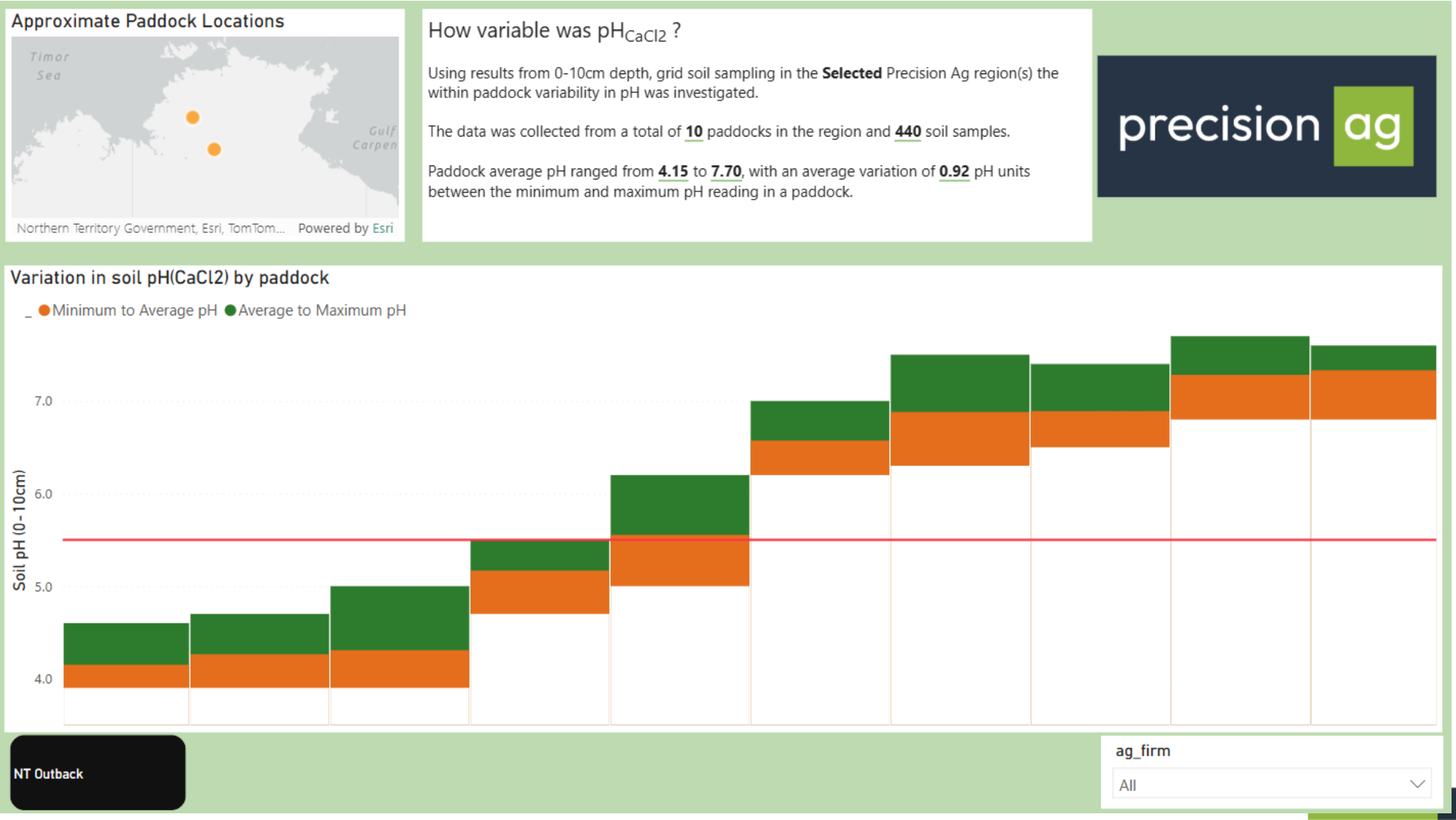
Managing variability of Northern Territory soils for optimising cotton production systems

Update on results

Project Background

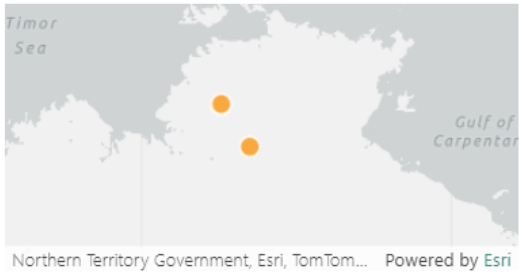
- In the NT, high yield variability across paddocks and farms has been linked to variability in soil constraints.
- Variable rate strategies for targeted amelioration has been effective and economical in other regions where cotton is grown and in other agricultural crops.
- A grid-based approach to soil sampling is used in other regions to provide an objective view of soil variability. Some initial sampling (July 2024) of NT cottons soils showed poor pH and nutrient levels which can be effectively mapped using grid-based sampling to generate variable rate solutions.
- The project was developed to achieve the following outcomes:
  - Understand sub-paddock variability in surface soil characteristics in the region
  - Provide variable rate amelioration recommendations based on the soil data.
  - Investigate alternative methods for mapping soils including a Gamma Radiometric Surveys

Soil Variability observed in NT



Soil Variability observed in NT

Approximate Paddock Locations



How variable was Colwell P (mg/kg) ?

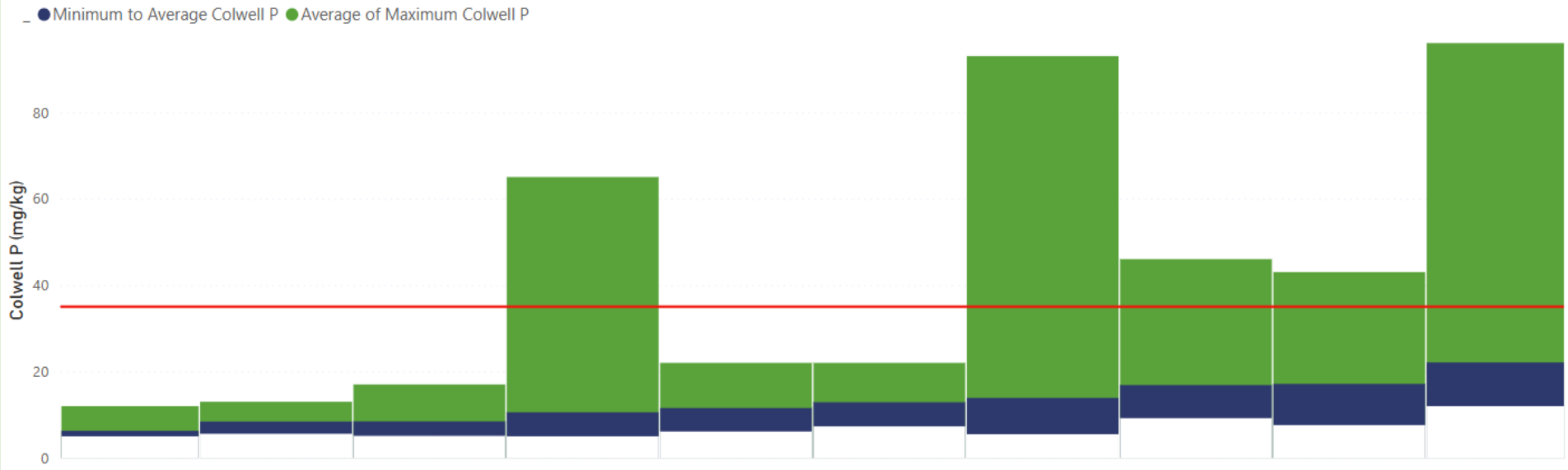
Using the results from 0-10cm depth, grid soil sampling in the **Selected** Precision Ag region(s) the within paddock variability in Colwell P was investigated.

The data was collected from a total of 10 paddocks in the region and 440 individual samples.

Paddock average Colwell P ranged from **6** to **22**, with an average variation of **36.06** mg/kg between the minimum and maximum Colwell P readings in a paddock.

precision ag

Variation in Colwell P (mg/kg) by paddock



NT Outback

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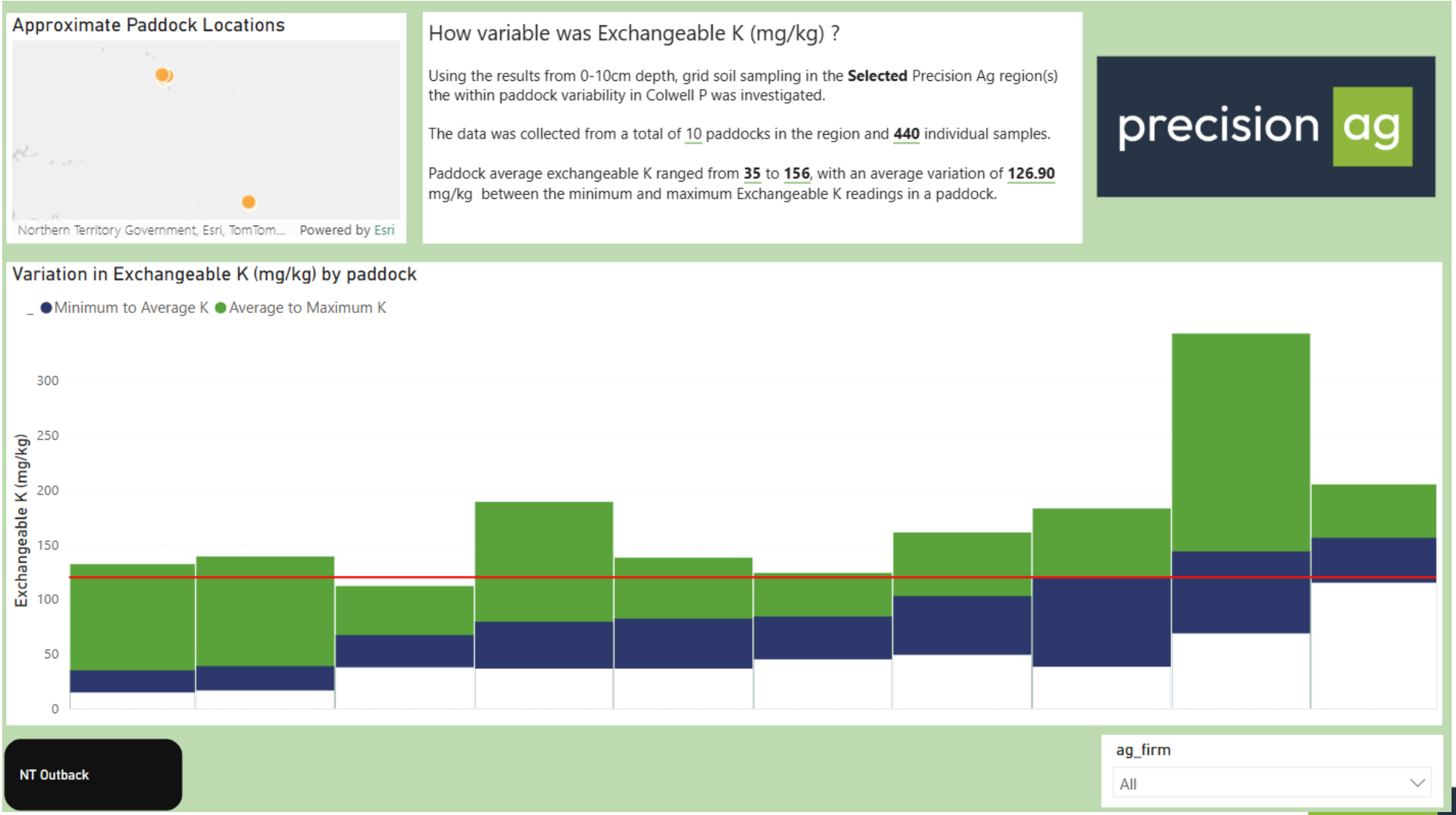
All

Soil Variability observed in NT

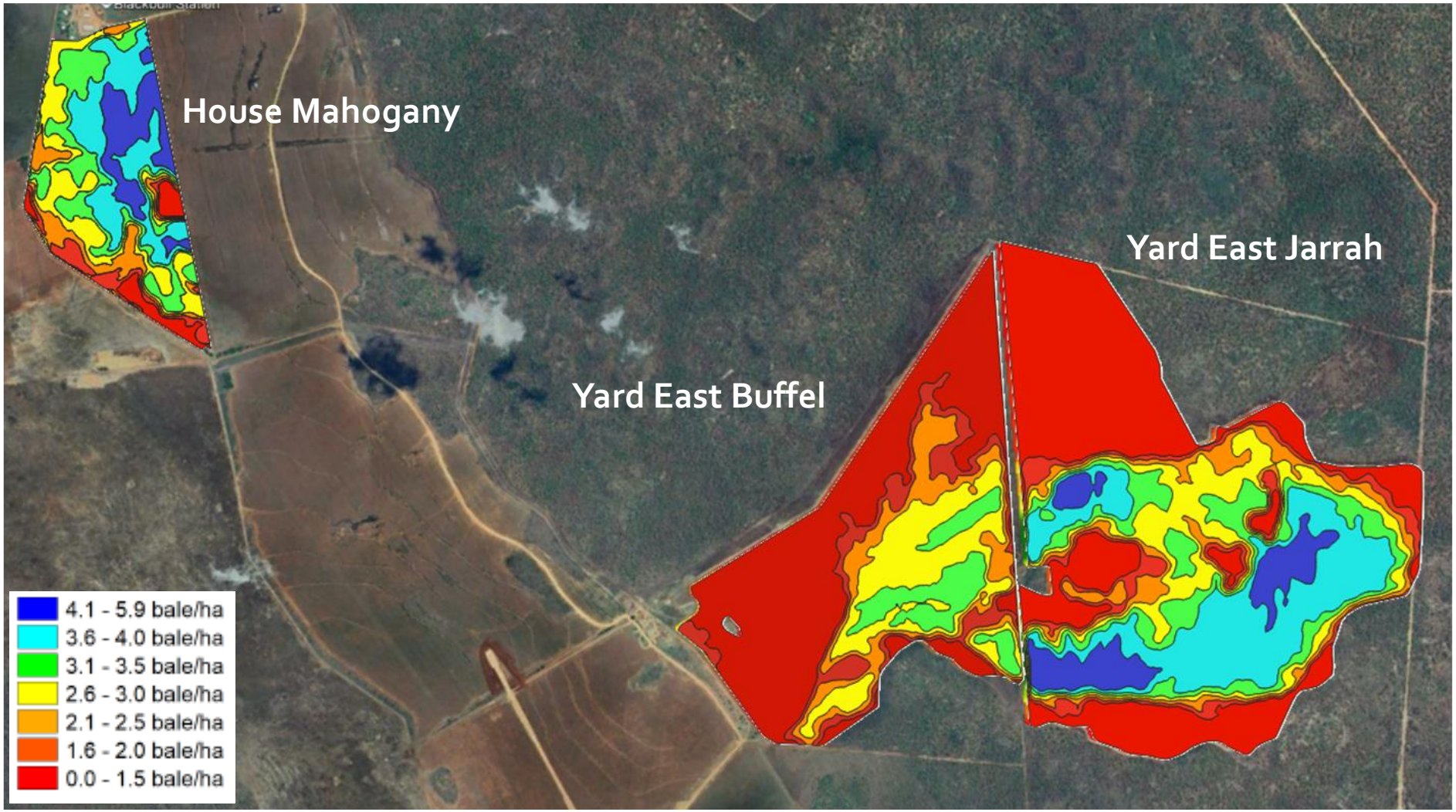


Black Bull Station

- ~ 10,000 grazing + ~5,000ha arable
- Hay production – including Jarra and Cavalcade
- Rainfed and Irrigated Cotton (~2000ha)
- Irrigated Cotton ~ 150 ha increasing to around 650ha
- Aims:
  - Increase the area of both rainfed and irrigated cotton
  - Looking for best farming system and crop rotations
  - Maintain good ground cover especially as wet season begins

