alkaline, likely driven by the presence of carbonate (free lime). Organic carbon levels were found to be low, reducing soil structural stability and water holding capacity, which is particularly important for lighter textured soils. EC(1:5) did not show excess salts present at this site, however, when considering EC(se) salt levels will reduce productivity of legume crops due to toxicity. Magnesium and sodium salts are driving this. Phosphorous levels were low at this site, with a low PBI, reducing P tie up. Potassium levels are good with sulphur levels low.	This core was found to be highly alkaline, increasing down the core, with very low organic carbon levels. Soil texture ranged from a loamy sand to a silty loam, making organic carbon important to contribute to the CEC of this site in addition to the overall structure. Colwell P was low at this site, with a moderate to low PBI, long-term P should be built at this site. Sulphur was also found to be low, likely due to leaching as a result of lightly texture soils. EC(1:5) was considered low, with EC(se) showing a possible yield limiting constraint. Calcium was high in this soil, with magnesium, potassium and sodium within reasonable levels. Gypsum may be required here to correct toxicity issues.	The pH of this site was found to be extremely high (alkaline), again increasing as you move down the profile. This site has a very low organic carbon content. The texture throughout was sand, meaning this site will have a very low water holding capacity and nutrients will readily leach from the plant root zone. Therefore, increased organic carbon will lift yield at this site significantly. Phosphorous levels are bordering on low, with a low PBI. Sulphur is also low, likely due to leaching. Salt levels at this site are not of concern, with a very low likelihood of this site experiencing dispersion due to very low clay content. This site should be tested for hydrophobic characteristics. When coring this site, the corer hit a hard layer at approx. 40 cm's. This will reduce rooting depth and therefore water and nutrient availability to the crop.	This site was found to be strongly alkaline, driven by the presence of carbonate which increased with depth. The site had a low organic carbon content, with the texture of this site a sand throughout. Therefore, moisture holding capacity is low and nutrients are easily leached beyond the plant root zone. Phosphorous levels are low at this site, with a low PBI. Sulphur is also low, likely due to high water infiltration taking S beyond the plant root zone. Salt levels at this site are low, with very low likelihood of ever needing gypsum at this site due to high levels of water infiltration due to texture.

Notes:

*Structure not assessed (cannot do so when using cores) which could be a potential yield limitation of this paddock.
No comment on N as sampling did not suit this type of analysis.

Correlation between EM38 and CEC

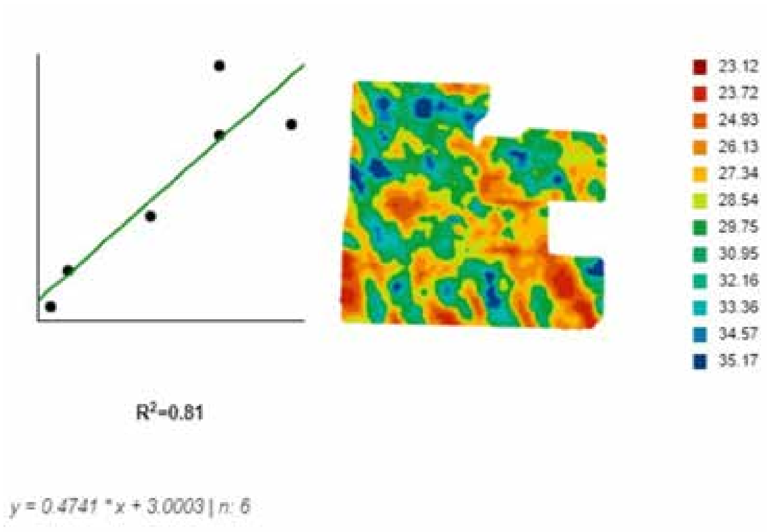


Figure 7 - *The 0-60cm CEC soil results at each core site plotted against EM38. The 0.81 regression indicates that the EM38 map is picking up soil type changes*

To be confident that the EM38 Map is a strong indicator of representative soil types, a regression was drawn between Soil CEC (Cation Exchange Capacity) and the EM38 map in the PCT AgCloud Analytics tool. Soil CEC is a good indicator of soil texture in this field due to the fact there are low organic carbon levels (so CEC is more linked to increasing clay). Regressions between soil test attributes and soil sensor layers such as EM38 can tell a powerful story. In this case, the strong correlation between soil CEC and the EM38 map gave us confidence to use the EM38 map as a base layer for a soil amelioration prescription map for biosolids application. The aim of this application was to increase yield potential on lighter textures areas of the paddock, by increasing water and nutrient holding capacity.

