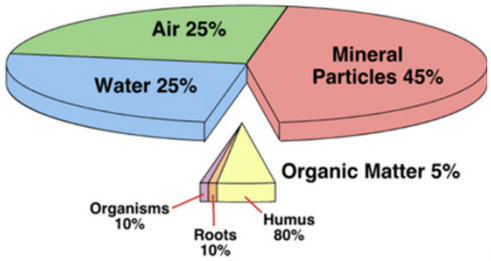
Managing fertility to build soil carbon

Declan McDonald
Principal Soil Scientist

REGEN SOILS
Bringing soils back to life

1

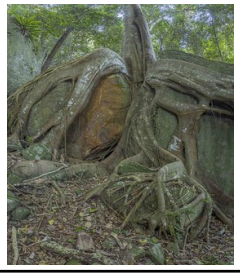
Components of a healthy soil



REGEN SOILS
Bringing soils back to life

2

What is the difference between the mineral and organic fractions?



- Minerals are the non-organic component of the soil
- Minerals fertilisers include all the synthetics plus mined products (e.g. urea, gypsum)
- Organic fertilisers came from something once living
- Nature specializes in organo-mineral bonding

REGEN SOILS
Bringing soils back to life

3

Q. What drives soil fertility?
A. Minerals

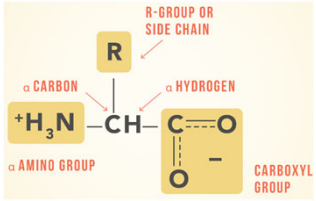
- Liebig's barrel
- Focus on chemical agriculture
- All macro and micro elements must be present in appropriate proportions
- Modern agriculture and horticulture has developed around this concept

REGEN SOILS
Bringing soils back to life

4

What formulation do plants need?

- Nitrates and ammonium (NO_3-, NH_4^+)
- Sulfates (SO_4^{2-})
- Orthophosphates (H_2PO_4-, HPO_4^{2-})
- Mineral ions, K^+, Ca^{2+}, Mg^{2+}, Zn^{2+}, Cu^{2+}, Mn^{2+}, $H2BO_3$-
- Amino acids (building blocks of proteins; contains carbon, nitrogen, oxygen and hydrogen)



REGEN SOILS
Bringing soils back to life

5

How do plant access nutrients to grow?

Via organic matter and / or mineralisation from rocks

Or from a bag

6

How much can be applied via SOM?

Element	Human	bacteria	fungi	Stubble	SOM humus	LF
Carbon	10,000	10,000	10,000	10,000	10,000	10,000
Nitrogen	2654	2504	1091	155	833	570
Phosphorus	325	494	109	15	200	50
Sulphur	330	264	87	15	143	50

Kirkby, nd

REGEN SOILS Bringing soils back to life

7

Soil organic matter has fixed ratios

- Carbon – 10
- Nitrogen – 0.83
- Phosphorus – 0.2
- Sulfur – 0.14
- Therefore, to sequester 10 tonnes of C in SOM, I need 833kg N, 200kg P, and 143kg S.
- It also means that if I have 5% SOM in my soil, I have 65t SOM/ha
- 65t SOM/ha = ~38t SOC and 3.17t nitrogen

REGEN SOILS Bringing soils back to life

8

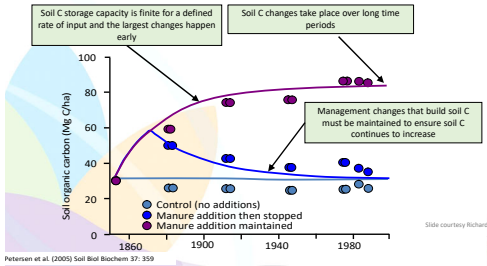
Key messages for SOC sequestration

- The supply of N, P or S (and not just C input) can limit the formation of humus.
- So where do the minerals come from?
- Many N-fixing organisms (Diazotrophes)
- P solubilising organisms
- Mineral resources (esp. K and trace elements)
- Nutrient cycling through organic fraction
- Importance of particulate organic matter to nutrient supply