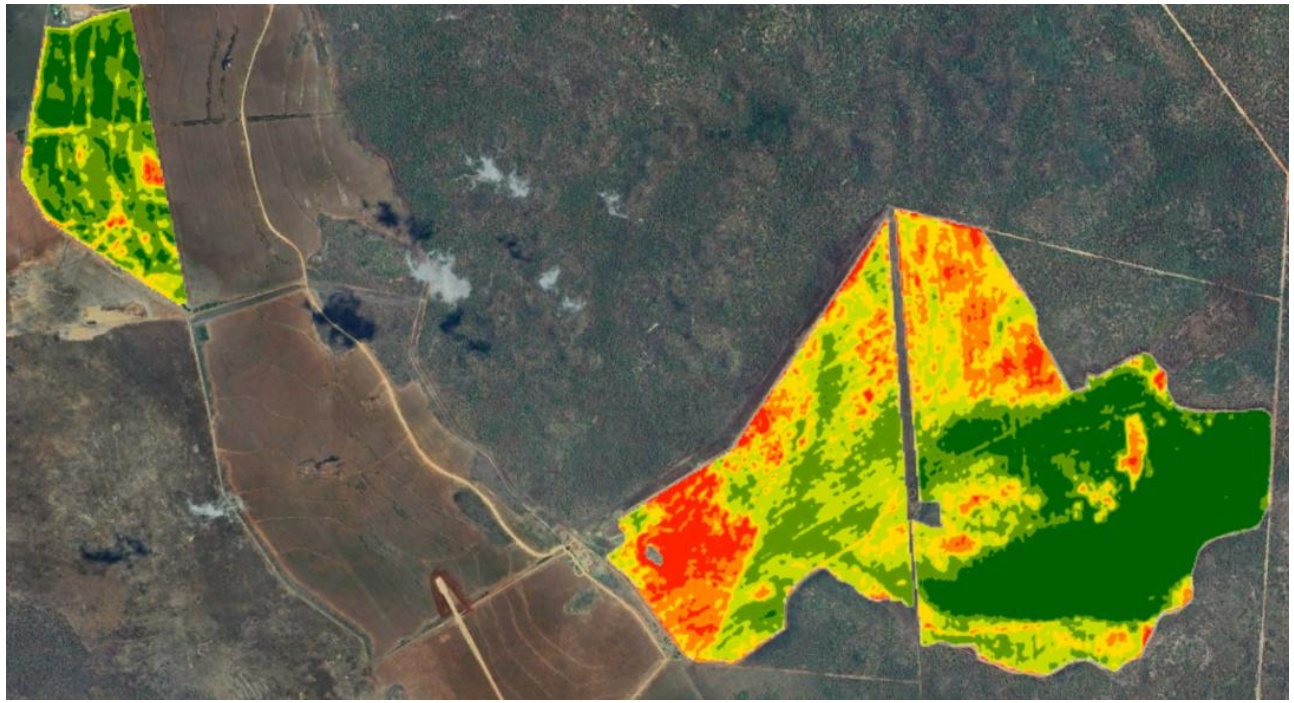
Observed Yield Variability – 2024 Cotton

Avg yield =
3.14 b/ha - house mahogany,
1.7 b/ha - yard east buffel,
2.37 b/ha - yard east Jarra)



Yield variability is reflected in crop NDVI

Mar 24



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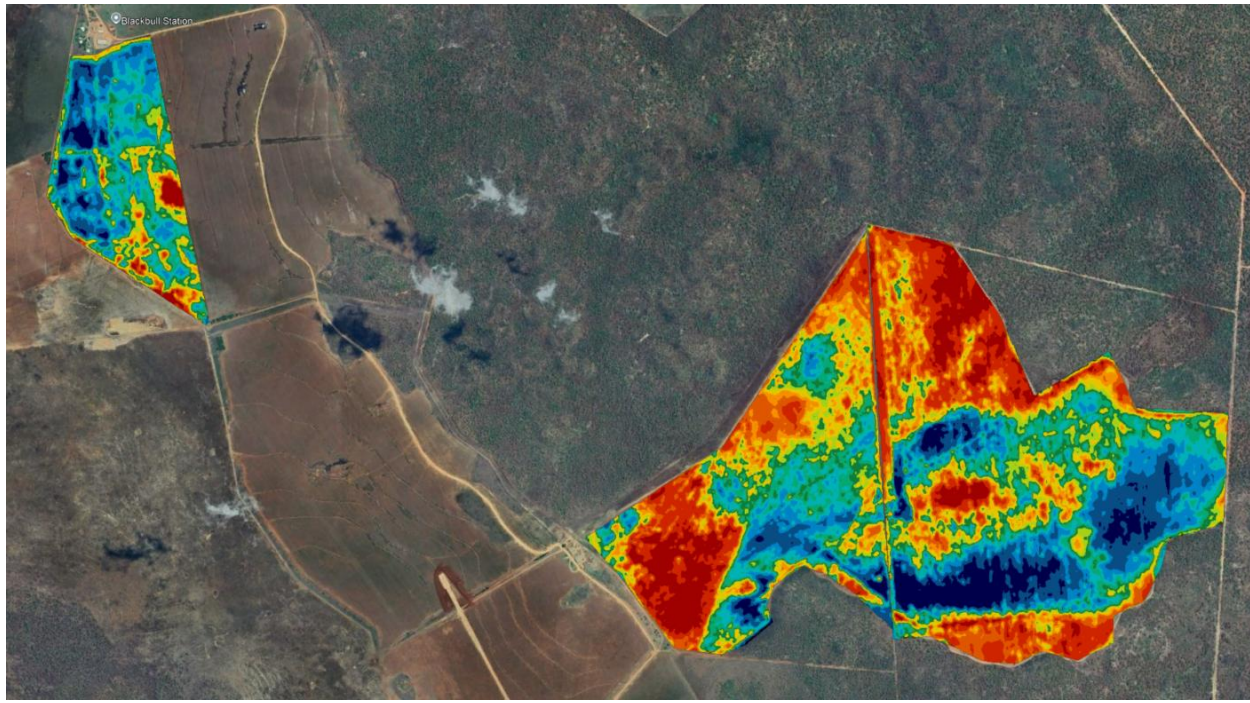


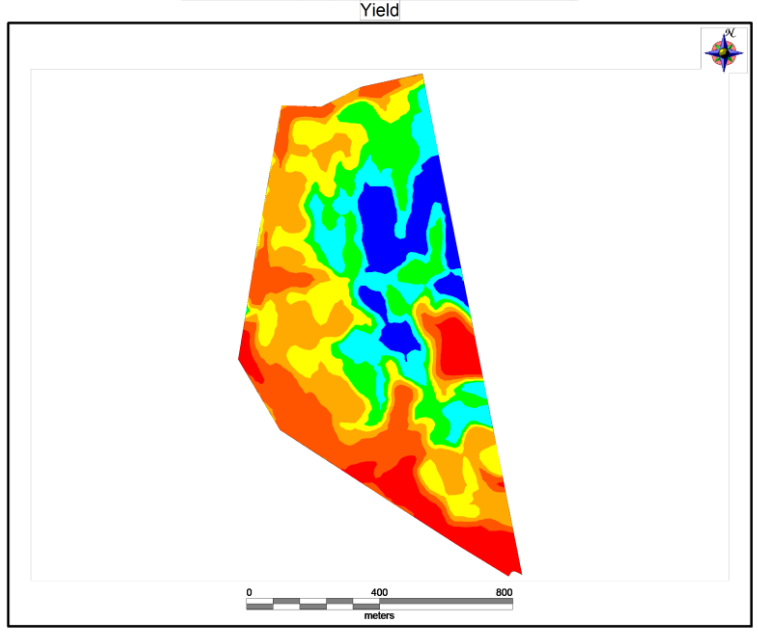
Strong correlation between yield and NDVI, strong year on year correlation of NDVI
(look at data summarised to 2ha grid correlation > 0.7 for 2024 NDVI and yield)

Variable yield = variable gross margin

Paddock	Avg yield	Cost	Sale	GM
	ba/ha	$/ha	$/bale	$/ha
House Mahogany	3.14	1707	600	$197*
Yard East Buffel	1.7	1707	600	-$685.37*
Yard East Jarra	2.37	1707	600	-$51*

*Based on Cotton Production budget – assumed all areas received all applications.

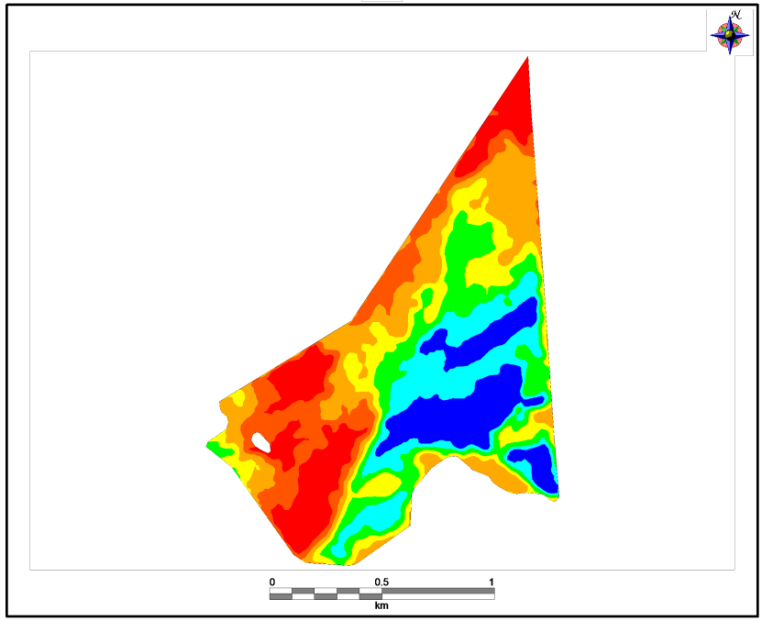
House Mahogany - 2024 Cotton: Harvesting
Yield



Client: Black Bull Station
Farm: Black Bull Station
Paddock: House Mahogany
Crop: 2024 Cotton
Name: housemahogany_gmanalysis
Type: Harvesting
Date: 5/03/2025
Harvest: 0.000 bale
Min: -1707 $/ha
Max: 1814 $/ha
Avg: 197 $/ha

1501 - 1814 $/ha	170 pts.
1001 - 1500 $/ha	6088 pts.
801 - 1000 $/ha	3925 pts.
601 - 800 $/ha	9552 pts.
401 - 600 $/ha	5262 pts.
201 - 400 $/ha	9382 pts.
1 - 200 $/ha	3702 pts.
-499 - 0 $/ha	8729 pts.
-1707 - -500 $/ha	9481 pts.

Yard East Buffel - 2024 Cotton: Harvesting
Yield



Client: Black Bull Station
Farm: Black Bull Station
Paddock: Yard East Buffel
Crop: 2024 Cotton
Name: yardeastbuffel_gmanalysis
Type: Harvesting
Date: 5/03/2025
Harvest: 0.000 bale
Min: -1668.00 $/ha
Max: 1274.00 $/ha
Avg: -685.37 $/ha

1000.01 - 1274.00 $/ha	67 pts.
800.01 - 1000.00 $/ha	73 pts.
600.01 - 800.00 $/ha	269 pts.
400.01 - 600.00 $/ha	2916 pts.
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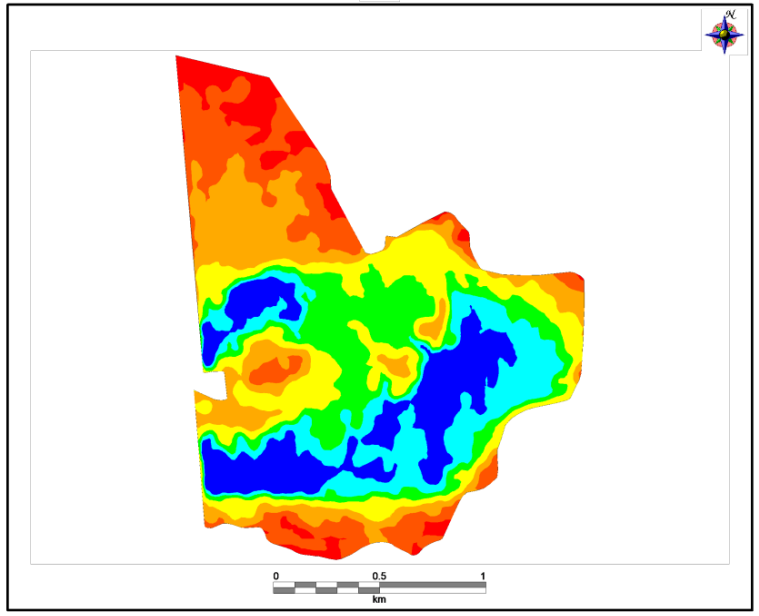
-999.99 - -500.00 $/ha	25202 pts.
-1499.99 - -1000.00 $/ha	31420 pts.
-1668.00 - -1500.00 $/ha	15908 pts.

