SFS

Southern Farming Systems

Soil Organic Carbon

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Our questions

1. What are the benefits of soil carbon? and What are the different water holding capacity under different soil carbon levels?
2. Able to measure and monitor soil carbon.
3. Understanding what you can achieve. What's the potential for my rainfall, soil type and topography? What's economical?
4. What are the different carbon levels under different management?

Benefits?

Production benefits

- Nutrient cycling
- Water infiltration and storage
- Plant growth & quality

Soil organisms – 'functional carbon'!

Increased cation exchange capacity (CEC)
SOC = 25 to 90% of CEC (depends on soil type, management, soil pH, OM type)

Nutrient reservoir
~1% increase in SOC in 0-10cm loam soil =
1080 kg N
228 kg P
168 kg S

Increased water holding capacity
1% increase in SOC = 20-30% extra WHC for sandy loam
10% extra in WHC for clay loam

1% change sounds easy: hard to do

- 1% change in SOC in 0-10cm with a soil of bulk density 1.3 g/cm^3, means the required change is 13 tonnes C per hectare.

- Organic matter (OM) contains 58% organic carbon, so 13t C/ha is equivalent to adding 22.4 t/ha of OM.
- Microbes eat <u>90%</u> of OM and <u>10%</u> remains to contribute to the C pool.
- Therefore we need to grow 224 t OM/ha of both roots and shoots.
- In pasture, the ratio is 40% shoots, 60% roots, so have to grow 90 t OM/ha above and 134 t OM/ha below.
- Typical pasture production 10 t DM/ha/year.
- An increase of pasture growth by 4 t DM/ha/year, would take 22.5 years to change organic C by 1%.

Soil moisture benefits – Fast Facts

- Soil organic carbon acts like a sponge, holds in 4 times its weight sandy soil, about 2 times in a clayey soil.

- An increase in 1% SOC in sandy soil = 5.6mm stored moisture 0-10cm (about an extra 5 L/m^2), but not all available.
- Most SOC is in topsoil or top 30cm (≈60%), not going to have much of an affect in subsoil
- The more clay you have, the less change in water holding capacity.

- As a rule each additional mm (where water limited), can produce an extra 20kg grain/ha, annual pasture 30 kg DM/ha, lucerne 12kg DM/ha
- In a good rainfall year, you may not benefit from an extra 5mm stored.
- In a wet year (1 every 10 yrs), maybe you could “soak up” more rain and reduce length of waterlogging or delay its onset.
- In a dry spring finish (1 every 10 years), pasture could hang on a bit longer (maybe a week?)

Essential functions of soil carbon

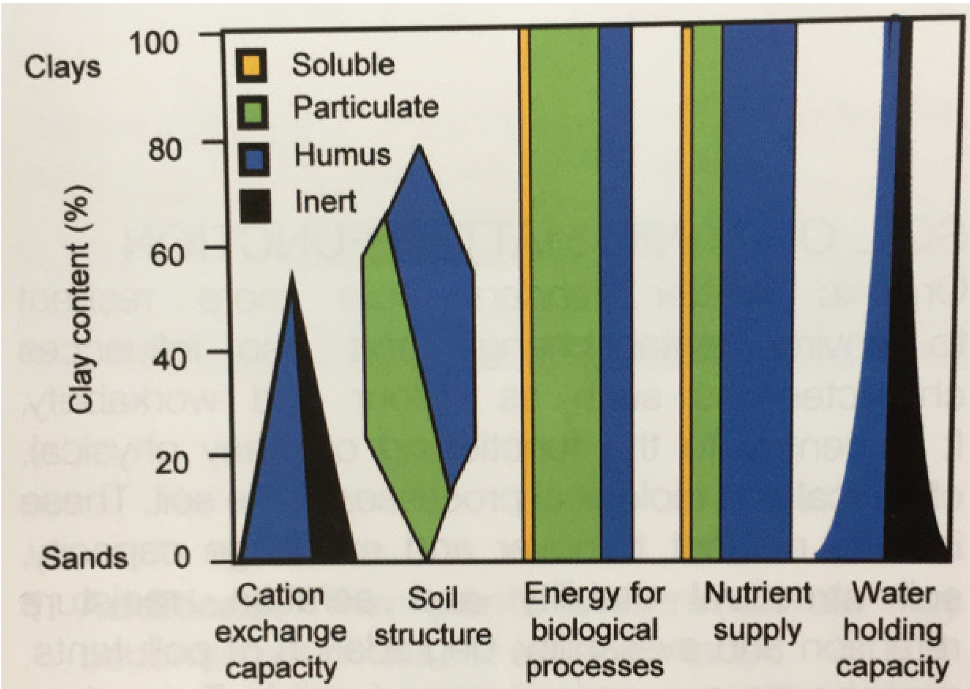


Figure 1.5 A conceptual representation of the role of soluble, particulate, humus and resistant (inert) organic matter fractions for a range of soil functions (from Hoyle et al. 2011).

- **Turnover time**
- Soluble – root exudates rapid (minutes to days)
- Particulate – fresh decomposing OM, 53um to < 2mm in size, (months to decades)
- Humus <53 micron. More resistant to breakdown (tens to hundreds year)
- Inert - Resistant to breakdown (hundreds to thousands years)

Building soil carbon bank

Deposits

Pastures

Stubble

Cover crops

Nutrients

Manure

Composts etc

Withdrawals

Decomposition

Erosion

Increasing biomass through good agronomy, grazing and residue management increases…

- Productivity AND
- Supply of organic matter

Therefore building SOC

Make more deposits each year than withdrawals

Evidence of changes we can achieve

SCARP Vic plains
69 t/ha SO & CH &
76 t/ha VE in 30cm

Nutrition & Grazing management

Management	Region (NSW)	C seq rate (t C/ha/yr 0-30cm)	Years	Reference
Pastures - NSW				
Liming	Riverina	0.46 to 0.55	18	Chan et al 2011
Nutrient management	Southern Tablelands	0.41	>25	Chan et al 2010; Orgill et al 2014; Orgill et al 2017
Rotational grazing	Southern Tablelands	0.35	>25	Chan et al 2010
Grazing management	Southern Tablelands & Western Division	1.04 to 1.46	>5	Orgill et al 2016; Orgill et al 2017
Nutrient mgmt & inc stocking rate (*60cm)	Southern Tablelands	0.60*	20	Coonan et al 2019
Organic amendments	Central West	1.09 to 2.47	5	Badgery et al 2020
Pastures - Australia meta-analysis				
Nutrient management		0.29	dns	Sanderman et al 2010
Irrigation		0.11		Sanderman et al 2010
Introduced perennial pastures		0.50	dns	Gifford et al 1992
Cultivated crop to pasture		0.50 to 0.70	22	Young et al 2009; Chan et al 2011; Conyers et al 2015
Min till crop to pasture		0.78 to 1.33	5	Badgery et al 2020

Pastures in rotation & crop, nutrient & residue management

Management	Region (NSW)	C seq rate (t C/ha/yr 0-30cm)	Years	Reference
Crop to pasture - NSW				
Cultivated crop to pasture	North West & Riverina	0.50 to 0.70	22	Young et al 2009; Chan et al 2011; Conyers et al 2015
Min till crop to pasture	Central West	0.78 to 1.33	5	Badgery et al 2020
Crop to pasture - Australia meta-analysis				
Nutrient mgmt, legumes, irrigation (30cm+)		0.30 to 0.60	dns	Sanderman et al 2010
Crop with pasture in rotation - NSW				
Pasture rotations	Riverina	0.22 to 0.40	>13	Chan et al 2011; Helyar et al 1997
No till wheat with 2 yr pasture rotation	Riverina	0.26	25	Chan et al 2011
Crop rotation with 2-6 yr pasture rotation	Riverina	0.23	18	Helyar et al 1997
Crop with nutrients - NSW				
Nutrients + stubble & incorp (*160cm)	South West Slopes	1.10*	5	Kirkby et al 2016
Organic amendments + direct drill crop	Central West	0.32 to 0.64	5	Badgery et al 2020

There are multiple strategies to build SOC




Pastures

- Grazing management
- Legumes and nutrients from microbes

Crops

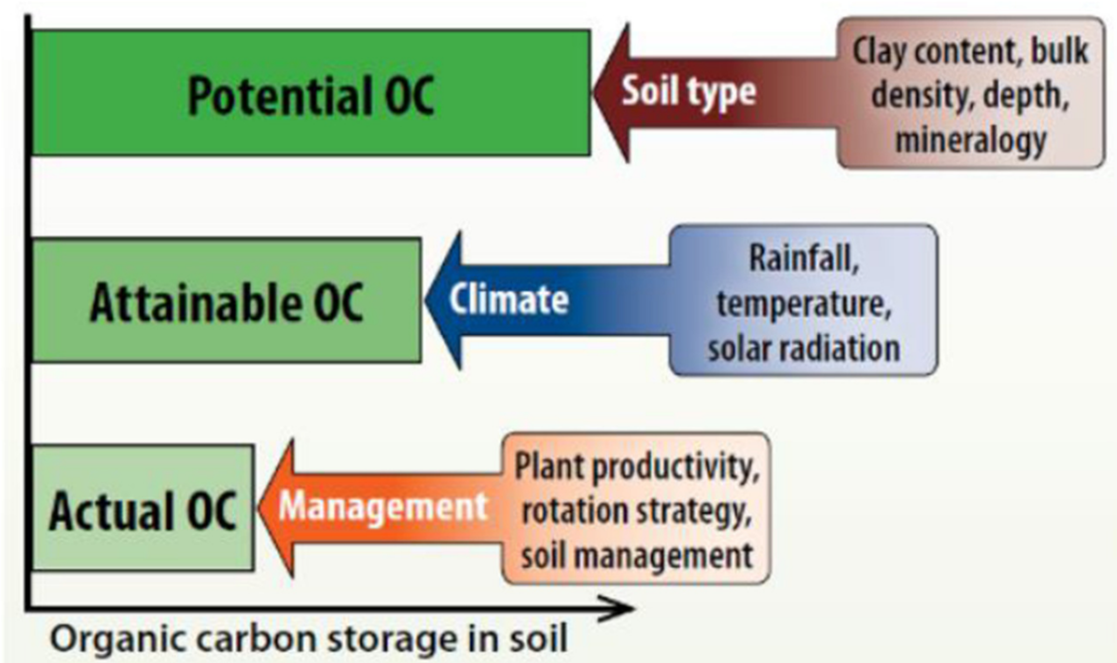
- Changing the crop and pasture sequence
- Minimising tillage, and in some cases considering strategic tillage (to overcome a soil constraint or plant disease)
- Retaining stubble

General

- Nutrients for plants and microbes (build humus)
- Liming to overcome acidic soil constraints
- Gypsum to overcome sodicity, compaction or surface sealing
- Changing practice or land use on degraded soils
- Adding carbon-rich materials (e.g. composts and manures)
- Mixed species plantings
- Biostimulants
- Microbes that store stable carbon

Understanding what you can achieve?

