Jobs,
Precincts
and Regions

Healthy soils and soil test interpretation

MASG Castlemaine Jan 2020

Rebecca Mitchell

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A bit about me?

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What we will cover today

What is soil

Soil Health and corresponding soil test indicator as defined by the soil health guide and its 9 easy tests to do on farm

1. *Ground cover* - *Soil organic matter and Soil C*
2. *Soil biological activity*
3. *Soil colour*
4. *Soil pH*
5. *Soil texture* - *Cation Exchange Capacity*
6. *Top soil* - *NPKS, trace elements*
7. *Soil structure*
8. *Soil compaction layers*
9. *Slaking and Dispersion – Exchangeable cations and percentages, Salinity*

Soil Test – Deane's Paddock Summary

Why soil test? – Plant agronomy

Nitrogen: - Essential for photosynthesis as is P and Mg. Plant growth, increasing seed and fruit production

Phosphorus : - Effects rapid growth, encourages blooming and root growth

- Fixing of P can make it unavailable to plants. Forms complexes with Ca, Fe, Al, Mn, clay minerals, Al and Fe oxides

Potassium : - Helps in building of protein, fruit quality and reduction of disease

Calcium : - Essential part of cell walls, provides for normal transport and retention of other elements as well as strength in the plant

Magnesium: - Helps activate plant enzymes needed for growth. Core element in chlorophyll.

Sulfur: - Essential for production of protein, enzymes and vitamins

- Deficiencies of S are often induced by applications of N fertiliser

Trace elements

- Essential for a wide range of metabolic functions

Why else?

- Establish a baseline soil nutrient status/ get a snapshot of the chemical properties
- Measure change in soil nutrient status over time
- Document soil nutrient management for certification requirements (biosolids, organic, carbon credits etc.)
- Determine nutrient application recommendations prior to planting
- Assess pH and the need for liming
- Avoid excessive nutrient applications or soluble salt accumulation
- Develop a plan for possible variable-rate nutrient application within a paddock
- Optimising physical and chemical conditions of the soil

Accreditation

There are many different Labs. Your agronomist may have a suggestion. However just double check that they have some accreditation (ASPAC or NATA, meaning that their results are reliable).

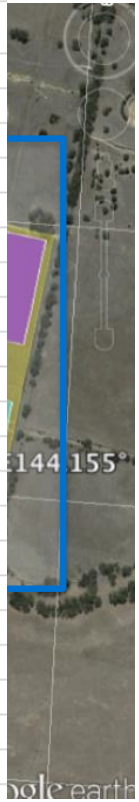
ASPAC- The Australasian Soil and Plant Analysis Council (ASPAC) is an independent international organisation consisting of individuals, laboratories, research and commercial organisations involved in soil and plant tissue analysis

NATA – National Association of Testing Authorities is a very high level of accreditation for research purposes. NATA is the authority that provides independent assurance of technical competence through a proven network of best practice industry experts for customers who require confidence in the delivery of their products and services.

ROUTINE AGRICULTURAL SOIL ANALYSIS REPORT

Job No:	F4748
No of Samples:	2
Date Supplied:	14th November 2016
Supplied by:	Eco2Sys Australia Pty Ltd

					Sample 1	Sample 2	Heavy Soil	Medium Soil	Light Soil	Sandy Soil
				Sample ID:	CEA01_Comp03_UL	CEA02_Comp03_UL				
				Crop:	N/G	N/G				
				Client:	D. Belfield	D. Belfield	e.g Clay	e.g Clay Loam	e.g Loam	e.g Loamy Sand
Method		Nutrient		Units	F4748/5	F4748/11	Indicative guidelines only- refer Note 6			
	Morgan 1	Calcium	Ca	mg/kg	188	179	1150	750	375	175
		Magnesium	Mg		60	50	160	105	60	25
		Potassium	K		68	53	113	75	60	50
		Phosphorus	P		1.3	0.7	15	12	10	5.0
	Bray1	Phosphorus	P	mg/kg	19	1.7	45 note 6	30 note 6	24 note 6	20 note 6
	Colwell				11	10	80	50	45	35
	Bray2				111	10	90 note 6	60 note 6	48 note 6	40 note 6
	KCl	Nitrate Nitrogen	N	mg/kg	5.7	10	15	13	10	10
		Ammonium Nitrogen			7.9	6.3	20	18	15	12
		Sulfur	S		22	6.5	10.0	8.0	8.0	7.0
	1:5 Water	pH		units	5.46	5.39	6.5	6.5	6.3	6.3
		Conductivity		dS/m	0.047	0.039	0.200	0.150	0.120	0.100
	Calculation	Estimated Organic Matter		% OM	1.7	1.6	>5.5	>4.5	>3.5	>2.5
	Ammonium Acetate + Calculations	Calcium	Ca	cmol+/Kg	1.56	1.45	15.6	10.8	5.0	1.9
				kg/ha	702	652	6250	4300	2000	750
				mg/kg	313	291	3125	2150	1000	375
		Magnesium	Mg	cmol+/Kg	0.70	0.55	2.4	1.7	1.2	0.60
				kg/ha	191	151	580	400	290	150
				mg/kg	85	67	290	200	145	75
		Potassium	K	cmol+/Kg	0.36	0.26	0.60	0.50	0.40	0.30
				kg/ha	313	224	470	380	300	200
				mg/kg	140	100	235	190	150	100
		Sodium	Na	cmol+/Kg	0.09	0.06	0.3	0.26	0.22	0.11
				kg/ha	49	29	138	120	101	51
				mg/kg	22	13	69	60	51	25
	KCl	Aluminium	Al	cmol+/Kg	0.16	0.20	0.6	5	0.5	0.2
				kg/ha	32	39	108	90	81	27
				mg/kg	14	18	54	45	41	14



Understanding your soil test

What?

This guide does not seek to advise on or promote fertiliser application.

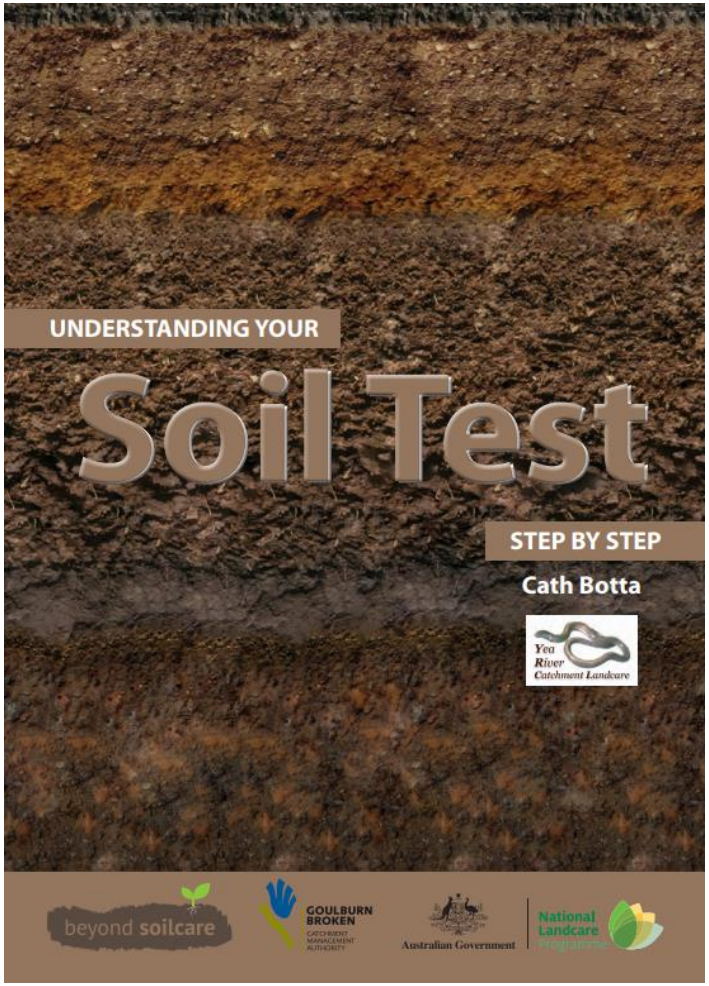
It contains material to help the reader understand their soil-test results

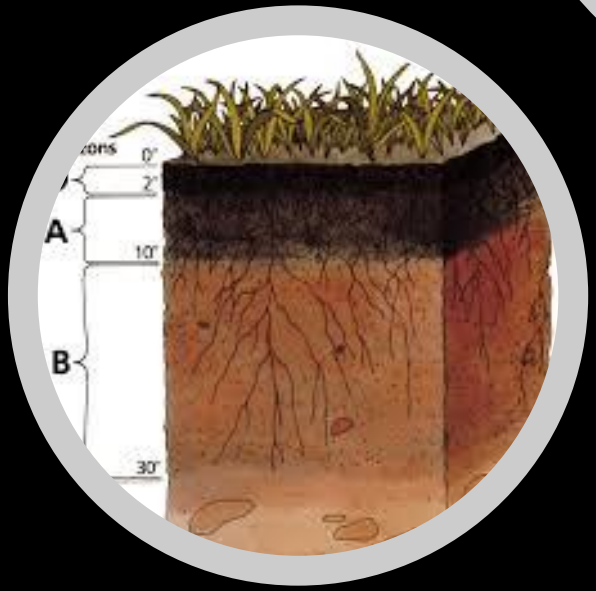
Who?

Developed by the GBCMA, the Yea River Catchment Landcare group and edited by soil scientist Cath Botta.

How?

A reference guide to look through your soil tests





What is soil?

What is soil?

Soil is a vibrant environment, full of life, full of activity (biological).

It provides the structural support (physical) and the source of water and nutrients (chemical) for plants.

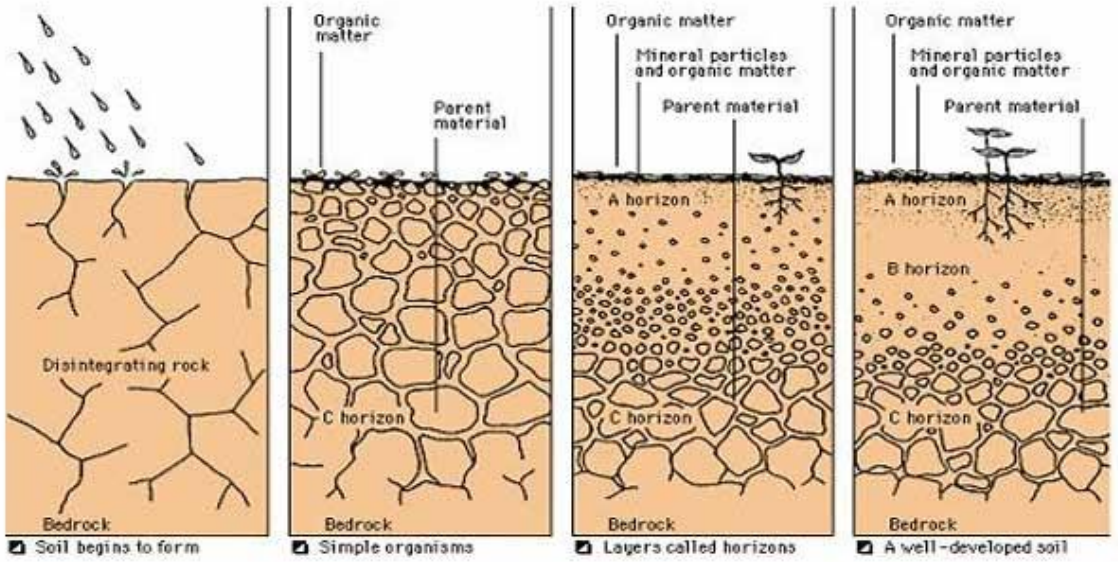
Lifeblood of your crop or pasture!!

How is soil formed?

- Soil starts with the breakdown of rocks (Granite, sands, Basalt, Shale) or the accumulation of sediments (Alluvium, Colluvium or Aeolian)
- It continues developing via physical, chemical, and biological processes
- It is slow, taking thousands of years to form and mature.

In 1000 years, just 1 - 5 cm of soil is formed

.1mm a yr

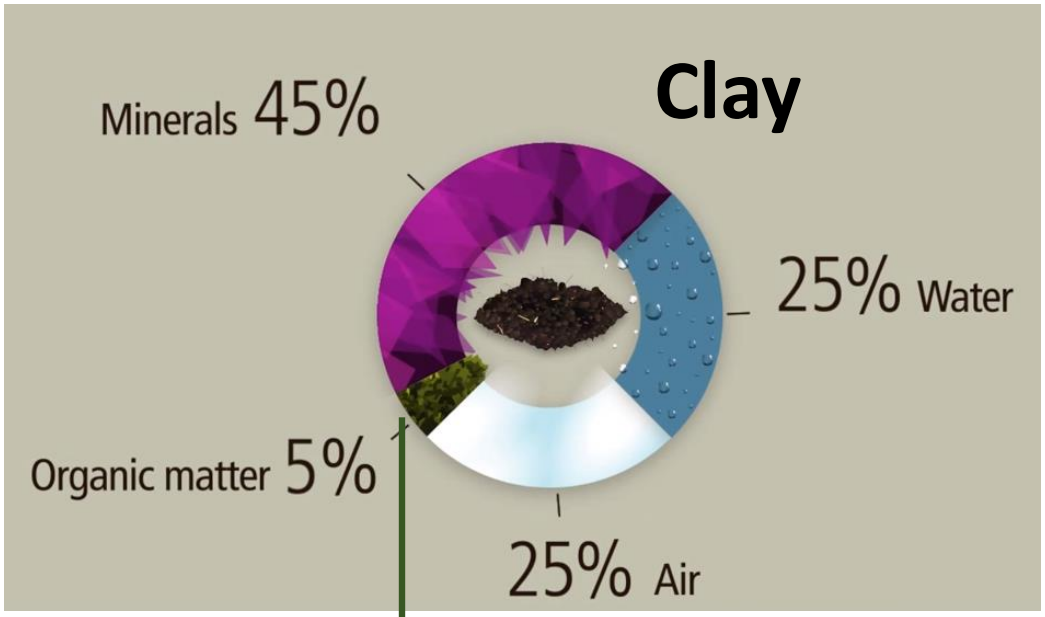


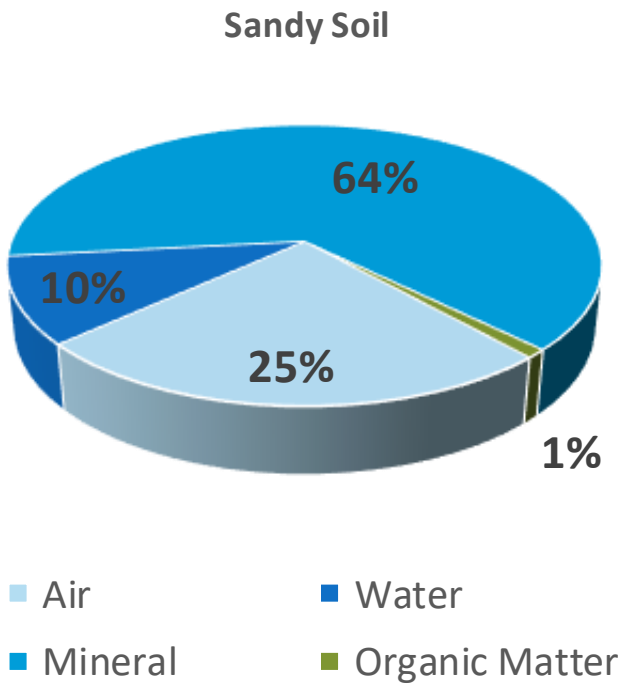
Soils form according to 5 soil forming factors:

1. **Parent material** (geology (Shale, Sandstone, Basalt (extrusive) and Granite (intrusive), transported sediments)
2. **Climate** (rainfall, temperature, wind)
3. **Topography** (shape, length and grade of slope, aspect, elevation)
4. **Organisms** (plants, bacteria, fungi, animals, worm, insects)
5. **Time**

What is soil?