Yard East Jarra - 2024 Cotton: Harvesting
Yield

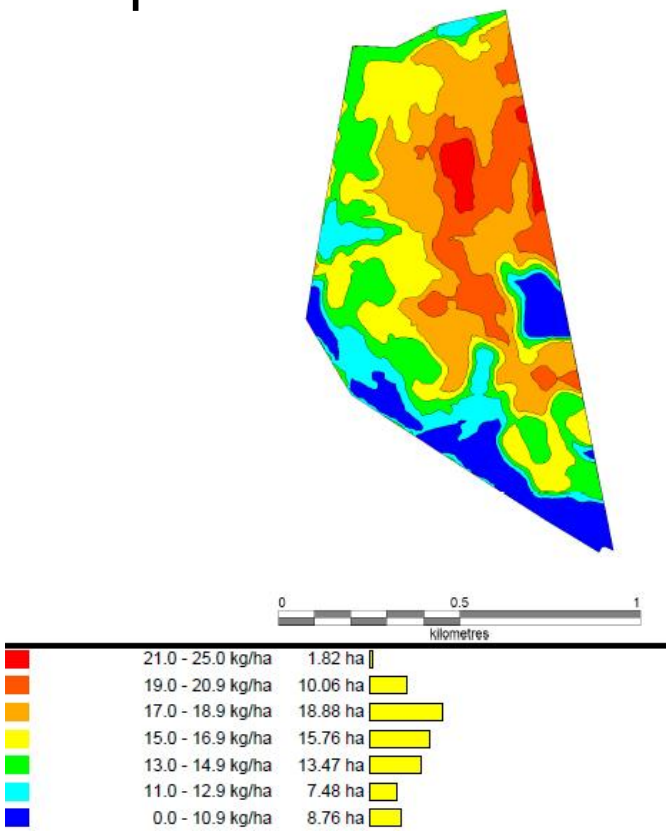


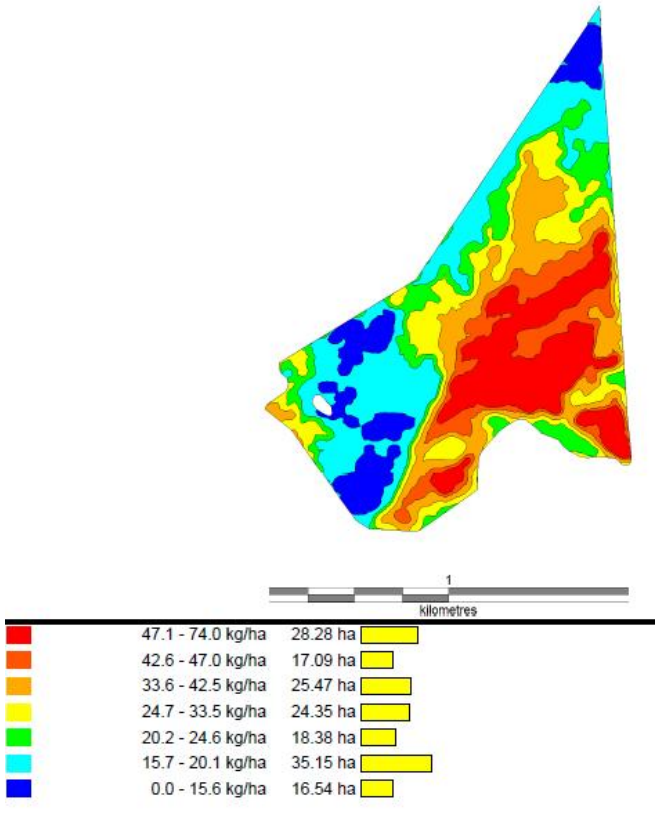
Client: Black Bull Station
Farm: Black Bull Station
Paddock: Yard East Jarra
Crop: 2024 Cotton
Name: yardeastjarra_gmanalysis
Type: Harvesting
Date: 5/03/2025
Harvest: 0.000 bale
Min: -1707 $/ha
Max: 1826 $/ha
Avg: -51 $/ha

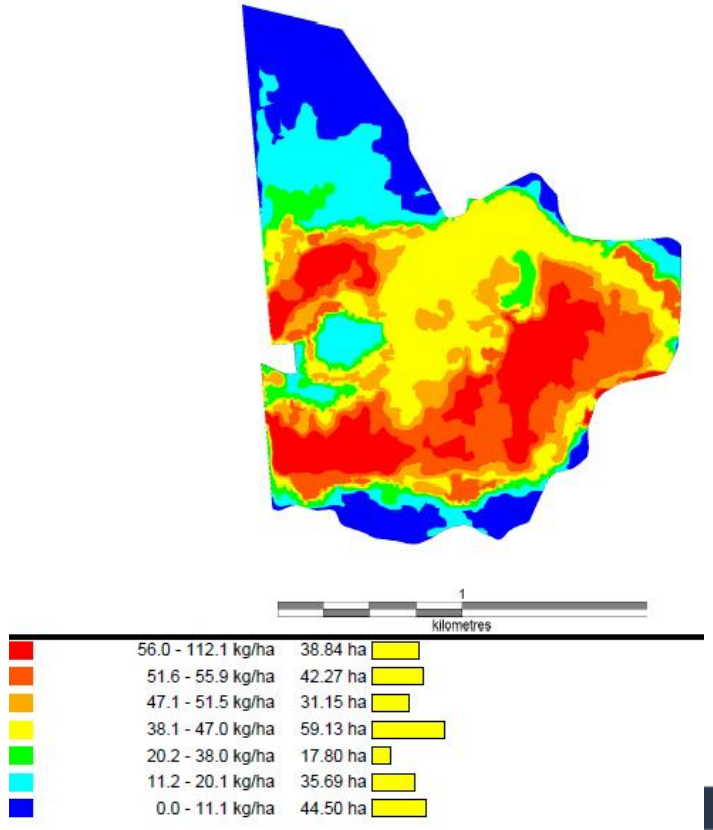
1601 - 1826 $/ha	169 pts.
1401 - 1600 $/ha	360 pts.
1201 - 1400 $/ha	2020 pts.
1001 - 1200 $/ha	3794 pts.
801 - 1000 $/ha	9042 pts.
601 - 800 $/ha	20245 pts.
401 - 600 $/ha	22572 pts.
201 - 400 $/ha	14517 pts.
1 - 200 $/ha	14747 pts.
-499 - 0 $/ha	26061 pts.
-1499 - -500 $/ha	50501 pts.
-1707 - -1500 $/ha	25338 pts.

Variable yield = variable nutrient export

- Nutrients applied 2023/24
  - 150 kg/ha Cotton Sustain (9.2 kg/ha N, 18 kg/ha P, 34 kg/ha K)
  - Urea
- Phosphorus

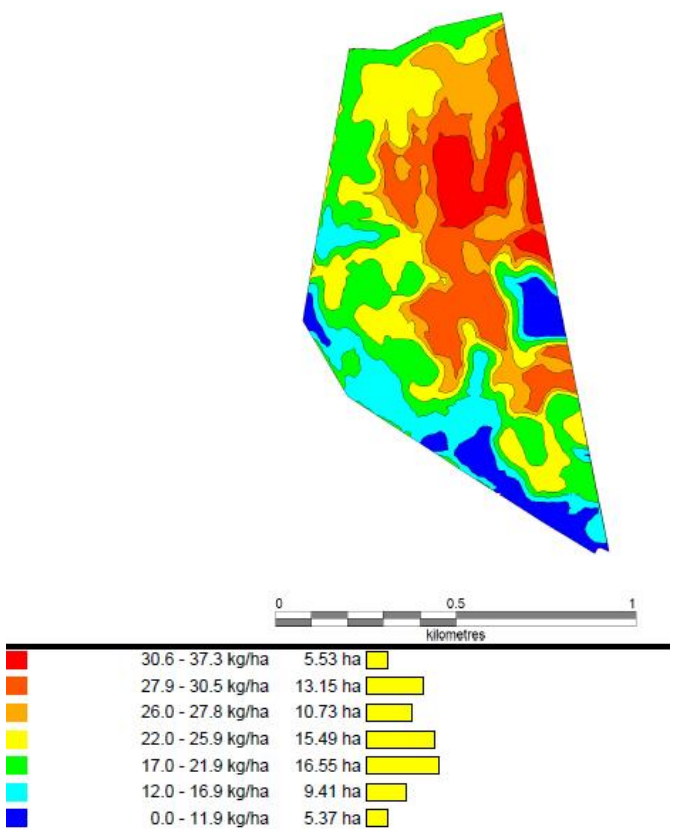


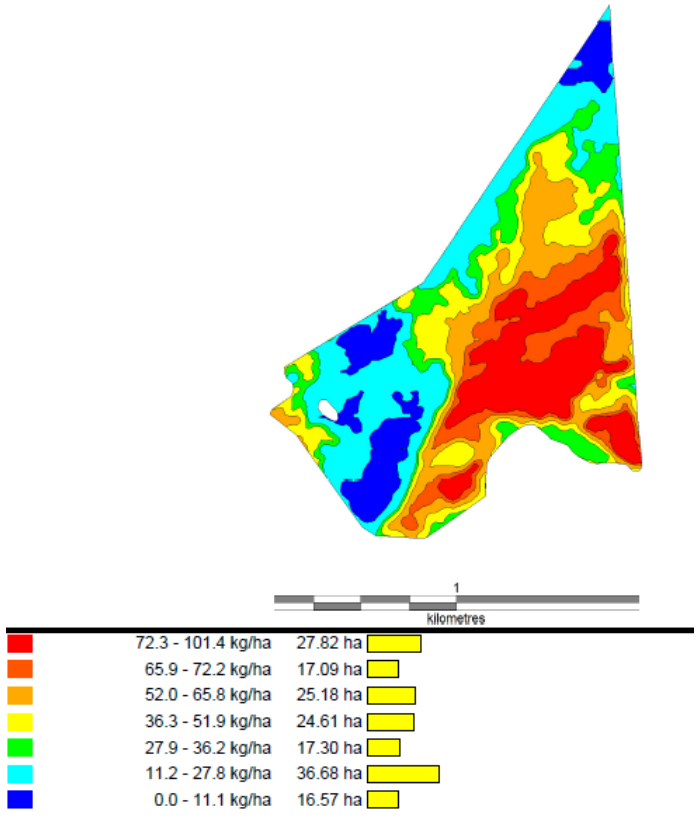


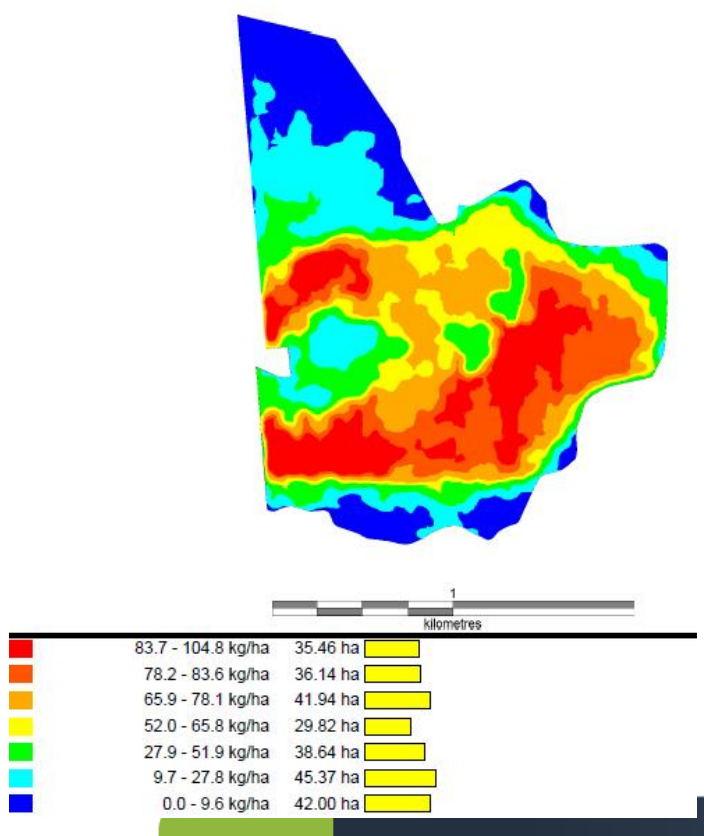


Variable yield = variable nutrient export

- Nutrients applied 2023/24
  - 150 kg/ha Cotton Sustain (9.2 kg/ha N, 18 kg/ha P, 34 kg/ha K)
  - Urea
- Potassium