REGEN SOILS Bringing soils back to life

9

Management of Soil Carbon – saturation and permanence



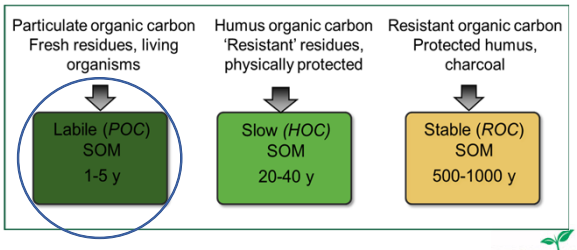
Peterson et al. (2005) Soil Biol Biochem 37: 359

Hoosfield continuous barley experiment, Rothamstead, UK, 1852 – present day

REGEN SOILS Bringing soils back to life

10

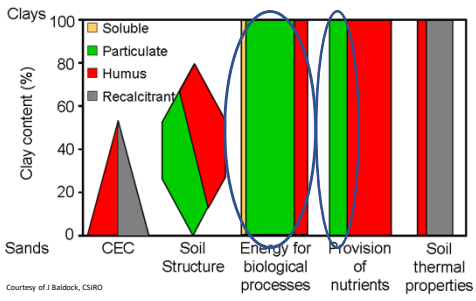
Different forms of Soil Organic Matter



REGEN SOILS Bringing soils back to life

11

Properties of Particulate SOM (POC)

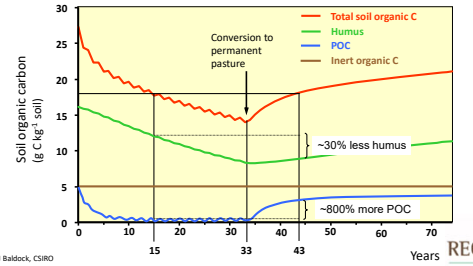


Courtesy of J Baldock, CSIRO

REGEN SOILS Bringing soils back to life

12

Soil carbon ain't soil carbon

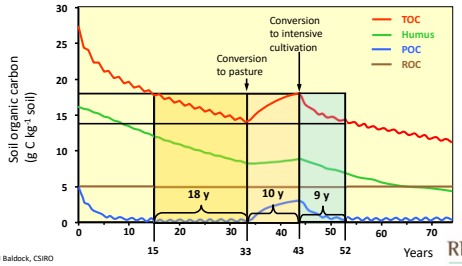


Courtesy of J Baldock, CSIRO

REGEN SOILS
Bringing soils back to life

13

Vulnerability of soil carbon content to variations in management practices



Courtesy of J Baldock, CSIRO

REGEN SOILS
Bringing soils back to life

14

The value of particulate organic matter

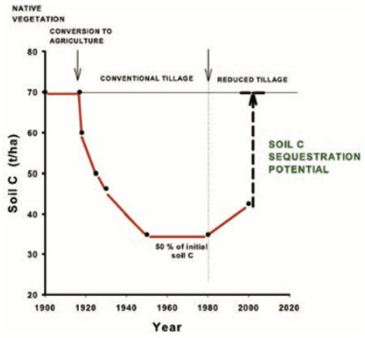
- Virgin soil (never farmed, never fertilised) - 3.5% SOC
- Long term pasture - 3.9% SOC
- Long term cropping - 2.1% SOC

- With particulate OM removed:
- Virgin soil (never farmed, never fertilised) - 2.1% SOC
- Long term pasture - 2.8% SOC
- Long term cropping - 2.0% SOC

REGEN SOILS
Bringing soils back to life

15

This explains why SOC loss is so rapid in the early stages



Chan, 2008. NSW Primefact 735

16

Case study: Harrington-Hawes

Courtesy P Ronalds

REGEN SOILS
Bringing soils back to life

17

Case study: Harrington-Hawes

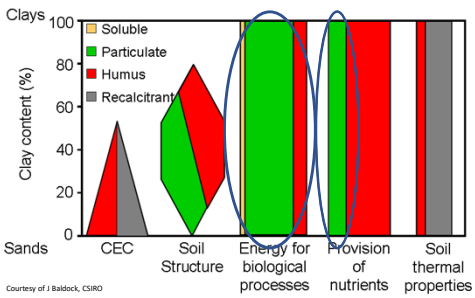
Ferrosol (Red) Soil – Nayook
Spud Paddock
Perennial pasture till 2010
Cropped to spuds in 2010
Returned to pasture in 2010
Carbon levels -163t/ha (0-30cm)
Carbon - 6% (0-10cm)
Soil Structure – compacted with a hard pan at 30cm
Coring – difficult with each core getting stuck in the coring tube
Pasture Paddock
Perennial pasture – continual
Carbon levels – 213t/ha (0-30cm)
Carbon - 10% (0-10cm)
Soil Structure – crumbly peds with good structure throughout the profile
Coring – easy with each core sliding through the coring tube