Influencing factors on the Soil carbon balance



Source: Soil quality.org.au

SCARP findings for Victoria

- General hierarchy of influence on SOC stock:
  climate > soil properties > management practices
- Soil organic C stocks varied with management in the order: continuous cropping (34 t C/ha) < crop-pasture rotation (45 t C/ha) < sheep/beef pasture (63 t C/ha) < dairy pasture (120 t C/ha).
- Soil organic C stocks varied with soil type in the order: Tenosol (8 t C/ha) < Calcarosol (26 t C/ha) < Sodosol (41 t C/ha) < Vertosol (48 t C/ha) < Chromosol (53 t C/ha) < Dermosol (106 t C/ha).
- The composition of the soil organic C stocks varied considerably, but averaged 20% particulate C, 51% humic C and 29% resistant C.

What some of the numbers mean

- Less than 1%, functionally impaired
- 2% is considered optimal for aggregate stability.

Targets: SOC greater than 2% in crops & 3% in pastures.

Examples

- Swamps high in SOC (anaerobic conditions)
- Roadsides/underdeveloped land generally less productive, so less carbon.
- Continuous cropping less compared to pasture

	%C
Adrian Laidlaw - Paddock 3, cropping, stubble incorporated last 3 years, removed 2 years before that	5.22
Adrian Laidlaw - roadway native pasture	5.47
Don Price - Cavendish 80ac, cropping, some hay cut in past	5.15
Don Price - Cavendish 3314 road side, no fert or stock ever	2.83
Don Price - Brums road side, no fert or stock ever	2.85
Don Price - Cavendish, swamp paddock, pasture sheep grazing	4.93
Graeme Moyle - Kelwin 1, cropping, stubble mainly chopped and spread	3.77
Graeme Moyle - Blakes, next door on fenceline, onion grass pasture, no fert	4.07
Graeme Moyle - Kelrowan No 7, cropping, stubble sometimes removed	3.61
Graeme Moyle - Kelrowan No 7, fence line - pasture 30 years	3.06
John Herrmann - cropping, stubble burnt	3.57
John Herrmann - cropping, chook manure added	3.99
John Herrmann - cropping, direct drill	3.90
John Herrmann - cropping, stubble incorporated	3.76
Dunkeld trial site - native grass roadside	3.43
Dunkeld trial site - phalaris roadside	3.06
Graham Rentsch- Wallacedale swamp, cropping stubble incorporated	14.5
Dunkeld trial site (ave value around site)	**3.70**

Soil Carbon levels – locally in sandy soils, 0-10cm

Site	Enterprise		SOC%	Soil Texture	Clay %	Soil order
GHCMA 49	Pasture -sheep beef	Frawley	3.8	Sand	2 to 5	
GHCMA 28	Pasture -sheep beef	Brook	3.3	Sandy Loam	12	
GHCMA 19	Pasture -sheep beef	Mcintyre	2.5	Loam	19	
GHCMA 31	Pasture -sheep beef	Lyons	3.1	Loam	19	
GHCMA 11	Pasture -sheep beef	Linke	5.9	Loam	19	
GHCMA 48	Pasture -sheep beef	Wootton	3.6	Sandy Clay loam	22	
			Range 2.5-5.9			

Upper Target about: 3.5 for lighter soils?

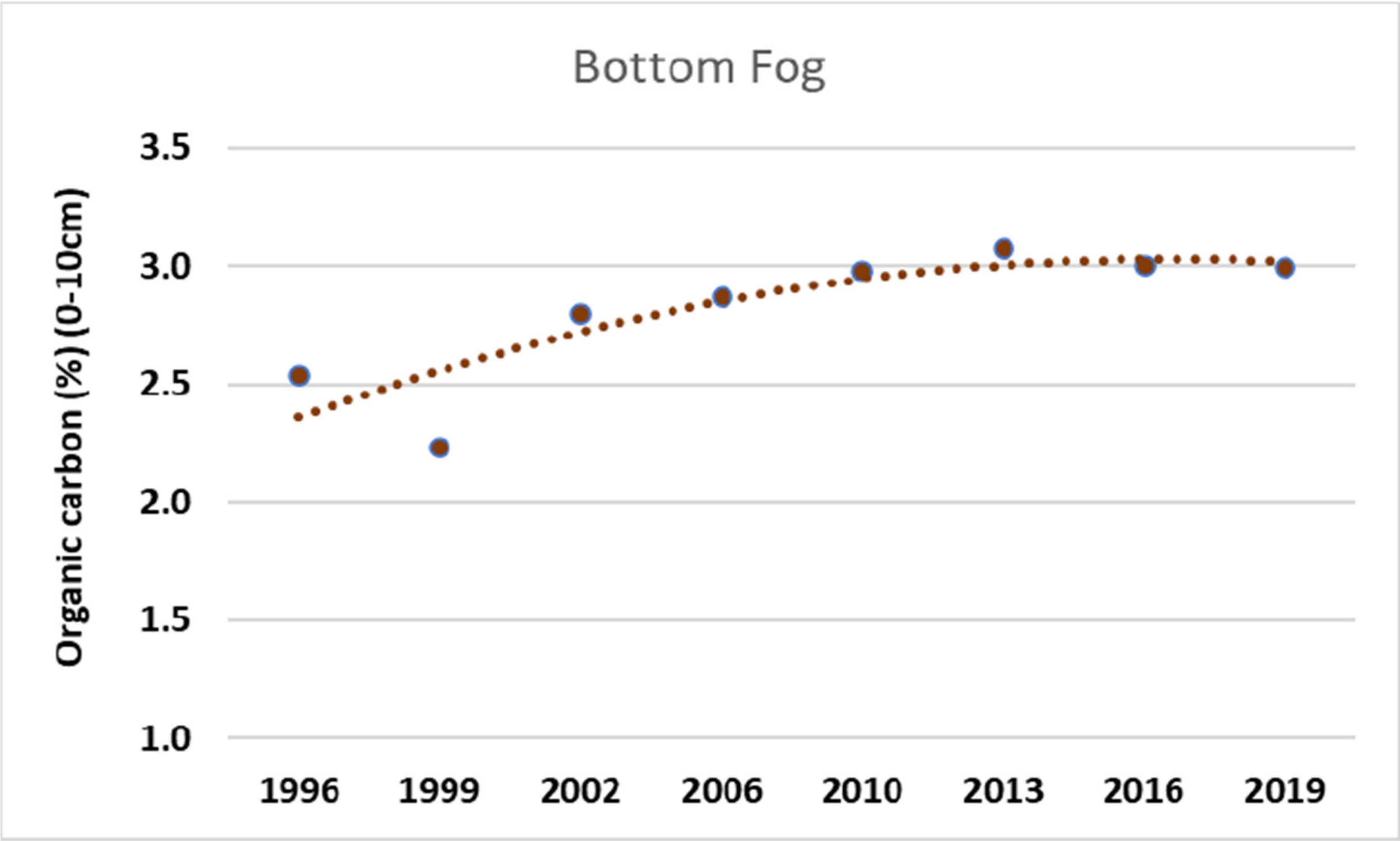
Site	Enterprise		SOC%	Soil Texture	Clay %	Soil order
GHCMA 55	Pasture -sheep beef	Hurley	2.1	Clay Loam		
Vic_0733	Crop-pasture rotation	Lawrence	2.7	Clay Loam	30	Chromosol
GHCMA 50	Pasture -sheep beef	Kruger	2.8	Clay Loam?	30	Chromosol?
Vic_0728	Pasture - sheep beef	Williams	3.2	Clay Loam	30	Chromosol
Vic_0732	Pasture - sheep beef	Lawerence	3.3	Clay Loam	30	Dermosol
Vic_0734	Pasture - sheep beef	Moyle	3.8	Clay Loam	30	Sodosol
Vic_0730	Pasture - sheep beef	Gardner	3.8	Clay Loam	30	Sodosol
Vic_0736	Pasture - sheep beef	Robertson	4.0	Clay Loam	30	Chromosol
Vic_0737	Crop-pasture rotation	Herrmann	4.0	Clay Loam	30	Chromosol
Vic_0731	Pasture - sheep beef	Jarvis	4.3			Sodosol
GHCMA 32	Pasture -sheep beef	Vennings	4.4	Clay Loam		Sodosol?
Vic_0739	Pasture - sheep beef	Herrmann	5.3	Clay Loam	30	Chromosol
			Range 2.1-5.3	Target 4%?		