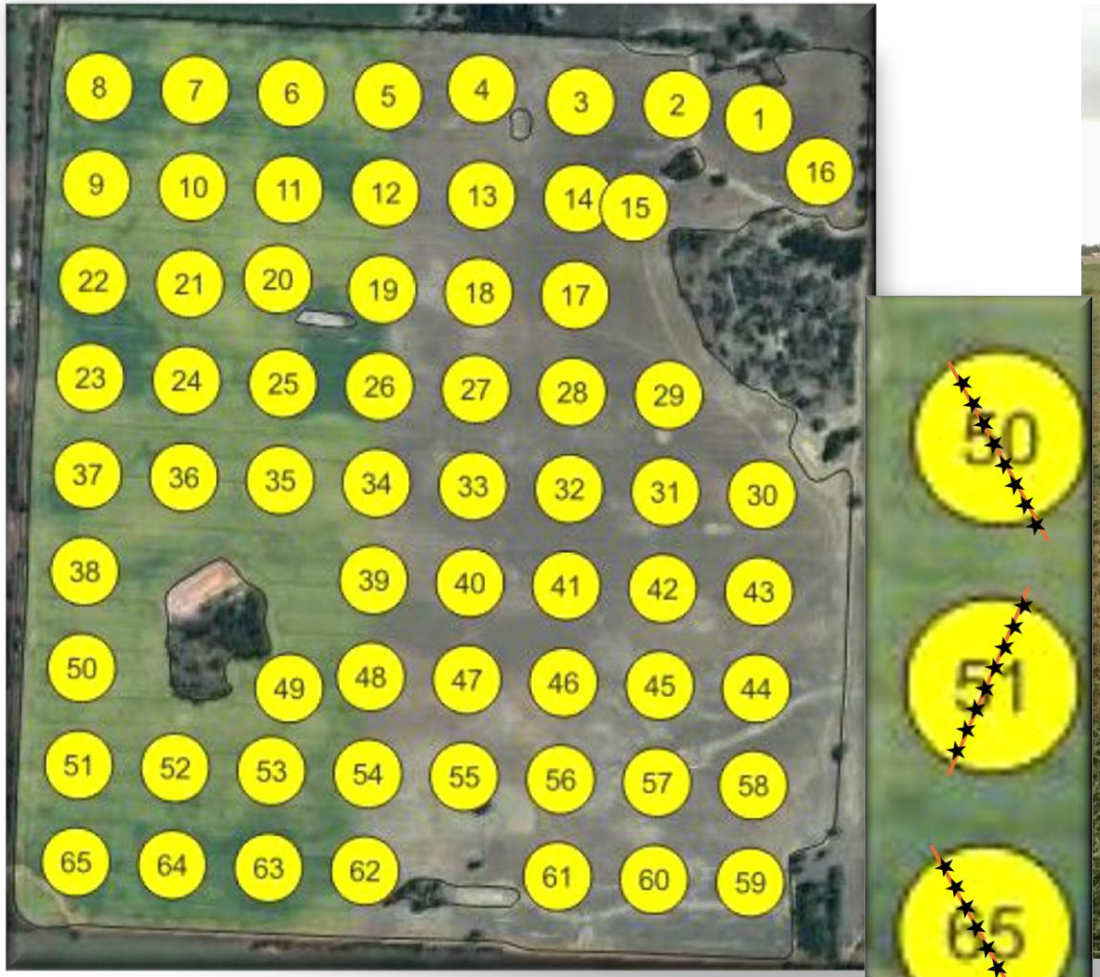


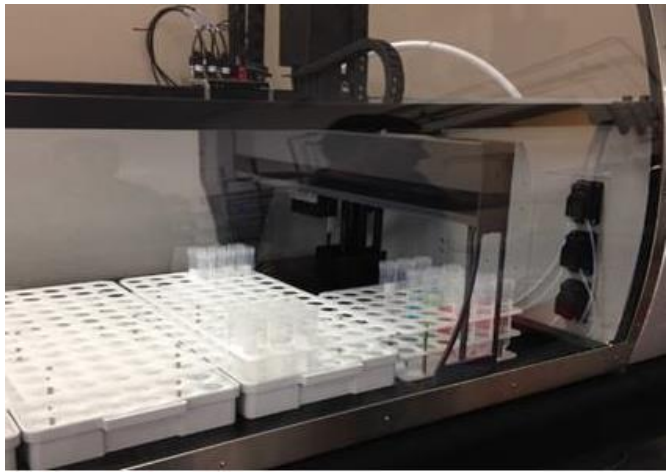


Soil characteristics

- Grid soil sampling was used to map soil variability
- 2 ha grid, 0-10cm soil samples
- Analysis included
  - pH_{CaCl_2},
  - Exchangeable Cations (Ca, Mg, K, Na),
  - Colwell P
- Selected samples were analysed for a complete soil analysis which included
  - Micro-nutrients (Cu, Bo, Fe, Mn, Zn)
  - Electrical conductivity, chloride
  - Organic Carbon
  - Soil texture and colour

Grid soil sampling to measure topsoil variability





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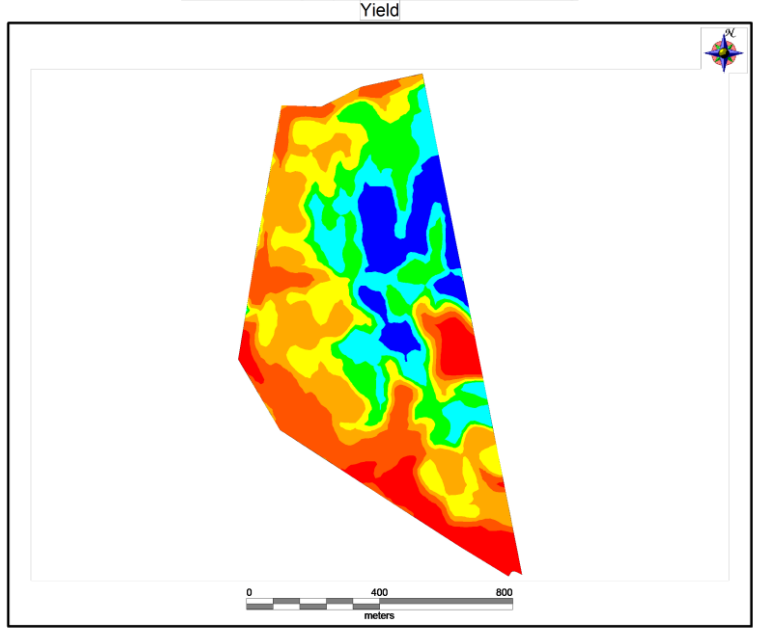

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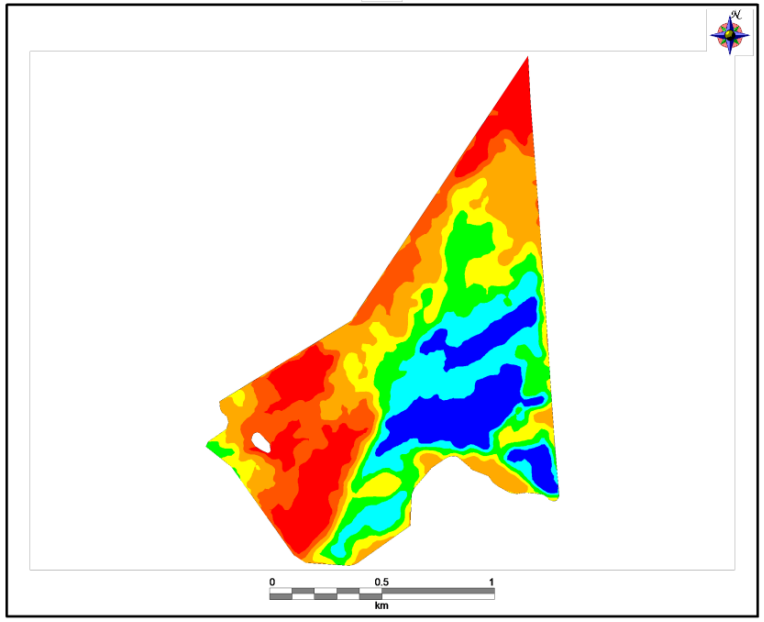
Yield



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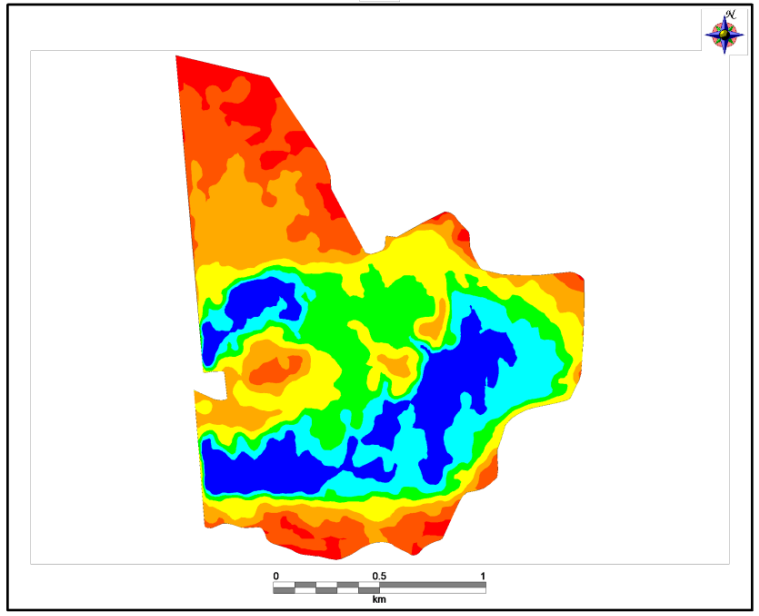
Yard East Jarra - 2024 Cotton: Harvesting
Yield



Client: Black Bull Station
Farm: Black Bull Station
Paddock: Yard East Jarra
Crop: 2024 Cotton
Name: yardeastjarra_gmanalysis
Type: Harvesting
Date: 5/03/2025
Harvest: 0.000 bale
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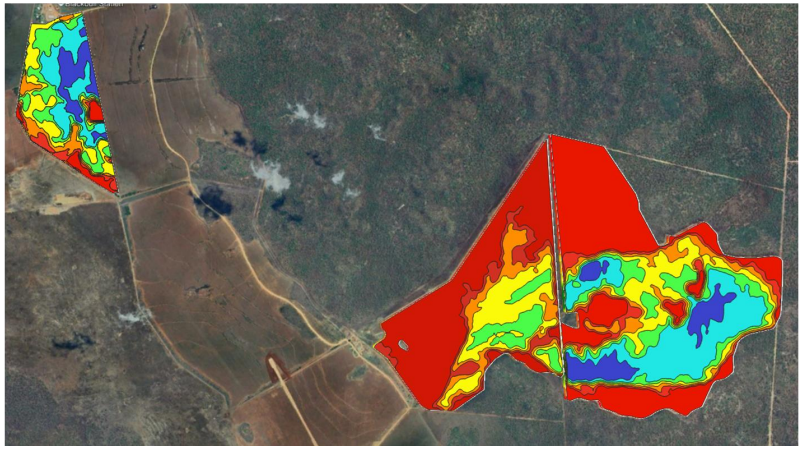
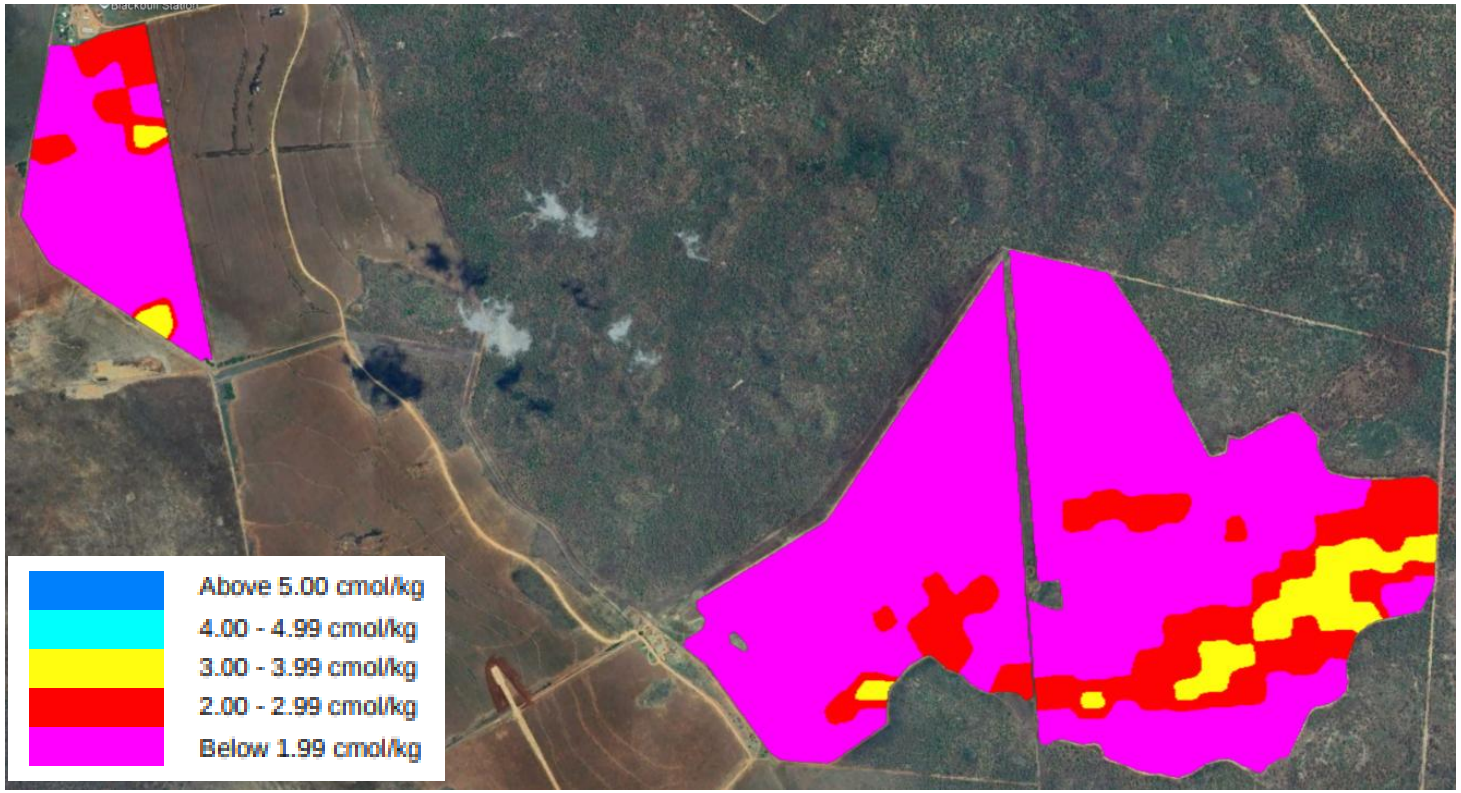
  - Soil texture and colour