Courtesy P Ronalds

REGEN SOILS
Bringing soils back to life

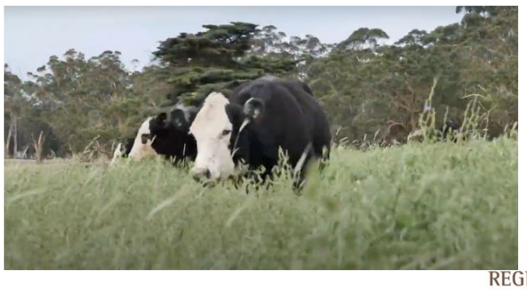
18

Properties of Particulate SOM (POC)



19

Where does POC come from?



20

And how it gets into the soil

21

Nutrient use efficiency

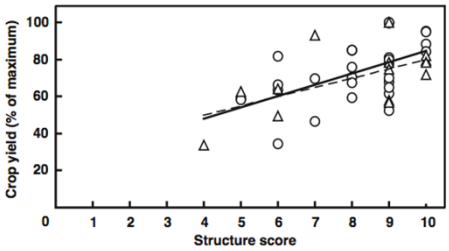


Figure 1. Relationship between crop yield and soil structure score on dermosols and ferrosols. ○ Ferrosol potatoes; △ dermosol poppies.
(Cotching et al., 2004)

22

The way we farm is most important

		Overall mean ranking	
Farm 5	Conv + compost	45.4	1
Farm1	Conv + compost	44.7	2
Farm 6	Conv + compost	35.7	3
Farm 8	Conventional	32.3	4
Farm 11	Conventional	31.5	5
Farm 4	Conv + compost	29.2	6
Farm 2	Conv + compost	25.2	7
Farm 7	Conventional	24.1	8
Farm 9	Conventional	23.3	9
Farm 3	Conv + compost	22.3	10
Farm 12	Conventional	17.4	11
Farm 10	Conventional	17.3	12

23

Questions during the week

- Why present the same information with different testing types?

Soluble Calcium (mg/kg)		**Inhouse S10 - Morgan 1	1150	750	375	175
Soluble Magnesium (mg/kg)			160	105	60	25
Soluble Potassium (mg/kg)			113	75	60	50
Soluble Phosphorus (mg/kg)			15	12	10	5.0
Exchangeable Calcium	(cmol,/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	15.6	10.8	5.0	1.9
	(kg/ha)		7000	4816	2240	840
	(mg/kg)		3125	2150	1000	375
Exchangeable Magnesium	(cmol,/kg)		2.4	1.7	1.2	0.60
	(kg/ha)		650	448	325	168
	(mg/kg)		290	200	145	75
Exchangeable Potassium	(cmol,/kg)		0.60	0.50	0.40	0.30
	(kg/ha)		526	426	336	224
	(mg/kg)		235	190	150	100
Exchangeable Sodium	(cmol,/kg)		0.3	0.26	0.22	0.11
	(kg/ha)		155	134	113	57
	(mg/kg)		69	60	51	25
Exchangeable Aluminium	(cmol,/kg)	**Inhouse S37 (KCl)	0.6	0.5	0.4	0.2
	(kg/ha)		121	101	73	30
	(mg/kg)		54	45	32	14
Exchangeable Hydrogen	(cmol,/kg)	**Rayment & Lyons 2011 - 15G1	0.6	0.5	0.4	0.2
	(kg/ha)		13	11	8	3
	(mg/kg)		6	5	4	2

24

Questions during the week

- Do you have a rule of thumb on nutrient use efficiency and cost?