Soil Carbon levels – locally in clay soils

Site	Enterprise		SOC%	Soil Texture	Clay %	Soil order
Vic_0729	Crop-pasture rotation	Gardner	2.2	Light Med Clay	41	Vertosol
Vic_0735	Crop-pasture rotation	Robertson	3.2	Heavy Clay	43	Sodosol
GHCMA 54	Pasture -sheep beef	Gardner	3.4	Light Clay	39	
Vic_0741	Pasture - sheep beef	Mibus	3.5	Light Clay	39	Vertosol
GHCMA 34	Crop-pasture rotation	Mibus	4.0	Med Heavy Clay	41	
Vic_0892	Pasture - sheep beef	Hand	4.3			Chromosol
Vic_0738	Pasture - sheep beef	Herrmann	6.3	Heavy Clay	43	Vertosol
Vic_0740	Pasture - sheep beef	Northcott	7.4	Light Clay	39	Vertosol
			Range 2.2-7.4			

Target 4%?

Cam Nicholson's monitoring



Measuring & Monitoring

Organic C tests

- Walkley Black, Wet Oxidation method – reported by most laboratories but underestimates total soil carbon, detecting only approximately 80%.

- Leco, dry combustion method- it's the most accurate test that is used. It directly measures carbon by burning off the organic matter and measuring carbon dioxide. More expensive. The Leco test also measures Nitrogen and gives farmers an accurate reading of available nitrogen and nitrogen that is contained within organic matter that has not been broken down. So is very useful for their nitrogen budgeting of crops.

Monitoring

0-10 cm (+) monitoring

- Monitor frequently (with other soil testing); set your own benchmarks; GPS the location

Carbon Trading 0-30 cm

Getting Aust C Credit Units (C trading) is a different game; lots of paperwork, planning, mapping, specialised sampling gear & process (work with project managers).

- Costs of sampling and analysis can range from $30 to $100 per ha, depending on the precision aimed for and the natural variability of the system.
- C price $36.50 t Nov 6, 2021

Carbon fractions

* important more for research than monitoring

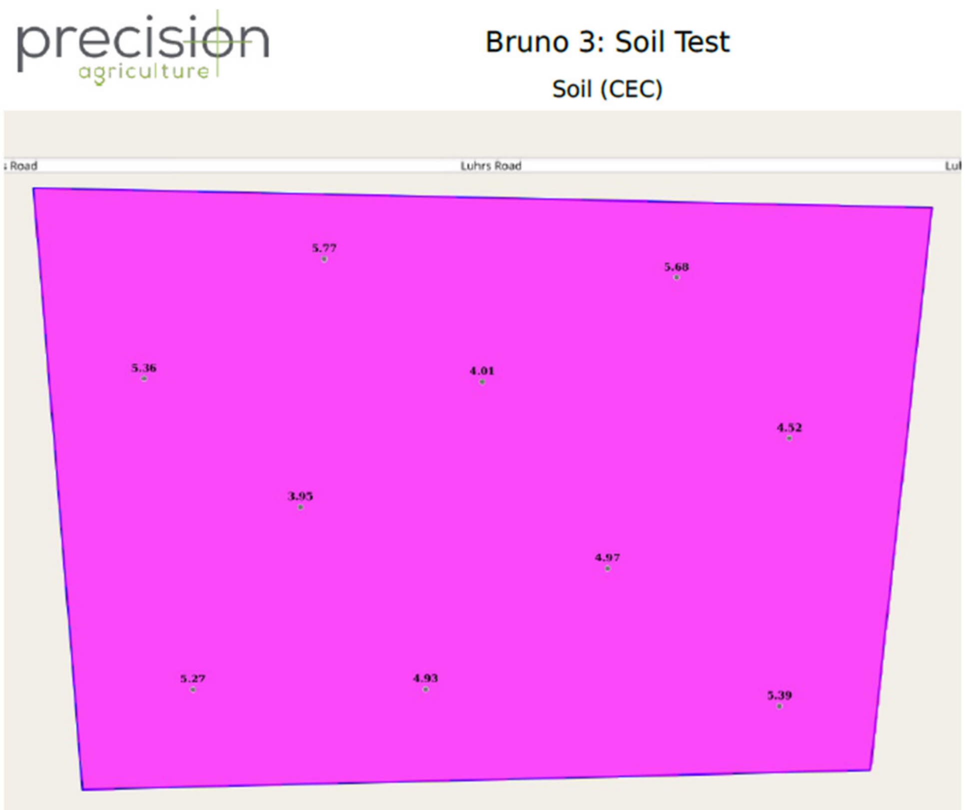
Case study

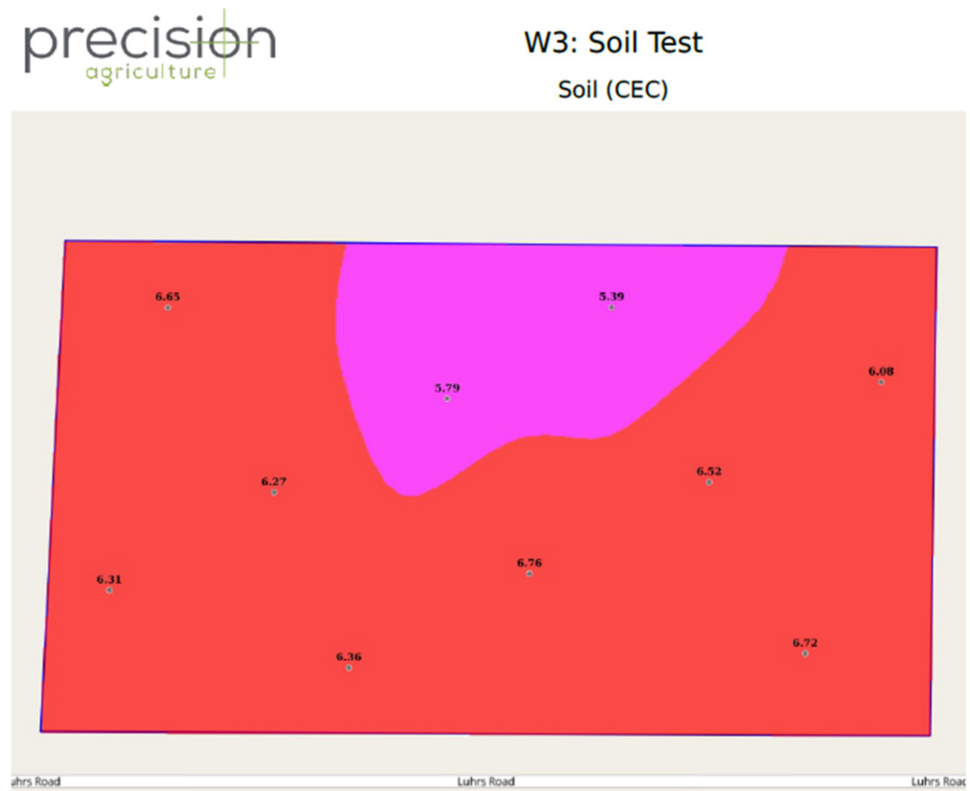
Q. Can we influence soil carbon with management and can we measure a change?

- Rick Luhrs
- Sam Bye, Precision Ag

Bruno: set stocked and fertilisers.

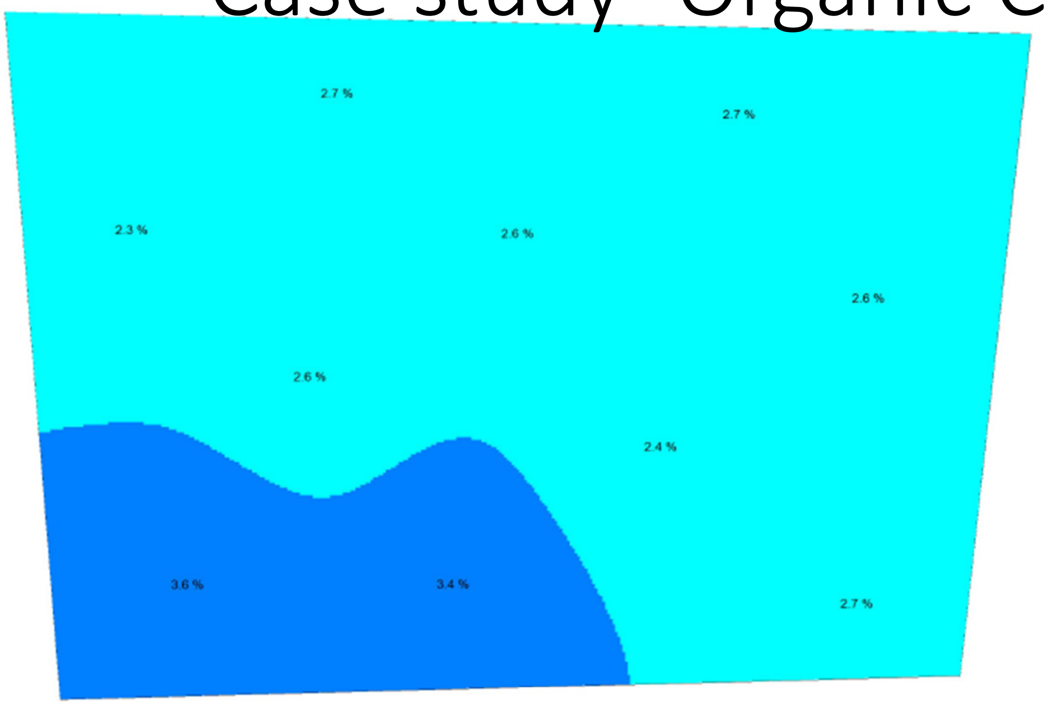
W3: Natural fertilisers, reactive rock phosphate, dolomite, chook manure for 7 years, rotational grazing





Case study- Organic C - Can we see an improvement?