Cation Exchange Capacity (CEC)



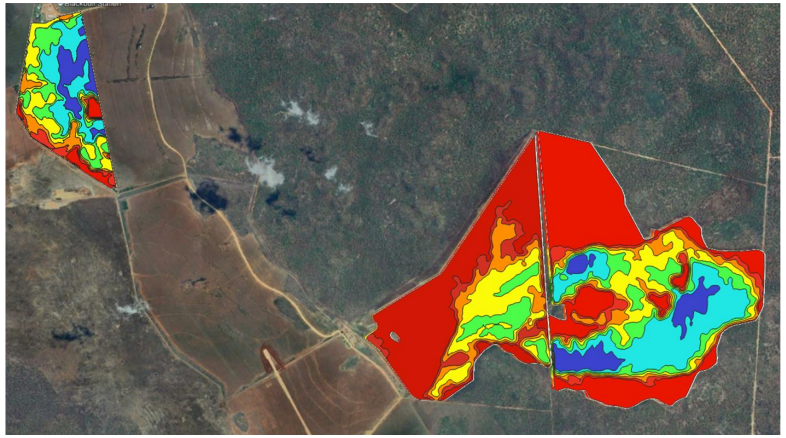
- Overall, CEC is low (< 4 cmol+/kg)
- Indicative of soil texture (sandy), capacity of soil to hold provide nutrients, buffer changes in soil pH
- While low, the higher CEC soils generally correlated to higher yield and NDVI
- CEC is highly correlated with both Ca and Mg levels (these were the dominant base cations)



- Correlation between CEC and yield (on 2ha grid)

Paddock	Avg yield	CEC:Yield	Overall CEC:Yield
	ba/ha	correlation	correlation
House Mahogany	3.1	0.27	0.74
Yard East Buffel	1.7	0.72	
Yard East Jarra	2.4	0.81	

Colwell Phosphorus (P)



- Generally low (majority < 20 mg/kg)
- Critical level for cotton = 25 mg/kg

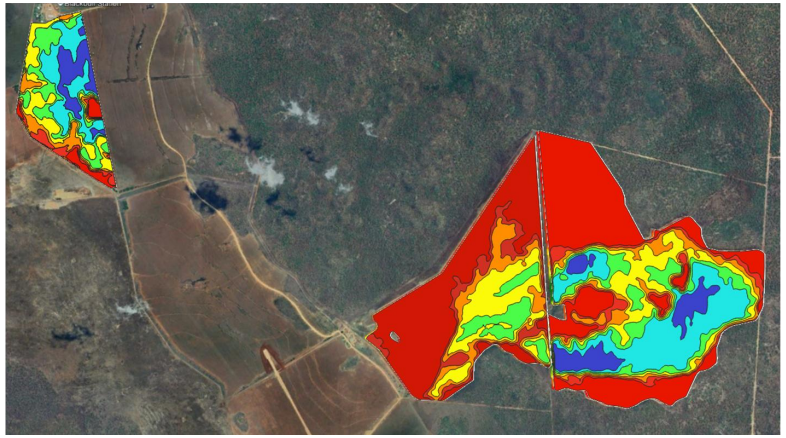
- Correlation to CEC (soil texture))

Paddock	Avg yield	CEC:P	Overall CEC:P
	ba/ha	correlation	correlation
House Mahogany	3.1	-0.01	0.17
Yard East Buffel	1.7	0.32	
Yard East Jarra	2.4	0.07	

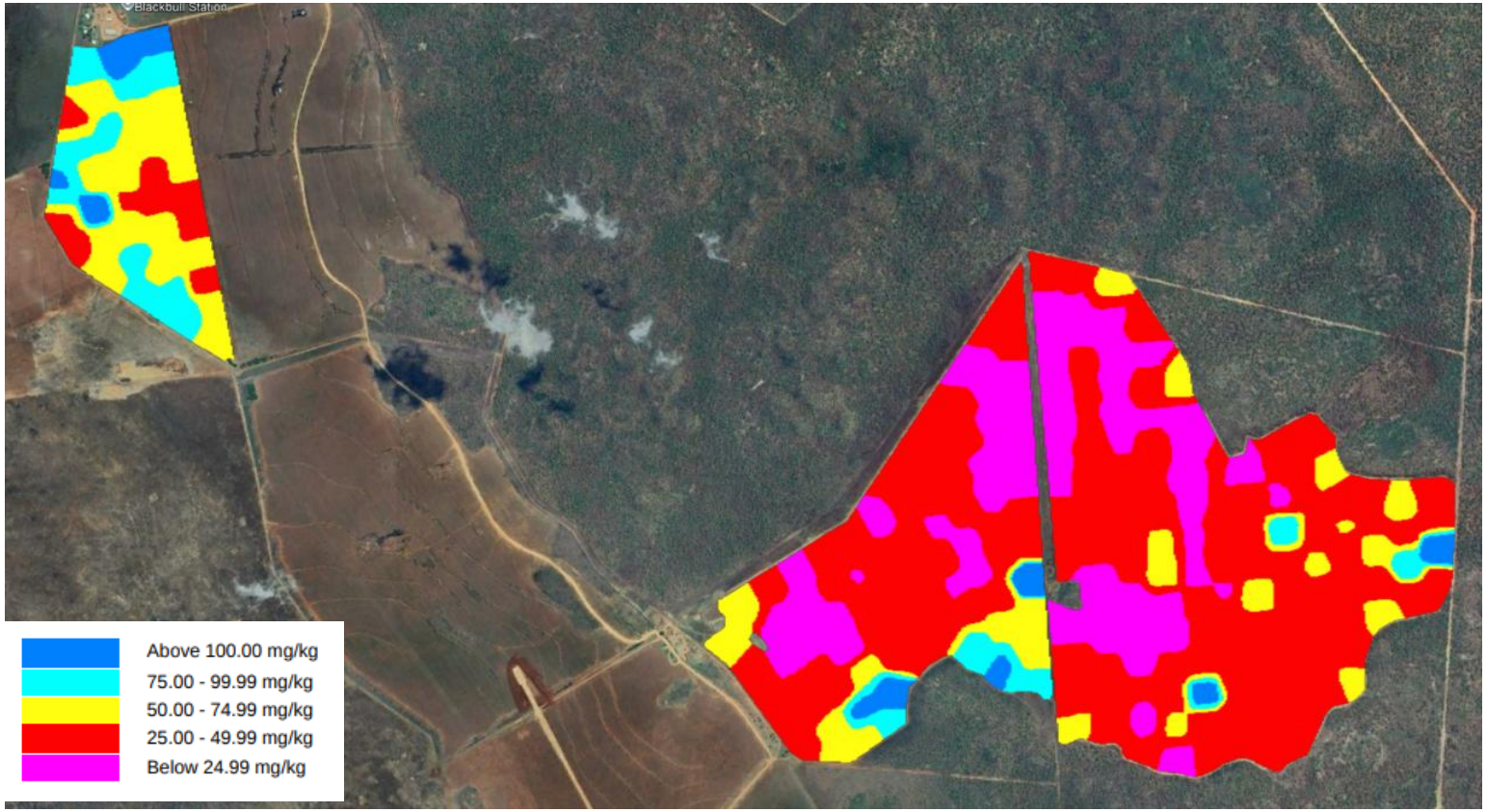
- Correlation to yield

Paddock	Avg yield	P:Yield	Overall P:Yield
	ba/ha	correlation	correlation
House Mahogany	3.1	-0.26	0.02
Yard East Buffel	1.7	0.26	
Yard East Jarra	2.4	-0.04	

Potassium (K)



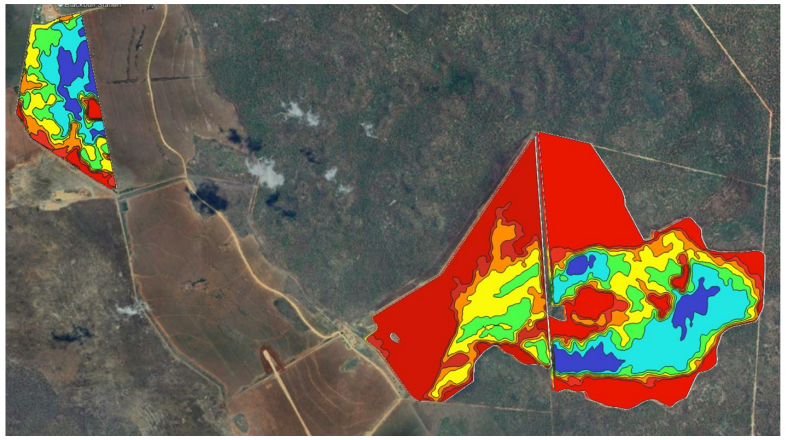
- Overall it is low (majority < 100 mg/kg)
- Critical level for cotton = 120 mg/kg
- Correlation to CEC (soil texture))



Paddock	Avg yield	CEC:K	Overall CEC:K
	ba/ha	correlation	correlation
House Mahogany	3.1	0.66	0.39
Yard East Buffel	1.7	0.67	
Yard East Jarra	2.4	0.39	

Paddock	Avg yield	K:Yield	Overall K:Yield
	ba/ha	correlation	correlation
House Mahogany	3.1	0.06	0.21
Yard East Buffel	1.7	0.31	
Yard East Jarra	2.4	0.21	