'Soil consists of two things, stuff and spaces between the stuff'





Organisms: 10%
Roots and crop residues: 10 %
Humus: 80%

What is a Healthy Soil ?!?

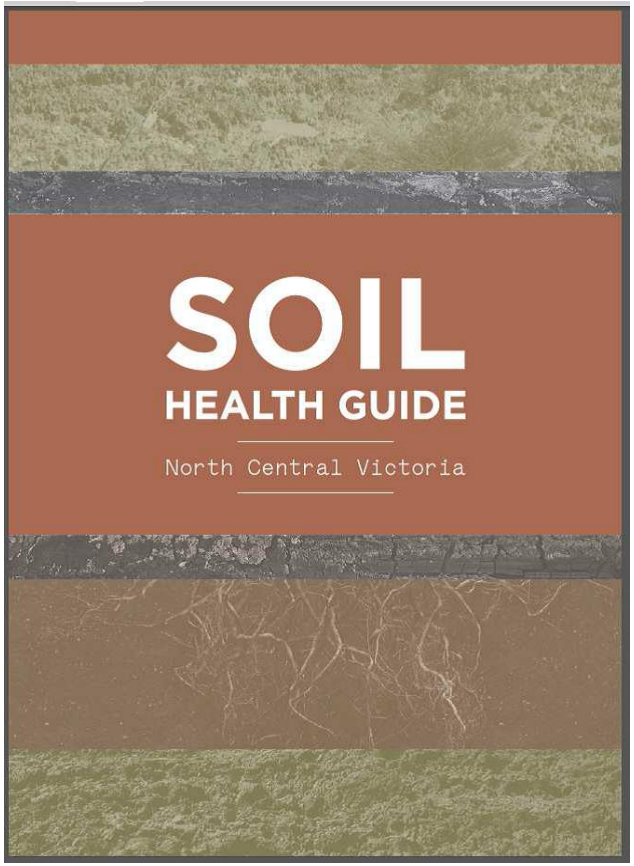
Soil that is physically, nutritionally and biologically balanced to be productive and stable.

Good soil health is about creating a robust soil that can withstand impacts, such as agriculture, without loss of fertility, structure and biological activity.

How can we understand if we have a healthy soil?

NCCMA Soil Health Guide attempts to do this

- Indicators of soil health.
- Information to identify possible soil health issues.
- Simple visual tests conducted in the paddock.
- Together with the Soil Health Score Card aims to complement laboratory test results.
- Providing real-time information on a soils physical, chemical and biological characteristics



SOIL HEALTH SCORE CARD

Name:	Date:	Site location: *(Map transect location on following page)*

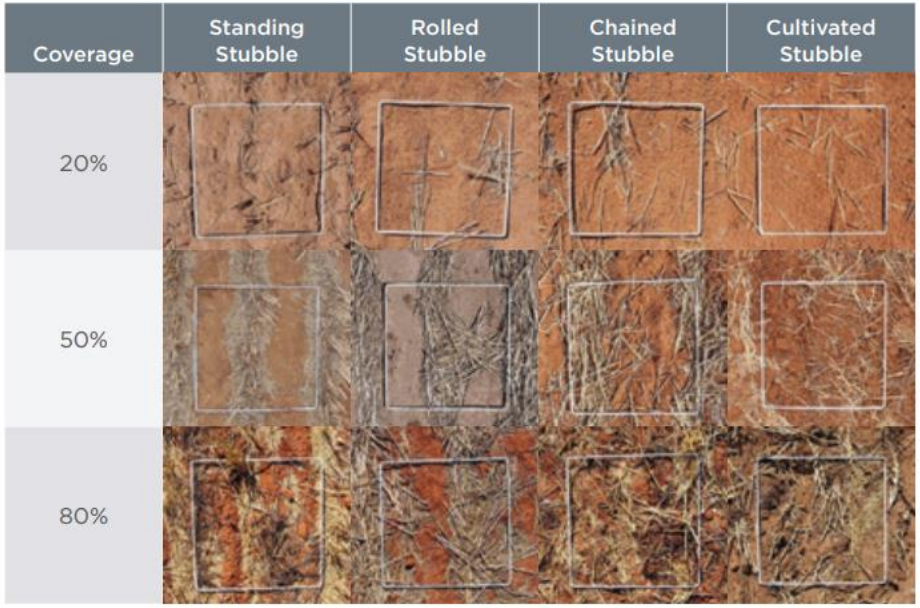
Test	Poor Score = 1	Fair Score = 2	Good Score = 3	Weighting	Site 1	Site 2	Site 3
					(score x weighting)		
1. Groundcover	Less than 50% groundcover (plants dead or alive; stubble)	50% to 70% groundcover (plants dead or alive; stubble)	More than 75% groundcover (plants dead or alive; stubble)	x3			
2. Evidence of soil biological actiivity	Fewer than two types of soil organisms	Two to five types of soil organisms	More than five types of soil organisms	x2			
3. Soil colour	Grey	Light (Yellow/ Red/Brown)	Dark (Red/ Brown/Black)	x1			
4. Soil pH (water) (use lowest pH value from top and/or sub soil)	pH 5.0 or lower; greater than pH 8.5	pH 5.0 - 6.0; pH 7.5 - 8.5	pH 6 to pH 7.5	x2			
5. Soil texture	Soil texture abruptly changes from the top soil (e.g. sandy loam) to the subsoil (e.g. clay)	Soil texture is the same throughout the profile	Soil texture gradually becomes heavier down the profile	x1			
6. Top soil	Top soil less than 10 cm deep	Topsoil greater than 10 cm deep overlaying a pale layer	Topsoil greater than 10 cm deep	x1			
7. Soil structure	Cloddy, hard or crusty,few cracks/holes, no pores visible.	Some visible crumbly structure. Few pores visible	Crumbly top soil. Soil forms stable aggregates	x3			
8. Soil compaction	Soil is hard; penetrometer will not penetrate the soil	Penetrometer penetrates with difficulty to less than 15 cm	Penetrometer easily penetrates beyond 15 cm	x2			
9. Slaking & Dispersion	Unstable structure; aggregates break down and disperse; milkiness of water	Evidence of slaking; aggregates break down; no milkiness of water	Maintains structure; aggregates remain intact. No swelling of clay particles	x2			

1 Groundcover and Soil Carbon

Soil health Guide – Ground cover

- Groundcover includes both living and dead plant material and litter
- **Reduces erosion risk (wind and water)**

Table 1: Estimating groundcover levels in a cropping situation



Blown soil trapped by stubble

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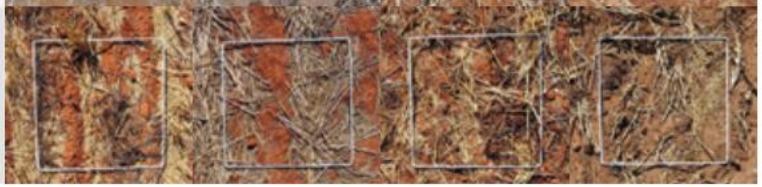
Just west of Swan Hill – 6th Feb 2019

Image credit: Martin Hamilton, Agriculture Victoria

Soil health Guide – Ground cover

- Groundcover includes both living and dead plant material and litter
- Reduced erosion (wind and water)
- **Increases organic matter**
- **Promotes a broad diversity of soil microbes that plants need to help them obtain nutrients and water from the soil**

Table 1: Estimating groundcover levels in a cropping situation

Coverage	Standing Stubble	Rolled Stubble	Chained Stubble	Cultivated Stubble
20%				
50%				
80%				

Soil health Guide – Soil Organic Matter, why important?

Ground cover is not only important for nutrients but also promotes a build up of soil organic matter (SOM)

SOM and soil biology are very closely linked

- Ground cover provides a food source for soil biology and therefore contributes to an increase soil carbon from the biology
  - Producing enzymes that break down plant material
  - They sequester carbon into their own biomass
  - They produce chemical substances that can adhere carbon within aggregates or to minerals

- SOM Binds soil together (structure)
- Retains soil nutrients

A decline in SOM leads to soil biological activity decline

C:N ratio of Soil organic matter

A useful determinant of biological turnover of nutrients

- C/N ratio influences mineralisation of N
- **C/N** ratio **>25:1** stimulates **immobilisation** (biology needs to get N from soil to break down product, more $C0_2$ released, slower decomposition)
- **C/N** ratio **<25:1** stimulates **mineralisation** (biology easily gets N from product, breaks it down fast and releases excess N into soil whilst sequestering C)

Organic material	C:N ratio
Soil Microorganisms (turn over 1/3 of C consumed into biomass, therefore to grow and decompose need a diet of 1 N for every 24 carbon consumed)	8:1
Sewage Sludge	9:1
Soil Organic Matter	10:1
Composts	20:1
Farmyard manure	20:1
Legume residues	25:1 (ideal for microbe diet)
Grain Straw	70:1
Crude oil	400:1
Conifer wood	625:1

Soil Test Interpretation – Soil Organic Matter, Soil Carbon

			Heavy Soil e.g Clay	Medium Soil e.g Clay Loam	Light Soil e.g Loam	Sandy Soil e.g Loamy Sand
Nutrient		Units	Indicative guidelines only			
Phosphorus	P		15-23	15-23	15-23	15-23
Nitrate Nitrogen	N	mg/kg	15	13	10	10
Ammonium Nitrogen			20	18	15	12
Sulfur	S		10	8	8	7
pH		units	6.5	6.5	6.3	6.3
Conductivity		dS/m	0.200	0.150	0.120	0.100
Organic Matter		% OM	>5.5	>4.5	>3.5	>2.5
Calcium	Ca2+	mg/kg	3125	2150	1000	375
Magnesium	Mg2+	mg/kg	290	200	145	75
Potassium	K+	mg/kg	235	190	150	100
Sodium	Na+	mg/kg	69	60	51	25
Aluminium	Al3+	mg/kg	54	45	41	14
Hydrogen	H^+	mg/kg	6	5	5	2
Effective Cation Exchange Capacity (ECEC)		$cmol^+/Kg$	20	14	7	4
Calcium	Ca2+	%	77	75	69	60
Magnesium	Mg2+		11	12	16	20
Potassium	K+		3	4	5	8
Sodium - ESP	Na+		2	2	3	3
Aluminium	Al3+		7	7	7	9
Hydrogen	H^+					
Calcium/ Magnesium Ratio		ratio	7.0	6.3	4.3	3.0

Soil Test Interpretation – Soil Organic Matter, Soil Carbon

Amount of SOM and SOC a soil can hold is Influenced by

- Soil texture

(sand silt clay fractions, more clay is a stronger holding capacity)

- Climate

(rainfall and temp for cycling/breakdown of plant matter and nutrients)

Soil Test Interpretation - Organic Carbon

Organic Carbon Levels	Low Rainfall	High Rainfall
Low Moderate High	<1.9% 1.9 – 2.8% >2.8%	<3.1% 3.1 – 6.2% >6.2%

Soil Organic Matter (SOM)% = SOC x 1.72

E.g. OM = 4.79%

Organic Carbon = 4.79/1.72 = 2.78%

Soil Test Interpretation - Organic Carbon

Organic Carbon Levels	Low Rainfall	High Rainfall
Low Moderate High	<1.9% 1.9 – 2.8% >2.8%	<3.1% 3.1 – 6.2% >6.2%

*CEA01 (0-30cm): 0.95% OC = Low levels

*CEA02 (0-30cm): 0.94% OC = Low levels

WholeFarm (0-10cm) : 2.78% OC = Moderate levels

*The LECO IR method uses automated analyzers in which the sample under analysis is combusted by heating it to a high temperature by a resistance furnace in a stream of purified oxygen. The CO2 produced by combustion is measured by a selective, solid state, infrared detector.