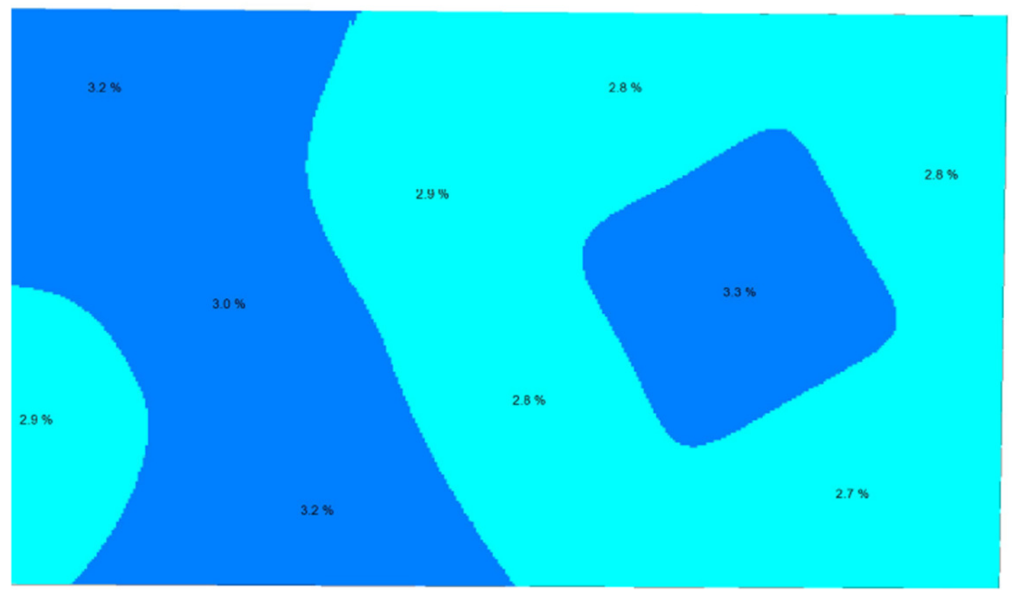
Bruno 3: Soil Test
Organic Carbon



Client: Southern Farming Systems
Farm: Southern Farming Systems
Paddock: Bruno 3
Name: 2109101-precision agricultur
Type: Soil Test
Date: 12/11/2021
Min: 2.3 %
Max: 3.6 %
Avg: 2.8 %

3.0 - 3.6 %	1.99 ha
1.9 - 2.9 %	8.08 ha
1.1 - 1.8 %	0.00 ha
0.4 - 1.0 %	0.00 ha
Below 0.4 %	0.00 ha

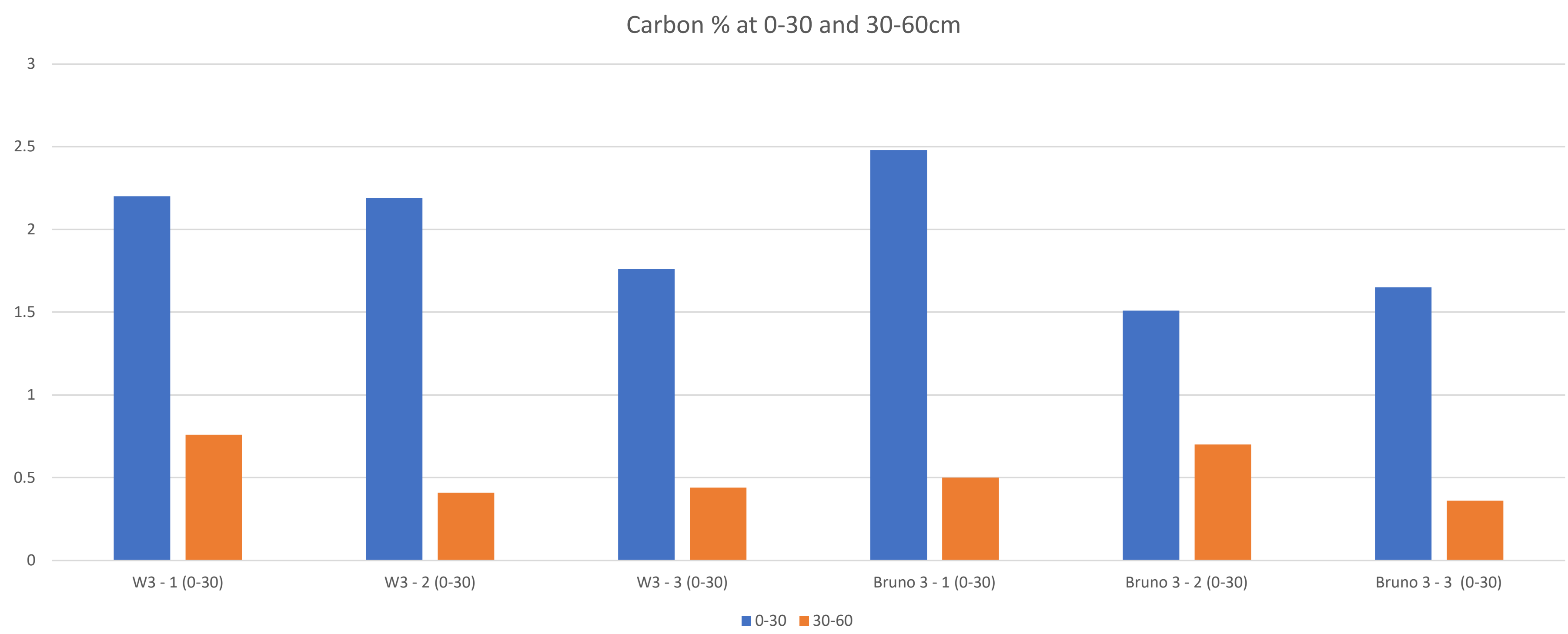
W3: Soil Test
Organic Carbon



Client: Southern Farming Systems
Farm: Southern Farming Systems
Paddock: W3
Name: 2109112-precision agricultur
Type: Soil Test
Date: 12/11/2021
Min: 2.7 %
Max: 3.3 %
Avg: 3.0 %

3.0 - 3.3 %	4.27 ha
1.9 - 2.9 %	5.78 ha
1.1 - 1.8 %	0.00 ha
0.4 - 1.0 %	0.00 ha
Below 0.4 %	0.00 ha

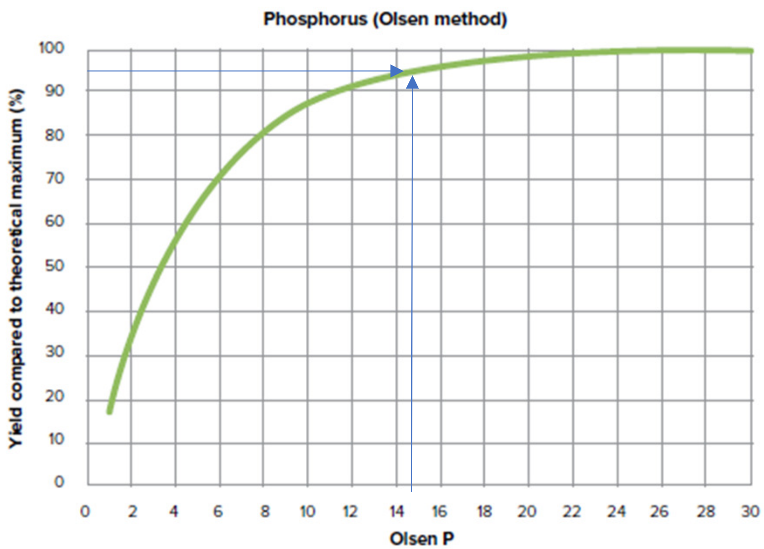
0-30 cm & 30-60cm soil carbon levels

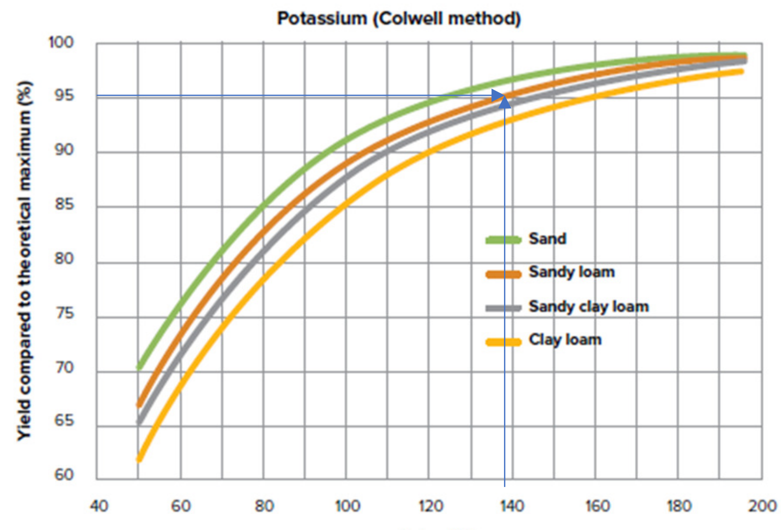


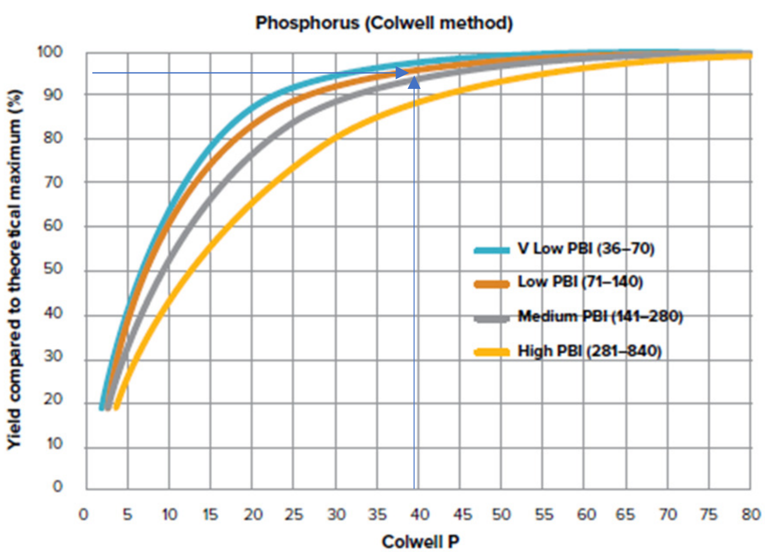
Can we improve organic C further?