$pH_{(CaCl2)}$

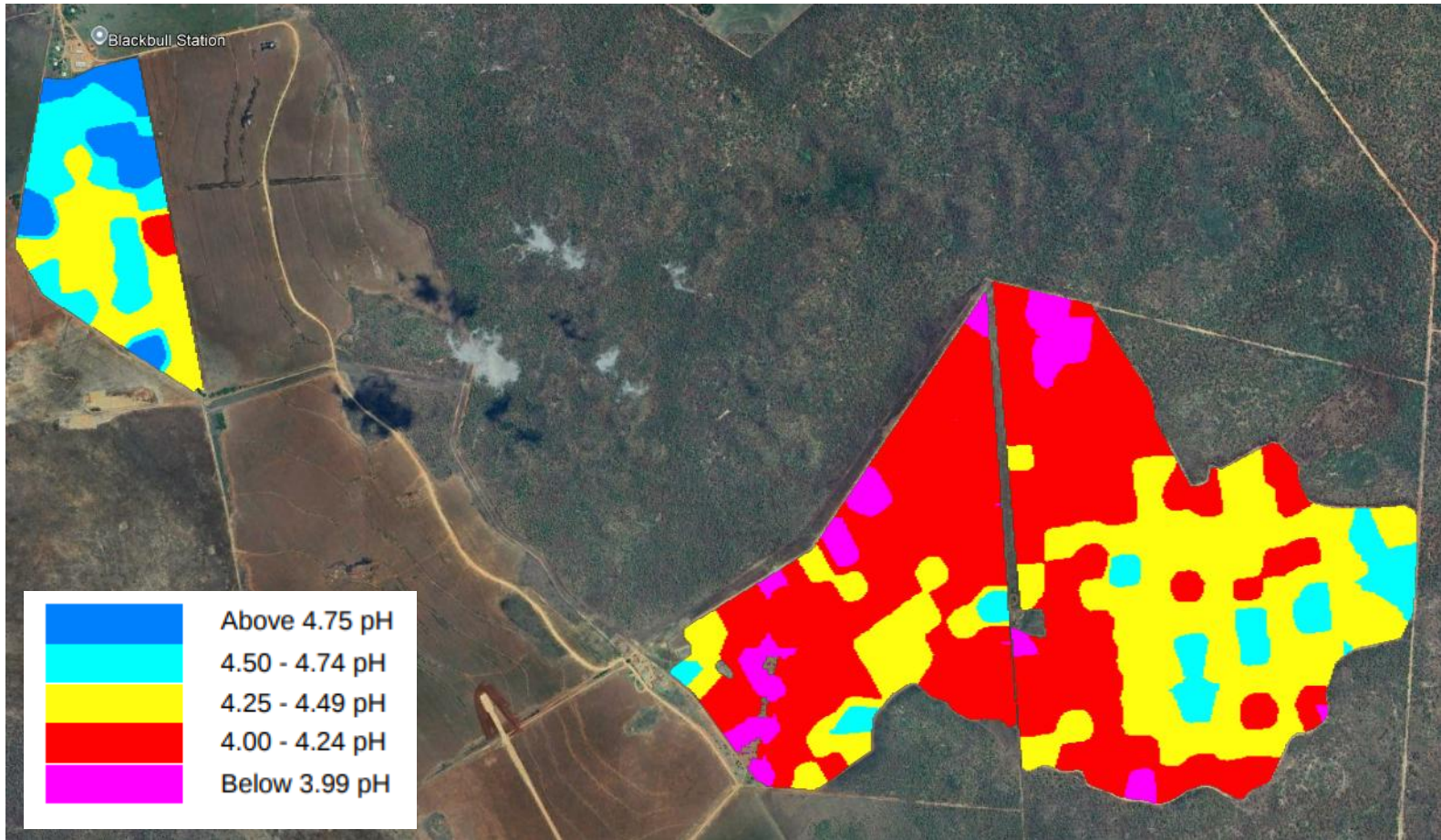


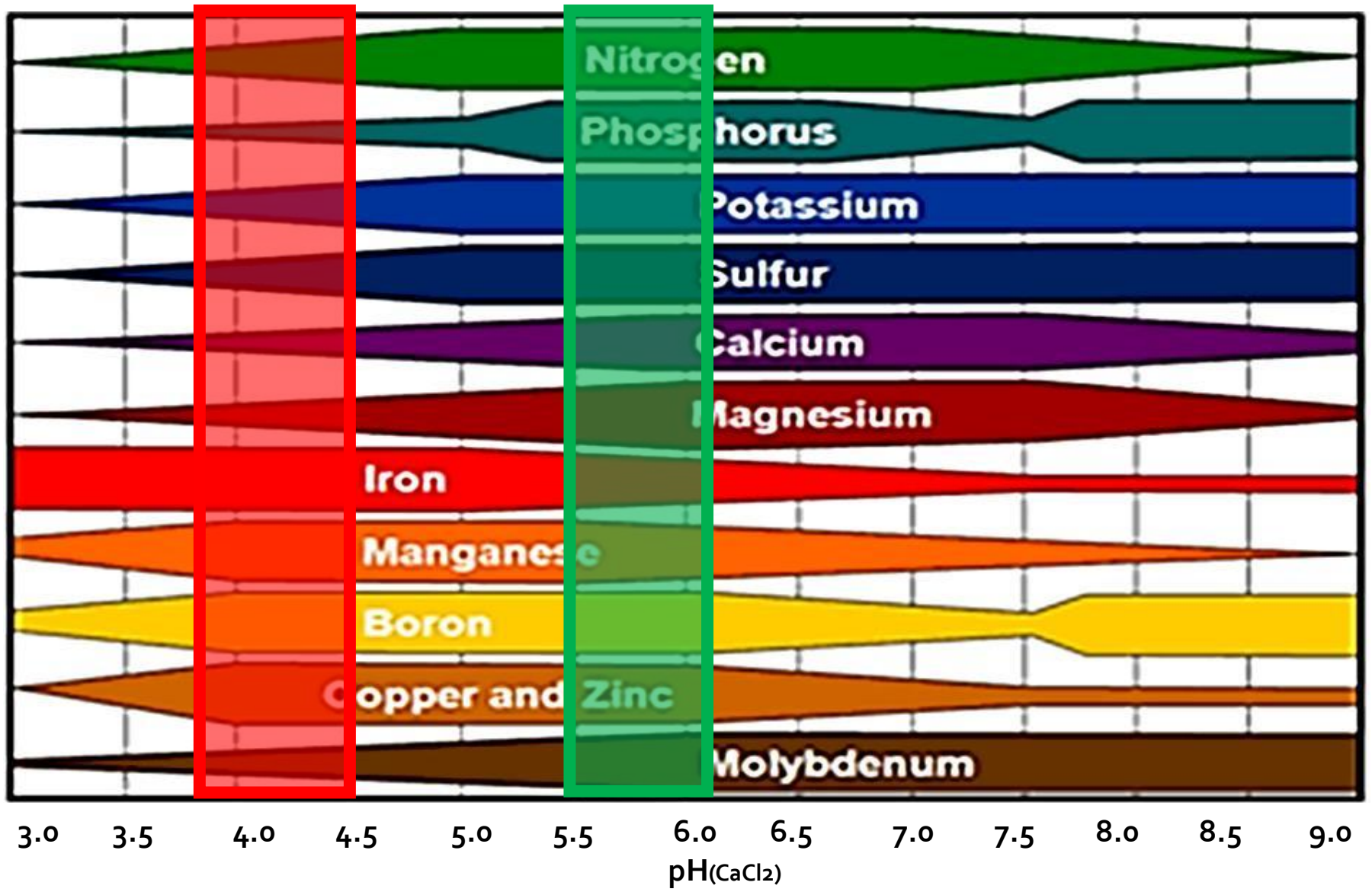
- Overall it is low (majority < 5.2)
- Red and purple areas, pH will be affecting nutrient availability, crop growth
- Correlation to CEC (soil texture))

Paddock	Avg yield	CEC:pH	Overall CEC:pH
	ba/ha	correlation	correlation
House Mahogany	3.1	0.80	0.78
Yard East Buffel	1.7	0.78	
Yard East Jarra	2.4	0.80	

- Correlation to yield

Paddock	Avg yield	pH:Yield	Overall pH :Yield
	ba/ha	correlation	correlation
House Mahogany	3.1	0.40	0.55
Yard East Buffel	1.7	0.55	
Yard East Jarra	2.4	0.61	





Black Bull pH

Optimum pH

Soil pH influences plant growth by affecting nutrient availability, microbial activity, and toxicity of certain elements. A pH in CaCl just below neutral neutral (around 5.5-6.5) promotes optimal nutrient uptake, while extreme pH values can lead to deficiencies or toxicities.

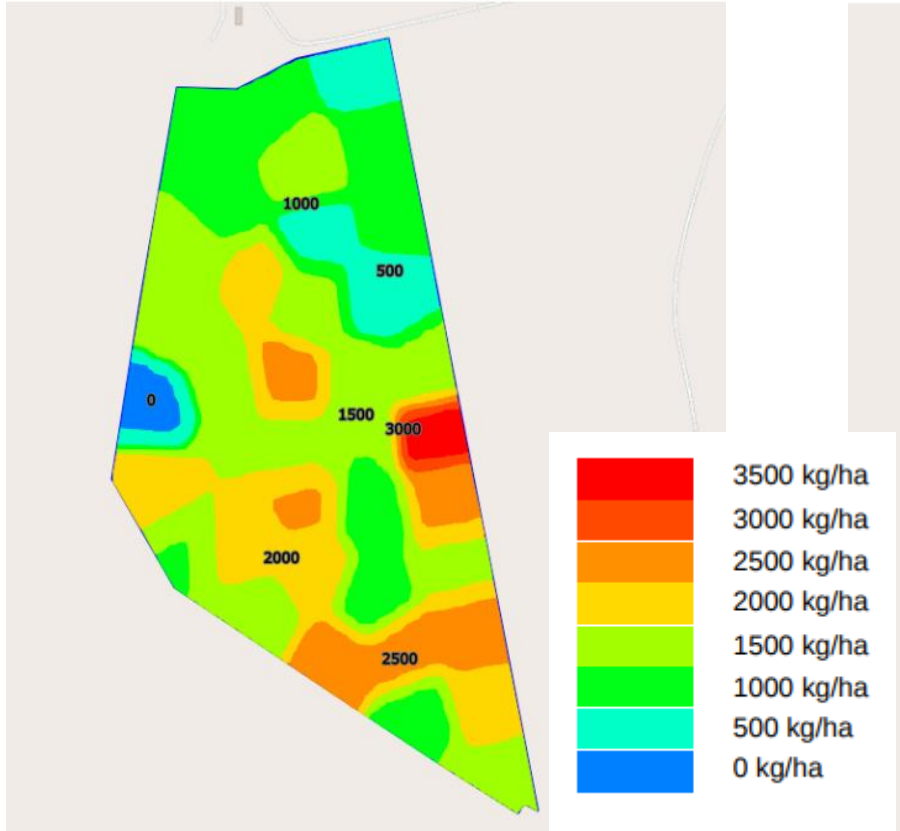
Acidic soils Can make phosphorus, calcium, and magnesium less available, while increasing the solubility of potentially toxic elements like aluminium and manganese.

VR Soil Amelioration

Paddock	Avg Rate	Max Rate	Costs (Lime/Dolomite at $150/t) VR Mapping -$40/ha			
			Blanket at 2.5t/ha	VR	Saving	Total Saving
	t/ha	t/ha	$/ha	$/ha	$/ha	$
House Mahogany	1.41	3	$375	$251.50	$123.50	$9,374
Yard East Buffel	2.01	3.5	$375	$341.50	$24.50	$4,033
Yard East Jarra	1.76	3.5	$375	$304	$71	$19,078