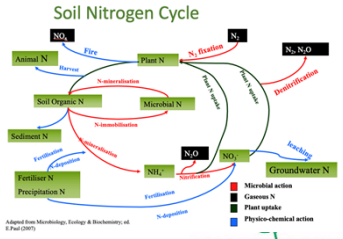
		Nutrient efficiency including fertiliser (%)			
		N	P	K	S
Farm1	Conv + compost	45.3	61.3	21.2	50.9
Farm 2	Conv + compost	20.3	18.2	15.1	47.3
Farm 3	Conv + compost	20	23.3	12.1	33.7
Farm 4	Conv + compost	31.6	46.5	16.8	21.8
Farm 5	Conv + compost	44.5	50.3	33.7	52.9
Farm 6	Conv + compost	37.7	53.1	28.7	23.4
Farm 7	Conventional	37.7	26.3	13	19.4
Farm 8	Conventional	11.1	39.8	27.4	51
Farm 9	Conventional	23	40.1	14.9	15
Farm 10	Conventional	28.9	16.9	10.4	12.9
Farm 11	Conventional	41.7	33.3	21.4	29.7
Farm 12	Conventional	20.6	22.8	12.1	14

REGEN SOILS Bringing soils back to life

25

Questions during the week

- How would you characterise the difference between soil organic nitrogen and synthetic nitrogen
- Are slow release applications such as rock phosphate or slow-release urea better to use if you have to address deficiency with fertilisers? Can they be used to control release of nutrients into the system?

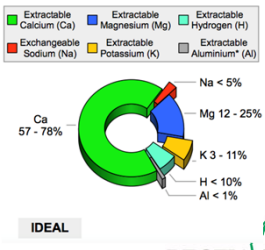


REGEN SOILS Bringing soils back to life

26

Questions during the week

- Are there optimal ratios of Organic Matter to Calcium to Mg for building soil structure?



REGEN SOILS Bringing soils back to life

27

Questions during the week

- What is the importance of soil structure at depth and how does this impact the growing zone?

REGEN SOILS Bringing soils back to life

28

Questions during the week

- How do soil microbiological communities impact on making nutrients available for building soil structure (Ca, Mg etc)?

- Calcium:
  - Increases mechanical strength of plant;
  - Enzyme activator;
  - Stimulates microbial activity;
  - Controls ionic balance and membrane permeability.
- Magnesium:
  - Important for phosphate metabolism, protein synthesis;
  - Enzyme activation.

REGEN SOILS Bringing soils back to life

29

Questions during the week

- What tests are available to show how well the carbon building process is going in our soil and can they indicate what part of the process needs to be tweaked?

- Three main types:
  - Potassium permanganate oxidation
  - Walkley-Black
  - Leco / Dumas combustion
- Microbial testing:
  - Microbial biomass
  - PLFA
  - Genomic

REGEN SOILS Bringing soils back to life

30

Questions during the week

- What is the role of fulvic acid in improving nutrient efficiency?
- What is the effect of compost tea compared to compost and impact on nutrition?
- Lots of 'stimulants' and 'activators' on the market
- *Caveat emptor!*
- Fulvic acid is a chelator
- Compost tea introduces novel organisms
- Compost introduces novel organisms *plus* substrate
- Is the nutrient contribution significant?

REGEN SOILS
Bringing soils back to life

31

Summary

- Managing fertility is about creating a soil environment for everything that will live in that soil – macro- and micro-organisms and plant roots
- Relying on urea and superphosphate to grow pastures and crops is not creating an agroecosystem
- Managing fertility has always been about organic matter
- OM buffers pH and salinity and facilitates de-toxification of soils
- OM has a central role in soil structure (ventilation and drainage)
- OM is the primary energy source in soils
- You will never go broke from having too much OM

REGEN SOILS
Bringing soils back to life

32

Agriprove modules

1. How soil works and how plants grow; the drivers of the case for change (acidification, SOC loss, erosion)
2. Organic matter – the cornerstone of soil health and sustainable production
3. Soil biology – millions of years in the making
4. Mineral management – the role of macro and micro elements
5. Managing fertility to build soil carbon.
6. Management practices to grow soil carbon – grazing, cropping and perennial horticulture
7. Bringing it all together – monitoring and evaluation. Soil and tissue testing – chemistry, physics and biology (and the role of soil health cards)

REGEN SOILS
Bringing soils back to life

33

THANK YOU

Declan McDonald
Principal Soil Scientist
B.Sc (Urban Hort), M.SustAg (Soils)

CPSS Certified Professional Soil Scientist Declan McDonald

REGEN SOILS
Bringing soils back to life

34