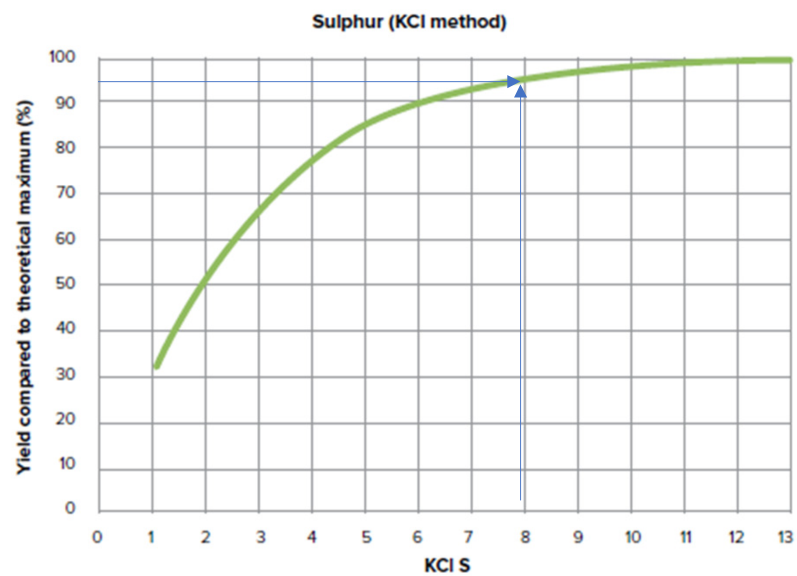
Our main levers for improving growth

- Fertility/Soil condition
- Grazing management
- Weed control
- Pests & disease control







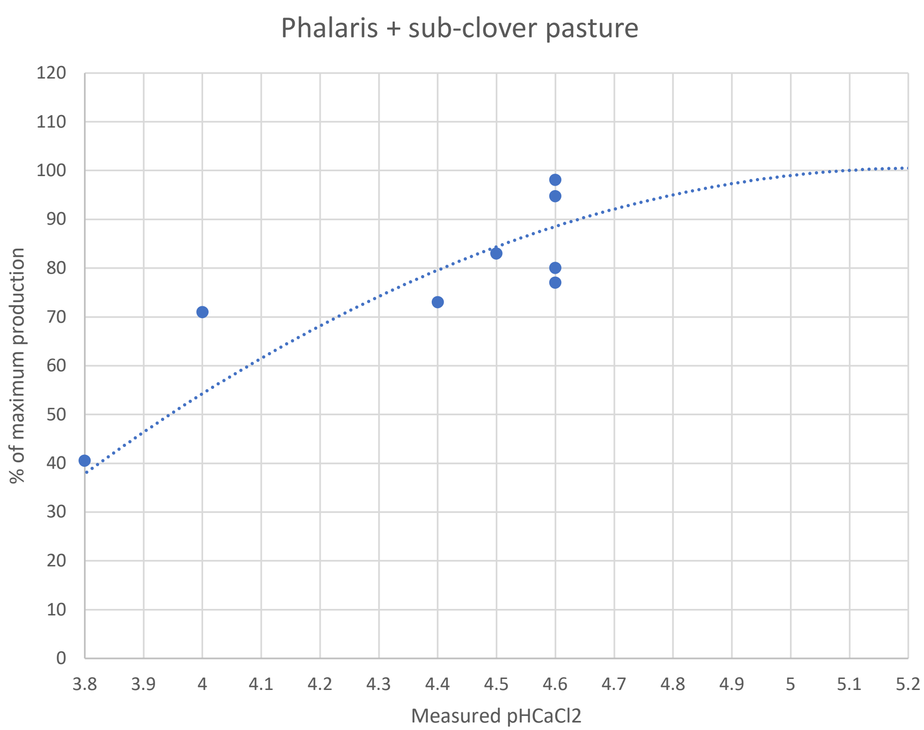


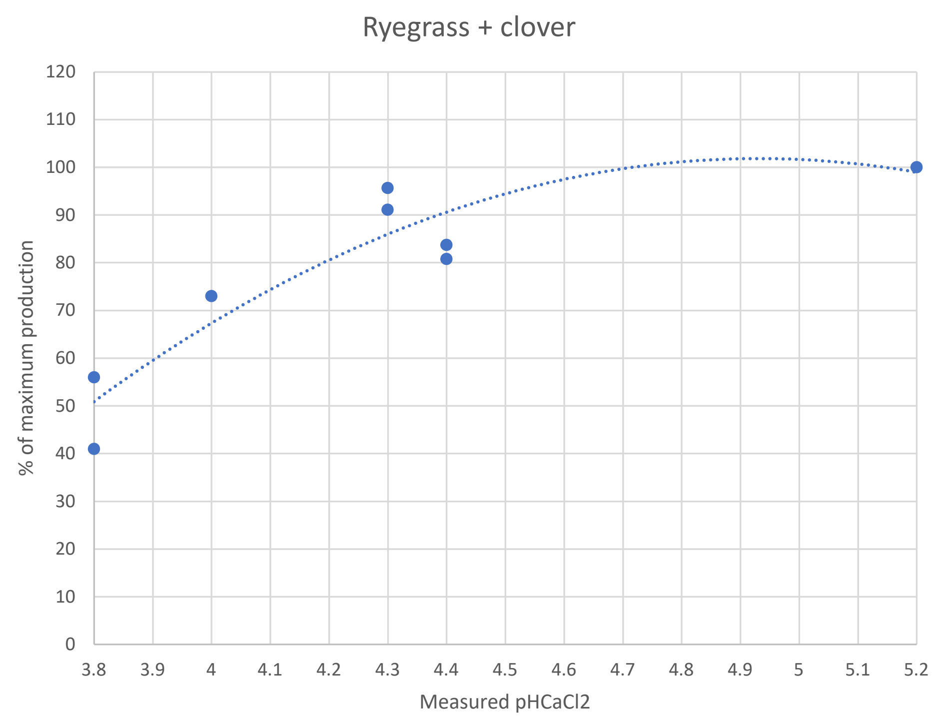
Critical values – 95% of optimal growth

Sandy loam?
PBI about 100

Ref. PayDirt

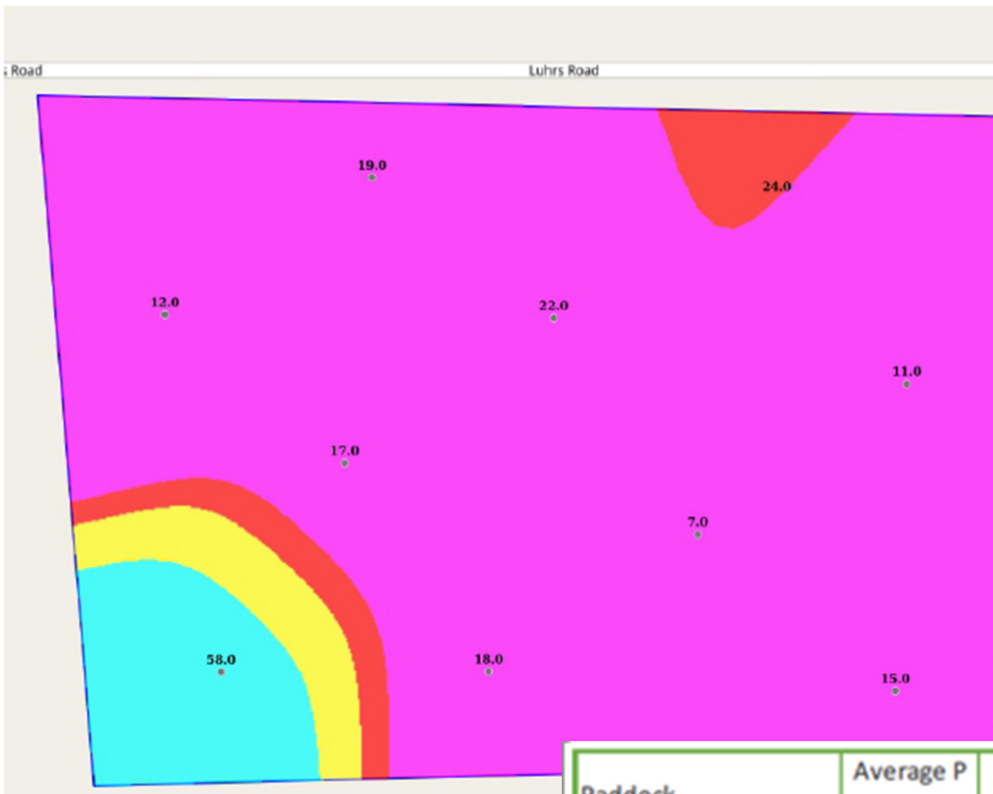
Pasture responses curves created for LimeAssist based on measured reductions in carrying capacity DSE/ha