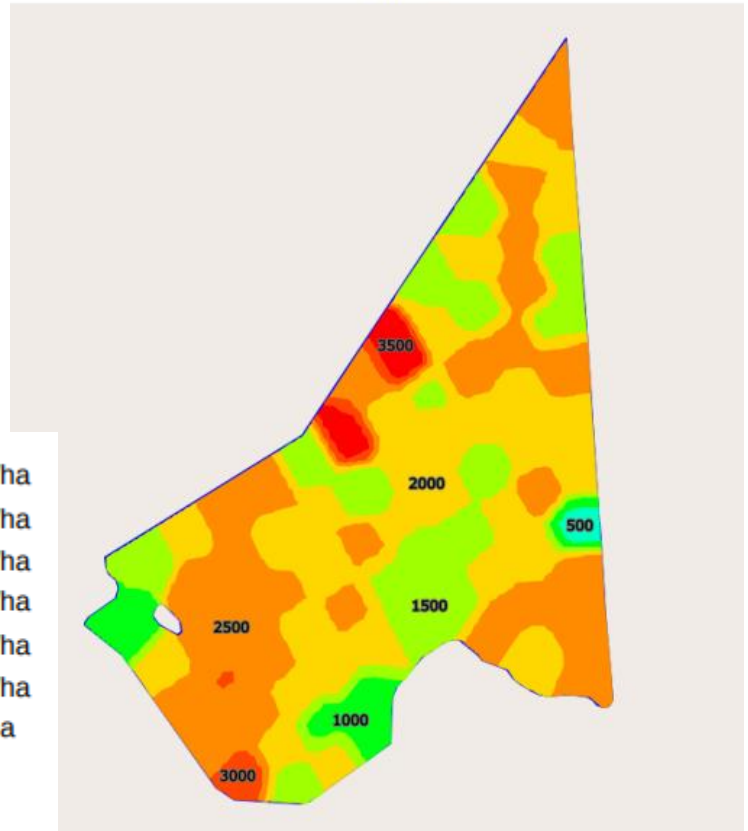
House Mahogany: Lime pH Target 5.2

Lime



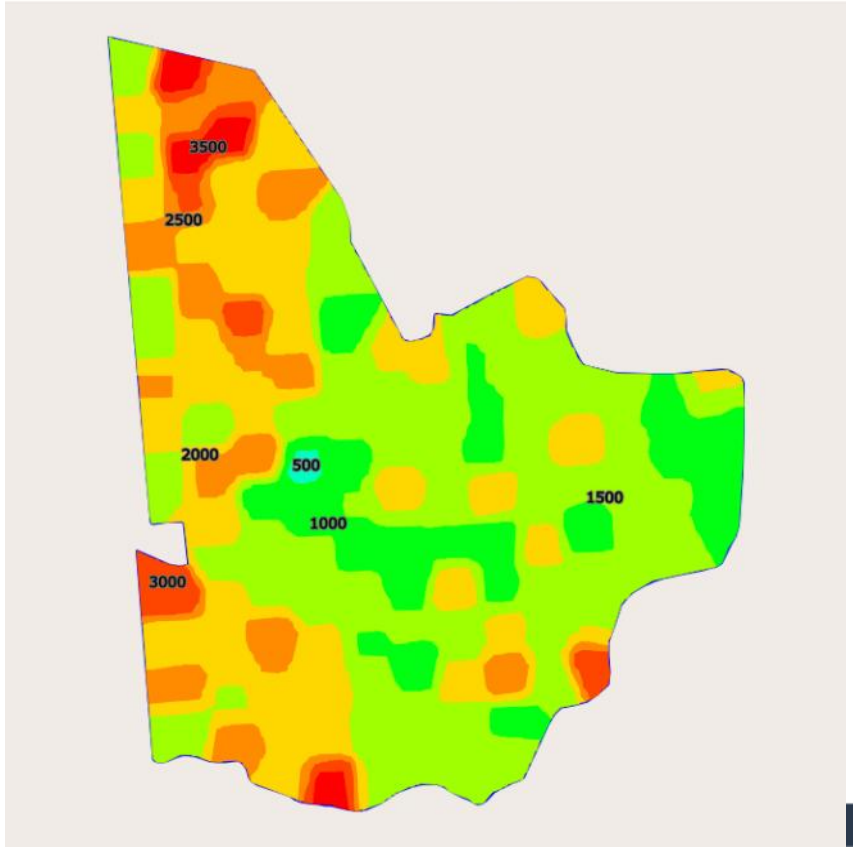
Yard East Buffel: Lime pH Target 5.2

Lime



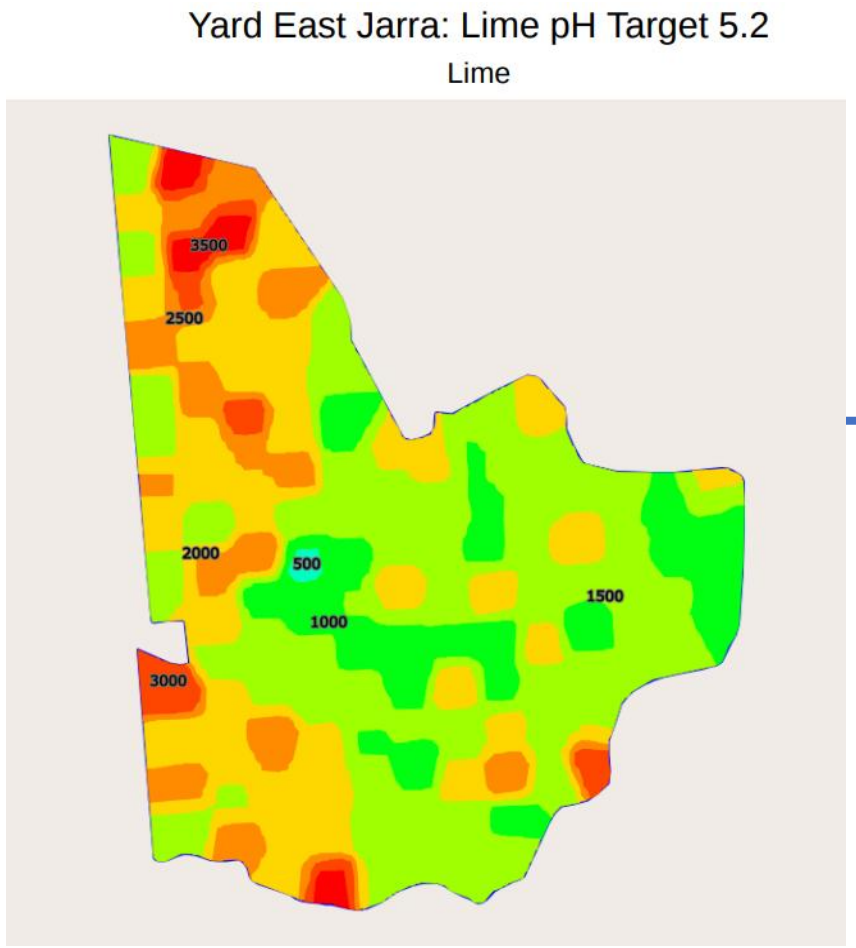
Yard East Jarra: Lime pH Target 5.2

Lime



Next Step - Implementation of VR strategies

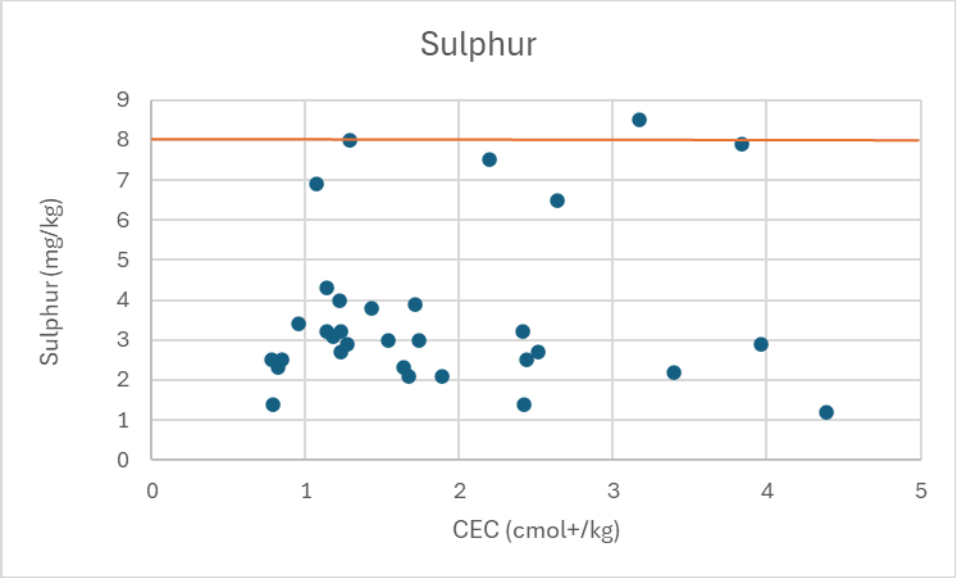
Automated generation of VR file to suit screen type

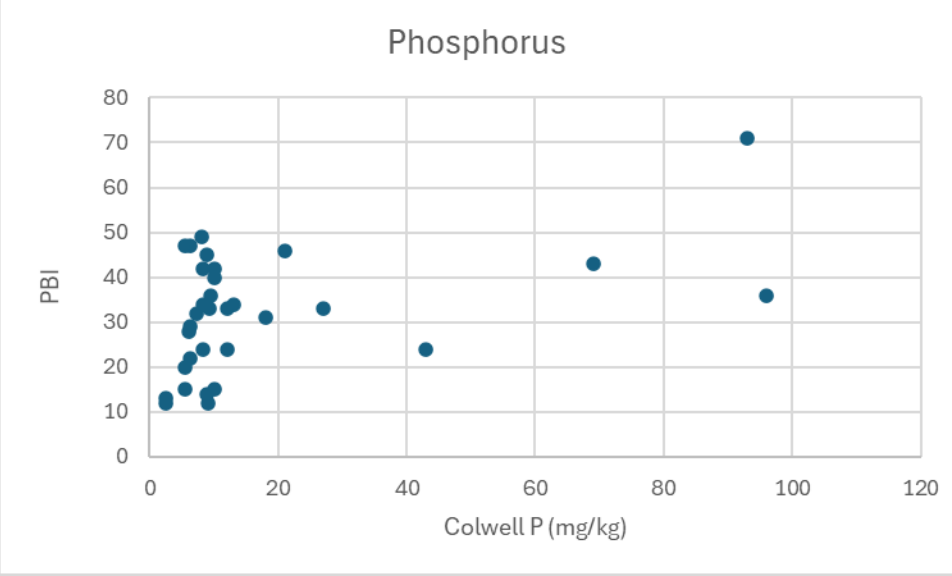


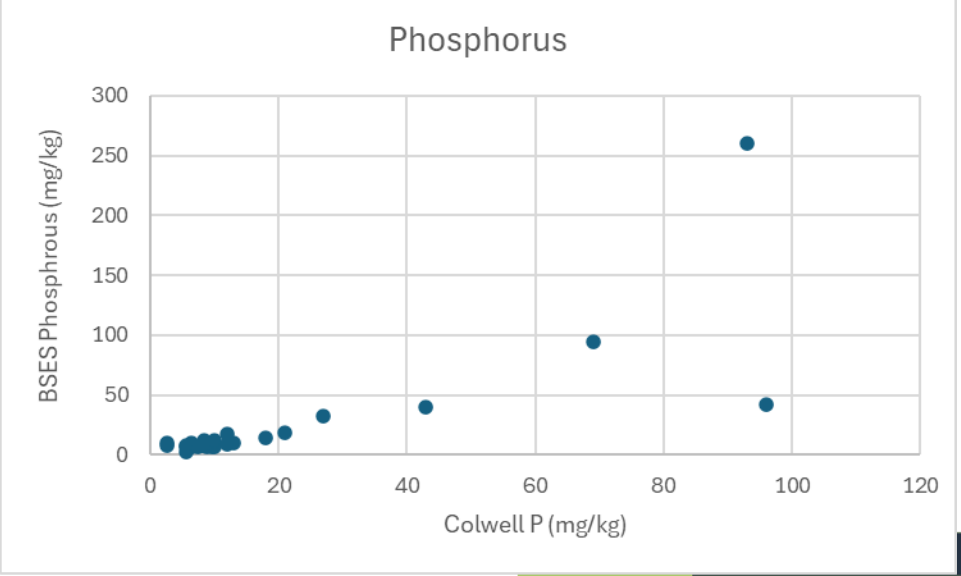
Other soil characteristics

Sulphur and Phosphorus

- Majority Colwell P below 20 mg/kg
- Strong relationship between Colwell and BSES P



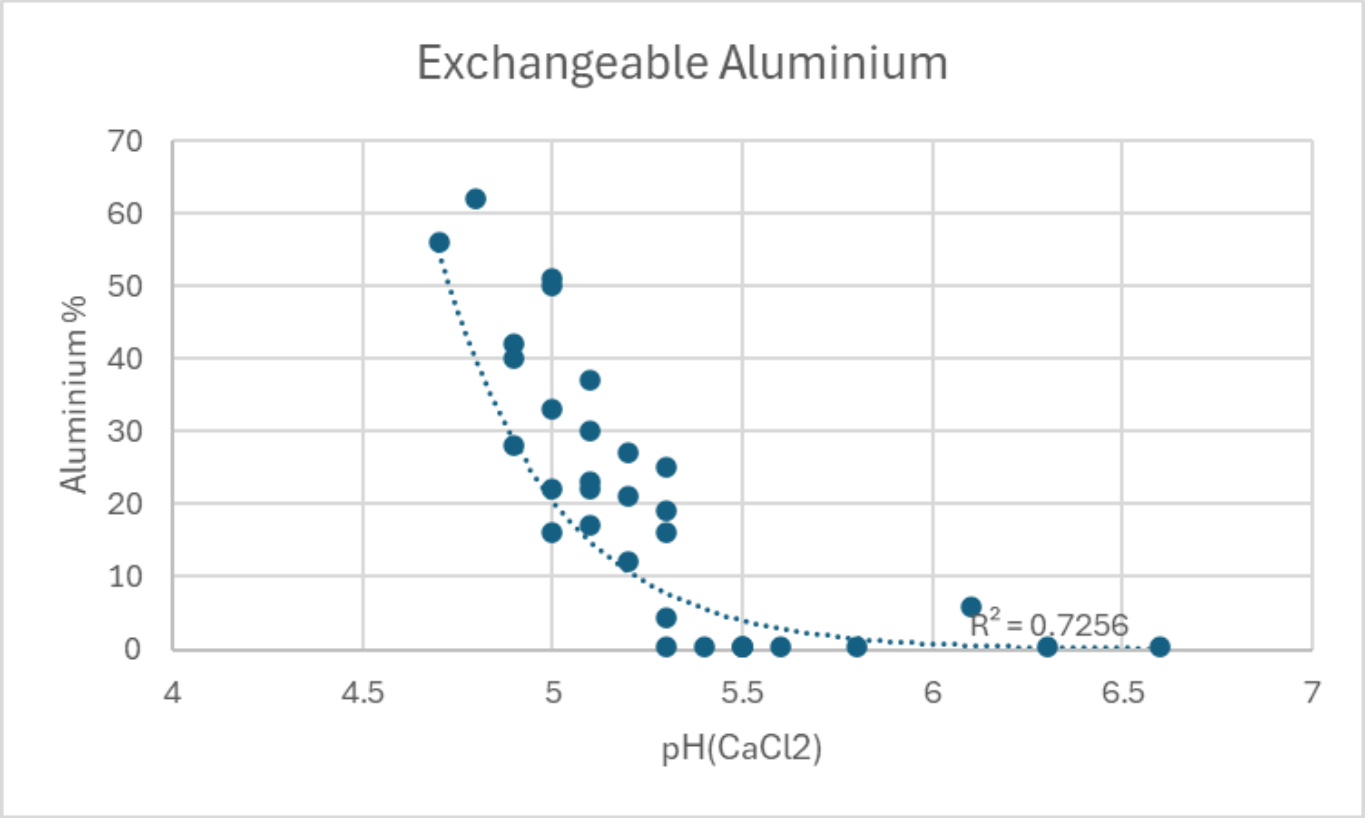


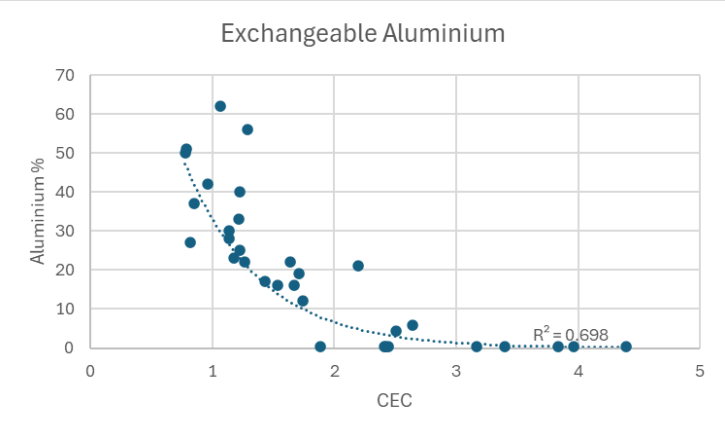


Other soil characteristics

Aluminium %

- Significantly affects crop production
- Ideally < 15%
- Strongly affected by pH
- Also correlated to CEC but more due to effect CEC on Al than anything else

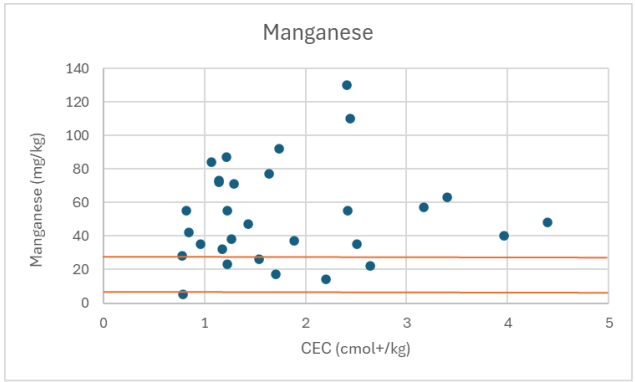


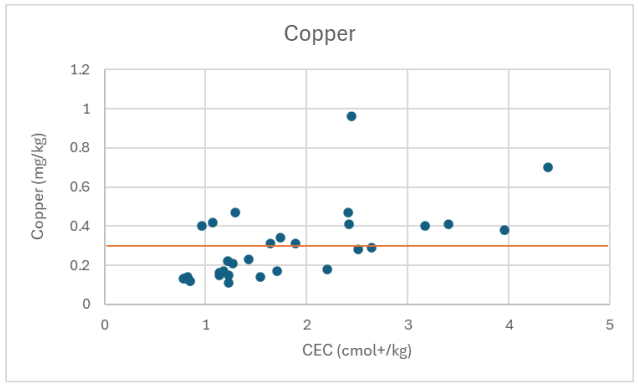


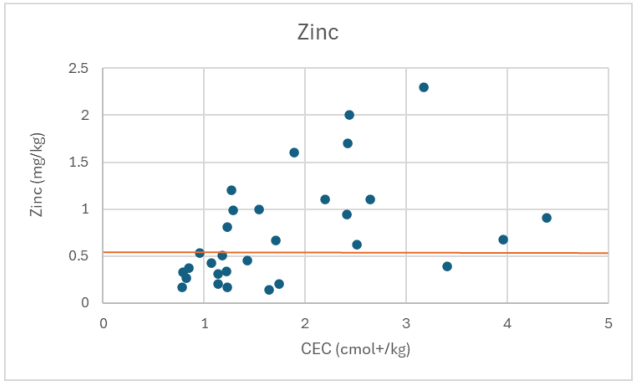
Other soil characteristics

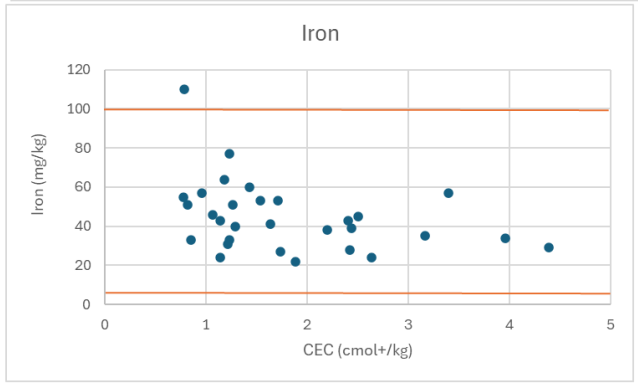
Micro-nutrients

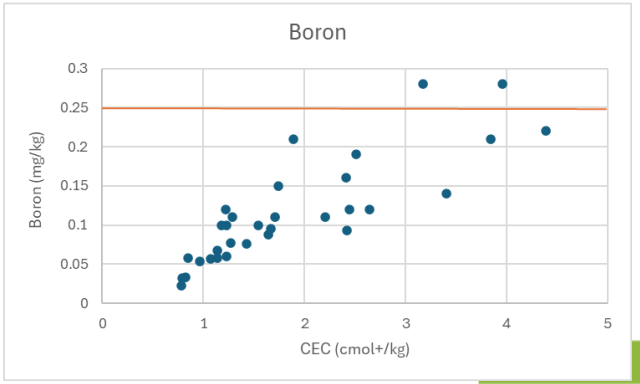
- Soil tests are an indicator for micro-nutrients (tissue testing more reliable)
- Zinc, Copper and Boron levels significant number samples below minimum critical value
- Manganese, significant points above optimum range.





