# The capacity of our soils to store carbon

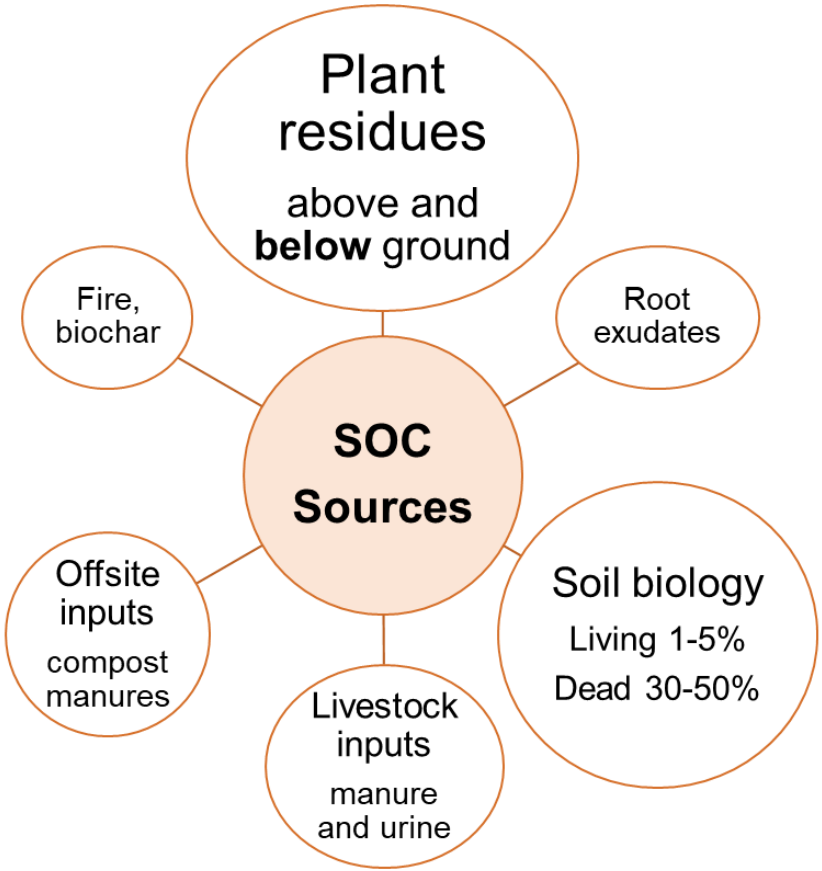
## Update on recent SA based work

**Coorong and Tatiara Carbon, Climate and your farm workshop - Keith**

Dr Amanda Schapel

22 August 2022 – Keith Institute

# What is OC?






Decomposition losses are between 70-90% of C inputs

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# Five functions reliant on organic matter

OM + Soil biology
= C, H, O, N, P, S

$CO_2$

**PRODUCTIVITY BIOMASS**

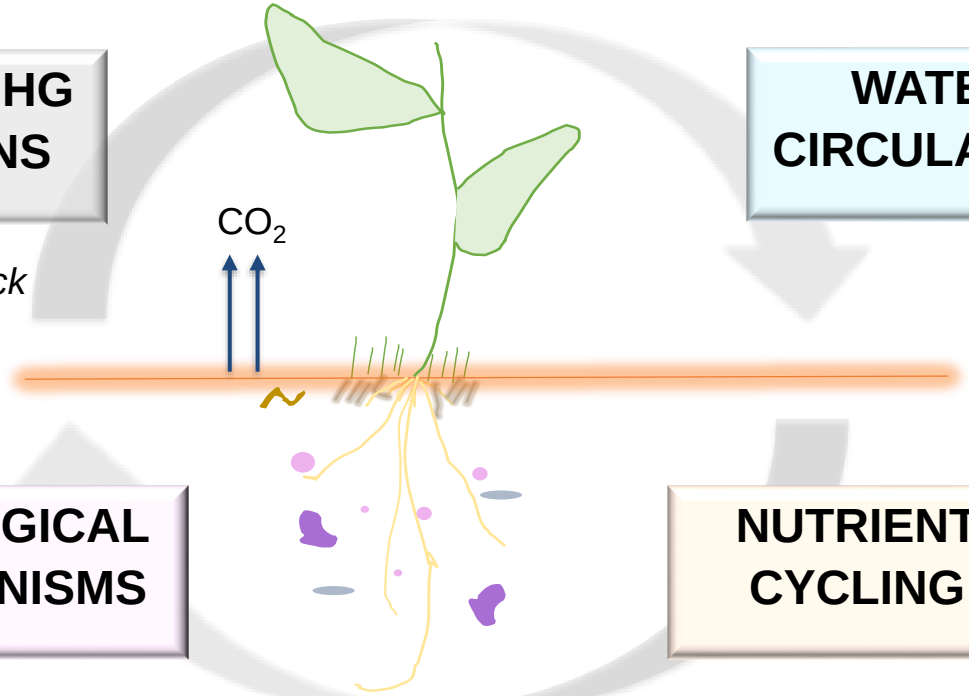
*OC inputs*
*Less bare ground*

**OFFSET GHG EMISSIONS**

*70-90% of $CO_2$ lost back to the atmosphere*

**WATER CIRCULATION**

*Water holding capacity*




*Energy source*
*Diversity*

**BIOLOGICAL ORGANISMS**

**NUTRIENT CYCLING**

*Nutrients and CEC*

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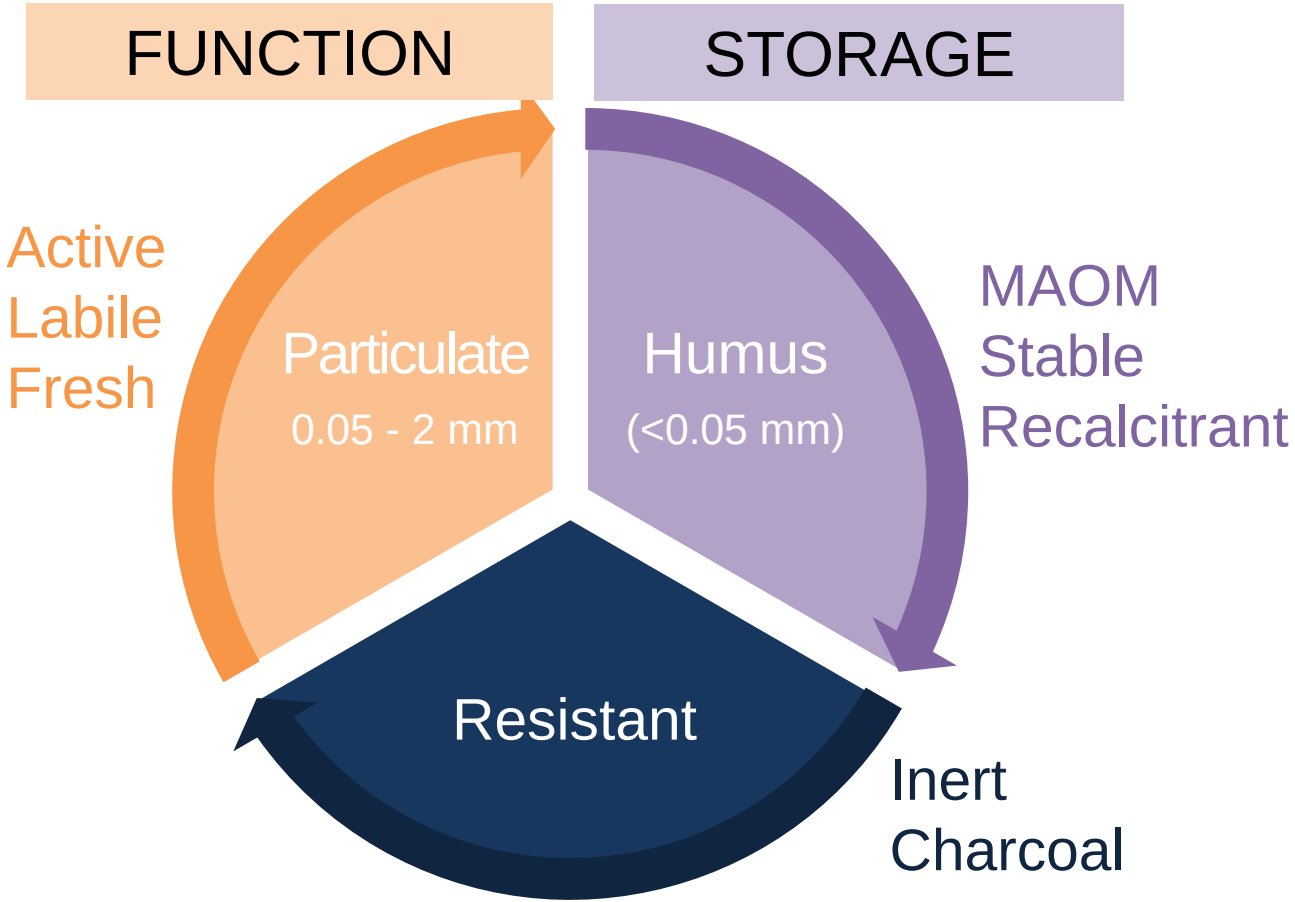
# OC is made up of 3 fractions / pools