The bell curve to the right helps to explain the main yield driving factors of this paddock. As EM38 increases (and hence clay content), so does the yield response to a point. This can be directly attributed to an increase in plant available water and nutrients. However, beyond a tipping point, other limitations come into play. In this scenario, this is nutrient toxicity and salinity levels. In the heavier textured soils leaching of salts and nutrients is reduced and hence held in the plant root zone creating toxicity issues.

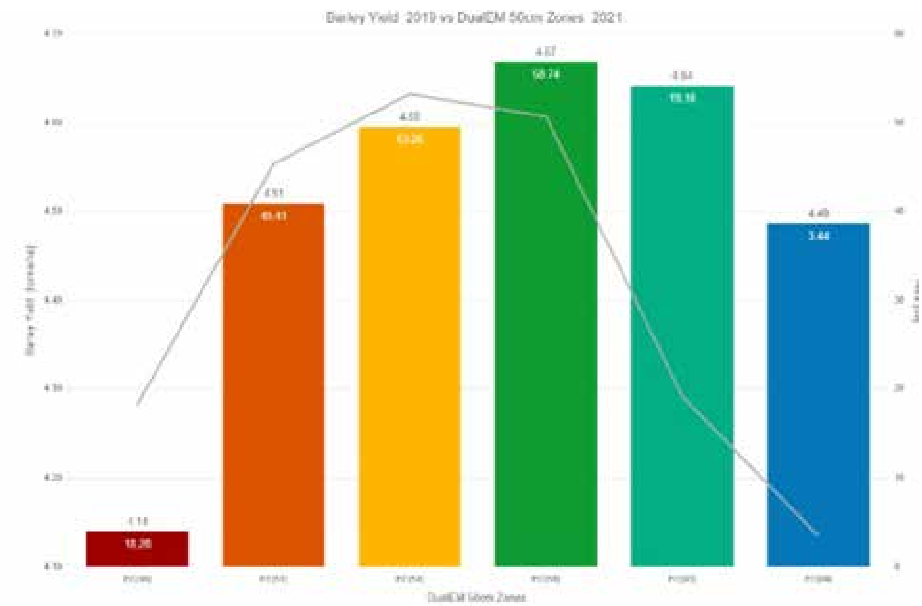


Figure 8 - *A graph with the Dual EM38 50cm zones vs the yield within that zone in t/ha*

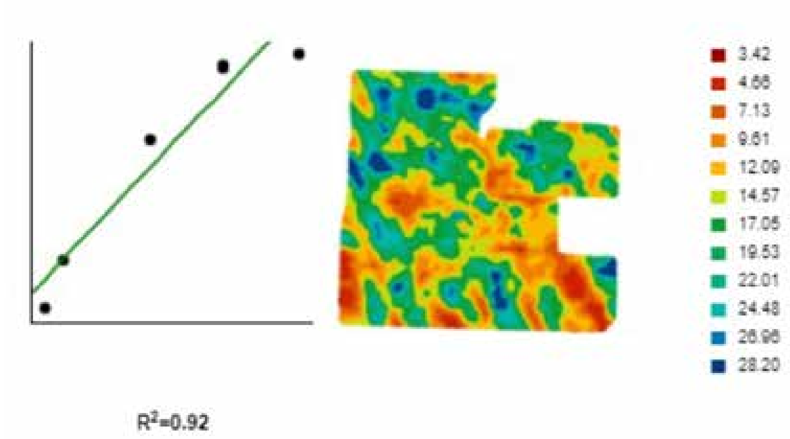


Figure 9 - *Soil Clay % from 0-60cm at all 6 sites plotted against EM38, a strong regression, once again indicating that the EM38 map is a good indicator of soil texture*