2
Evidence of biological activity

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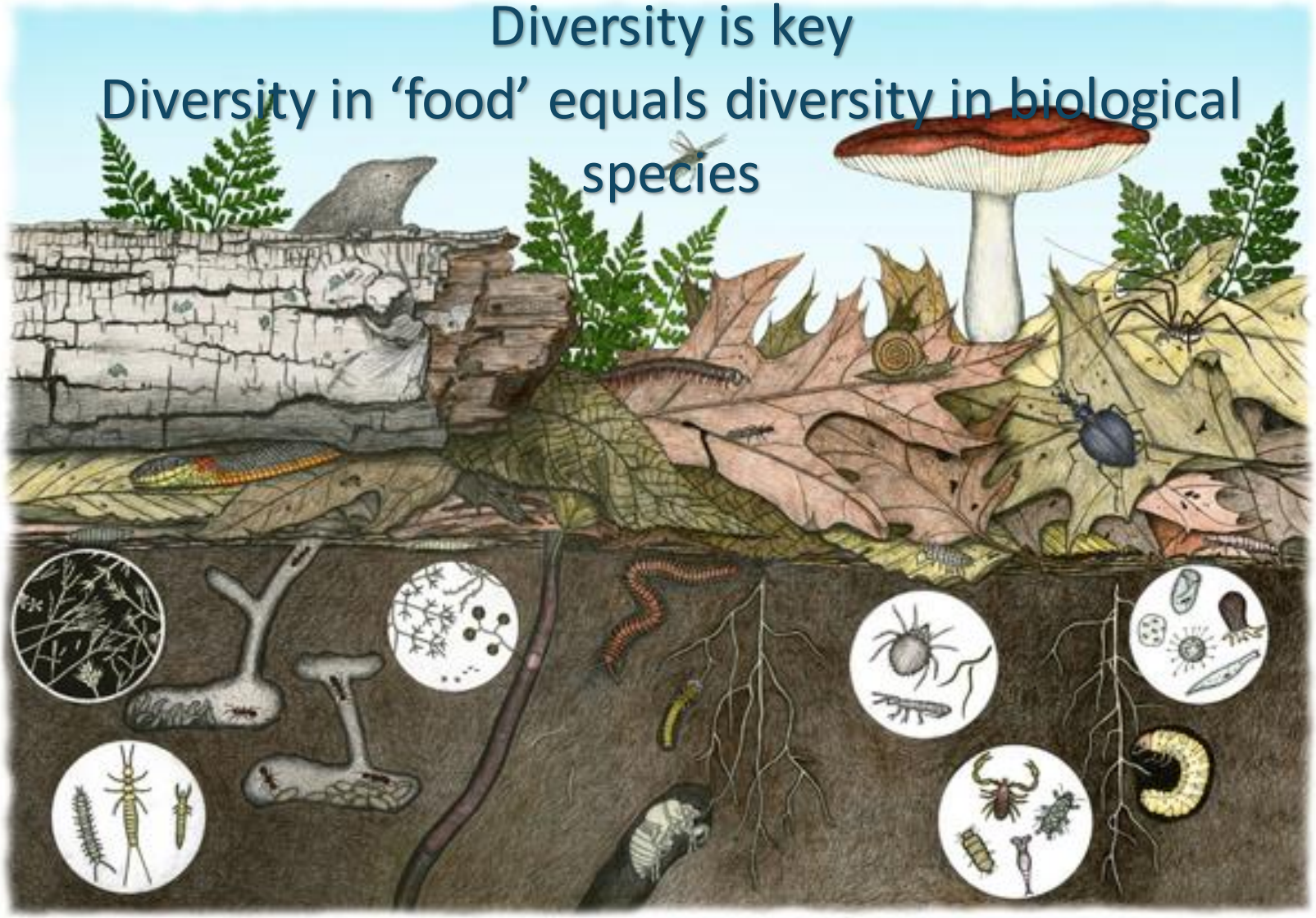


Soil health Guide – Evidence of soil biological activity

Soil health Guide – Evidence of soil biological activity

- How we deal with crop residues and how we manage crop rotations affects microbial activity and diversity

Case Study	Treatment Duration (yrs)	Cropping system	Microbial biomass	Potential Mineralisable N	Catabolic Diversity
1	17	Stubble burnt	98	ND	14.5
		Stubble retained	153	ND	15.5
2	4 years	Continuous wheat rotation	308	30	15.8
		Faba bean:wheat:canola:wheat	317	30	16.4
		Medic:wheat	415	25	18
		annual pasture - Ryegrass	417	45	16.5
		Perennial pasture - Lucerne	421	67	16.5

Cover cropping/perennial systems allow for some biological organisms (eg Fungi) to complete their life cycles and increase their presence in the soil

Population size

Making N available to plants

Ability to utilise a range of C-substrates

Soil health Guide – Evidence of soil biological activity

The test

Test (as you measure groundcover, also assess the range of soil animals on the surface of the soil): Move away from the hole and take a shovelful of topsoil, approximately 20 cm square and 10 cm deep. Carefully sift through the plant litter and soil and note how many different soil animals you see, such as worms, ants, beetles, spiders, millipedes, etc. Fungi may also be present as a network (often white) of hyphae structure in the soil. It is the variety of different soil organisms that is important, not the numbers of individual soil organisms (NSW DPI, 2002).

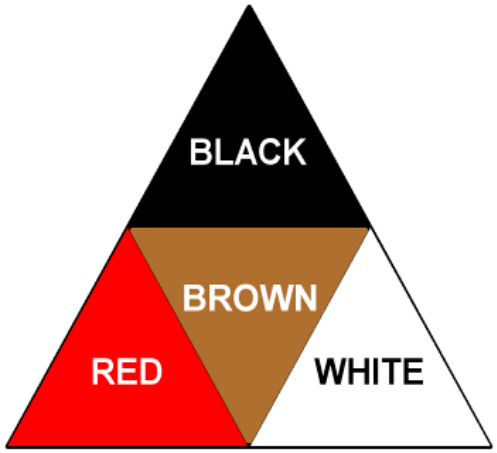
Test	Poor Score = 1	Fair Score = 2	Good Score = 3	Weighting	Site 1	Site 2	Site 3
					(score x weighting)		
2. Evidence of soil biological actiivity	Fewer than two types of soil organisms	Two to five types of soil organisms	More than five types of soil organisms	x2			

3
Soil colour

Soil health Guide – Soil colour

Colour is an obvious feature that has always been used for describing, identifying and classifying soils

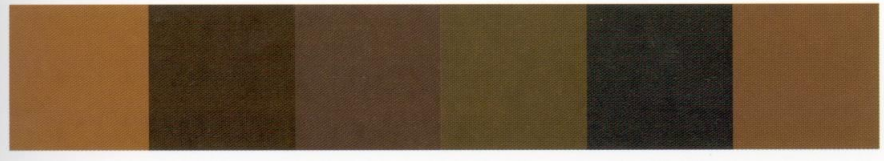
- Soil colour is related to chemical properties, aeration or drainage, and organic matter
- It may also help determine the different layers (horizons) of the soil, such as topsoil and subsoil



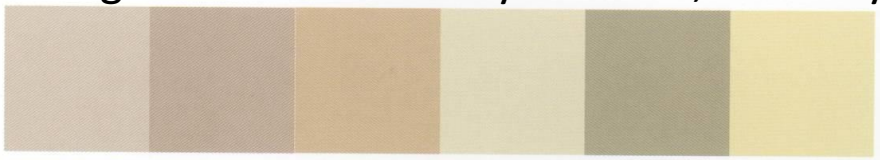
Soil health Guide – Soil colour

BLACK - Soils rich in humus, often fertile.

BROWN - Presence of organic matter, often relatively fertile.

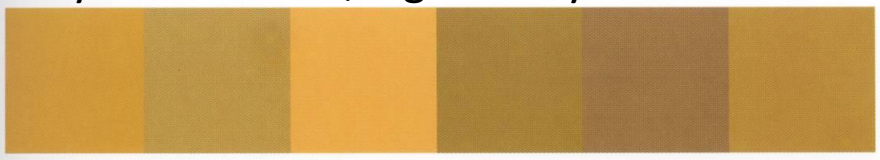


PALE - Low levels of organic matter and clay minerals, normally infertile.



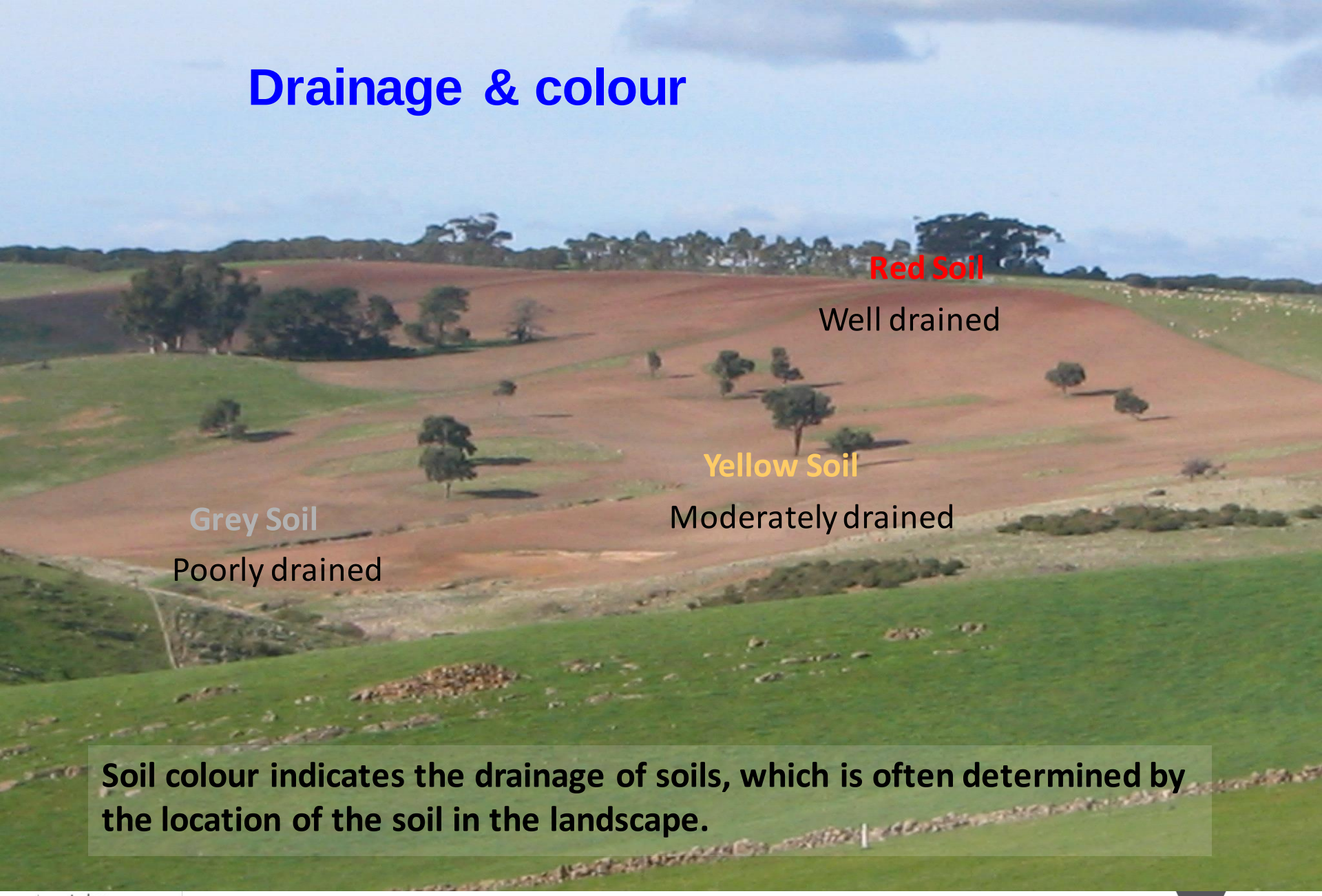
RED - Well drained soil, high in clay and iron minerals.

YELLOW - Moderately drained soils, high in clay and iron minerals.



GREY - Poorly drained soils, often waterlogged.

Drainage & colour



Soil colour indicates the drainage of soils, which is often determined by the location of the soil in the landscape.

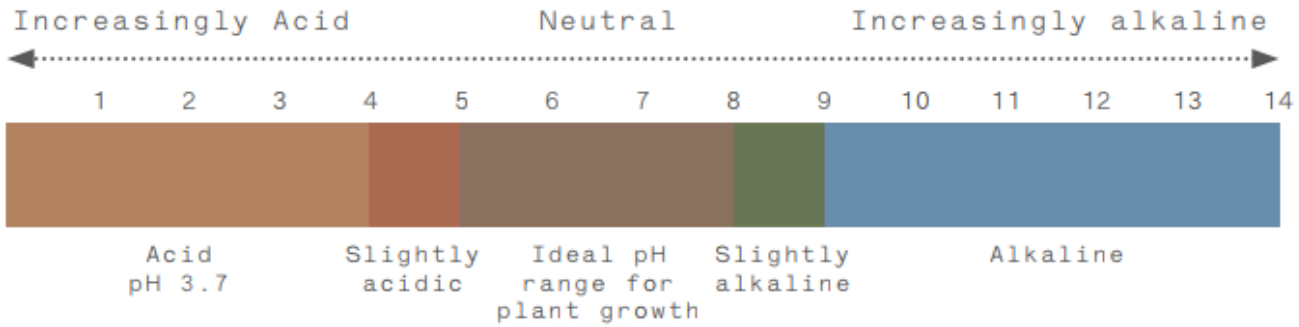
Mottling in waterlogged soil

Test	Poor Score = 1	Fair Score = 2	Good Score = 3	Weighting	Site 1	Site 2	Site 3
					(score x weighting)		
3. Soil colour	Grey	Light (Yellow/ Red/Brown)	Dark (Red/ Brown/Black)	x1			

4
Soil pH

Soil health Guide – Soil pH

- measure of the acidity or alkalinity of a soil
- concentration of hydrogen ions (H+) in the soil solution



pH scale is logarithmic. A one-fold decrease in pH value signifies a tenfold increase in acidity.
pH 6 is 10 times more acidic than a soil at pH 7
pH 5 is 100 times more acidic than a soil at pH 7

Soil health Guide – Soil pH

Soil pH in calcium chloride This is the standard method of measuring soil pH in all states other than Queensland.
Soil pH in water Distilled water is used in place of 0.01M calcium chloride, and results are expressed as pH(w).