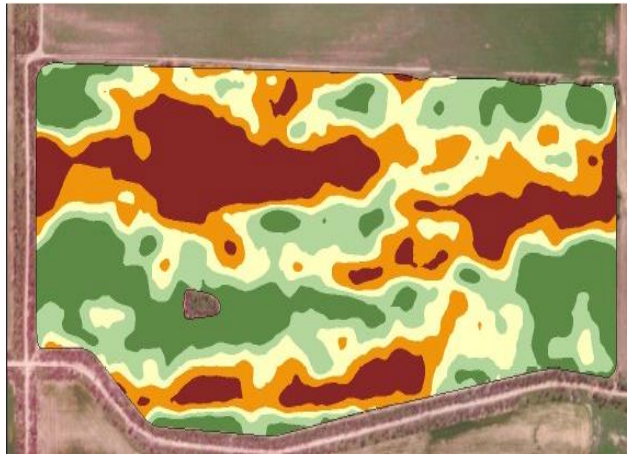






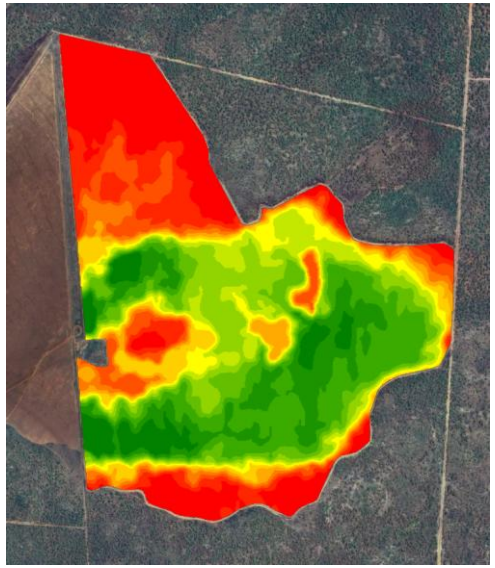
A gamma radiometrics overview

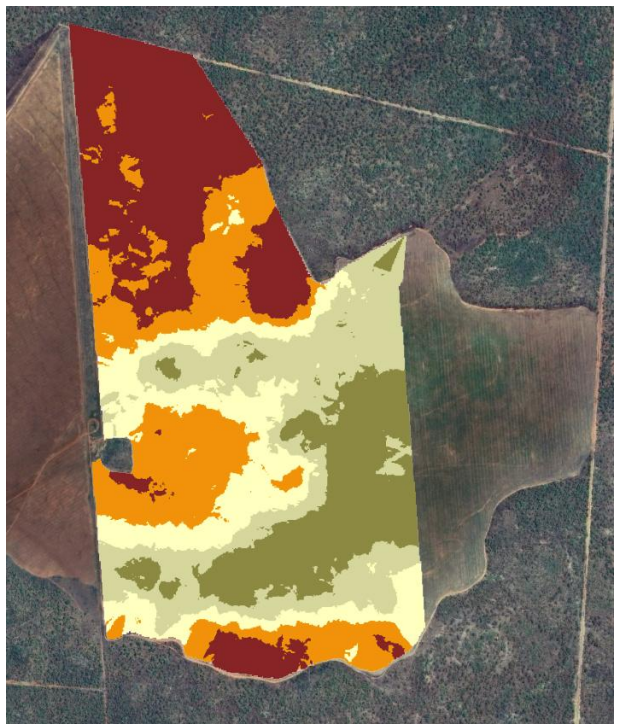
- Gamma radiometric surveys are a useful tool for mapping and identifying soil type and landscape changes
- Gamma radiometric surveys measure a type of high-energy radiation that is spontaneously emitted by potassium K, uranium U and thorium Th radioelements contained in the soil.
- Benefits include:
  - Gamma radiometrics can be particularly useful in shallow soils or where large amounts of gravel prevent the effective use of soil conductivity mapping devices like the EM38.
- Limitations:
  - Gamma radiometric data is best considered as part of a process, rather than a complete solution, for soil mapping and management. The factors can interact in ways that make interpretation challenging. For example, a wet clay and a highly weathered sand may give the same results.

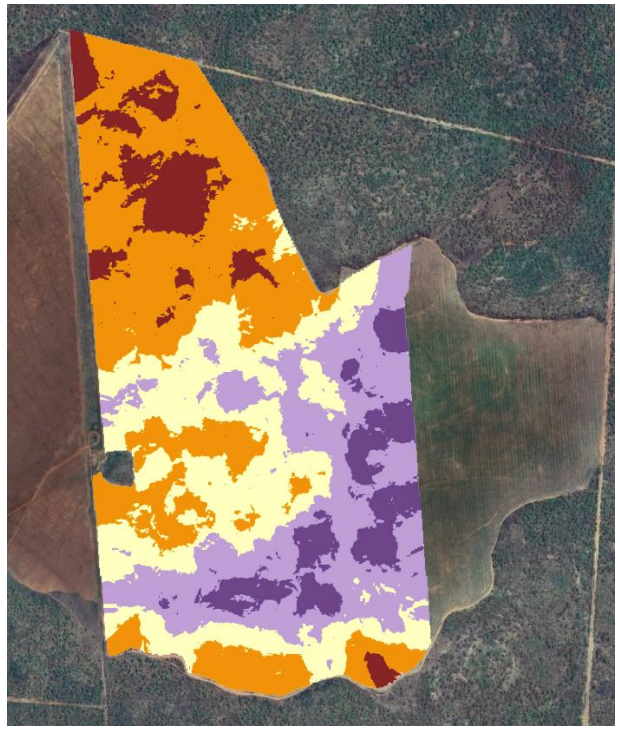


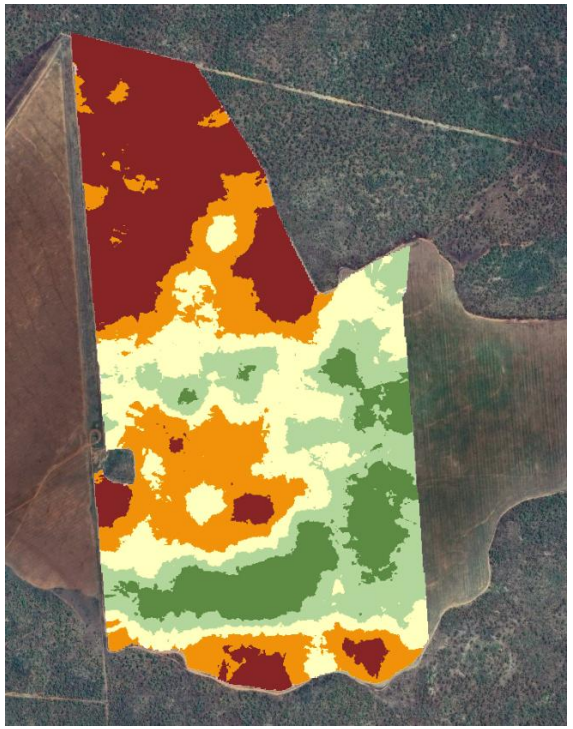
Gamma

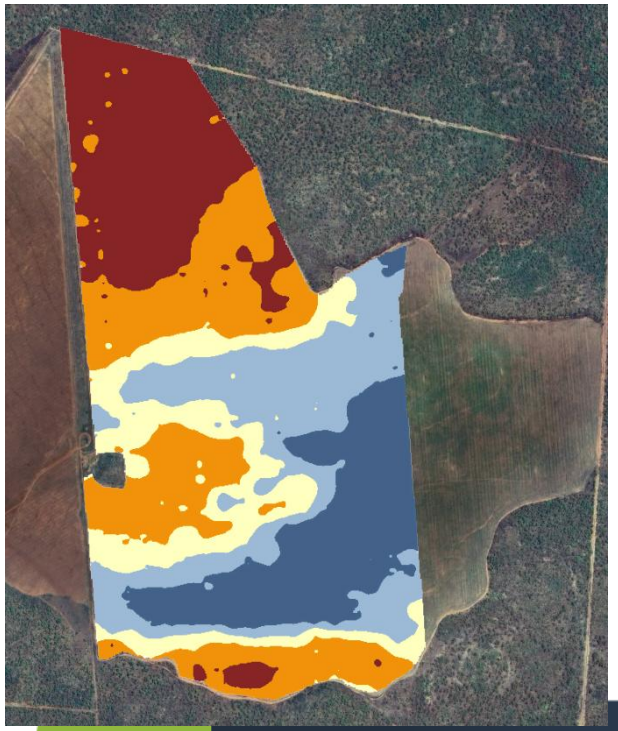
- Consistent readings between three different layers (correlation > 0.9)
- Highlights low production areas (correlation with yield >0.8)
- Good correlation to yield and also CEC (correlation =0.83) and pH (correlation (0.70)
- No correlation to Colwell P or exchangeable K





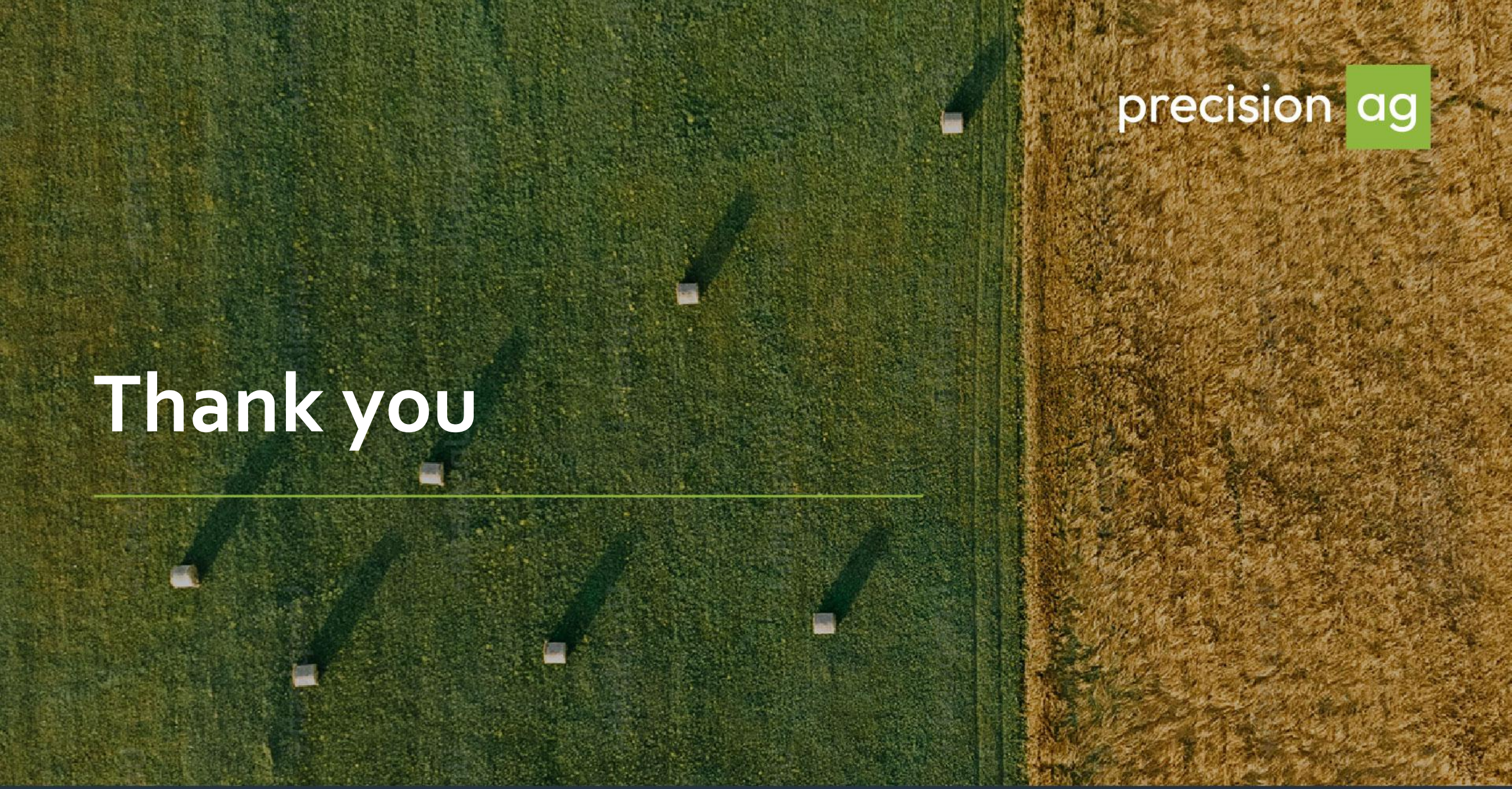






Summary

- Low CEC light textured soils.
- Significant variability in the soils which was identified through the grid soil mapping.
- Similar to what we see in other areas surface soil properties, particularly P doesn't necessarily follow soil textural/type changes
- Soil acidity and potassium appear to be most significant constraints and would benefit from a VR strategy.
- Gamma radiometrics appeared to map well to NDVI and yield variability as well as soil CEC and pH properties. Highlights potential of the tool for mapping surface soil variability, but need larger dataset across range NT soils to validate this.



Thank you

precision ag