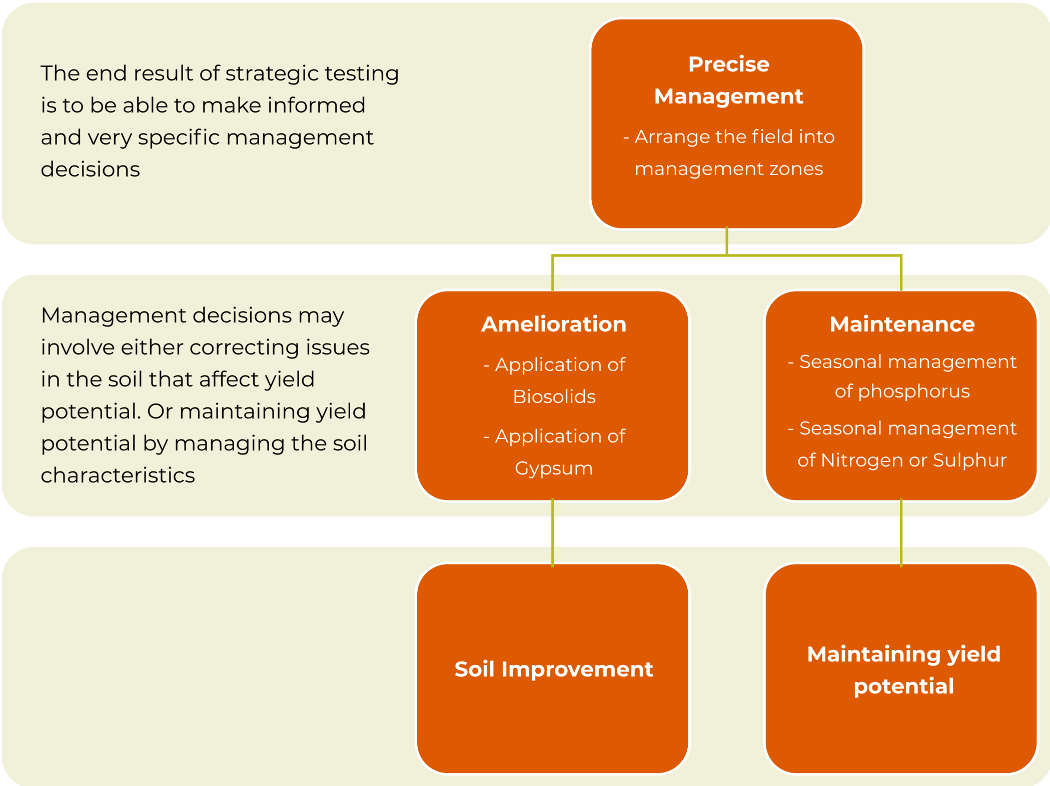
Looking at the figure above, the EM38 map is a very strong indicator of soil texture, therefore likely, available water content for the crop. The EM38 map layer would make a quality base layer for calculating target yields in different areas of the paddock and their associated input decisions, and of course taking soil tests, as has been done in this case study.

What Management Decisions can be drawn from soil testing by zones in this field?

The overarching purpose of strategically coring in different soil zones is to match inputs to the *productive capacity* of the soil. It is useful to think about variable management in two different management practices – Amelioration and Maintenance.

Fertilisers like nitrogen and sulphur can be tailored in season to capitalise on plant available water and seasonal requirements but can also be applied variably to match the yield potential of different soil types. These have been characterised in the table below as *maintenance* precision ag inputs.

Amelioration refers to long term improvement of the soil chemical and physical structure. In this case study at Baroota, the amelioration recommendation is prioritised around chemical inputs rather than physical amelioration like ripping.



Based on the soil results and the interpretation of the soil and yield maps, this paddock is a good candidate for variable rate maintenance and ameliorant applications. In consultation with soil consultants and agronomist the following was recommended: 'see below'

AMELIORATION

Variable Rate Biosolids

Biosolids is an organic rich amendment which increases organic carbon content of the soil resource, therefore increasing water holding capacity of the soil. The upper limit of the biosolids rate must be considered carefully as the product can have high levels of heavy metals which can accumulate within the soil. Additionally, the low rate will also be carefully considered, ensuring that there is enough product to achieve a uniform spread pattern.