The pH(CaCl2) test is the more accurate of the two pH tests, as it reflects what the plant experiences in the soil. The values of pH(CaCl2) are normally lower than pH(w) by 0.5 to 0.9. The difference between the methods can be significant when interpreting results and it is important to know which method has been used.

pH 1:5 soil:water

- Closer to soil solution pH in winter
- Lots of data on plant sensitivity to acidity/alkalinity using this test
- Use either to assess extremes in acidity or alkalinity
- *Keep pH above 5.5*

pH 1:5 soil:0.01 M $CaCl_2$

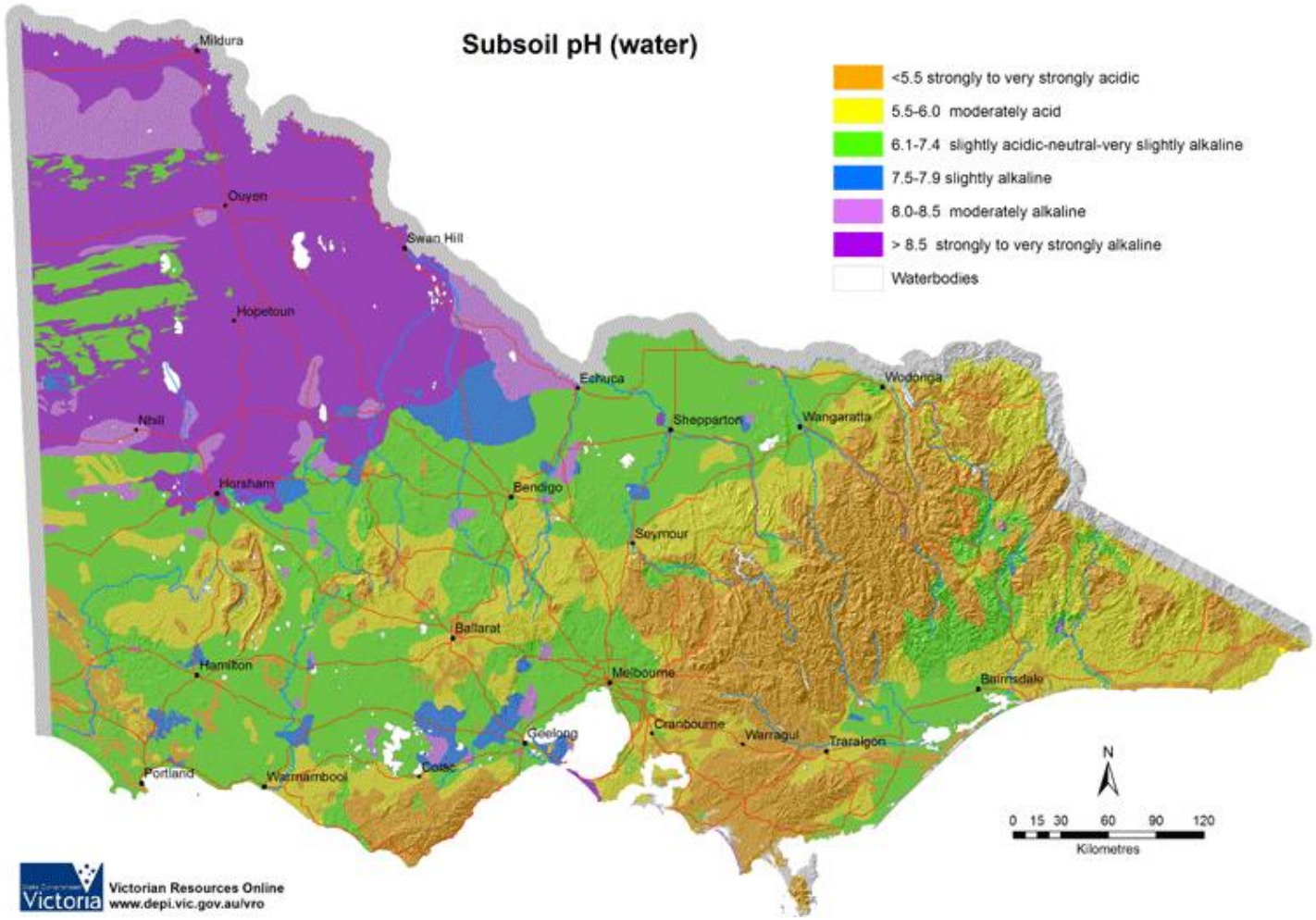
- Less affected by seasonal variation
- Closer to soil solution in summer
- Good test for monitoring acidification
- *Keep pH above 4.8*

pH field test kit

- Accurate to +/- 0.5

Soil pH – Linked to Climate (temp and rainfall)

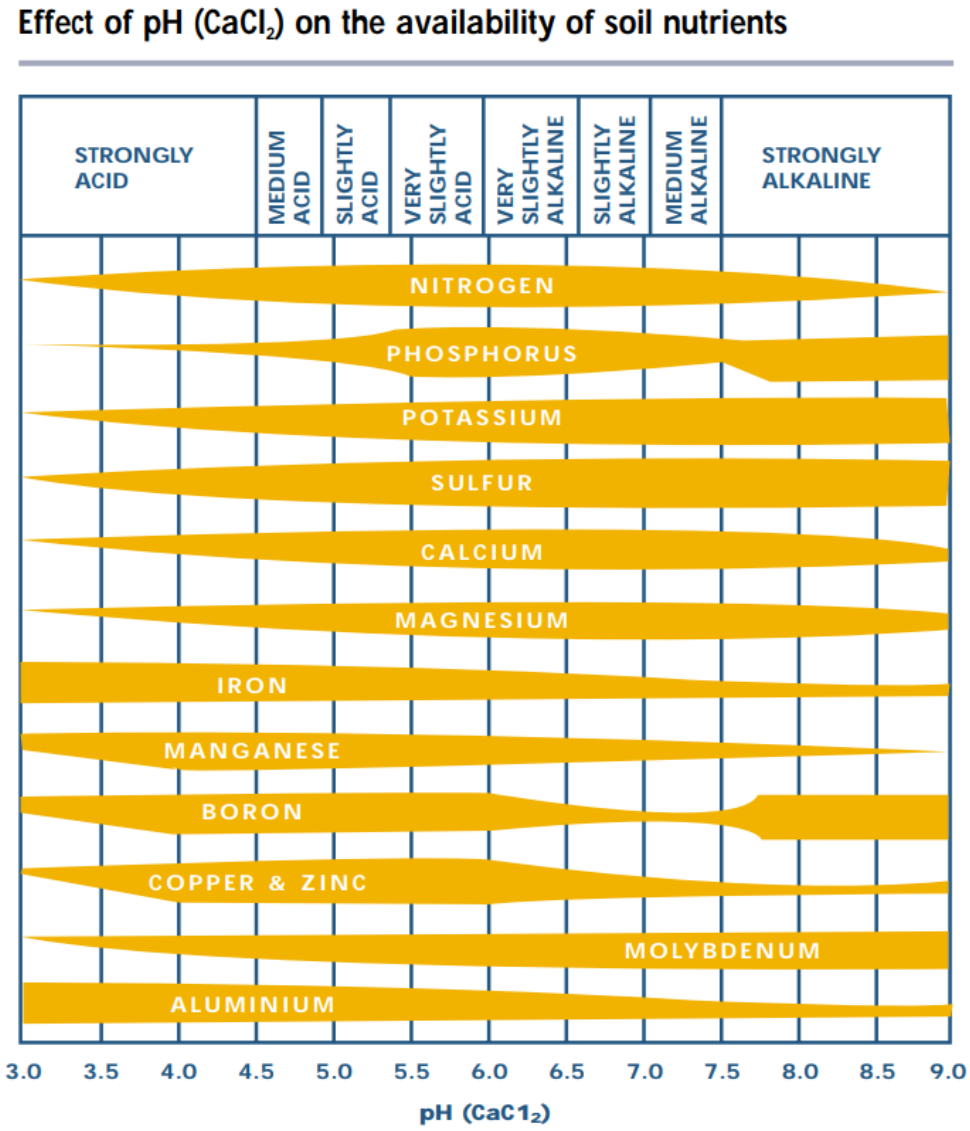
Acidification of the soil is a slow natural process and part of normal weathering. Many farming activities cause an increase in the rate of acidification of the soil.



Soil health Guide – Soil pH

Why is it important?

- Availability of nutrients change with pH
- Toxicities of Al, Mn & Fe
- Deficiencies of P, Mo & Ca
- Some plant roots wont be able to grow in too acidic or alkaline conditions
- Microbial activity is also affected by soil pH (they like it 5.0 to 7.0)



Soil pH – plant preferences

Ideal pH for most plants is 5.0 to 7.0 ($CaCl_2$) 5.5 to 8.0 (water)

	Species	pH_w range	pH_{Ca} range	
Pasture*:	Medic	6.0 - 8.5	5.3 - 8.0	Highly sensitive
	Phalaris	6.0 - 8.0	5.2 - 7.3	
	White clover	5.8 - 6.5	5.0 - 6.0	
	Lucerne	5.8 - 8.0	5.2 - 7.5	
	Sub clover	5.5 - 7.0	4.8 - 6.5	Sensitive
	Perennial rye	5.0 - 6.5	4.3 - 6.0	Moderately tolerant
	Cocksfoot	5.0 - 7.5	4.3 - 6.8	
Crop#:	Canola	6.0 - 7.5	4.9 - 6.5	Highly sensitive
	Barley	6.0 - 8.0	4.9 - 6.9	
	Wheat	5.5 - 8.0	4.4 - 6.9	Sensitive

Test	Poor Score = 1	Fair Score = 2	Good Score = 3	Weighting	Site 1	Site 2	Site 3
					(score x weighting)		
4. Soil pH (water) (use lowest pH value from top and/or sub soil)	pH 5.0 or lower; greater than pH 8.5	pH 5.0 - 6.0; pH 7.5 - 8.5	pH 6 to pH 7.5	x2			

Practical – Soil pH

Deane	pH water	
0-30cm		
CEA01:	5.46	Mildly Acidic
CEA02:	5.39	Mildly Acidic
0-10cm		
WholeFarm:	4.9	Acidic

Note: That soils generally get less acidic at depth, so the new readings may be higher because including deeper soil

5
Soil texture and CEC

Soil health Guide – Soil Texture

Loamy sand

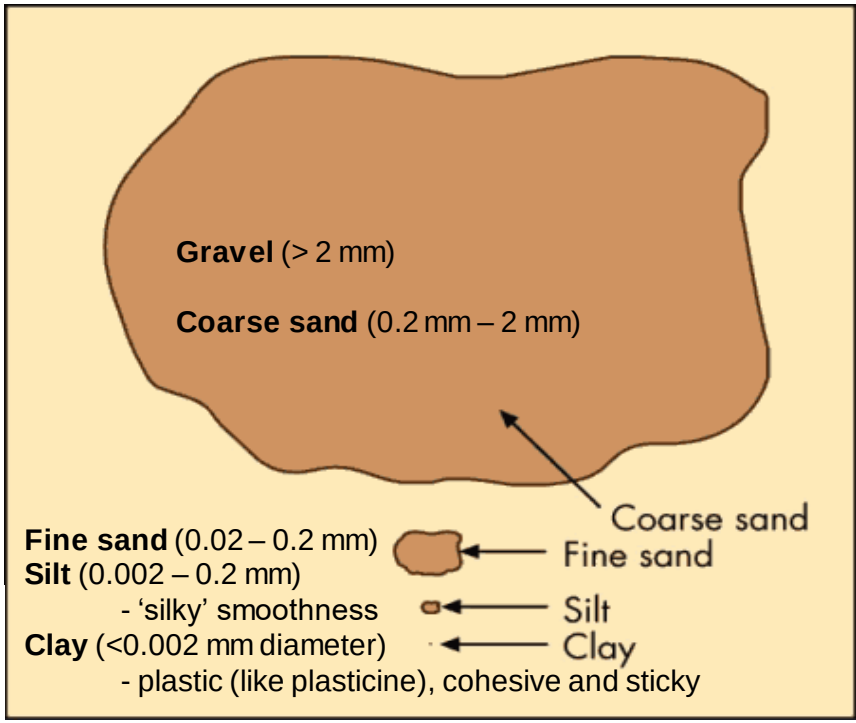
This is soil ‘texture’
The feel of the soil

Heavy clay

Soil health Guide – Soil Texture

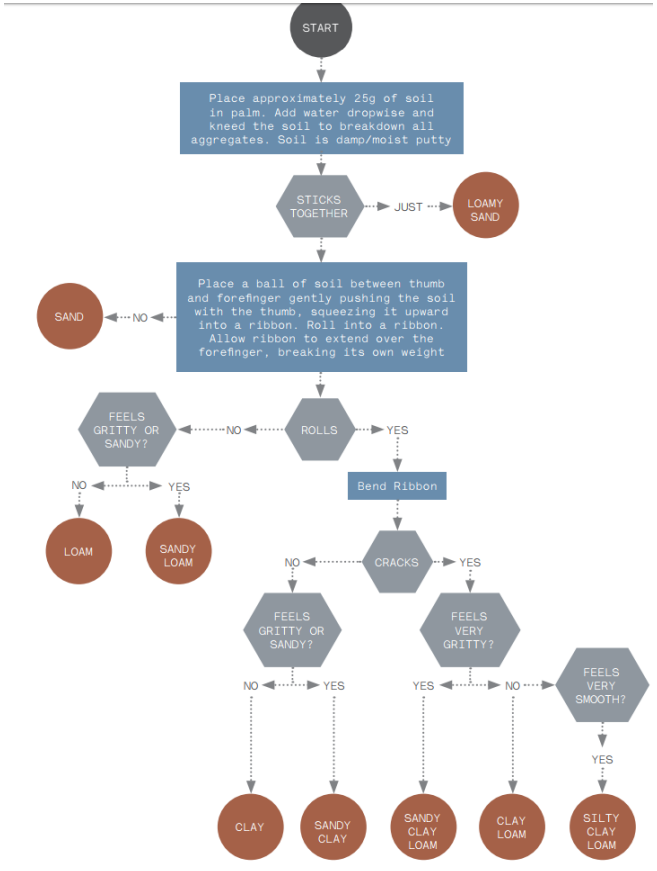
Why is soil texture important?

- measure of sand, silt and clay proportions in soil
- influences other soil properties (water holding capacity, porosity, permeability and the soils behavior in water)



Sand	Poor water holding capacity (WHC), good aeration, poor nutrient retention (low CEC), rapid drainage
Sandy loam/ Loam/ Clay loam	Good WHC, good aeration, good nutrient retention, good drainage
Clay	Good WHC, poor aeration, good nutrient retention but nutrients may be unavailable, poor drainage, slow drying

Soil health Guide – Soil texture flow chart



Soil texture can be estimated by feel. Take a small handful of soil from the top 10cm of soil, at the side of the hole. Remove any gravel, stone or organic matter.

Add water drop-by-drop and knead to break down aggregates. The soil has reached the proper consistency when it is plastic and mouldable like moist putty.

Soil texture should be measured separately for the topsoil and subsoil. Follow the flow chart below to determine the soil texture for each soil layer.