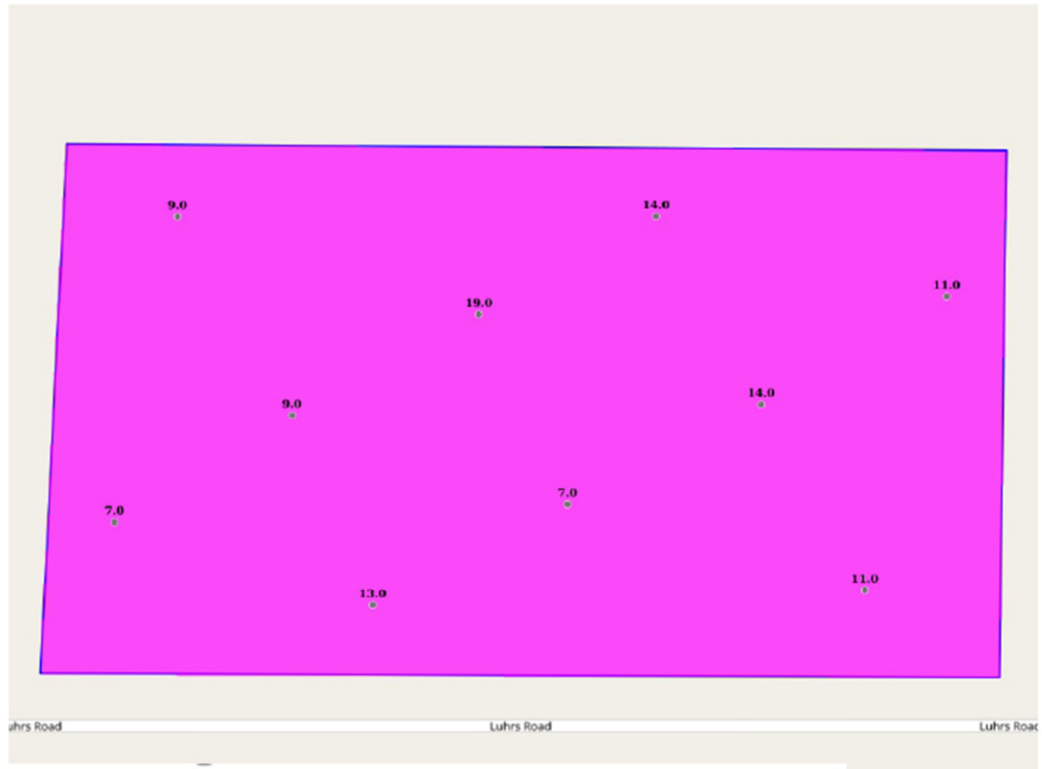
Bruno 3: Soil Test

Soil (Phosphorus)

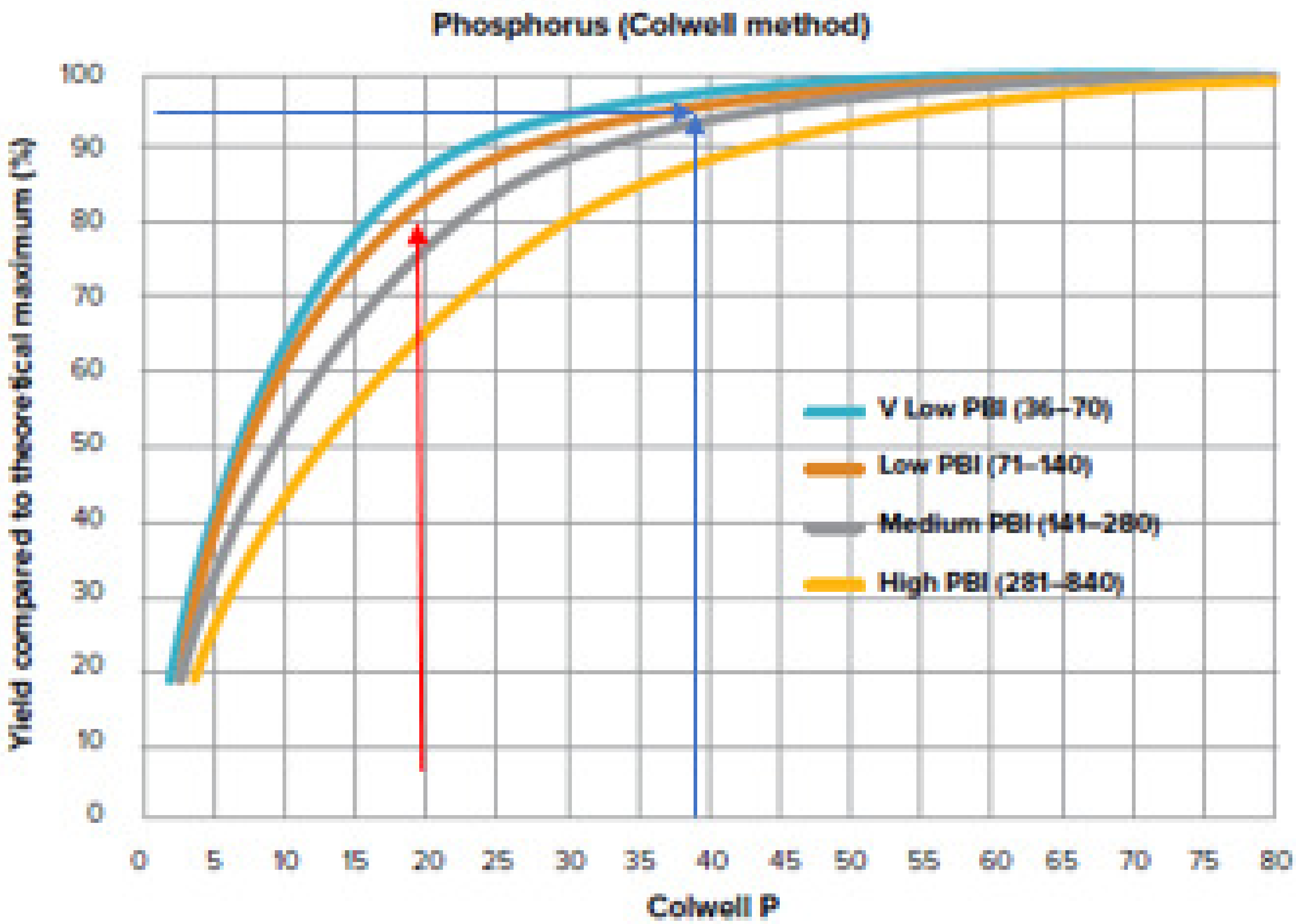


W3: Soil Test

Soil (Phosphorus)



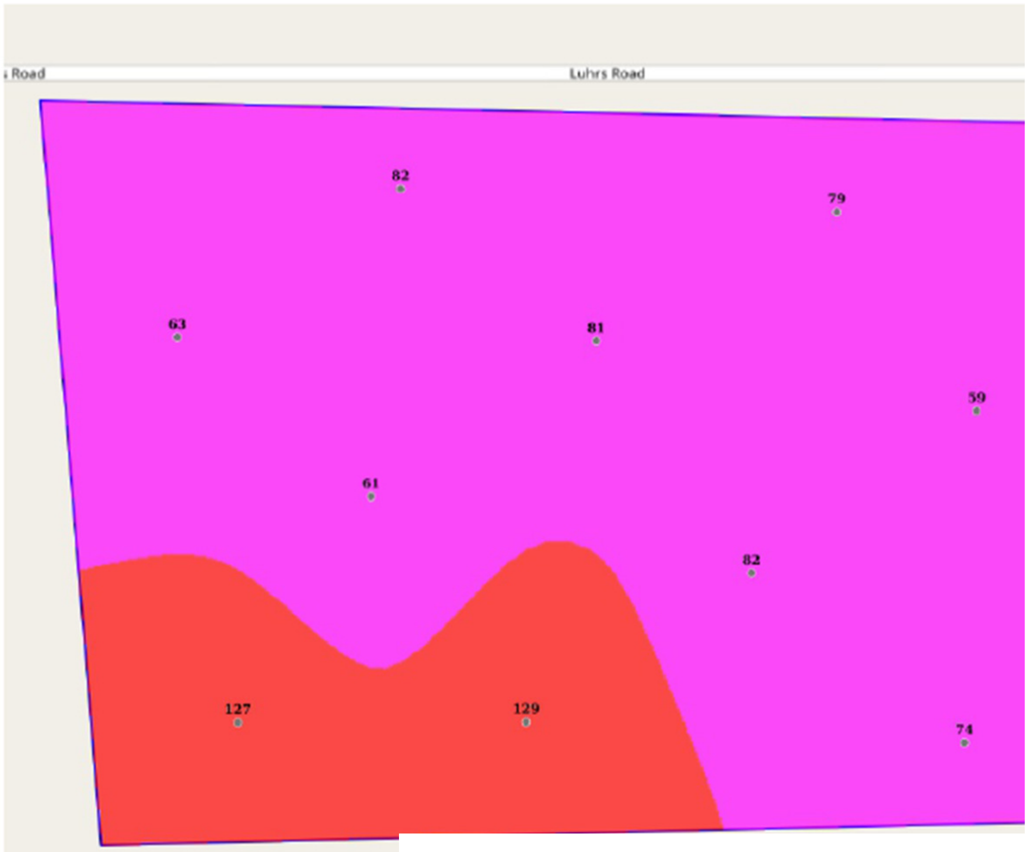
Paddock	Average P (mg/kg)	Average PBI	0-24 (mg/kg)	24-35 (mg/kg)	35-53 (mg/kg)	53-71 (mg/kg)	>71 (mg/kg)
Bruno 3	20	0	85%	5%	3%	7%	
W3	11	0	100%				



Phosphorus (Colwell method)
Yield compared to theoretical maximum (%)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Colwell P
V Low PBI (36–70)
Low PBI (71–140)
Medium PBI (141–280)
High PBI (281–840)