OC turnover

POC = years

HOC = decades

ROC = centuries

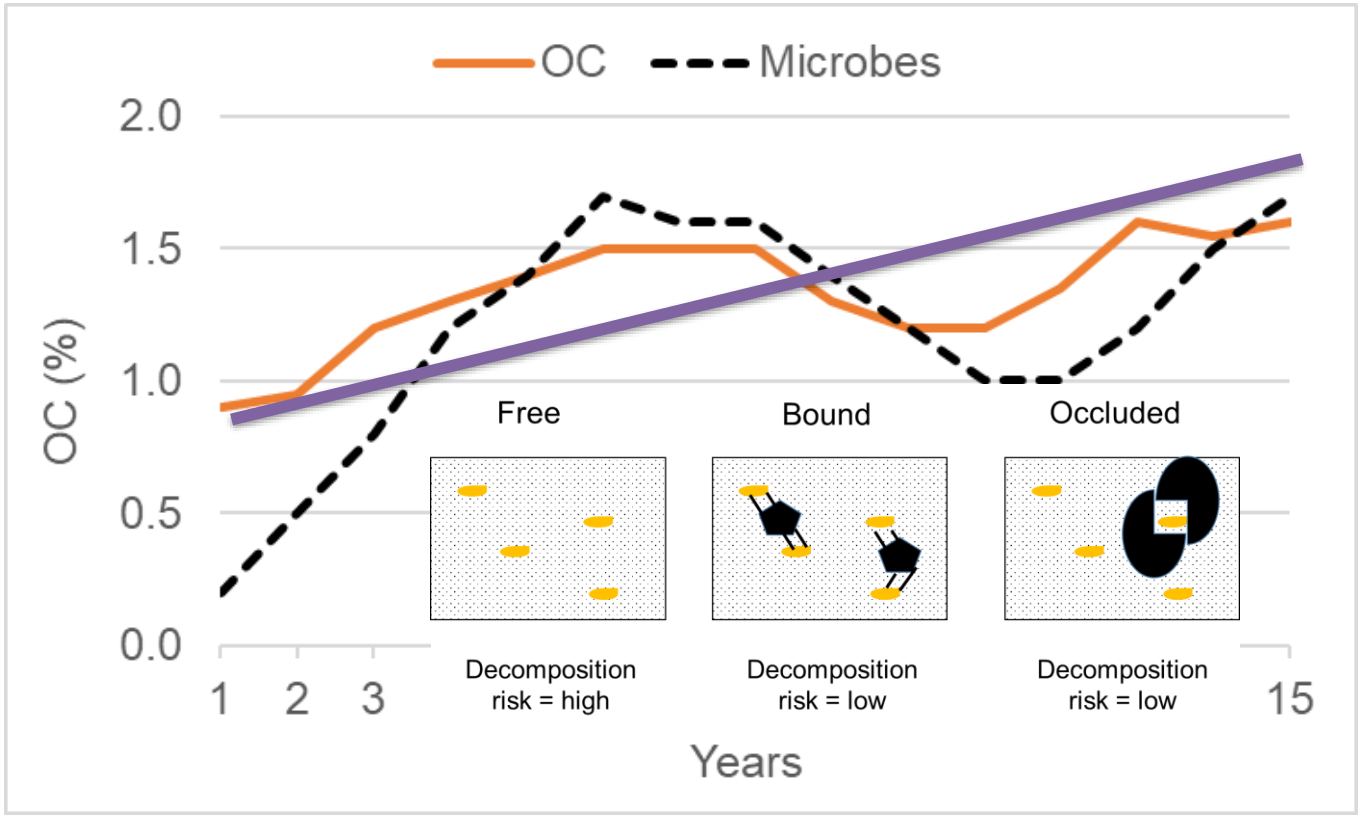
After J. Baldock CSIRO

# What factors influence soil OC?

| | |
|---|---|
| POTENTIAL SOC<br>Upper Limit | DEFINING FACTORS<br>**Soil type, texture (clay)**<br>Mineralogy, Density |
| ATTAINABLE SOC | LIMITING FACTORS<br>**Rainfall, temperature**<br>Climate, Solar radiation |
| ACTUAL SOC<br>Lower Limit | REDUCING FACTORS<br>Management decisions<br>**Tillage, ground cover** |


*After Ingram and Fernandes 2001*

# Soils capacity to stabilise and build OC




OC change is not linear

OC can be decomposed if not stabilised in soil

Stabilised with clay minerals, Fe, Al, Ca and aggregates (MAOC)

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# How do you know if there is an opportunity to store more OC?

## Benchmarks

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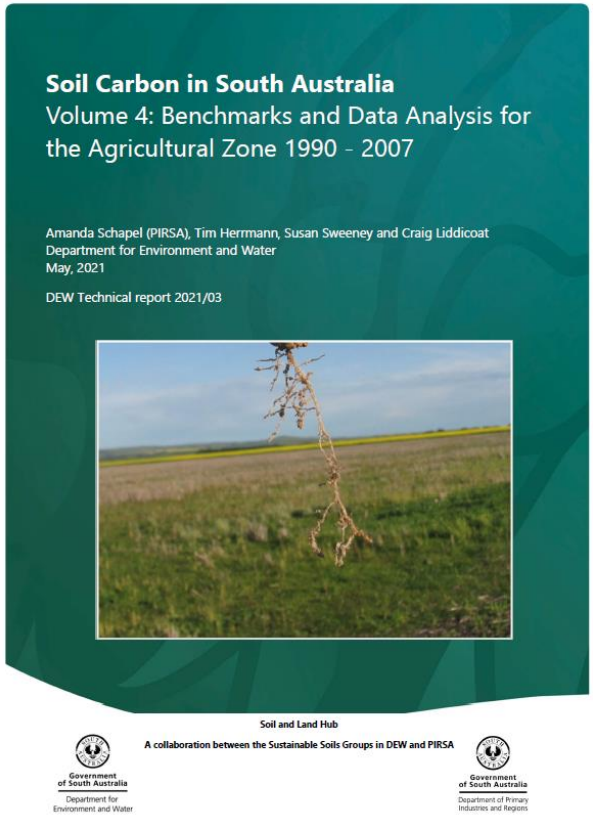
# OC Benchmarks





Upper South East

Includes LGA Coorong, Tatiara, Kingston

Lower South East

Includes LGA Naracoorte Lucindale, Robe, Wattle Range and Grant

Land Resources Home (environment.sa.gov.au) under All Reports for Soil C in SA Volume 4

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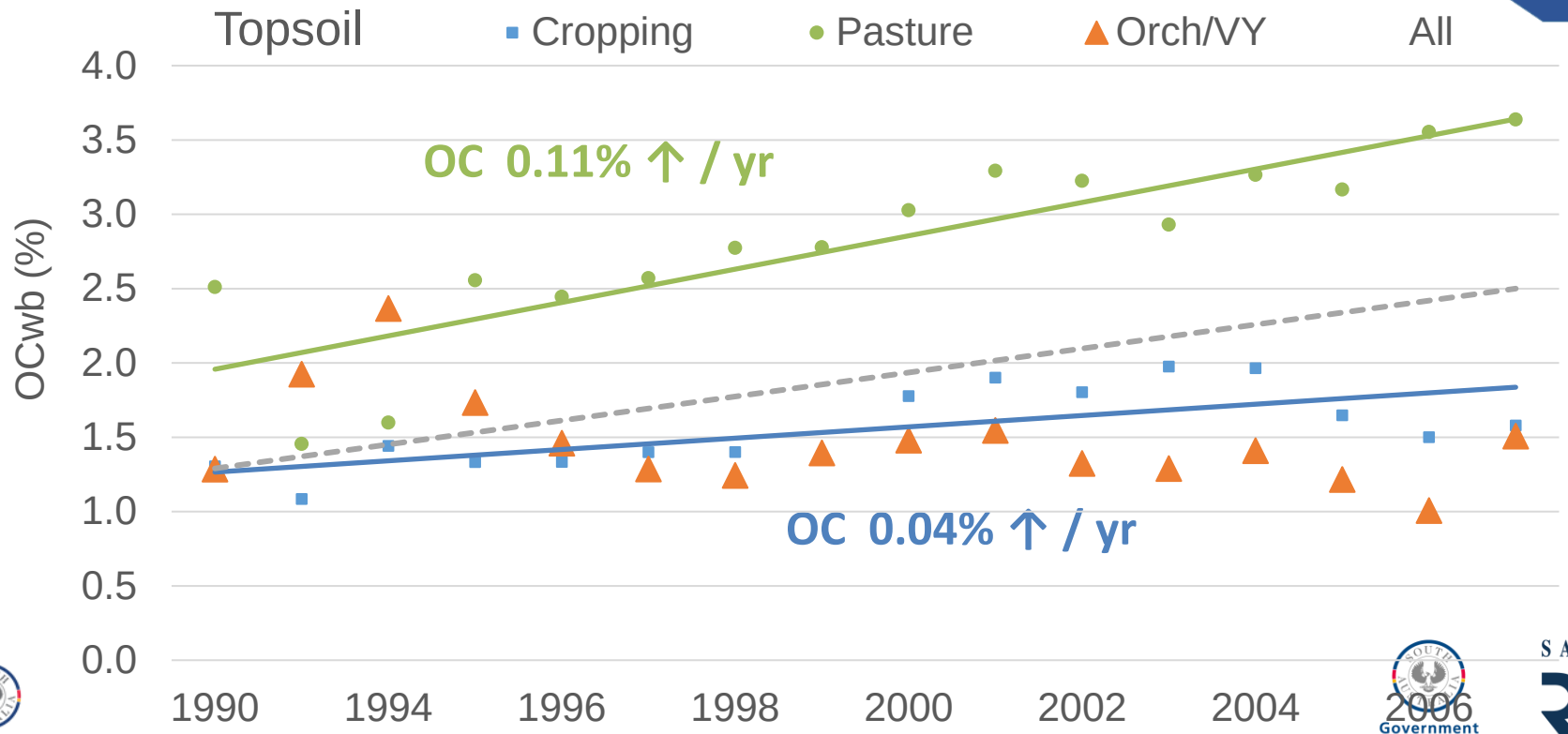
# Soil Carbon 1990-2007

36,000 soil tests

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*Soil and Land Hub – Collaboration between Sustainable Soils groups in DEW and PIRSA*

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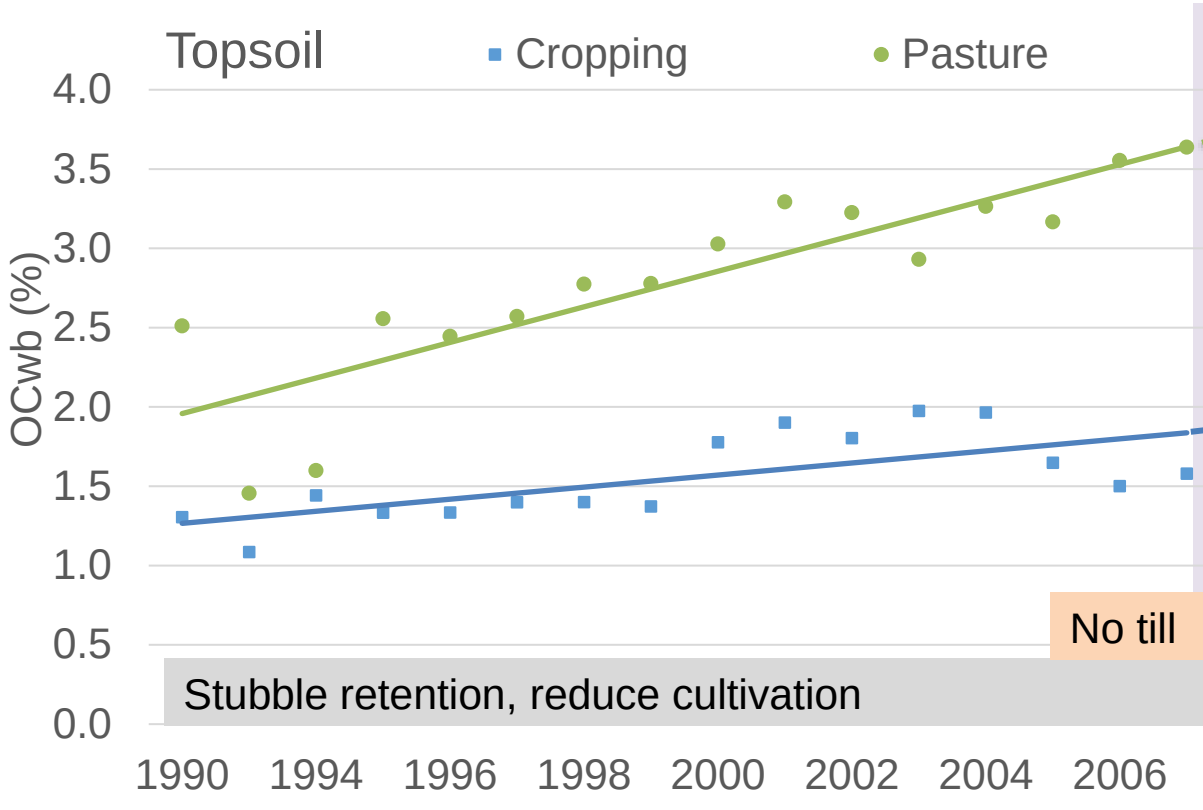
# Soil Carbon 1990-2007




**What has happened since 2007?**

Have we reached a new equilibrium?