Test	Poor Score = 1	Fair Score = 2	Good Score = 3	Weighting	Site 1	Site 2	Site 3
					(score x weighting)		
5. Soil texture	Soil texture abruptly changes from the top soil (e.g. sandy loam) to the subsoil (e.g. clay)	Soil texture is the same throughout the profile	Soil texture gradually becomes heavier down the profile	x1			

Soil Test Interpretation –
Cation Exchange Capacity

Nutrient		Units	Heavy Soil e.g Clay	Medium Soil e.g Clay Loam	Light Soil e.g Loam	Sandy Soil e.g Loamy Sand
			Indicative guidelines only			
Phosphorus	P		15-23	15-23	15-23	15-23
Nitrate Nitrogen	N	mg/kg	15	13	10	10
Ammonium Nitrogen			20	18	15	12
Sulfur	S		10	8	8	7
pH		units	6.5	6.5	6.3	6.3
Conductivity		dS/m	0.200	0.150	0.120	0.100
Organic Matter		% OM	>5.5	>4.5	>3.5	>2.5
Calcium	Ca^{2+}	mg/kg	3125	2150	1000	375
Magnesium	Mg^{2+}	mg/kg	290	200	145	75
Potassium	K^{+}	mg/kg	235	190	150	100
Sodium	Na^{+}	mg/kg	69	60	51	25
Aluminium	Al^{3+}	mg/kg	54	45	41	14
Hydrogen	H^{+}	mg/kg	6	5	5	2
Effective Cation Exchange Capacity (ECEC)		$cmol^{+}/Kg$	20	14	7	4
Calcium	Ca^{2+}	%	77	75	69	60
Magnesium	Mg^{2+}		11	12	16	20
Potassium	K^{+}		3	4	5	8
Sodium - ESP	Na^{+}		2	2	3	3
Aluminium	Al^{3+}		7	7	7	9
Hydrogen	H^{+}					
Calcium/ Magnesium Ratio		ratio	7.0	6.3	4.3	3.0

Soil Test Interpretation –
Cation Exchange Capacity

Nutrient		Units	Heavy Soil e.g Clay	Medium Soil e.g Clay Loam	Light Soil e.g Loam	Sandy Soil e.g Loamy Sand
			Indicative guidelines only			
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pH		units	6.5	6.5	6.3	6.3
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Sodium	Na+	mg/kg	69	60	51	25
Aluminium	Al3+	mg/kg	54	45	41	14
Hydrogen	H^+	mg/kg	6	5	5	2
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Calcium	Ca2+	%	77	75	69	60
Magnesium	Mg2+	%	11	12	16	20
Potassium	K+	%	3	4	5	8
Sodium - ESP	Na+	%	2	2	3	3
Aluminium	Al3+	%	7	7	7	9
Hydrogen	H^+	%				
Calcium/ Magnesium Ratio		ratio	7.0	6.3	4.3	3.0

Available

Cations – Plant Agronomy

Or ppm

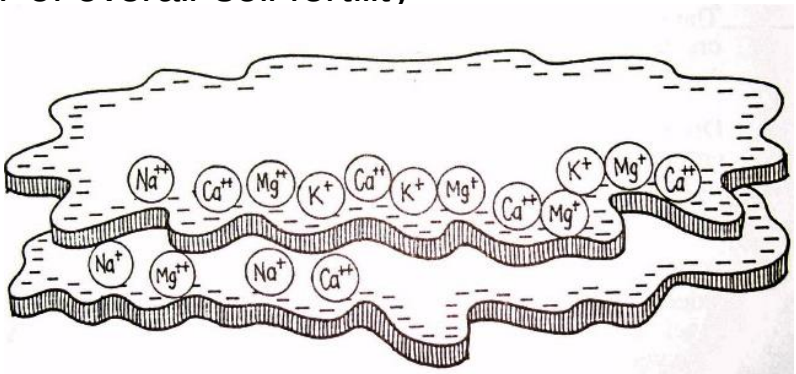
Cations – Soil Agronomy

Exchangeable

Soil Test Interpretation – Cation Exchange Capacity

- Is soil type/texture dependant (clay very influential, strong negative charges)
- Measures a soils ability to adsorb and hold cations (the amount of negative changes on your soil)
- Engine room for soil chemistry
- Cations removed by plants from the soil solution are replaced by those exchangeable cations held on the soil surface (clay) (therefore indicates how nutrients will be stored and made available in soil when added to increase soil nutrient levels)

- Used as an indicator of overall soil fertility



Cation Exchange Capacity (CEC): Milliequivalents (meq) is equivalent to centimoles (cmole); CEC is now given in centimoles (0.01 moles) of positive charge per kg of soil [cmole (+)/kg].

Soil Test Interpretation – Cation Exchange Capacity

Level determined by soil type generally: a CEC >12 $cmol^+/kg$ is considered moderate and soil has good nutrient-holding capacity.

Sand/sandy: < 10 $cmol^+/kg$

Clay: 10–15 $cmol^+/kg$

Organic matter: 200-400 $cmol^+/kg$

Sandy soils may be prone to leaching (can't hold nutrients as well). Consider splitting nutrient applications on such soils so that less nutrients are leached.

			Heavy Soil	Medium Soil	Light Soil	Sandy Soil
			e.g Clay	e.g Clay Loam	e.g Loam	e.g Loamy Sand
Nutrient		Units	Indicative guidelines only			
Phosphorus	P		15-23	15-23	15-23	15-23
Nitrate Nitrogen	N	mg/kg	15	13	10	10
Ammonium Nitrogen			20	18	15	12
Sulfur	S		10	8	8	7
pH		units	6.5	6.5	6.3	6.3
Conductivity		dS/m	0.200	0.150	0.120	0.100
Organic Matter		% OM	>5.5	>4.5	>3.5	>2.5
Calcium	Ca2+	mg/kg	3125	2150	1000	375
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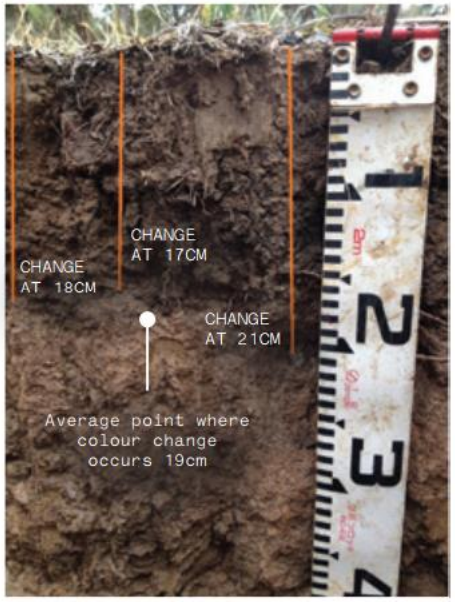
Potassium	K+		3	4	5	8
Sodium - ESP	Na+		2	2	3	3
Aluminium	Al3+		7	7	7	9
Hydrogen	H^+					
Calcium/ Magnesium Ratio		ratio	7.0	6.3	4.3	3.0

6
Top soil and soil nutrients

Soil health Guide – Top Soil

- Topsoil is the most organic-rich layer in the soil
- The main zone for water and nutrient uptake by plants and thus should be protected.
- The deeper the better



Test	Poor Score = 1	Fair Score = 2	Good Score = 3	Weighting	Site 1	Site 2	Site 3
					(score x weighting)		
6. Top soil	Top soil less than 10 cm deep	Topsoil greater than 10 cm deep overlaying a pale layer	Topsoil greater than 10 cm deep	x1			

Soil Test Interpretation – NPKS

- The top soil has higher levels of biological activity nutrients and organic matter.

			Heavy Soil e.g Clay	Medium Soil e.g Clay Loam	Light Soil e.g Loam	Sandy Soil e.g Loamy Sand
Nutrient		Units	Indicative guidelines only			
Phosphorus	P		15-23	15-23	15-23	15-23
Nitrate Nitrogen	N	mg/kg	15	13	10	10
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Magnesium	Mg2+		11	12	16	20
Potassium	K+		3	4	5	8
Sodium - ESP	Na+		2	2	3	3
Aluminium	Al3+		7	7	7	9
Hydrogen	H^+					
Calcium/ Magnesium Ratio		ratio	7.0	6.3	4.3	3.0

Soil Test Interpretation – NPKS Nitrogen

Important for amino acids and proteins in plants. There is three forms of N (all which fluctuate throughout the season)

Total N

- The total amount on N in the soil
- 98% of this N is contained in organic matter and is unavailable to the plants
- Controlled by soil biology

Nitrate N (No3-)

- Form taken up by plants
- Held by the soil loosely so is also mobile in soil

Ammonium-N (NH4+)

- Bonded tightly to the soil and organic matter
- This N is likely to become available

No real targets for N as they vary so widely throughout the season but the general rule is a level if 10mg/kg for ammonium and Nitrate N in pasture soils. Best to get this info from a local Agronomist who knows the area

Soil Test Interpretation – NPKS Nitrogen

Deane Paddock

Nitrate N (No3-)

CEA01 (0-30cm):	5.7 mg/kg	Low
CEA02 (0-30cm):	10 mg/kg	Moderate
WholeFarm (0-10cm) :	17.1 mg/kg	High

Ammonium-N (NH4+)

CEA01 (0-30cm):	7.9 mg/kg	Low
CEA02 (0-30cm):	6.3 mg/kg	Low
WholeFarm (0-10cm) :	24.1 mg/kg	High

Soil Test Interpretation – NPKS Phosphorous

Important for energy storage and plant shoot and root growth.
Australian soils generally low in P.

P can be measure through various chemical tests. It is important to use the best one for your region and situation. There are two main P tests.

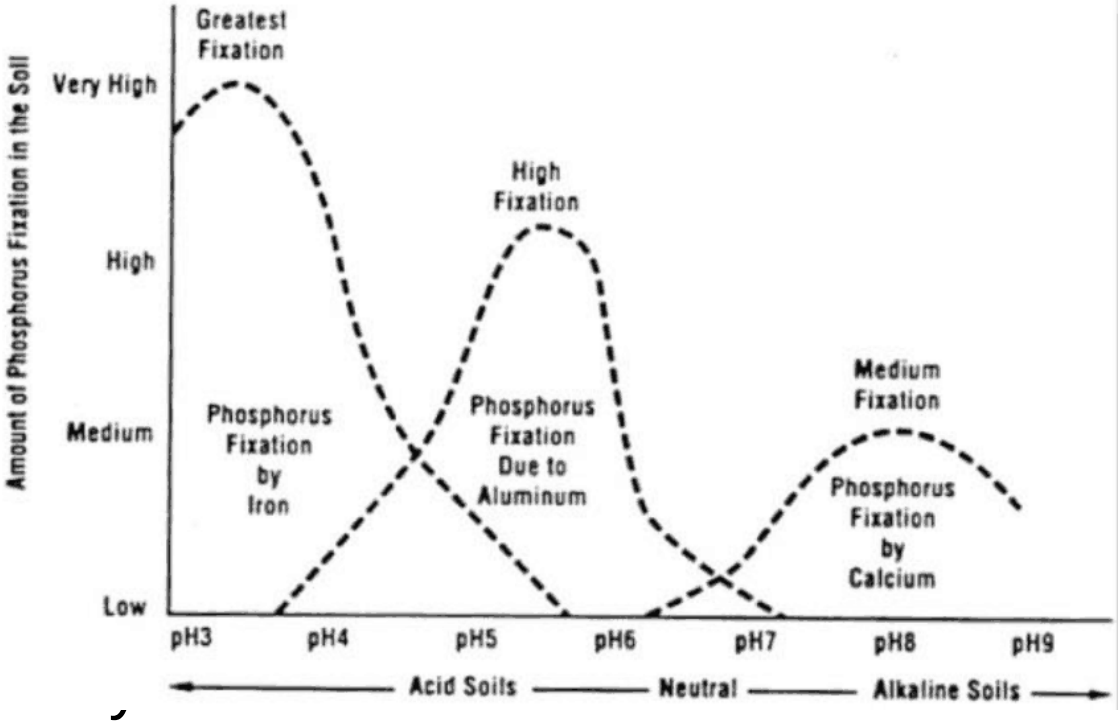
Olsen P
- Quick lab test that measures plant available P
- Better calibrated for pastures

Colwell P
- Similar to Olsen P, but longer test in the lab
- Extracts some of the plant available P, as well as some of the less available P (higher numbers)
- Needs to use a Phosphorous Buffering Index (PBI) with this value (to understand how the soil will hold onto P)

Bray
- More commonly used in NSW, particularly in the temperate areas on acid soils
- Your test also does Bray 1 and 2
- Bray I phosphorous indicates plant available results.
- Bray II phosphorous provides exchangeable values.

Phosphorous buffering Index (with Colwell P)

- Phosphorus is strongly adsorbed by soil, and varies by soil [illegible] oxides in soils
- This ca[illegible]
- Provide[illegible] chemic[illegible]
- PBI allo[illegible]ate of the amount of P required to raise available P levels in the soil. However you cannot change your PBI.