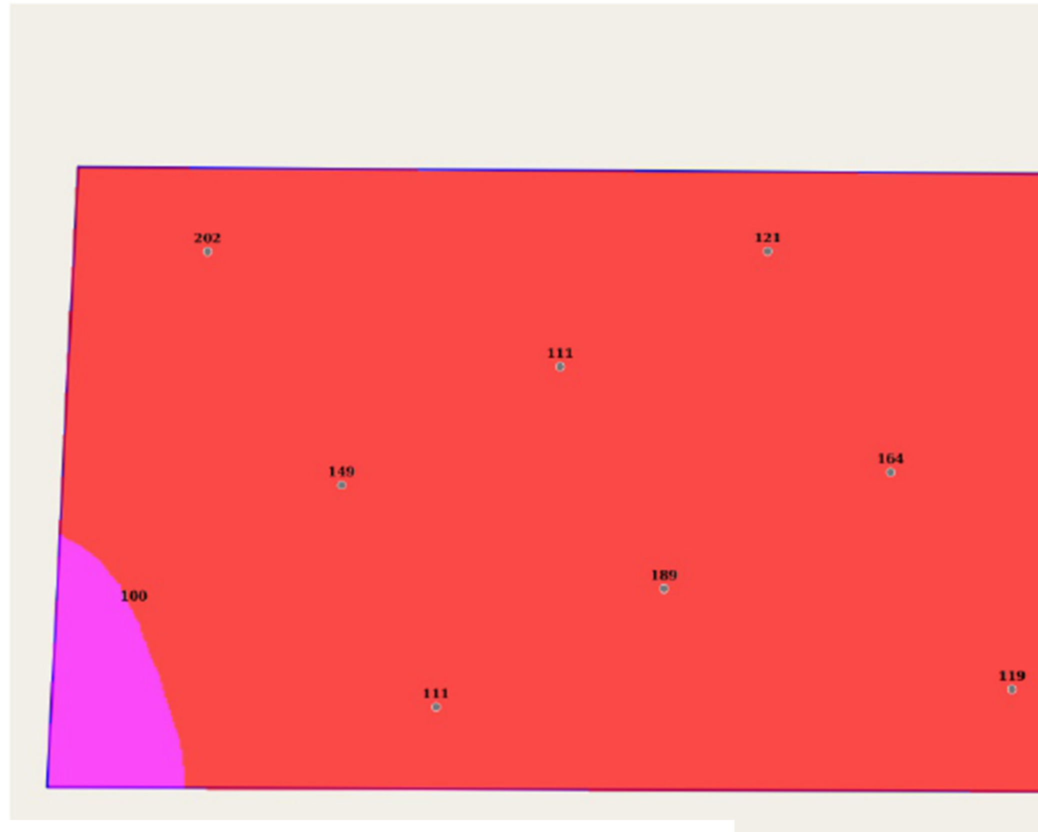
Bruno 3: Soil Test

Soil (Potassium)

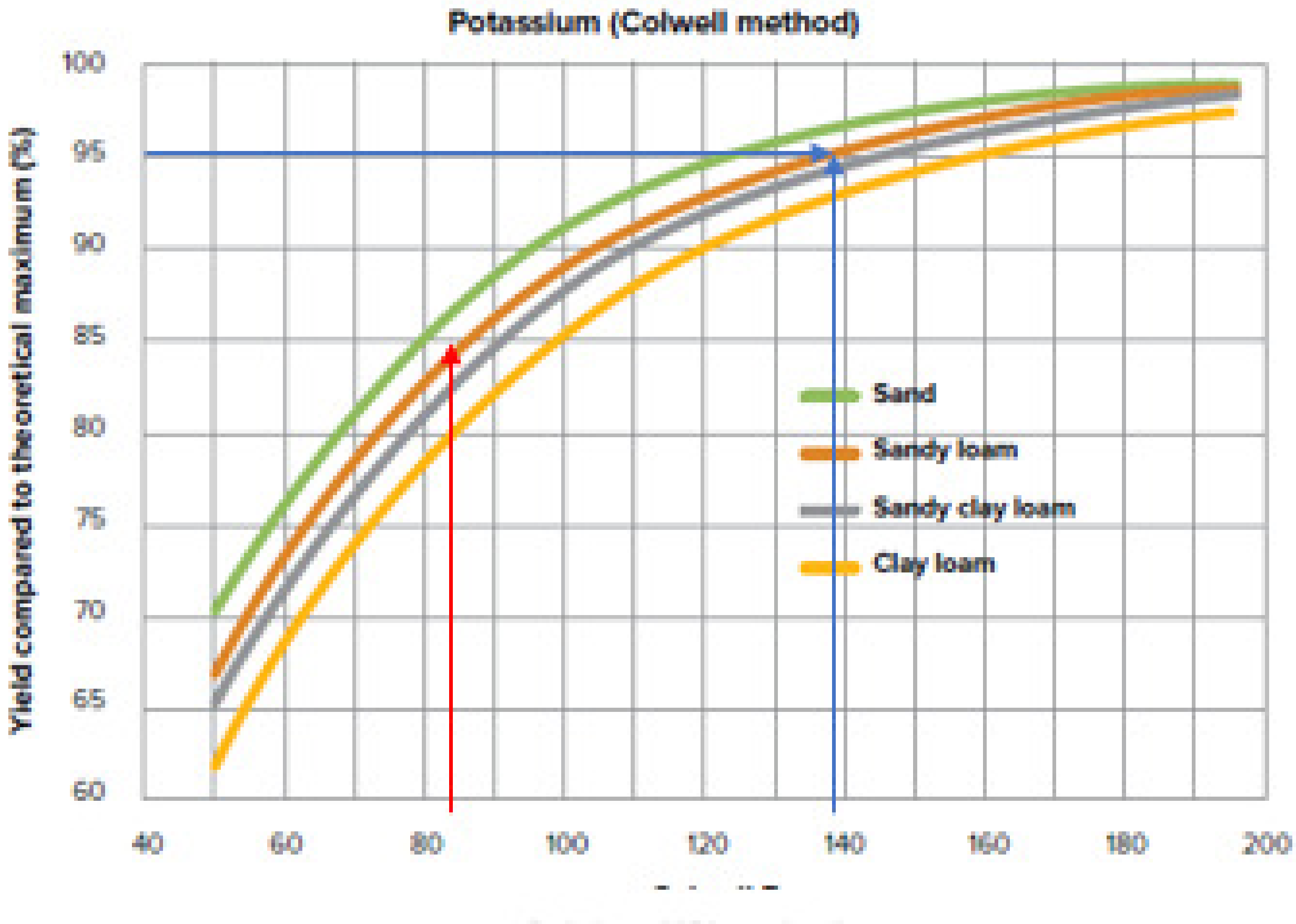


W3: Soil Test

Soil (Potassium)



Paddock	Average K (mg/kg)	<100 mg/kg	100-250 mg/kg	250-400 mg/kg	400-650 mg/kg	>650 mg/kg
Bruno 3	84	**81%**	19%			
W3	143	3%	**97%**			

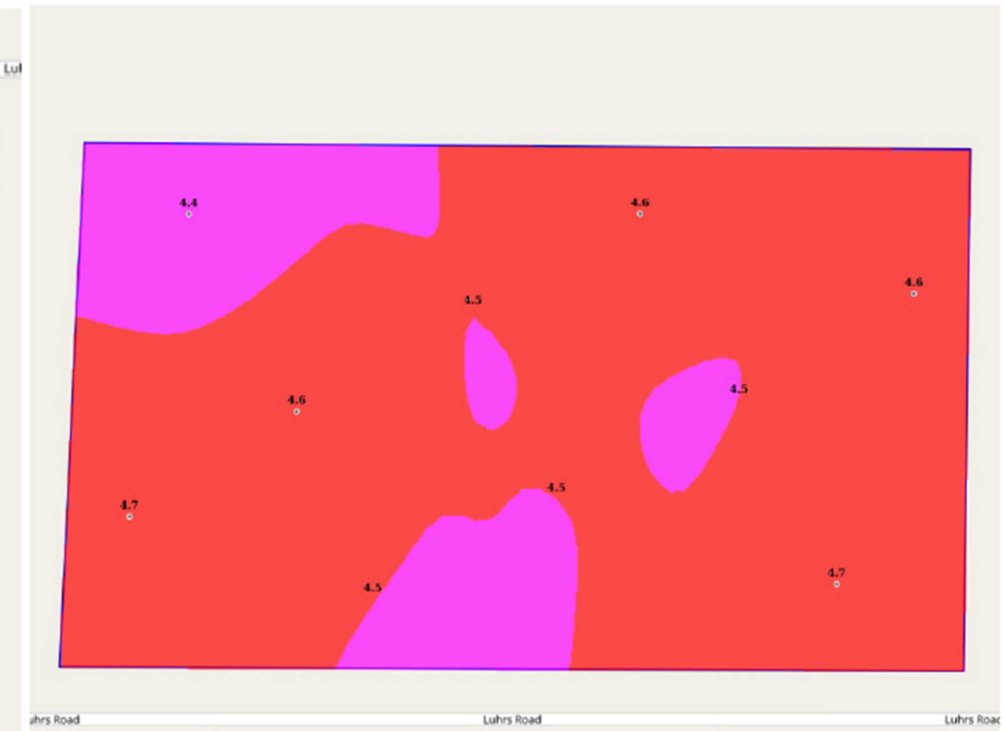

Potassium (Colwell method)
Yield compared to theoretical maximum (%)
100
95
90
85
80
75
70
65
60
40
60
80
100
120
140
160
180
200
Sand
Sandy loam
Sandy clay loam
Clay loam

Bruno 3: Soil Test

Soil pH (CaCl2)