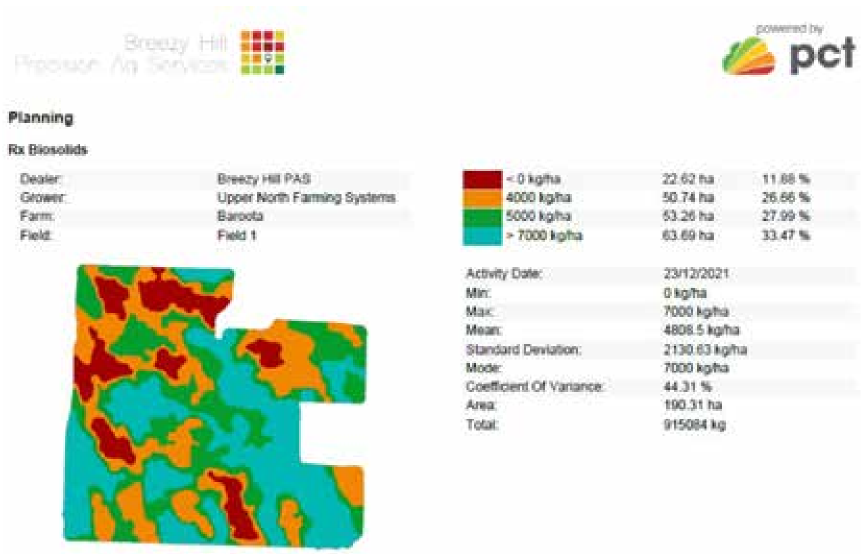


Figure 10 *- The biosolids variable rate prescription map, with higher rates on the lighter soil textures (confirmed by EM38 map)*

AMELIORATION

Variable Rate Gypsum Application

Gypsum is recommended in a variable rate application for this field to release sodium from the CEC, allowing it to leach beyond the plant root zone. This will ultimately prevent dispersion and compaction. When sodium is on the cation exchange site (CEC) of a clay / OC particle, upon wetting the sodium molecules will repel one another, pushing apart soil particles and causing dispersion. Upon drying, this leaves the soil resource 'structureless' increasing the required 'force' of plant roots to explore the profile and making it difficult to access water and nutrients.

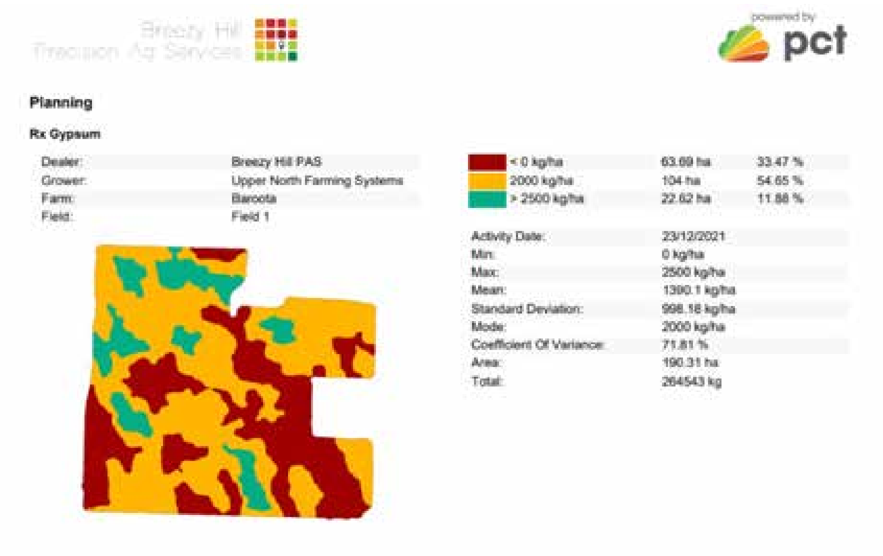


Figure 11 *- Gypsum variable rate map, using EM38 map as the base layer to make the zones. Gypsum would be applied at a higher rate on the heavier, clay soil types*

Sodicity Rating	Non	Slightly	Moderately	Highly
ESP rating %	6	6-10	10-15	>15
Rating and Action	No action	Apply 2.5t/ha	Apply 3.75t/ha	Apply 5t/ha

Ref: IPL Soil Manual

Cost of operation – comparing Variable Rate with blanket rate

Area of field: 190ha

Assumption of product sourced from closest supplier to Baroota, working on figures from the grower