Soil Test Interpretation – NPKS Phosphorous

Olsen P	Target
Native pastures Introduced pastures	12 mg/kg 16 – 20 mg/kg
Colwell P	
PBI category	
Very low/sandy soils (0 – 70) Low (71 – 140) Moderate (141 – 280) High (281 – 840) Very High >840	20 – 30 mg/kg 31 – 36 mg/kg 37 – 44 mg/kg 45 – 64 mg/kg >64 mg/kg

Soil Test Interpretation – NPKS Phosphorous

Colwell P	Target (loam)
PBI category	
Very low/sandy soils (0 – 70) Low (71 – 140) Moderate (141 – 280) High (281 – 840) Very High >840	20 – 30 mg/kg 31 – 36 mg/kg 37 – 44 mg/kg 45 – 64 mg/kg >64 mg/kg
Bray 1	24
Bray 2	48

Deane Paddock

	PBI	Colwell P	Bray 1	Bray 2	Rating
CEA01 (0-30cm):		11 mg/kg	19	111	Low/High
CEA02 (0-30cm):		10 mg/kg	1.7	10	Low
WholeFarm (0-10cm) :	65.15	16 mg/kg		112	Low/High

Low PBI means that it takes less P added to the soil for it to become plant available as the soil doesn't hold too tightly to it, less applied more frequently

Soil Test Interpretation – NPKS Phosphorous

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Bray

- More commonly used in NSW, particularly in the temperate areas on acid soils

DGT-P

- New P test, being developed for crops and represents the ability of the roots to extract the P from the soil

Soil Test Interpretation – NPKS Potassium

- Important for regulating water and nutrient uptake, and plant response to environmental issues.
- Different plant species have different requirements for K.
- Also dependant on soil type and texture.
- Soil tests measure extractable or exchangeable K

Colwell K (mg/kg, ppm)

- Measures extractable K in soil solution
- Estimating the available and potentially available K

Exchangeable K (cmol/kg)

- Measures only what is currently available

Skene K

- Older test, give equivalent level of K to Colwell K

Soil Test Interpretation – NPKS Potassium

Colwell K

Potassium level	sands	Sandy loams	Clay loams	Clay
low	<50	<80	<110	<120
Moderate	50 - 100	80 - 120	110 - 150	120 180
Ideal	101 - 150	121 - 200	151 - 250	181 - 300
High	>150	>200	>250	>300

Exchangeable K

Potassium level	
Ideal (loams)	.28 - .54 $(cmol^+/K)$
Ideal (loams)	150 (ppm)

Deane Paddock

CEA01 (0-30cm):	.36 $(cmol^+/K)$	Moderate
CEA02 (0-30cm):	.26 $(cmol^+/K)$	Low
WholeFarm (0-10cm) :	152 (ppm)	Moderate

Soil Test Interpretation – NPKS Sulphur

- More than 95% of S in contained in the OM
- Similar biological process to N mineralisation in soil
- Sulphate is a negative ion, so not held by clay but remains in soil solution (highly mobile)

Potassium Chloride – 40 (KCL 40) test

- Measures the S in the sulphate ion form, plant available and some of the tied up organic S

Target levels are around 6-12 (mg/kg) or 20-30 (ppm)

Deane Paddock

CEA01 (0-30cm):	22 (mg/kg)	Moderate
CEA02 (0-30cm):	6.5 (mg/kg)	Low
WholeFarm (0-10cm) :	10 (ppm)	Very Low

Soil Test Interpretation – Trace Elements

- Zn, Cu, B, Mo, Fe, Mn, Co
- Leaf Analysis is a better predictor of plant performance
- Availability controlled by soil chemistry and soil pH

(ppm = mg/kg)

Trace element	Symbol	Total content (ppm)	Optimum pH range
Boron	B	10–630	5.0–7.0
Cobalt	Co	1–40	5.0–5.5
Copper	Cu	1–960	5.0–6.5
Chloride	Cl	5–800	not affected
Iron	Fe	3000–100 000	4.0–6.0
Manganese	Mn	30–5000	5.0–6.5
Molybdenum	Mo	0.1–18	6.0–8.5
Zinc	Zn	2–1600	5.0–6.5

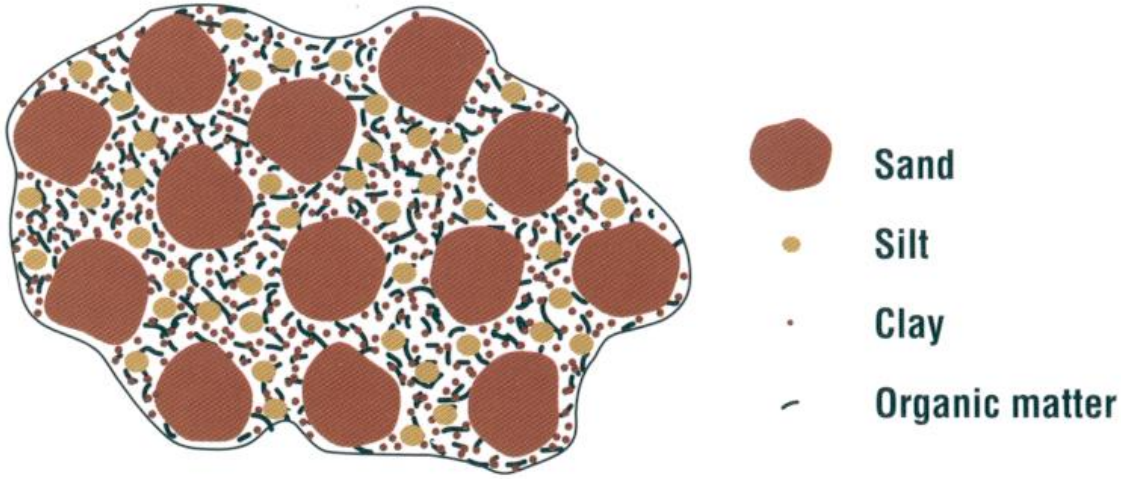
7
Soil structure

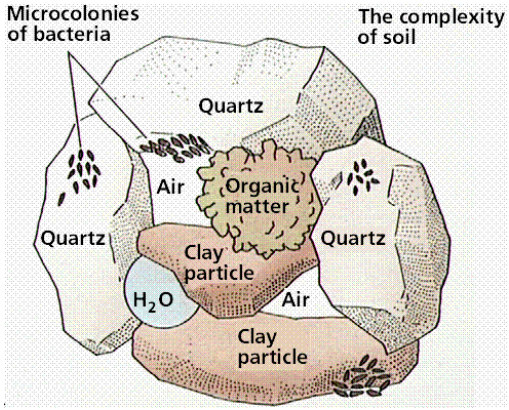
Soil health Guide – Soil structure

Soil particles (sand, silt, clay, Organic Matter) can be cemented together to form **aggregates**.

- Its the electrical attraction properties found in clay and organic matter that cement all soil material together.

Soil structure refers to the arrangement of soil aggregates and their size, shape, strength, and stability.





Soil health Guide – Soil structure and porosity

Soil porosity refers to the spaces within the soil which allow air, water and root movement

Soil requires pores and channels large enough to be readily seen by the eye – e.g. worm burrows or old root channels.

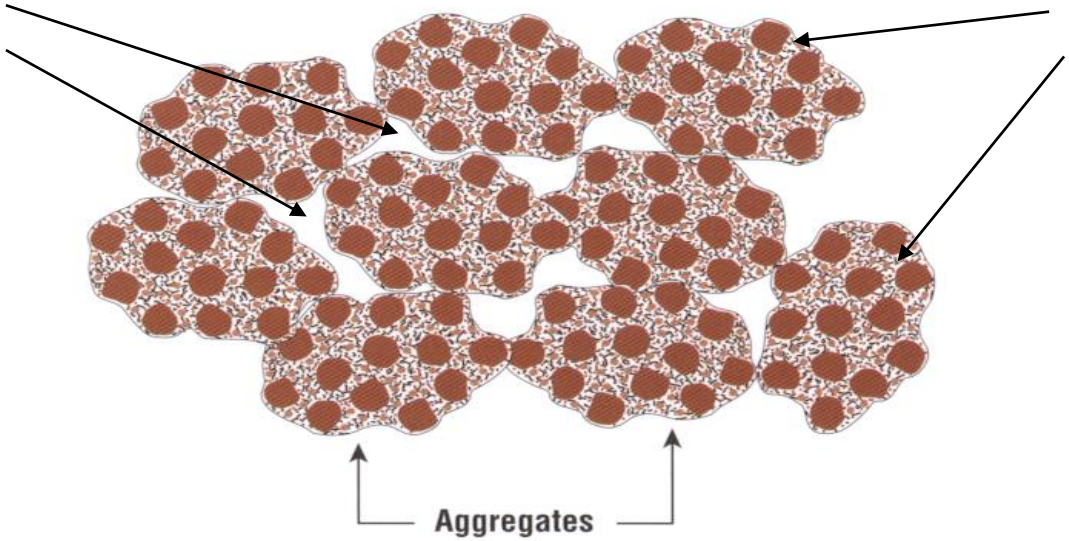
These pores are called **macropores,** and are important for water movement.

Pores within the aggregates/particles are called **micorpores** and are important for water storage.

Macropores between aggregates

Water transmission:

- Drainage
- Aeration
- Root growth



Micropores within aggregate

Water storage:

- Plant available & residual soil water

Poorly structured

- particles packed tightly
- high density and low porosity

Well structured

- particles formed into aggregates
- loosely packed, low density, high porosity

Subsoil structure and macropores – Roots

What do the roots really experience?

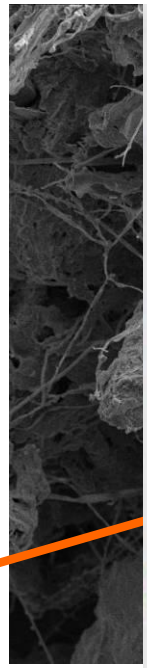
→ Roots grow in the spaces between dense soil

Soil structure & soil biology

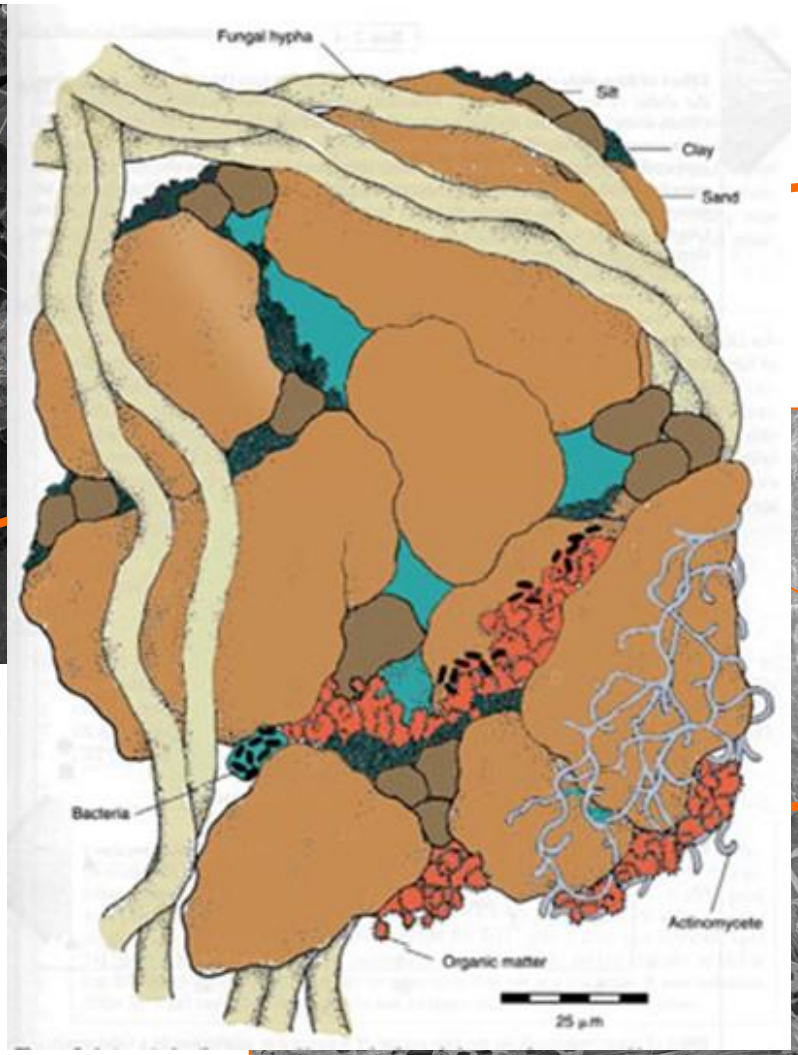
Fungal hyphae, bacteria etc

- ↑↑ aggregation and porosity

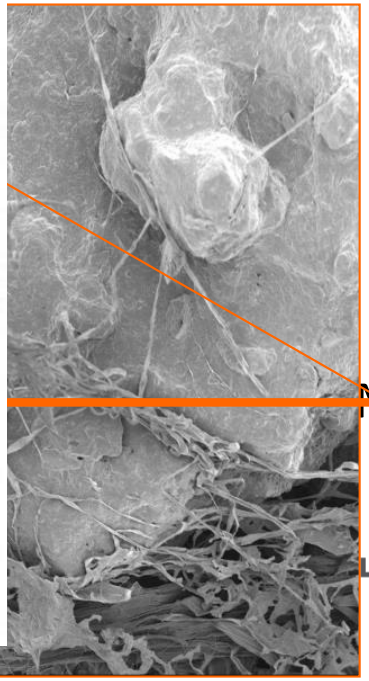
Soil pores
- water
- air



Macropores



Soil aggregate (ped)



Micropores

Soil health Guide – Soil structure

Visual appearance	Assessment score	Interpretation
	Poor soil structure.	• Soil dominated by large soil clods. • Very few fine soil aggregates. • Soil clods are very firm and/or angular in shape. • Soil clods have very few pores. Note: some 'poor' soils can have no structure at all, like a sand because of the absence of clods.
	Fair soil structure.	• Soil contains roughly equal proportions of large soil clods and fine aggregates. • Soil clods are very firm and/or angular in shape. • Soil clods have very few pores. • Comparisons.
	Good soil structure.	• Soil is dominated by fine soil aggregates. • There is only a small amount of large soil clods. • Soil aggregates are generally rounded and often quite porous.

Test	Poor Score = 1	Fair Score = 2	Good Score = 3	Weighting	Site 1	Site 2	Site 3
					(score x weighting)		
7. Soil structure	Cloddy, hard or crusty,few cracks/holes, no pores visible.	Some visible crumbly structure. Few pores visible	Crumbly top soil. Soil forms stable aggregates	x3			

8
Compaction

Soil health Guide – Soil compaction layers

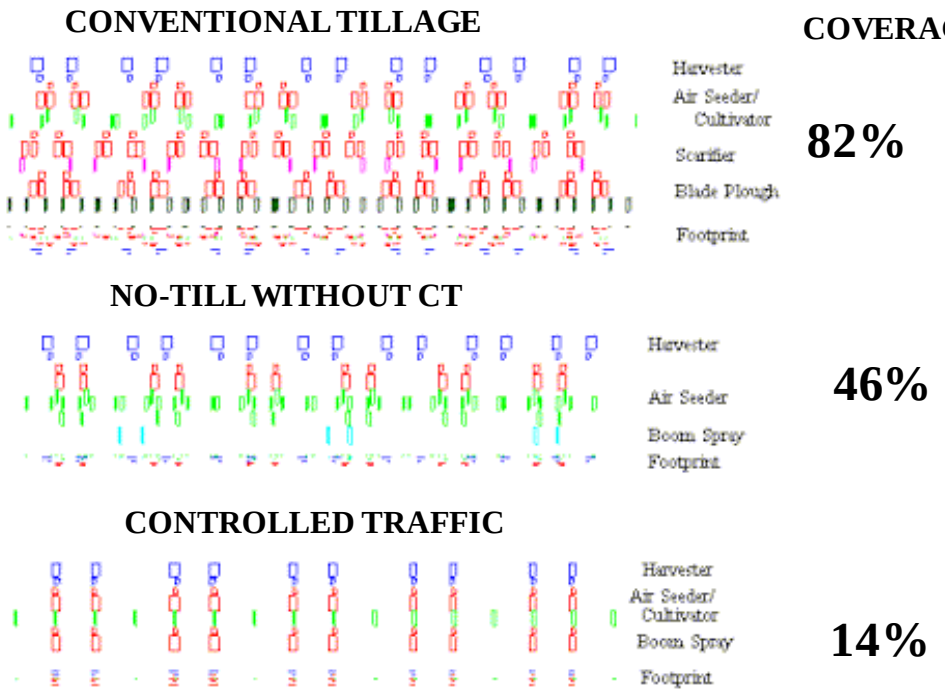
Soil compaction refers to the **compression of soil into a hard mass after passage of :**

- Heavy machinery travelling on soil surface, especially when its moist
- Implements such as cultivating equipment's cutting at the same depth of soil year after year
- Animal movement

Bulk density is the measure of soil compaction

Controlled traffic (CT)

Wheel tracks in your paddock



- ☒ Compaction by traffic reduces yields (10-40%)
- ☑ CT reduces compaction

AGRICULTURE VICTORIA

Source: Precision farming in the northern grains region - QLD - DPI, 2004.