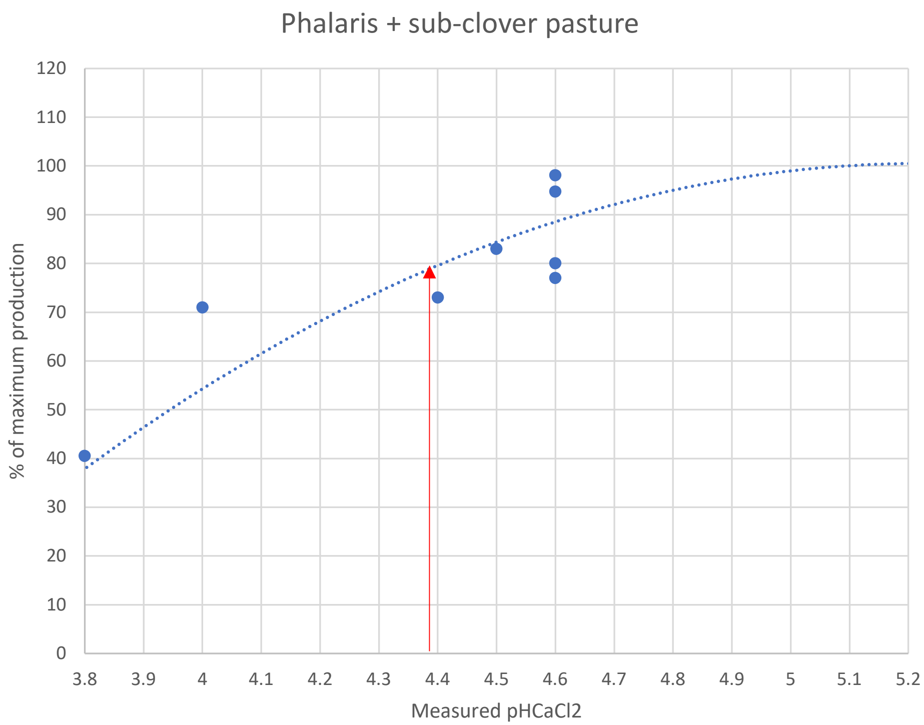
W3: Soil Test

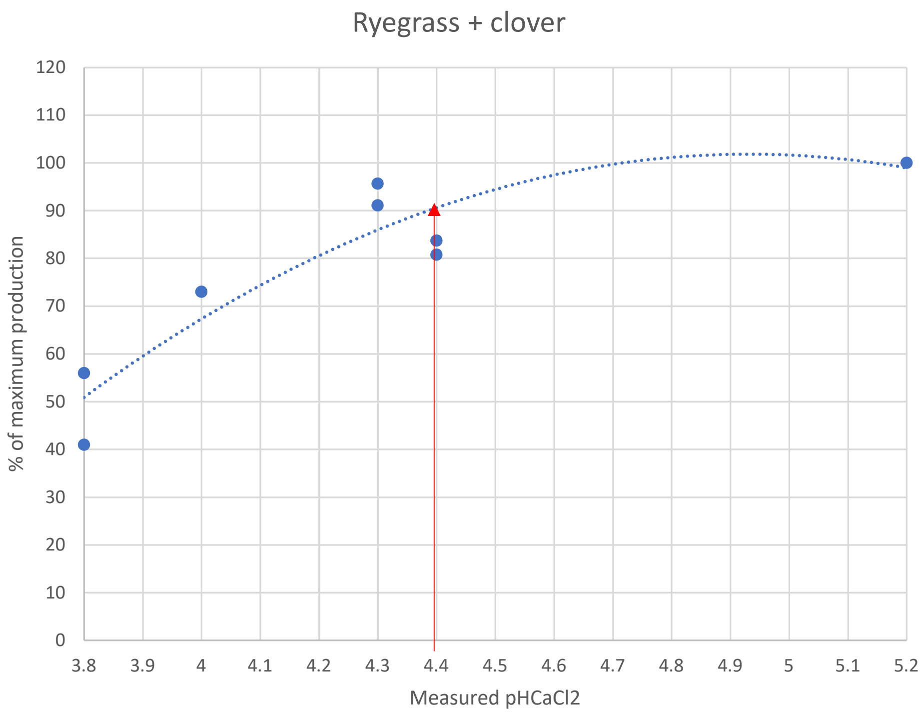
Soil pH (CaCl2)



Paddock	Average pH	Extremely low	Very low	Low	Acceptable	
		<4.5	4.5-4.8	4.8-5.2	5.2-5.8	>5.8
Bruno 3	4.4	**79%**	21%			
W3	4.6	20%	**80%**			

Pasture responses curves created for LimeAssist based on measured reductions in carrying capacity DSE/ha

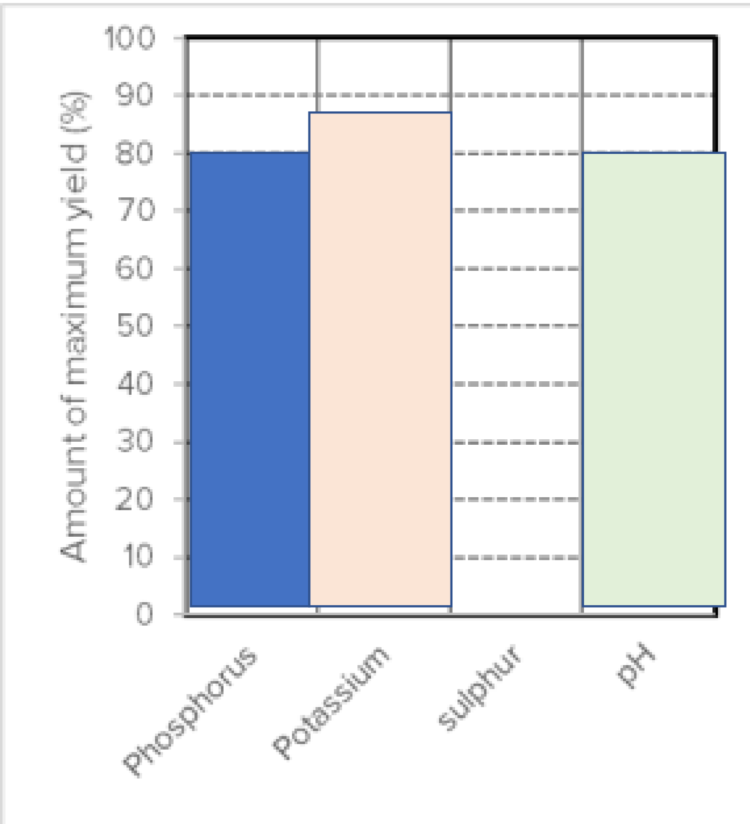


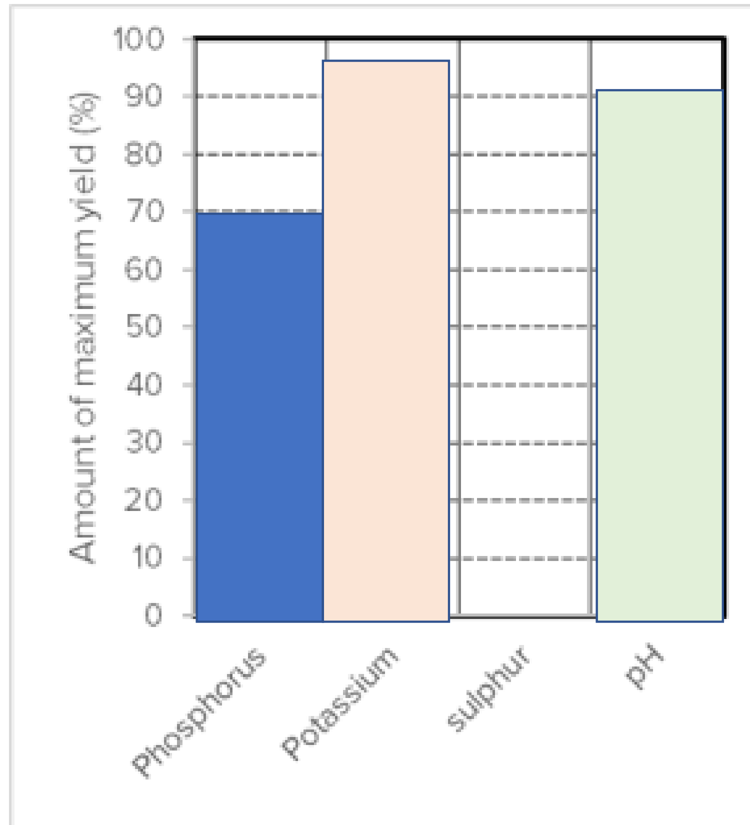


Bruno paddock

W3 paddock

From MLA:
Training package
PayDirt





What was most limiting? What would you need to apply? But are there species that could respond and is utilisation high?

Comparing costs of fertilisers

Work out the cost per kg of nutrient spread you need

For example, Superphosphate cost spread is $400/t and contains 8.8% P:

The cost per kg of P is: ($400 ÷ 8.8)÷10 =$4.5/kg P.

Compare to MAP with 22% P is ($575÷22)÷10 =$2.6/kg P.

In this case: MAP is a cheaper source of P

The checklist of best practice management for increasing desirable grass content

Consideration	Yes, No or NA	Additional notes
SOIL CONDITION		
Olsen P at least 12 mg/kg, Cowell P at least 35 mg/kg (moderate category PBI =141-280) for introduced perennials. PBI= Phosphorus Buffering Index		Native grasses are favoured by lower fertility levels, e.g no more than 12mg/kg for moderate responsive native grasses (e.g. Wallaby grass or Weeping grass) and less than 8 mg/kg for low fertility native grasses (e.g Spear grass, Poa tussock, Windmill grass).
Colwell K at least 105 mg/kg for sandy loam or 120mg/kg clay loam?		Avoid sampling urine patches as these are high in potassium and can artificially increase soil test results.
KCl sulphur at least 6mg/kg?		
Soil pH ($CaCl_2$) at least 4.5 & exchangeable Aluminium less than 10% for sensitive species or less than 20% for acid tolerant species.		Acid sensitive species include phalaris. Acid tolerant species include perennial ryegrass, tall fescue and cocksfoot and Phalaris cultivars Advance AT and Landmaster).
Nitrogen Levels are sufficient (at least 20% legume in early spring with healthy nodules or Nitrogen % - Kjeldhal test greater than 3.2-5.5 mg/kg in a tissue test.		Tissue tests of tillers taken in early spring prior to flowering.
GRAZING – green pasture		