Are our soils functioning / producing more?

No till

Stubble retention, reduce cultivation

*Soil and Land Hub – Collaboration between Sustainable Soils groups in DEW and PIRSA*

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# Upper SE OCwb %  0-10cm  1990-2007

Cropping 54%
Pasture 31%

Annual Δ OCwb
0.0103% ↔

| | *Ag Zone* | Ag District Benchmarks | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Texture** | ***Mean*** | **Count** | **Mean** | **25%** | **40%** | **50%** | **60%** | **75%** |
| Sand | *1.12* | 23 | 1.08 | 0.90 | 1.05 | 1.12 | 1.19 | 1.31 |
| Loamy sand | *1.42* | 933 | 1.21 | 0.85 | 1.01 | 1.10 | 1.24 | 1.51 |
| Sandy loam | *1.79* | 636 | 1.43 | 0.96 | 1.20 | 1.35 | 1.50 | 1.80 |
| Loam | *1.96* | 437 | 1.66 | 1.20 | 1.40 | 1.50 | 1.70 | 1.97 |
| Clay loam | *1.93* | 308 | 1.81 | 1.40 | 1.59 | 1.74 | 1.87 | 2.13 |
| Clay | *1.66* | 288 | 1.63 | 1.00 | 1.26 | 1.40 | 1.60 | 1.92 |
| Weighted Mean (all texture) | *1.77* | 2625 | 1.45 | 1.02 | 1.22 | 1.33 | 1.49 | 1.77 |

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Soil Carbon in SA Vol 4 - SA Ag Benchmark Analysis 1990-2007 June 2021 Final.pdf (environment.sa.gov.au)

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# Opportunity to increase soil OC depends on

1. OC starting point and capacity to store more OC
2. Soil texture and any soil constraints to inputs
3. Rainfall/moisture and temperature – affect inputs (growth) and outputs (decomposition - microbial activity)
4. Ability to grow or apply sufficient OC inputs
5. Supply sufficient nutrition to grow biomass and enable transformation of POC to HOC

OC inputs have to be **MORE** than OC outputs

Nutrients required to create 1t humus *Clive Kirkby ratio*

- 80 kg N
- 20 kg P
- 14 kg S

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# Soil carbon concentration vs stock

# Scrub vs Paddock

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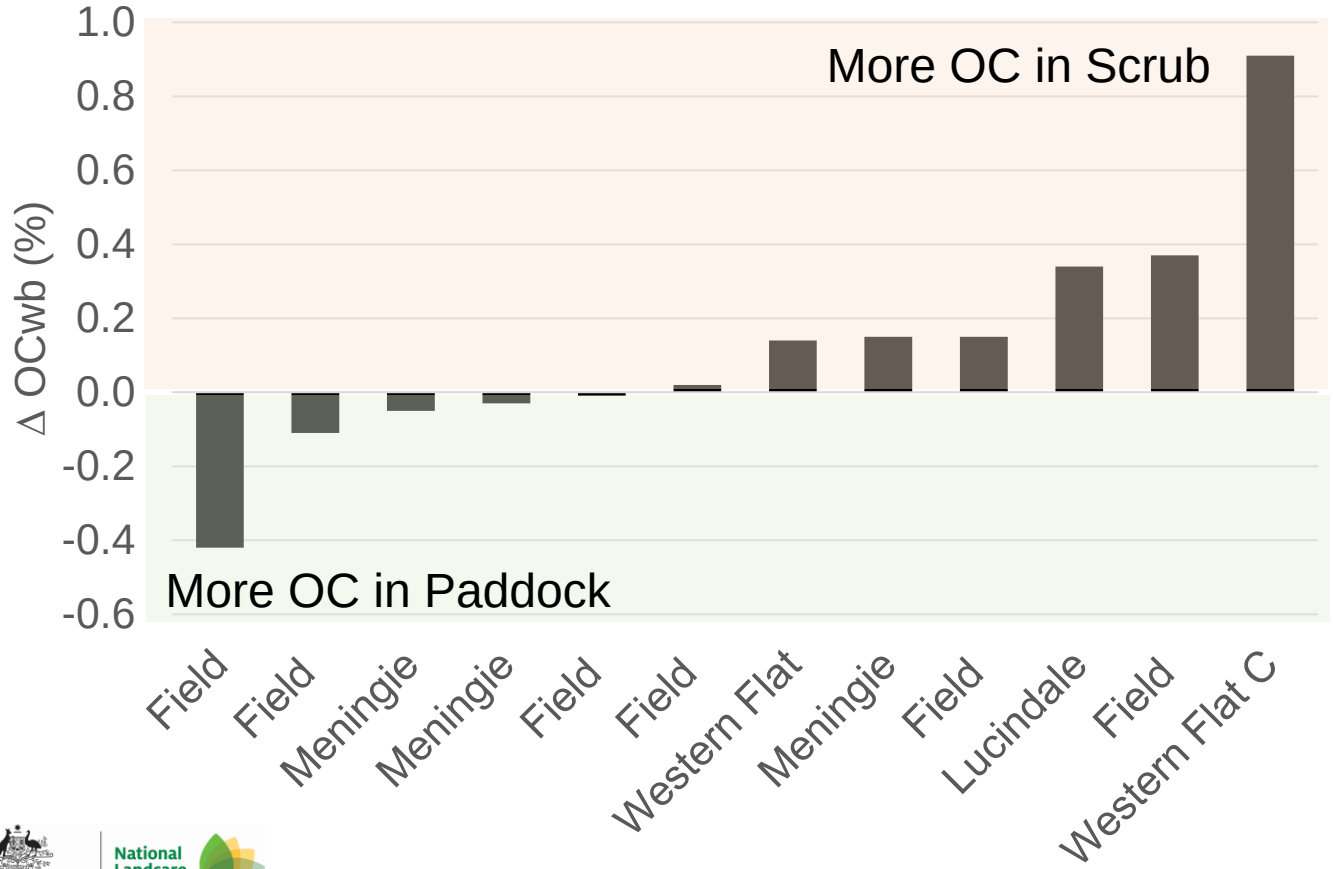
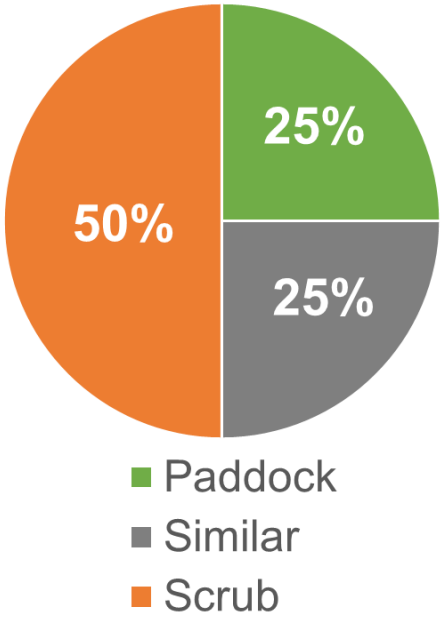
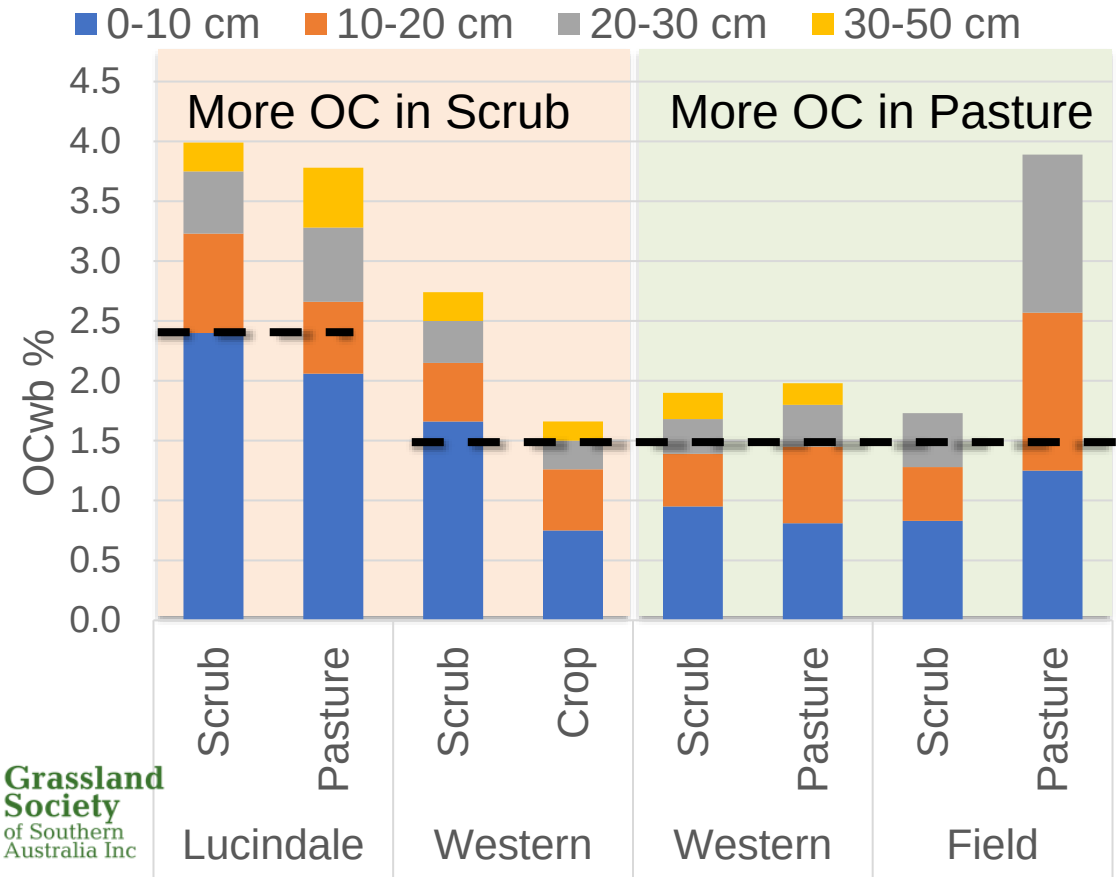
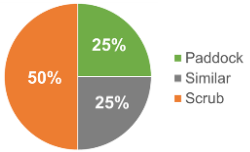
# OCwb % 0-10cm Scrub v Paddock