How to measure compaction:

Soil penetration resistance

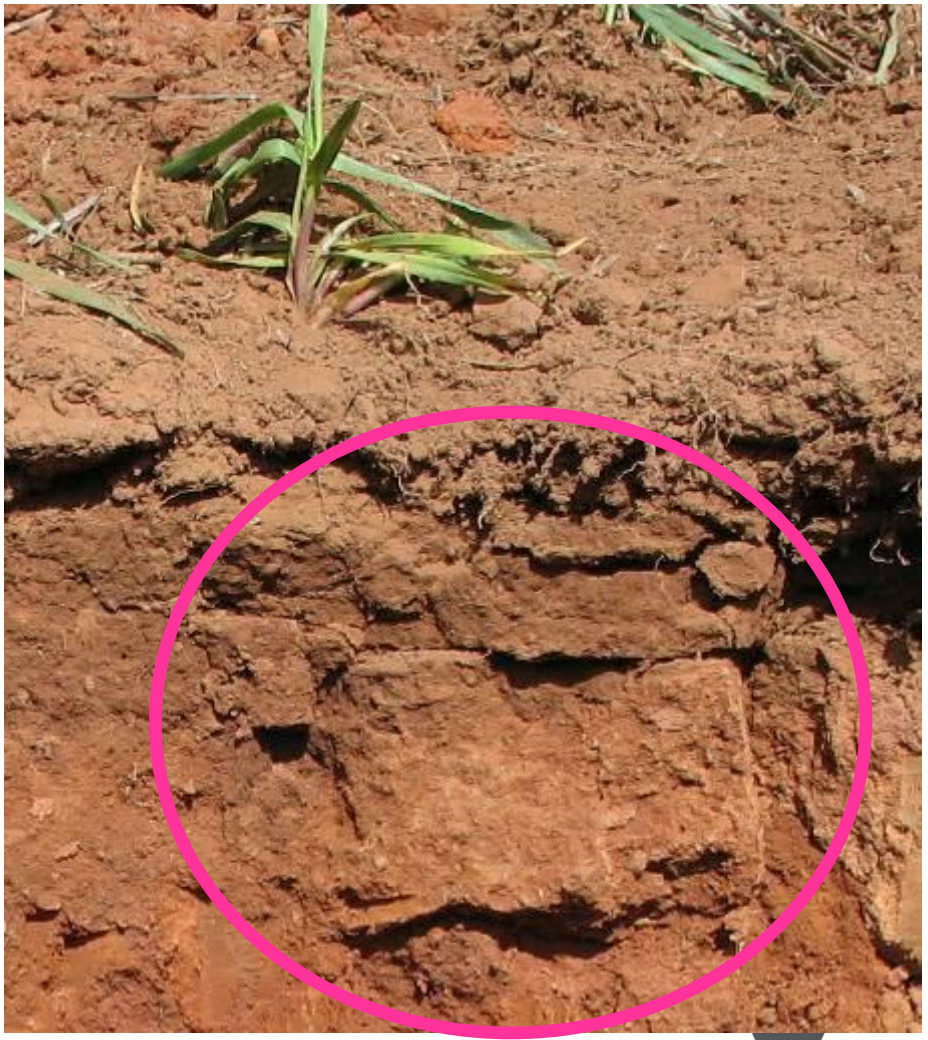
No wheel tracks

Wheel tracks

Subsurface compaction – platy structure

Non-trafficked

Trafficked



Soil health Guide – Soil compaction layers

Test	Poor Score = 1	Fair Score = 2	Good Score = 3	Weighting	Site 1	Site 2	Site 3
					(score x weighting)		
8. Soil compaction	Soil is hard; penetrometer will not penetrate the soil	Penetrometer penetrates with difficulty to less than 15 cm	Penetrometer easily penetrates beyond 15 cm	x2			

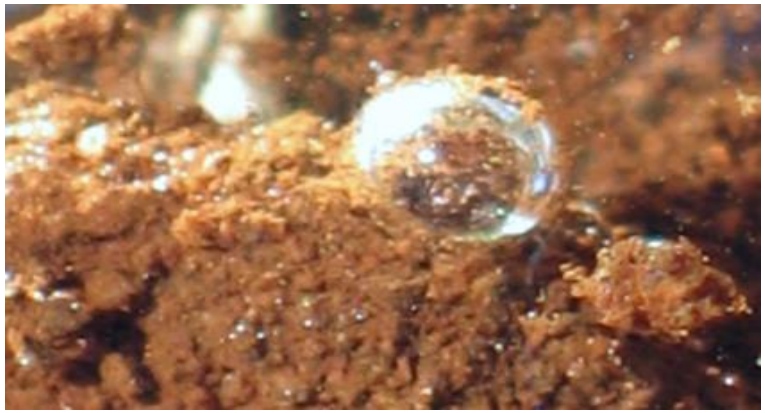
9
Slaking and dispersion

Soil health Guide – Soil slaking and dispersion

Stability of the soil when wet - Slaking (physical)

- Slaking occurs when weak soil aggregates break down into smaller fragments as a result of rapid wetting (clays swell).
- This results in the blocking of macropores, which in turn reduces the movement of water and air into and through the soil

- **Organic matter** reduces slaking by binding mineral particles and slowing rate of wetting
- **Crusting or hard-setting soils** slake into small fragments and set hard on drying



Soil health Guide – Soil slaking and dispersion

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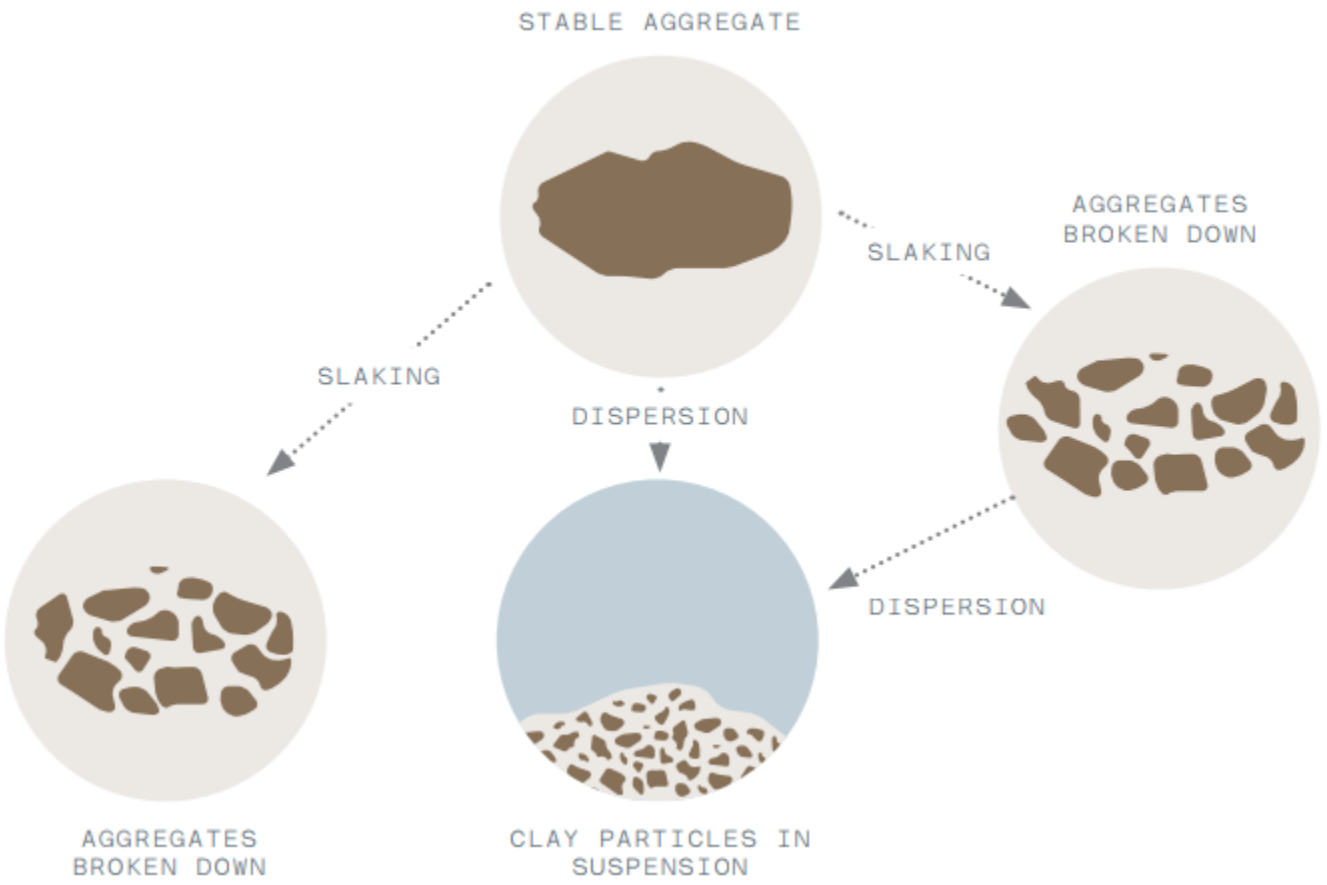
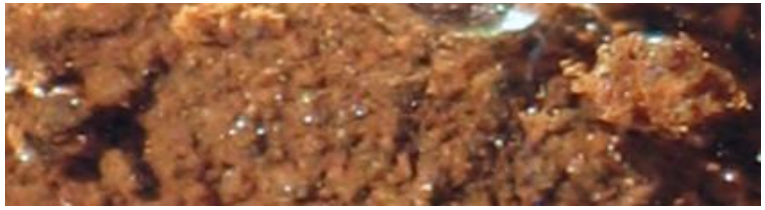
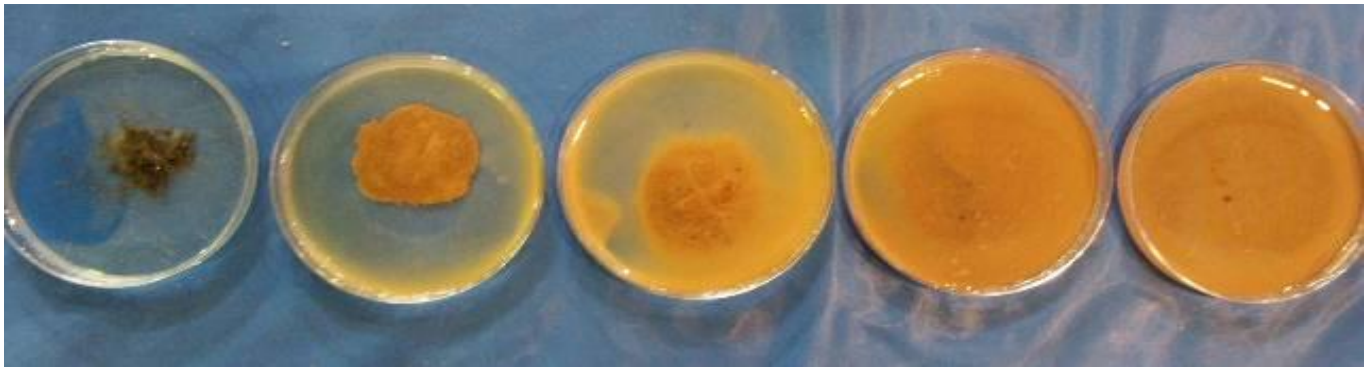




Soil health Guide – Soil slaking and dispersion

Dispersion (chemical)

- A chemical process whereby clay particles separate from soil aggregates when the soil is wet.
- Clay particles carry a negative electrical charge and repel each other.
- Dispersive soils are usually sodic, structurally unstable, and require special consideration for development.
- Disintegration of soil aggregates into particles <2mm (clay)
- Controlled by exchangeable cations, soil texture, clay type, organic matter & salinity