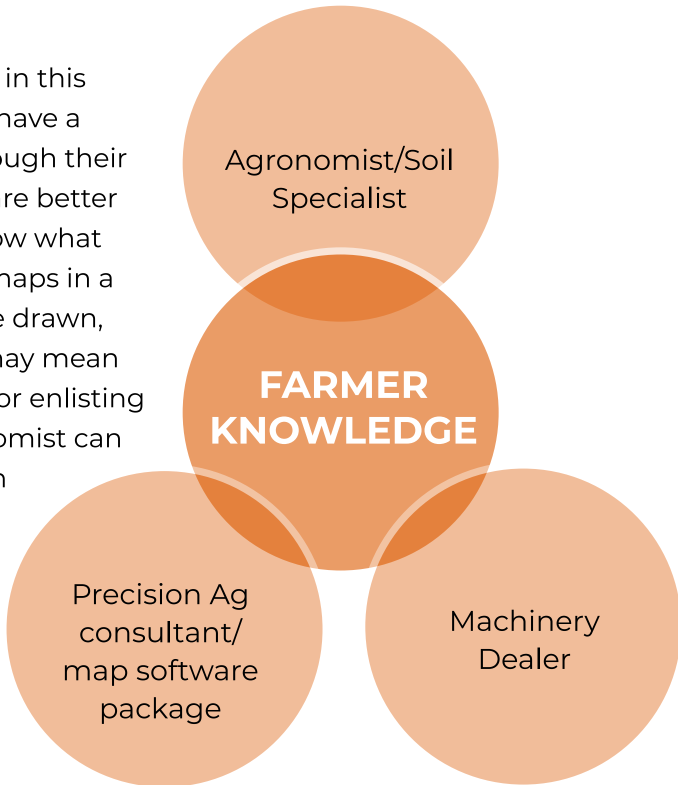
Biosolids	Area Spread	Tonnes required for operation	Cost/tonne (product and freight)	Total Cost of product required	Spreading costs per hectare	Total cost Spreading	Total cost of operation
Blanket Rate	190ha	950	$23.50	$22,325	$12	190 x 12 = $2280	***$24,605***
Variable Rate	167ha	915	$23.50	$21,503	$12	167 x 12 = $2004	***$23,507***

Gypsum	Area Spread	Tonnes required for operation	Cost/tonne (product and freight)	Total Cost of product required	Spreading costs per hectare	Total cost Spreading	Total cost of operation
Blanket Rate	190ha	380	$48	$18,240	$12	190 x 12 = $2280	***$20,520***
Variable Rate	127ha	265	$48	$12,720	$12	127 x 12 = $1524	***$14,244***

Ref: Agworld 14/01/2021

SUMMARY

The value of involving a network of professionals in this process cannot be understated. The grower will have a great understanding of the paddock history through their management, and the areas of their fields that are better yielding will generally be known regardless of how what maps they have available. However, having the maps in a format that is organised allows correlations to be drawn, and makes the maps simpler to interpret. This may mean paying for a more specialised software package or enlisting the help of a precision ag consultant. The agronomist can assist with interpreting map layers and advise on where to take the soil cores. A machinery dealer can assist with enabling easy flow of data into and out of hardware equipment in the machine. Each of these parties are integral in moving forward with precision ag in the business.



The goal in this process is to make a more informed decision. Crop management involves making many decisions throughout the growing season. Year on year, the grower will make many passes over the field, most of the time at a blanket rate. A blanket rate pass is a decision in itself. By knowing the spatial variability throughout the field, and the soil attributes in the major soil types, this can be considered in every pass of product, whether in an *amelioration or maintenance* application to better match the *yield potential* of the soil zone.

Beth Sleep, Agronomist said 'with some layers the grower already had in hand (yield data and NDVI imagery), we were able to add an EM38 map and 6 cores to gain a deeper insight into the soil properties of this field. The grower now has the confidence in managing this paddock variably, with scientific backing behind them. There are significant savings to be made in the gypsum and biosolids spreads alone, and the opportunities for other inputs like phosphorus can be explored'.

Things to consider

- Use map layers to determine patterns
- Take cores in strategic zones, to help determine the overarching soil type zones and their characteristics
- Consider the soil attributes in each horizon
- Once overarching soil types have been determined, use the information to manage inputs accordingly
- Pick the low hanging fruit first - eg. soil ameliorants to correct soil issues if applicable
- Soil information can assist in upfront fertiliser decisions at seeding time and when making nitrogen management decisions throughout the season

Acknowledgements

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The data and analysis was compiled and written by Jessica Koch, Breezy Hill Precision Ag Services in conjunction with Bethany Sleep, Elders Jamestown.

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