# OCwb Concentration (%) 0-50cm Scrub v Paddock




| | | 0-10 | 10-20 | 20-30 | 30-50 |
|---|---|---|---|---|---|
| Lucindale | Scrub | 2.40 | 0.83 | 0.52 | 0.24 |
| | Pasture | 2.06 | 0.60 | 0.62 | 0.50 |
| Western Flat | Scrub | 1.66 | 0.49 | 0.35 | 0.24 |
| | Crop | 0.75 | 0.51 | 0.24 | 0.16 |
| Western Flat | Scrub | 0.95 | 0.44 | 0.29 | 0.22 |
| | Pasture | 0.81 | 0.64 | 0.35 | 0.18 |
| Field | Scrub | 0.83 | 0.45 | 0.45 | |
| | Pasture | 1.25 | 1.32 | 1.32 | |

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COORONG DISTRICT COUNCIL

Tatiara the good country

Coorong Tatiara Local Action Plan

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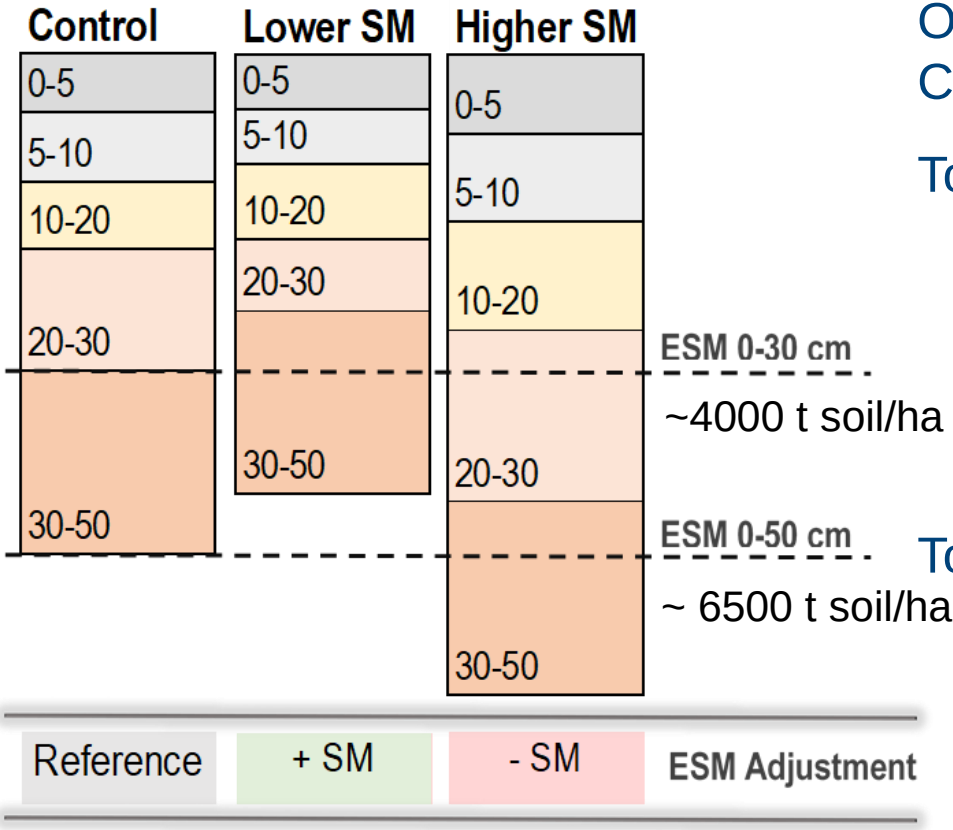
# Carbon Stock – Equivalent soil mass




OC stock is the unit used in C accounting

To calculate (tC/ha)

OC (%) x
bulk density (g/cm$^3$) x
depth (cm) x
(100 - gravel %)

To convert 1tC/ha to CO2e
X by 3.67

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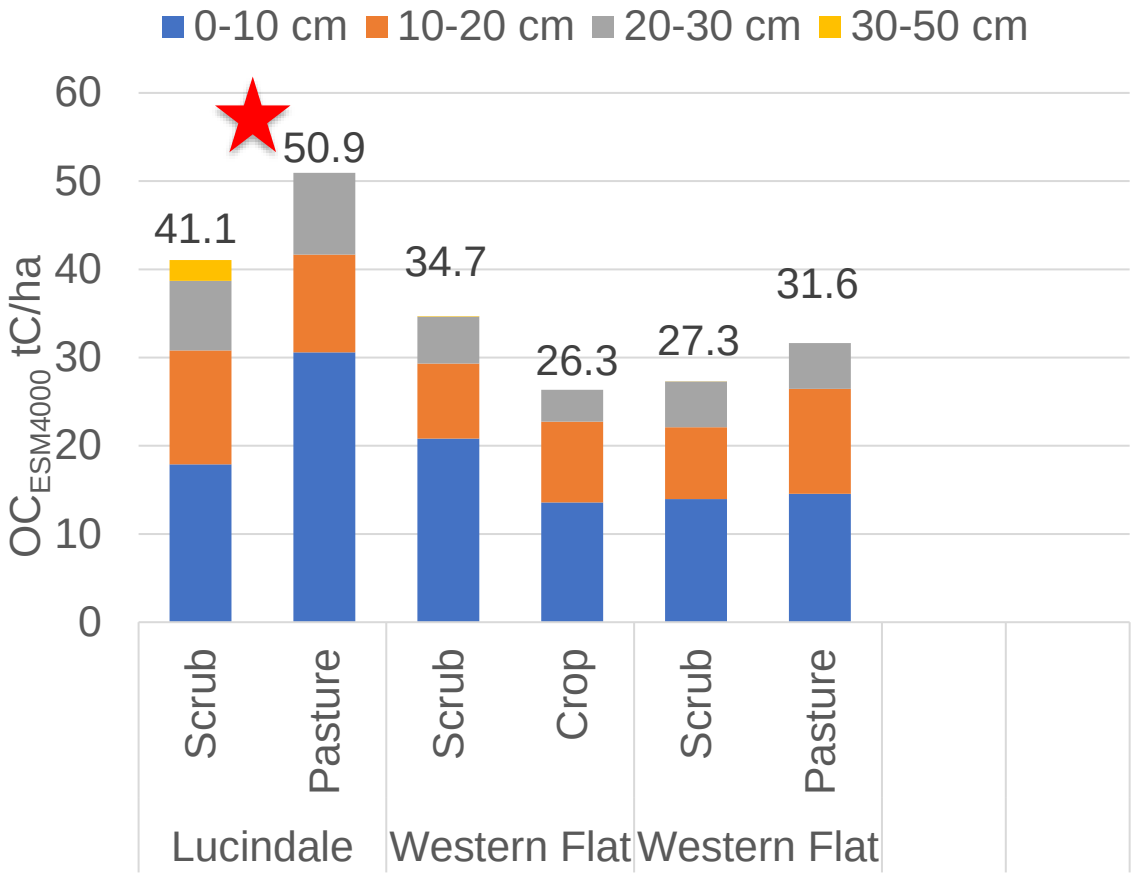
# OC Stock $ESM_{4000}$ (tC/ha) 0-30cm Scrub v Paddock




| | | 0-10 | 10-20 | 20-30 | 30-50 |
|---|---|---|---|---|---|
| Lucindale | Scrub | 17.9 | 12.9 | 7.9 | 2.4 |
| | Pasture | 30.6 | 11.1 | 9.3 | |
| Western Flat | Scrub | 20.8 | 8.5 | 5.3 | 0.1 |
| | Crop | 13.6 | 9.2 | 3.6 | |
| Western Flat | Scrub | 14.0 | 8.1 | 5.2 | 0.0 |
| | Pasture | 14.6 | 11.9 | 5.2 | |
| Field | Scrub | | | | |
| | Pasture | | | | |