0 1 2 3 4

No sodicity Highly sodic/low salt

Soil health Guide – Soil slaking and dispersion

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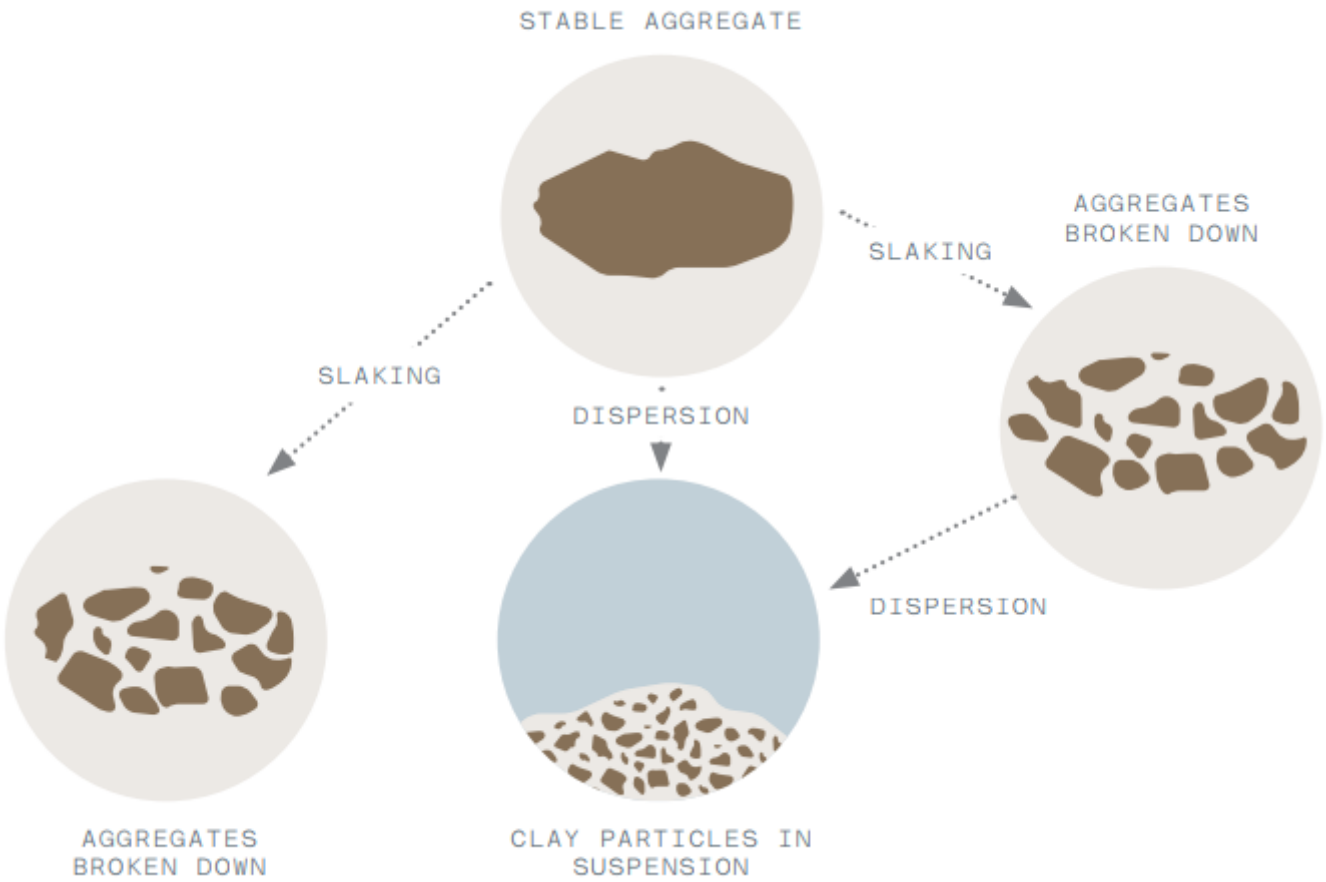
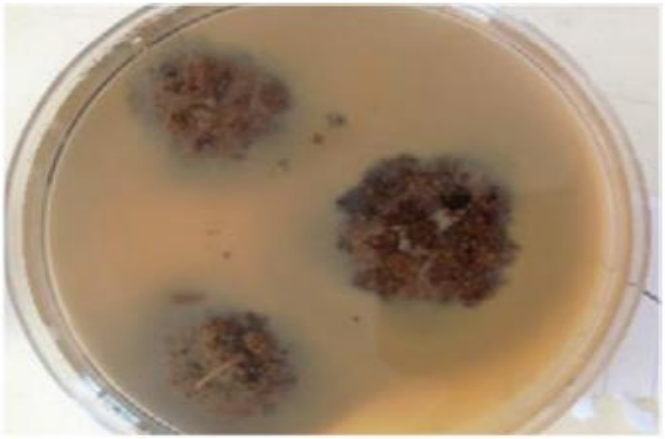


0 1 2 3 4

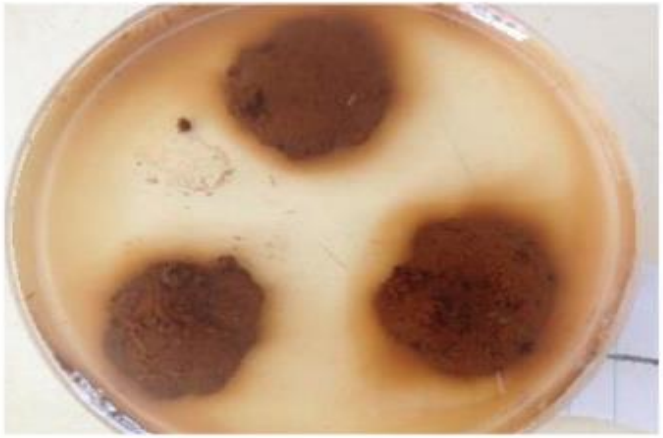
No sodicity Highly sodic/low salt

Soil health Guide – Soil slaking and dispersion

Slaking



Complete dispersion



Incomplete dispersion

No dispersion or slaking

Impacts of dispersive clays

- Surface crusting
- Reduced seedling emergence
- Reduced soil aeration
- Increased run-off and erosion risk
- Less groundcover and organic matter
- Less microbial activity

Test	Poor Score = 1	Fair Score = 2	Good Score = 3	Weighting	Site 1	Site 2	Site 3
					(score x weighting)		
9. Slaking & Dispersion	Unstable structure; aggregates break down and disperse; milkiness of water	Evidence of slaking; aggregates break down; no milkiness of water	Maintains structure; aggregates remain intact. No swelling of clay particles	x2			

Soil Test Interpretation – Sodium

Nutrient		Units	Heavy Soil e.g Clay	Medium Soil e.g Clay Loam	Light Soil e.g Loam	Sandy Soil e.g Loamy Sand
			Indicative guidelines only			
Phosphorus	P		15-23	15-23	15-23	15-23
Nitrate Nitrogen	N	mg/kg	15	13	10	10
Ammonium Nitrogen			20	18	15	12
Sulfur	S		10	8	8	7
pH		units	6.5	6.5	6.3	6.3
Conductivity		dS/m	0.200	0.150	0.120	0.100
Organic Matter		% OM	>5.5	>4.5	>3.5	>2.5
Calcium	Ca2+	mg/kg	3125	2150	1000	375
Magnesium	Mg2+	mg/kg	290	200	145	75
Potassium	K+	mg/kg	235	190	150	100
Sodium	Na+	mg/kg	69	60	51	25
Aluminium	Al3+	mg/kg	54	45	41	14
Hydrogen	H^+	mg/kg	6	5	5	2
Effective Cation Exchange Capacity (ECEC)		$cmol^+/Kg$	20	14	7	4
Calcium	Ca2+	%	77	75	69	60
Magnesium	Mg2+		11	12	16	20
Potassium	K+		3	4	5	8
Sodium - ESP	Na+		2	2	3	3
Aluminium	Al3+		7	7	7	9
Hydrogen	H^+					
Calcium/ Magnesium Ratio		ratio	7.0	6.3	4.3	3.0

Soil Test Interpretation– Sodium

Sodicity

- The ratio of the Na cations in the eCEC. This is the Exchangeable Sodium Percentage (ESP)
- Divide the sodium mg/kg by the total eCEC
- Less than 6% is non-sodic, ESP 6-15% is highly sodic, strongly sodic if grater that 15%

Salinity

Total soluble salt concentration in the soil solution. The salts make it harder for the plants to extract water from the soil

EC

- Electrical conductivity of the soil.
- Less than 0.5 dS/m are ideal

ECe

- Can also measure the electrical conductivity of a saturated extract, to determine salt tolerance of plants.
- Want levels under 1.8 dS/m. If above 2 dS/m, sensitive plants may be effected. Saline soil over 4 dS/m

Soil Test Interpretation – Sodium

Salinity

Total soluble salt concentration in the soil solution. The salts make it harder for the plants to extract water from the soil

EC

- Electrical conductivity of the soil.
- Less than 0.5 dS/m are ideal

Chloride

Critical levels

120 mg/lg sands to sandy loam

180 mg/kg loam to clay loam

300 mg/kg clays

Deane Paddock

	% Na	EC	
CEA01 (0-30cm):	2.2	0.047	Optimum
CEA02 (0-30cm):	1.6	0.039	Optimum
WholeFarm (0-10cm) :	2.6	0.08	Optimum

SOIL HEALTH SCORE CARD

Name: | Date: | Site location: *(Map transect location on following page)*

Test	Poor Score = 1	Fair Score = 2	Good Score = 3	Weighting	Site 1	Site 2	Site 3
					(score x weighting)		
1. Groundcover	Less than 50% groundcover (plants dead or alive; stubble)	50% to 70% groundcover (plants dead or alive; stubble)	More than 75% groundcover (plants dead or alive; stubble)	x3			
2. Evidence of soil biological actiivity	Fewer than two types of soil organisms	Two to five types of soil organisms	More than five types of soil organisms	x2			
3. Soil colour							
4. Soil pH (water) (use lowest pH value from top and/or sub s							
5. Soil texture							
6. Top soil	Top soil less than 10 cm deep	Topsoil greater than 10 cm deep overlaying a pale layer	Topsoil greater than 10 cm deep	x1			
7. Soil structure	Cloddy, hard or crusty,few cracks/holes, no pores visible.	Some visible crumbly structure. Few pores visible	Crumbly top soil. Soil forms stable aggregates	x3			
8. Soil compaction	Soil is hard; penetrometer will not penetrate the soil	Penetrometer penetrates with difficulty to less than 15 cm	Penetrometer easily penetrates beyond 15 cm	x2			
9. Slaking & Dispersion	Unstable structure; aggregates break down and disperse; milkiness of water	Evidence of slaking; aggregates break down; no milkiness of water	Maintains structure; aggregates remain intact. No swelling of clay particles	x2			

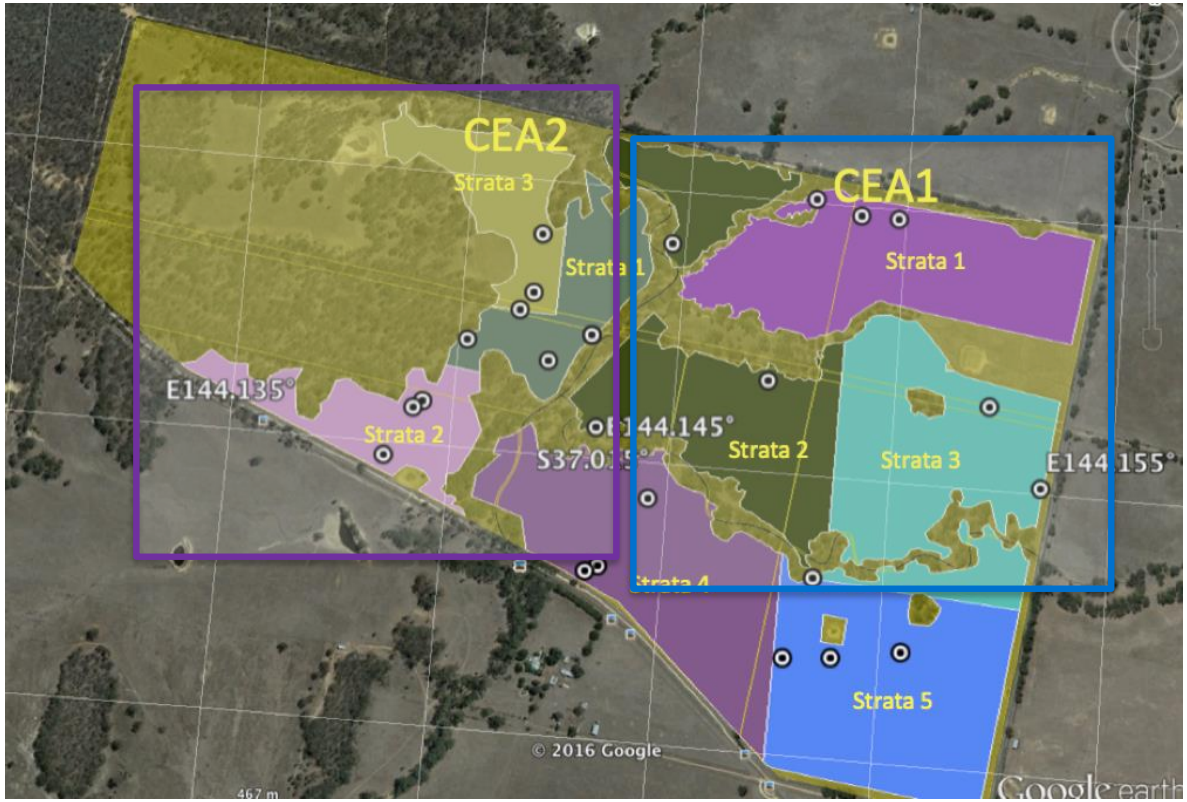
Remember its not about comparing with your neighbour, but creating your own benchmark for a particular paddock or soil/management type !

Soil Test – Deane Belfield

CEA1 – CFI Soil Carbon test as per methodology, 40mm diameter core and two depths 30cm and 100cm. (30 cm used for today.)

CEA2 – CFI Soil Carbon test as per methodology, 40mm diameter core and two depths 30cm and 100cm (30 cm used for today.)

WholeFarm – 20mm core and 10cm depth randomly selected across farm before purchase



Soil Test – Deane Paddock

	CEA1	CEA2	WholeFarm	Comments
	0-30 cm	0-30 cm	0-10 cm	
Organic C	.95% (low)	0.94% (low)	2.78% (moderate/High)	Less carbon deeper in the profile.
Soil pH (CaCl2)	5.46 Mildly Acidic	5.39 Mildly Acidic	4.9 Strongly Acidic	Soil less acidic moving down profile, some remedy taking place
Texture	Loam	Loam	Loam?	Increasing the OM will increase the CEC, however, due to the low clay content in the soil, there is a limit to its improvement. Could also be a lower CEC connected with the OC decreasing due to the sample size.
Cation Exchange Capacity	4.33	3.58	7.4	
Nitrogen (Nitrate N (No3-)	5.7 mg/kg	10 mg/kg	17.1 mg/kg	Less N moving down the profile and less in CEA1. But could also be tie up of N, which would be released later in the season.
Phosphorous (Colwell P)	11 mg/kg	10 mg/kg	16 mg/kg	Phosphorous required. But as a low PBI, less will be bound to soil, so a positive
Potassium (Exchangeable K)	.36 ($cmol^+/K$)	.26 ($cmol^+/K$)	152 (ppm)	OK
Sulphur	22 (mg/kg)	6.5 (mg/kg)	10 (ppm)	Either sulphur down the profile, or it has been increased over time. Could use some on CEA2
Salt EC 1:5	.047 ds/m	.039 ds/m	.08 ds/m	Ok
Sodicity (% na)	2.2 %	1.6%	2.6%	Ok

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Take home messages

Conclusion

- Being able to assess soils, using what we have at our disposal, whether that be using lab based tests, in field tests or our ability to look smell and feel the soil, paired with an understanding of basic soil principles is important in managing our soils.
- Being able to observe and measure how your farming practices are impacting on the health of your soil is important for long term agricultural productivity and sustainability into the future
- It is important to manage not only the chemical, but biological and physical attributes of the soil
- Good soil management is about feeding the plant AND the soil

Thanks

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Jobs,
Precincts
and Regions

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