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Australian Government

National Landcare Program

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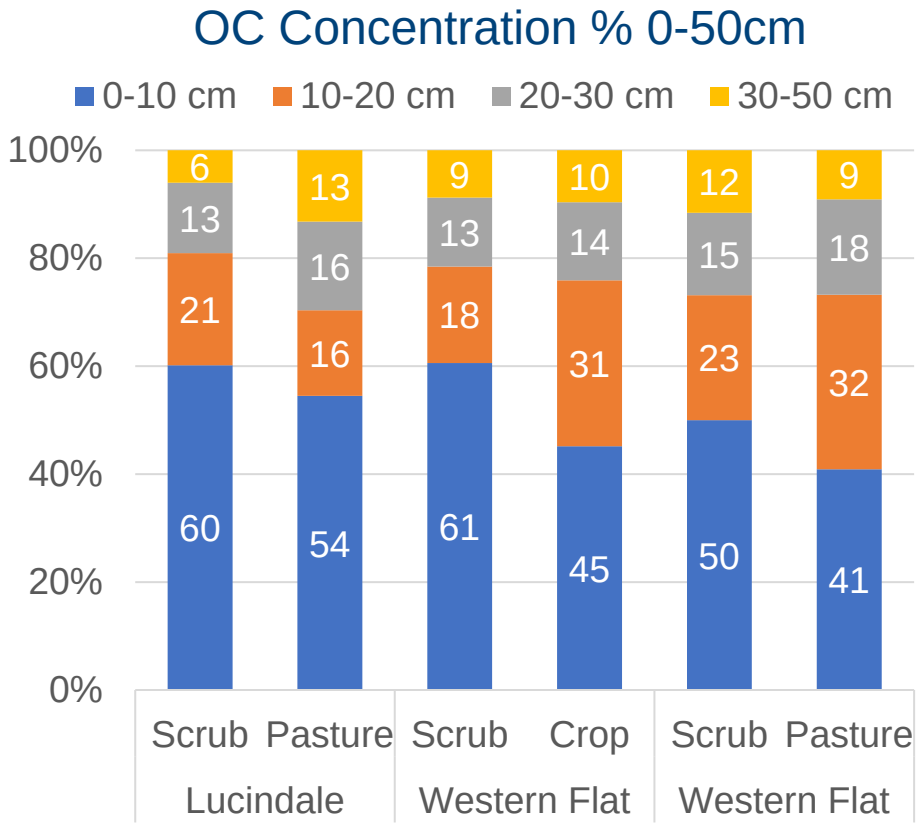
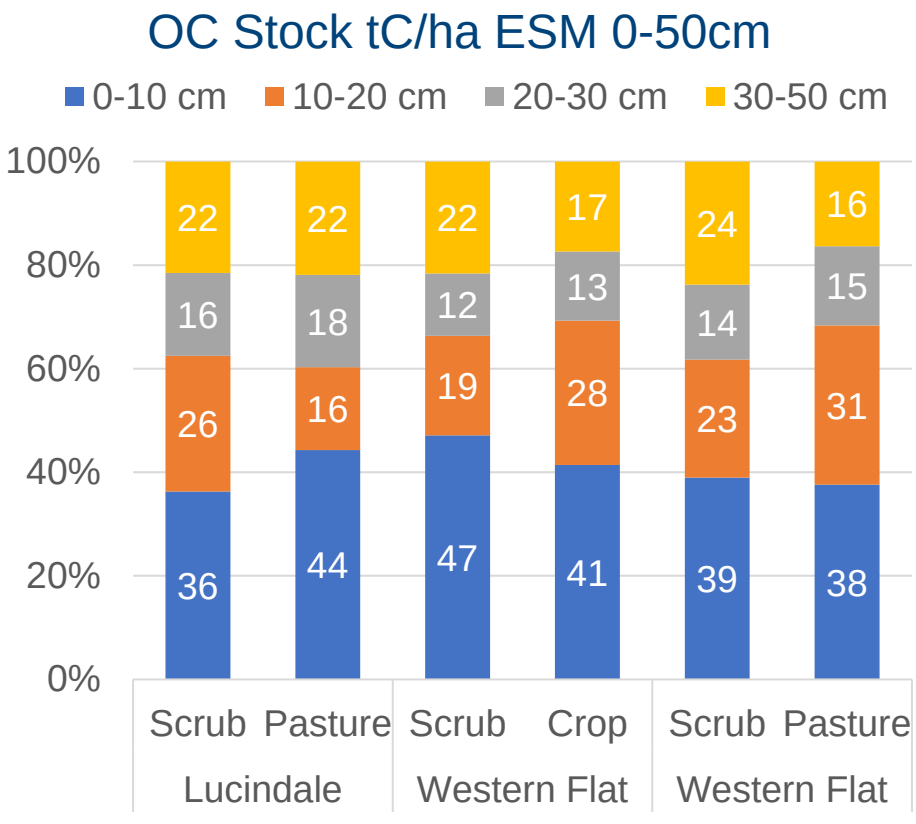
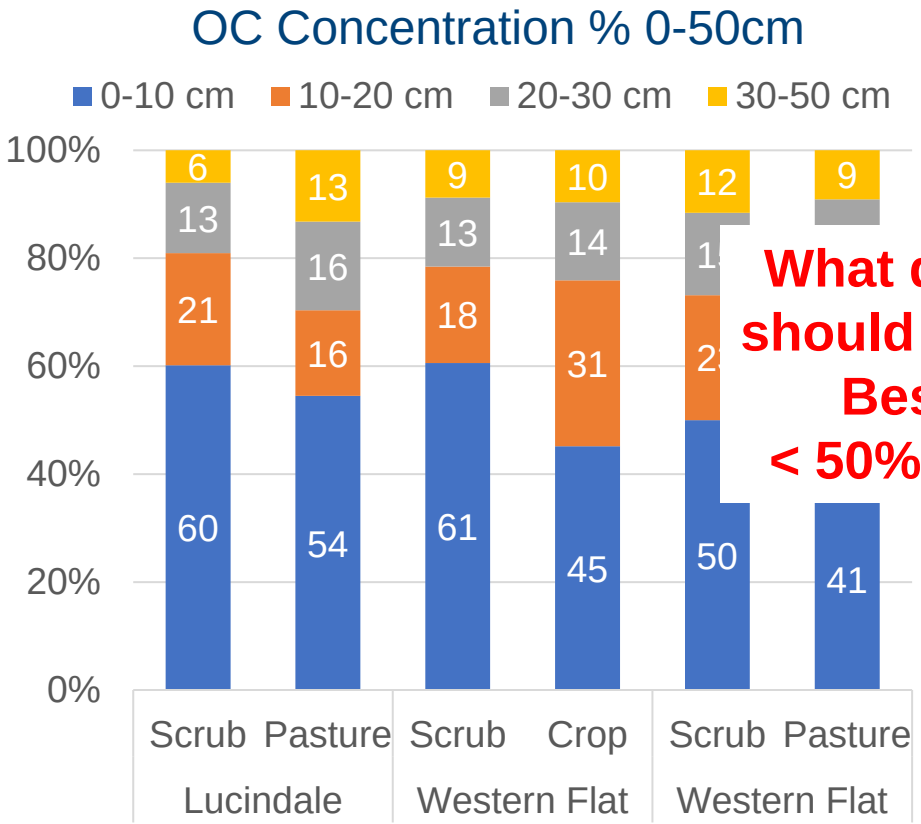
# OC Distribution down the soil profile

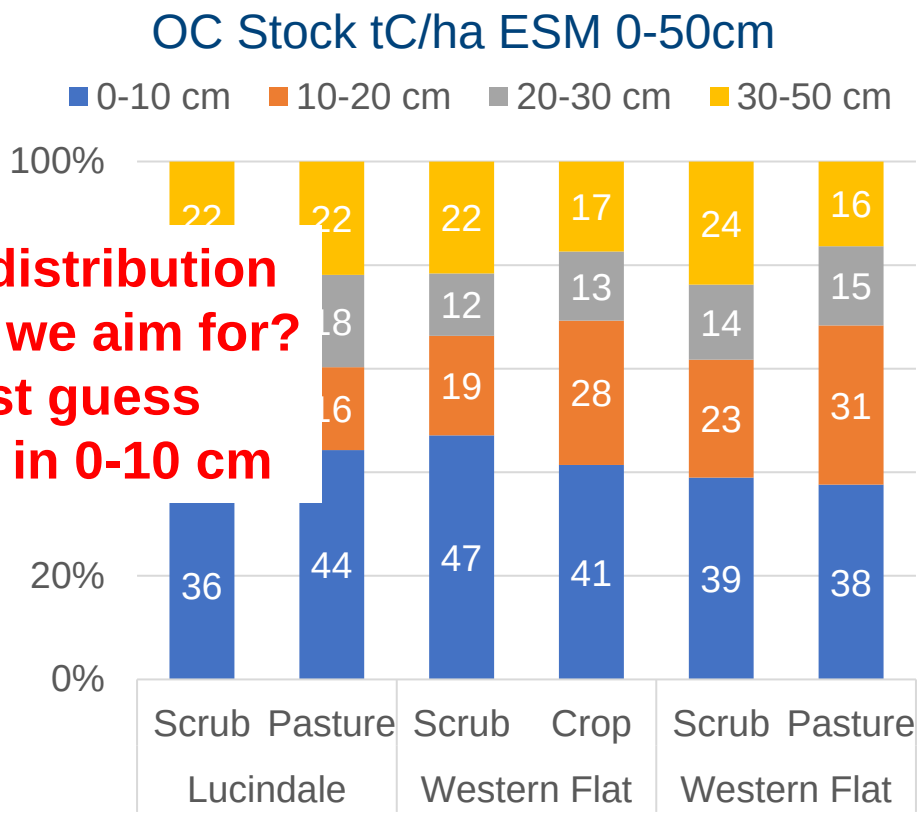


# OC Distribution down the soil profile




**What distribution should we aim for? Best guess < 50% in 0-10 cm**



# Soil carbon fractions

# POC v HOC v ROC

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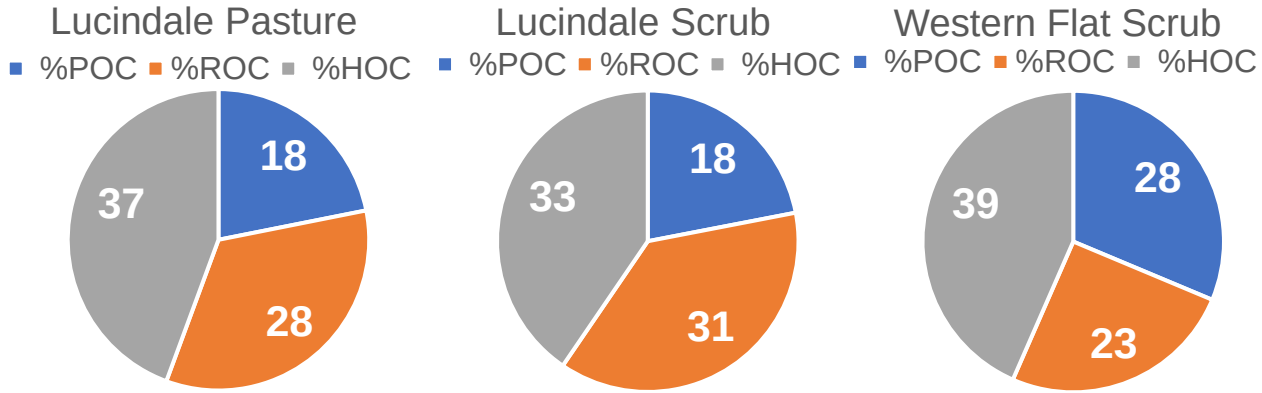
# MIR OC Fractions to determine OC Stability

## Something new

| Location | 0-10 cm | %POC | %ROC | %HOC | OC Stability Index |
|---|---|---|---|---|---|
| Lucindale | Pasture | 18 | 28 | 37 | 0.28 |
| Lucindale | Scrub | 18 | 31 | 33 | 0.28 |
| Western Flat | Scrub | 28 | 23 | 39 | 0.46 |




Limitations – Machines cannot detect **OC < 0.2%** not good for sands or deeper in profile

Sampling location is important

Soil texture vs topography or production zone

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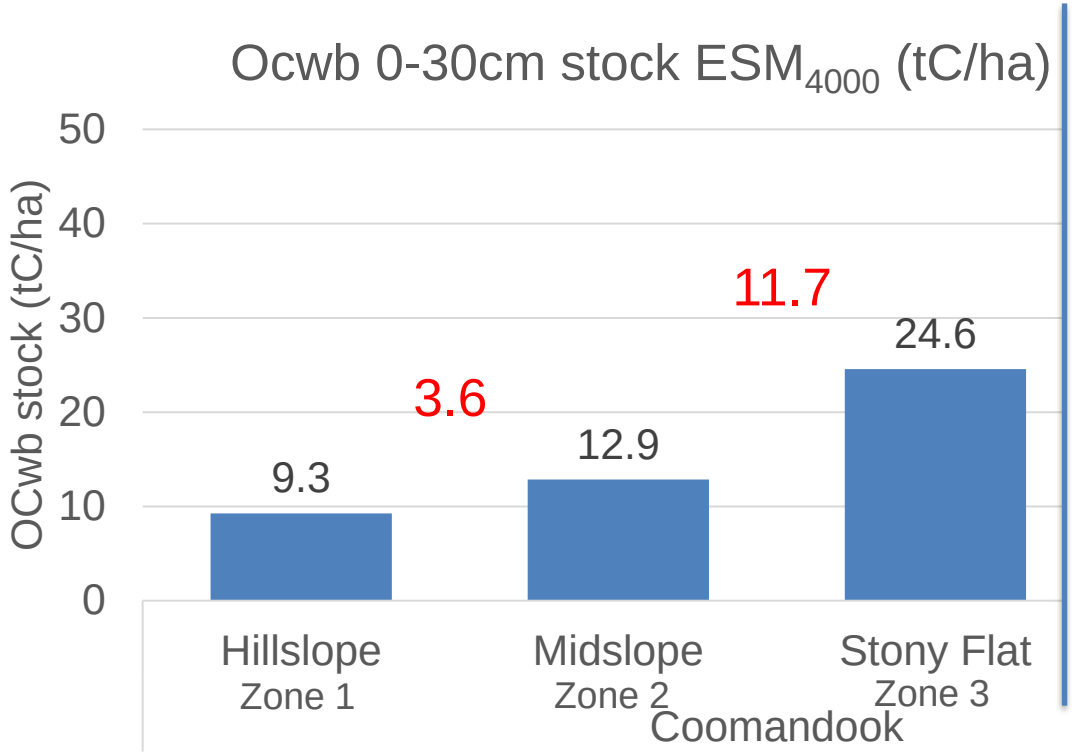
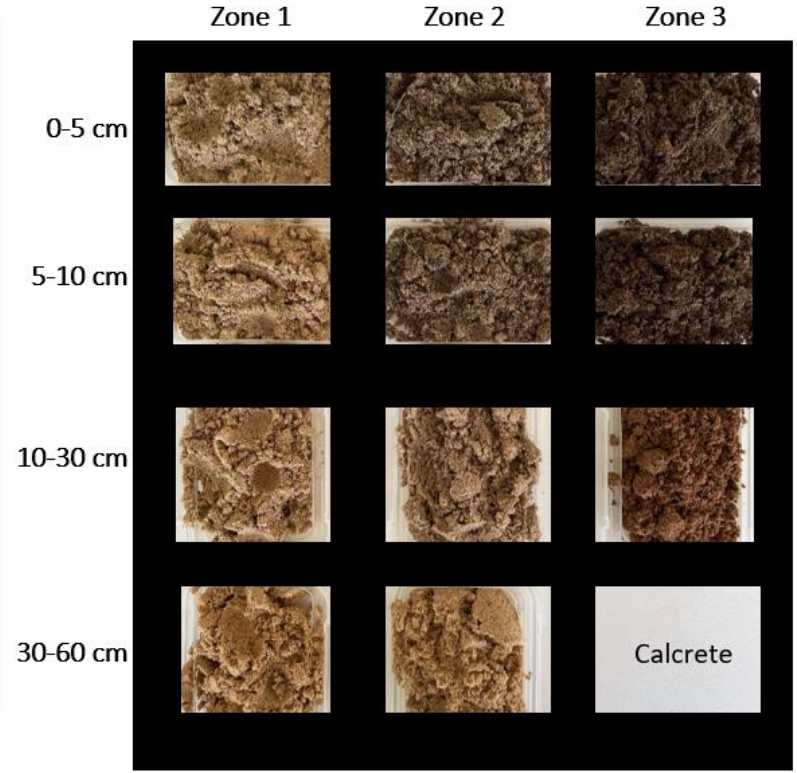
# Coomandook (2022)

15 t C/ha difference hill to flat



# Soil carbon change over time

## Need 3 measures to make a trend

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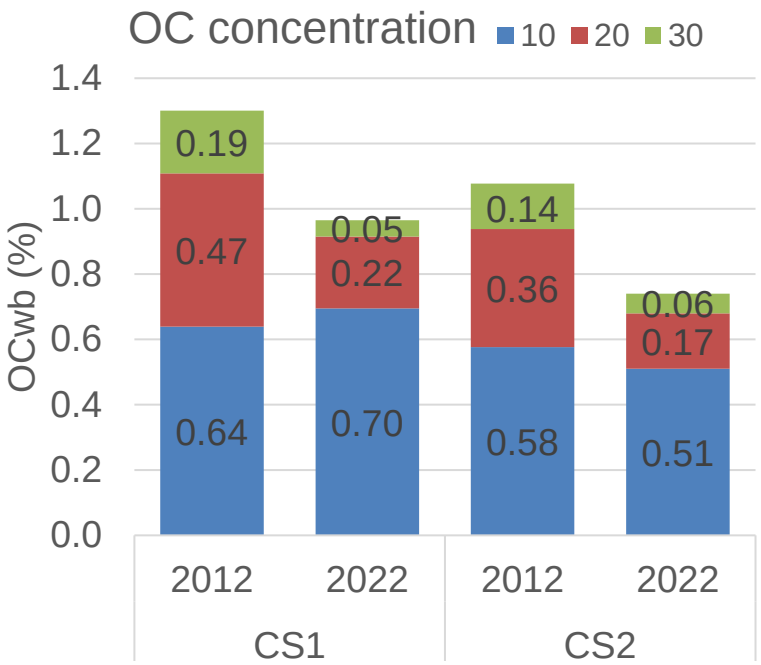
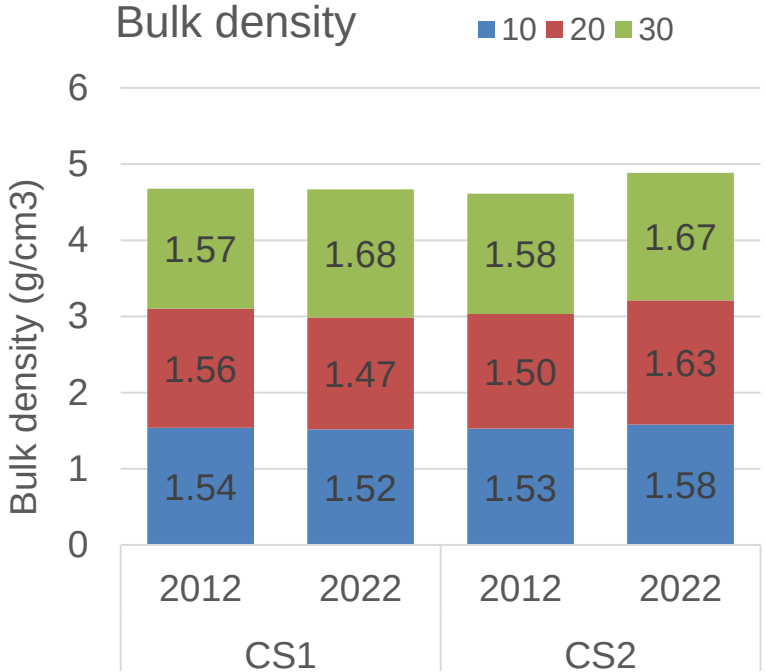
# Sherwood Clay spread (2012 and 2022)

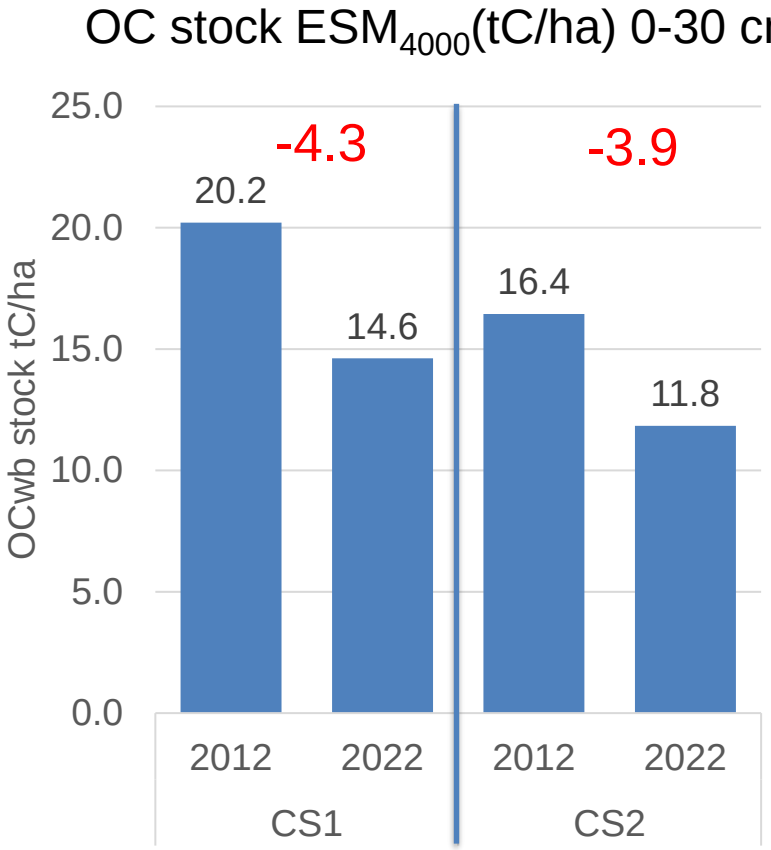
Lucerne + clover, grazed with occasional crop

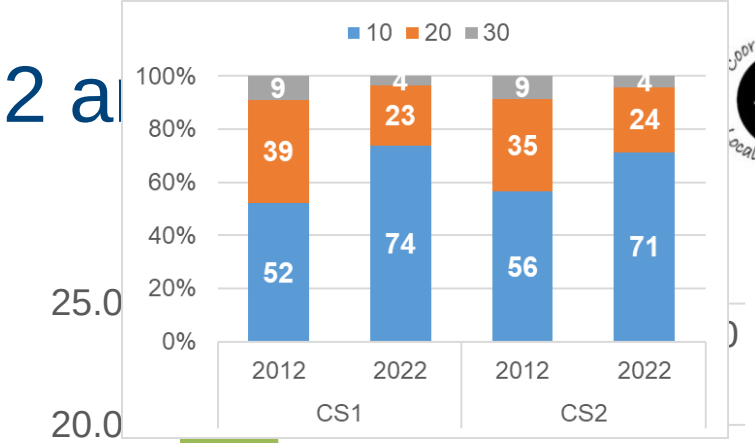
| | Clay spread 250t/ha | Spaded | Sampled | Delved | Offset disc x 2 | Sampled |
|---|---|---|---|---|---|---|
| CS1 | 1997 | 2010 | 2012 | | | 2022 |
| CS2 | 1998 | 2010 | 2012 | 2020 | 2020 | 2022 |

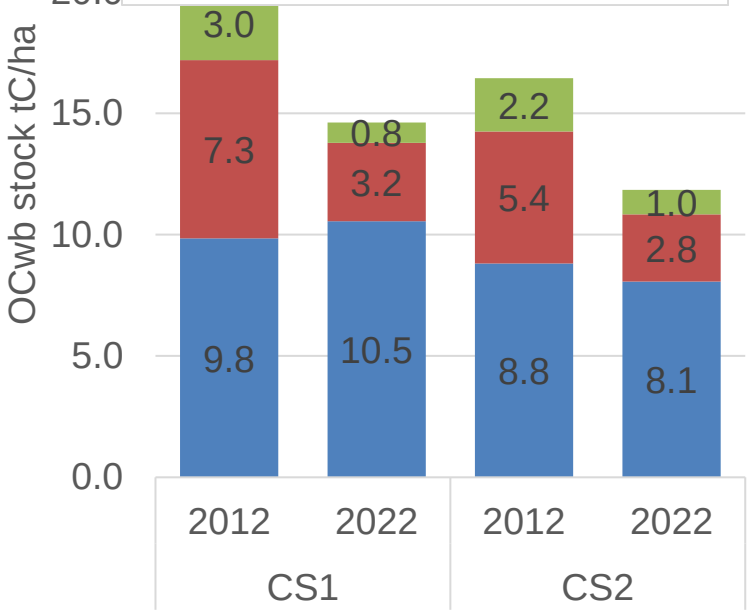


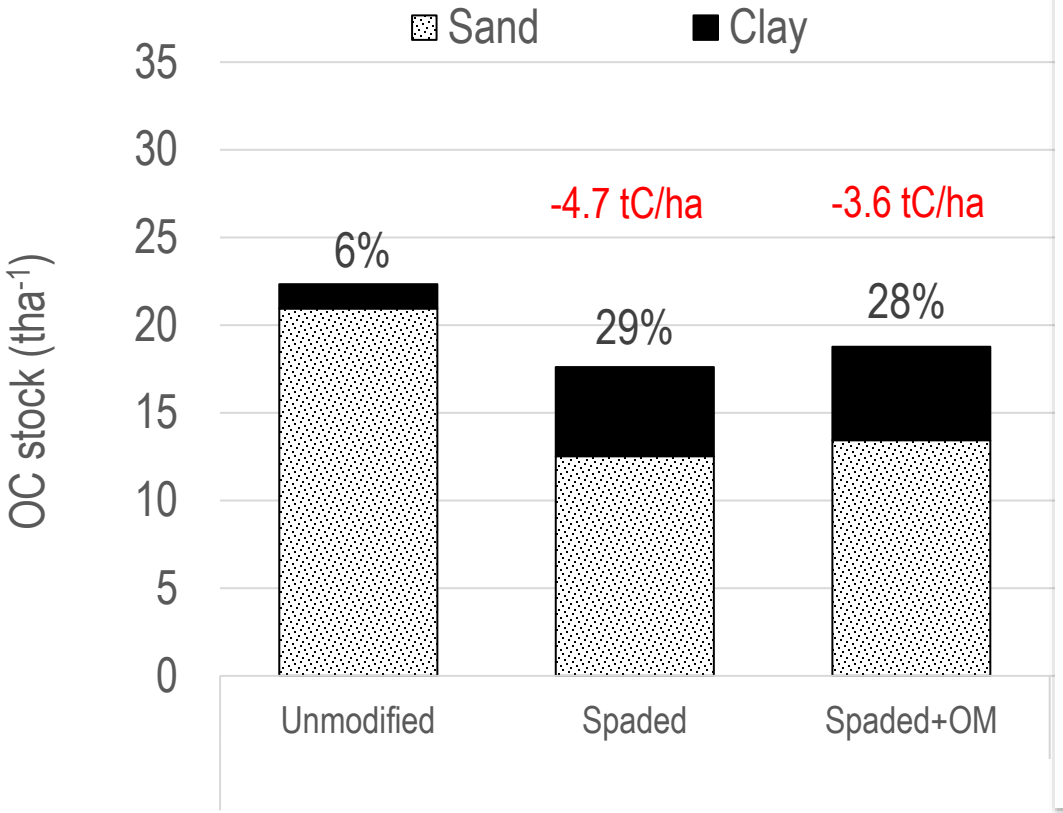
# Sherwood Clay spread (2012 a



# OC stock 0-30 cm clay and sand

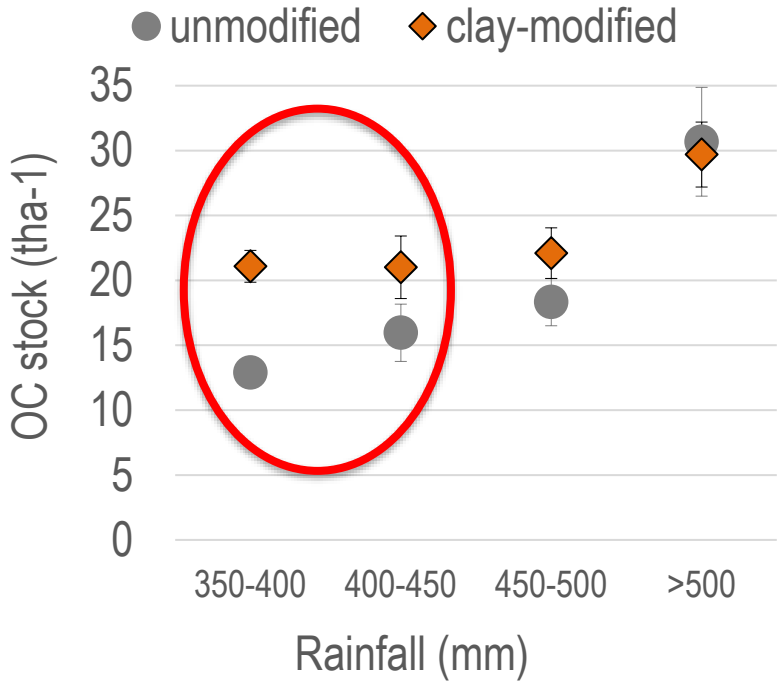



Mixing = 20% ↓ OC

70% of OC still in sand and vulnerable to decomposition

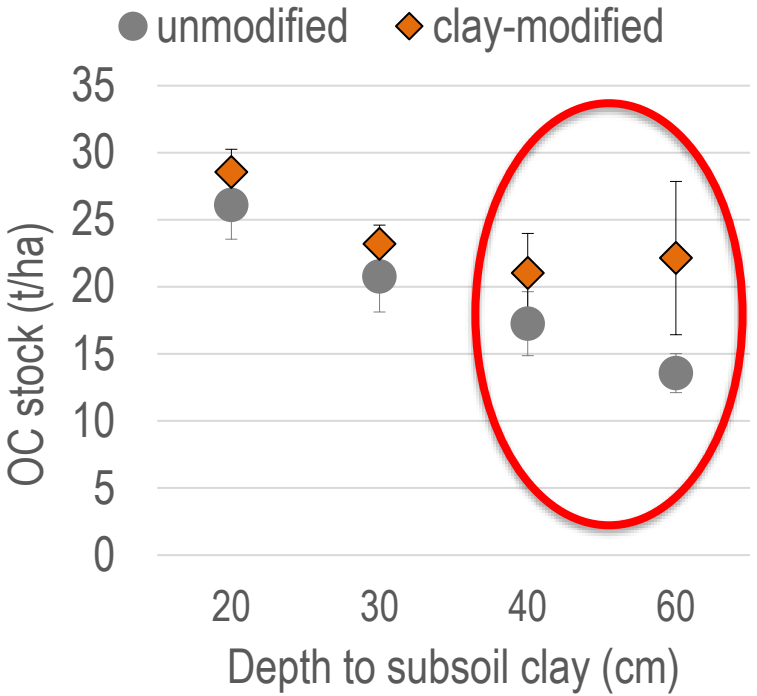
**Schapel et al. 2019*

# Clay addition on OC stocks - Goyder/DEW




Highest OC stock at > 500 mm but unmodified also high

*Greatest OC opportunity rainfall < 500 mm*




Highest OC stock at where clay < 30 cm

*For greatest OC opportunity subsoil clay should be > 30 cm*

## OPTIMISE OM INPUTS

### Management

- Address soil limitations to production where possible
- Optimise nutrition
- Grow green plants for longer
- Optimise plant diversity
- Consider growing perennial instead of annual plants
- Encourage root growth
- Minimise bare ground

## MINIMISE SOC LOSS

### Management

- Provide OM inputs to maintain or improve SOC
- Minimise bare ground
- Minimise soil disturbance
- Maximise capture and stabilisation of HOC

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# My 2 cents worth

- Sandy soils hardest to accumulate OC long-term
  - Most vulnerable as difficult to protect from decomposition
  - Change of particulate to humus form if get greater inputs????
- Rainfall < 600mm can we build OC?
  - Rainfall <400 - 450mm and warm temperatures - aim to maintain OC
- How to change decomposition losses from 90 to 70%
  - Microbes – functional groups?


# Amanda Schapel

## Senior Soil and Land Management Consultant

**0411 137 258**

**amanda.schapel@sa.gov.au**


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## OPTIMISE OM INPUTS

- Retain more biomass
- Grow more shoots
- Grow more roots and exudates
- Grow more soil organisms
- Add OM from elsewhere

## MINIMISE SOC LOSS

- Minimise soil erosion
- Minimise $CO_2$ loss from decomposition of OM
- Maximise stabilisation of SOC
- Maximise production of humus


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# Take Home Thoughts

## Determine why you want to change OC

- Function or GHG emissions

## Be realistic about how much you can change OC

- texture, rainfall, inherent limitations, induced limitations, fertility

## OC is variable and needs a long time (5-10yrs) to measure change

- at the surface, down the soil profile, over time

## Select management practices to build OC that

- suit your soil, climate and system

## Climate change will affect OC

- In a high rainfall area in a warming climate, OC levels can decrease

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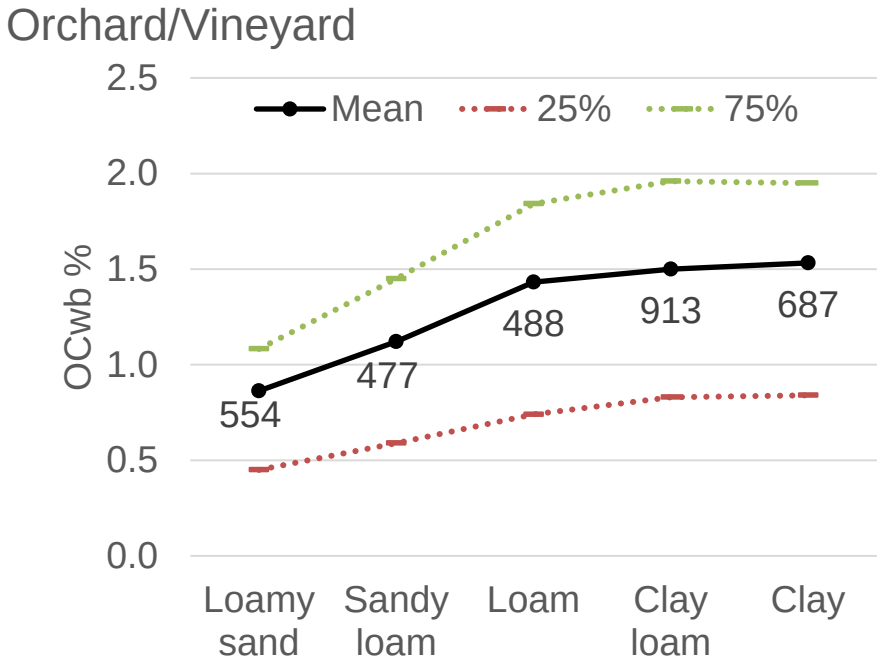
# Orchard Vineyard OCwb 0-10cm 1990-2007




## Orchard/Vineyard Benchmarks

| Texture | Count | Mean | 25% | 40% | 50% | 60% | 75% |
|---|---|---|---|---|---|---|---|
| Loamy sand | 554 | 0.86 | 0.45 | 0.61 | 0.74 | 0.90 | 1.08 |
| Sandy loam | 477 | 1.12 | 0.59 | 0.77 | 0.90 | 1.09 | 1.45 |
| Loam | 488 | 1.43 | 0.74 | 1.09 | 1.28 | 1.48 | 1.84 |
| Clay loam | 913 | 1.50 | 0.83 | 1.14 | 1.34 | 1.56 | 1.96 |
| Clay | 687 | 1.53 | 0.84 | 1.15 | 1.38 | 1.59 | 1.95 |

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[Soil Carbon in SA Vol 4 - SA Ag Benchmark Analysis 1990-2007 June 2021 Final.pdf (environment.sa.gov.au)]

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# Soil OC in clay modified soils

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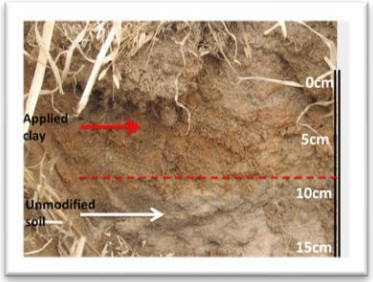
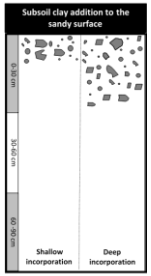
# Sandy soil clay amelioration techniques

SANDY UNAMENDED SOIL

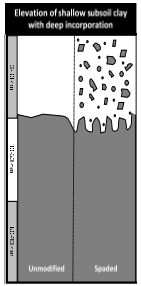

Clay spreader

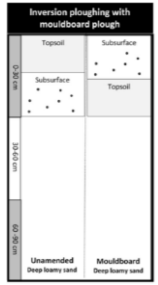


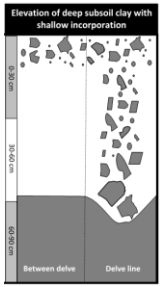

Spader


Mouldboard plough



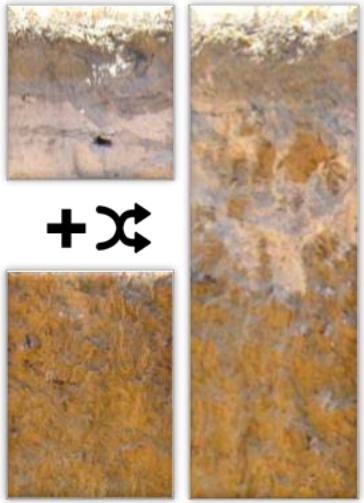




Delver


CLAY AMENDED SANDY SOIL

# Key messages

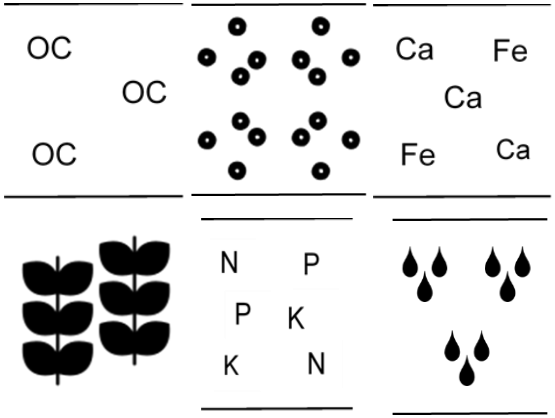


OC Stock$_{0-30}$

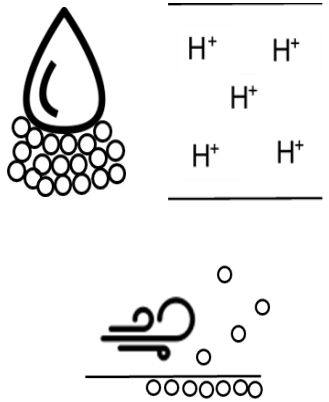
↑ **4.9** tC ha$^{-1}$

(-1.0 – 8.2 t ha$^{-1}$)

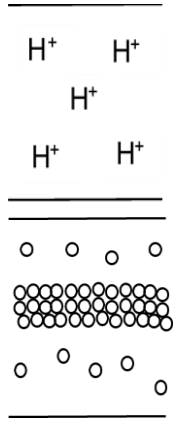
## Increased

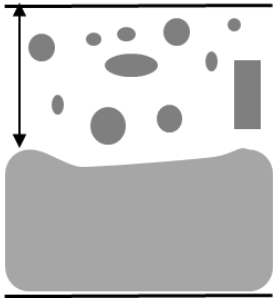



## Decreased




## Prone



Clod size and number important for accumulation and protection of OC

For OC < 6mm size best in surface 20cm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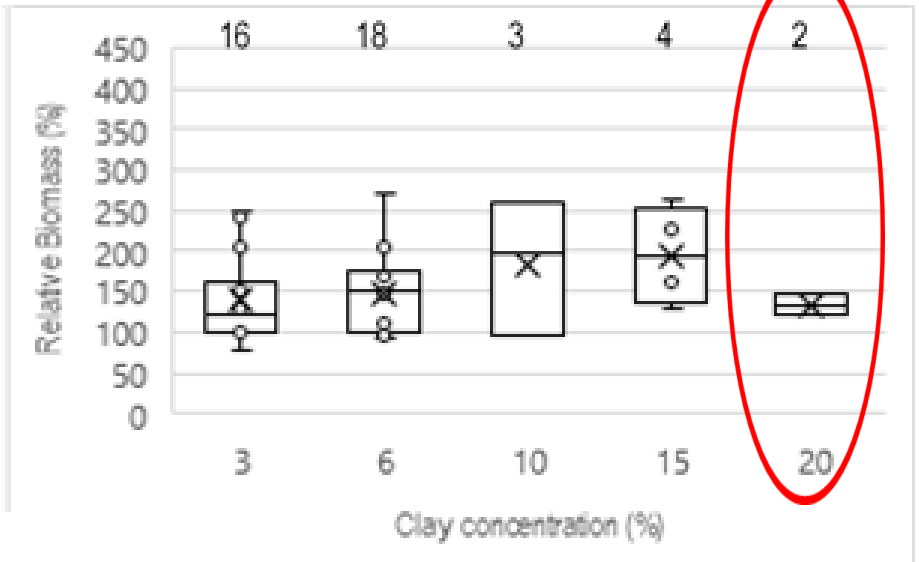
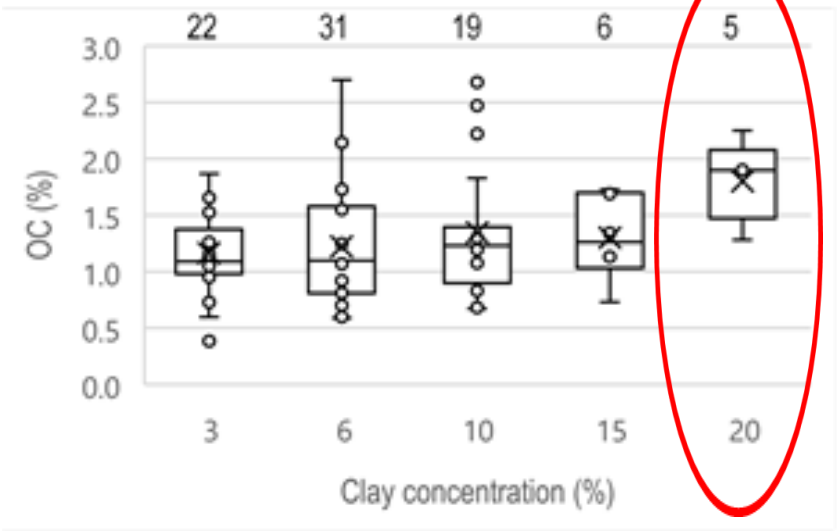
# Soil CRC Sandy Soil (2021) – Clay Concentration

## Productivity




## OC Concentration

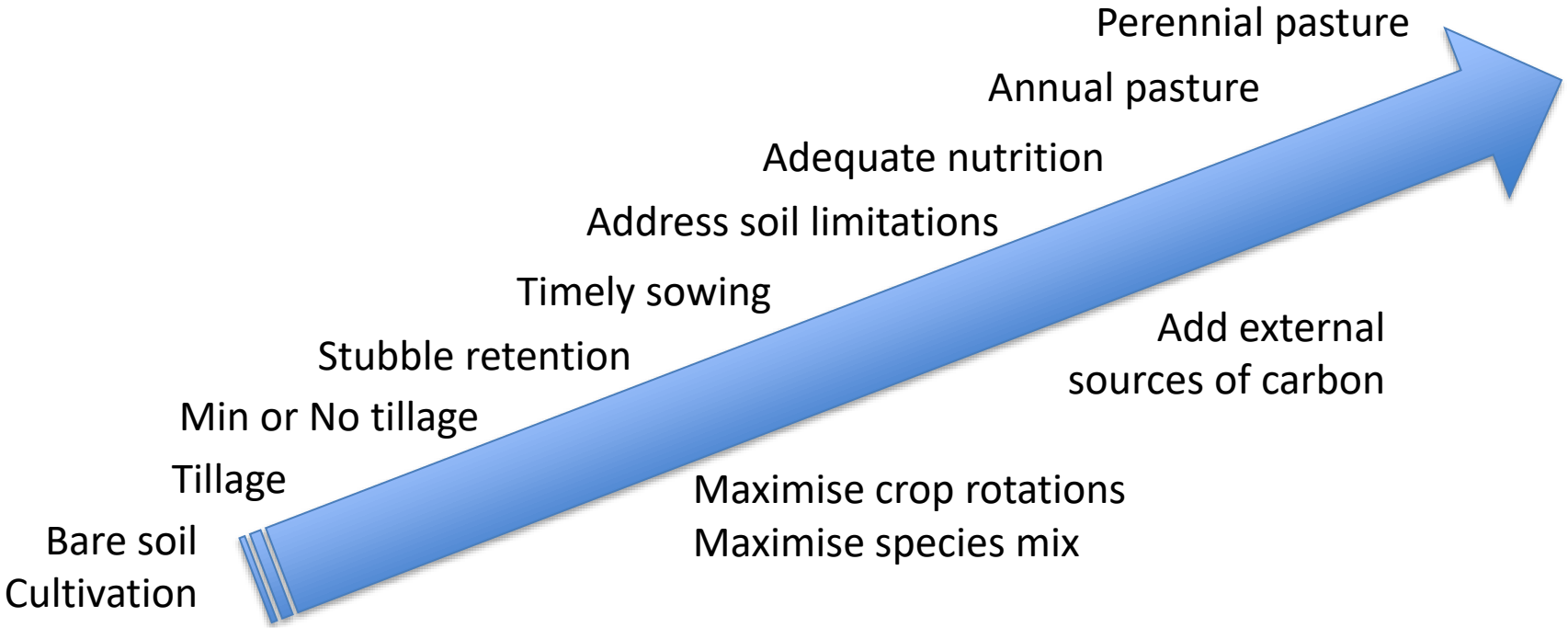



SOIL CRC
Performance through collaboration

270 records 0-10 cm

cumulative 0-30 cm

# The theory of OC increase by management




Maximise water use efficiency

Maximise productivity

CROPPING → PASTURE

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