Department of Primary Industries

Soil carbon – What the excitement is all about, and why you should be taking notice

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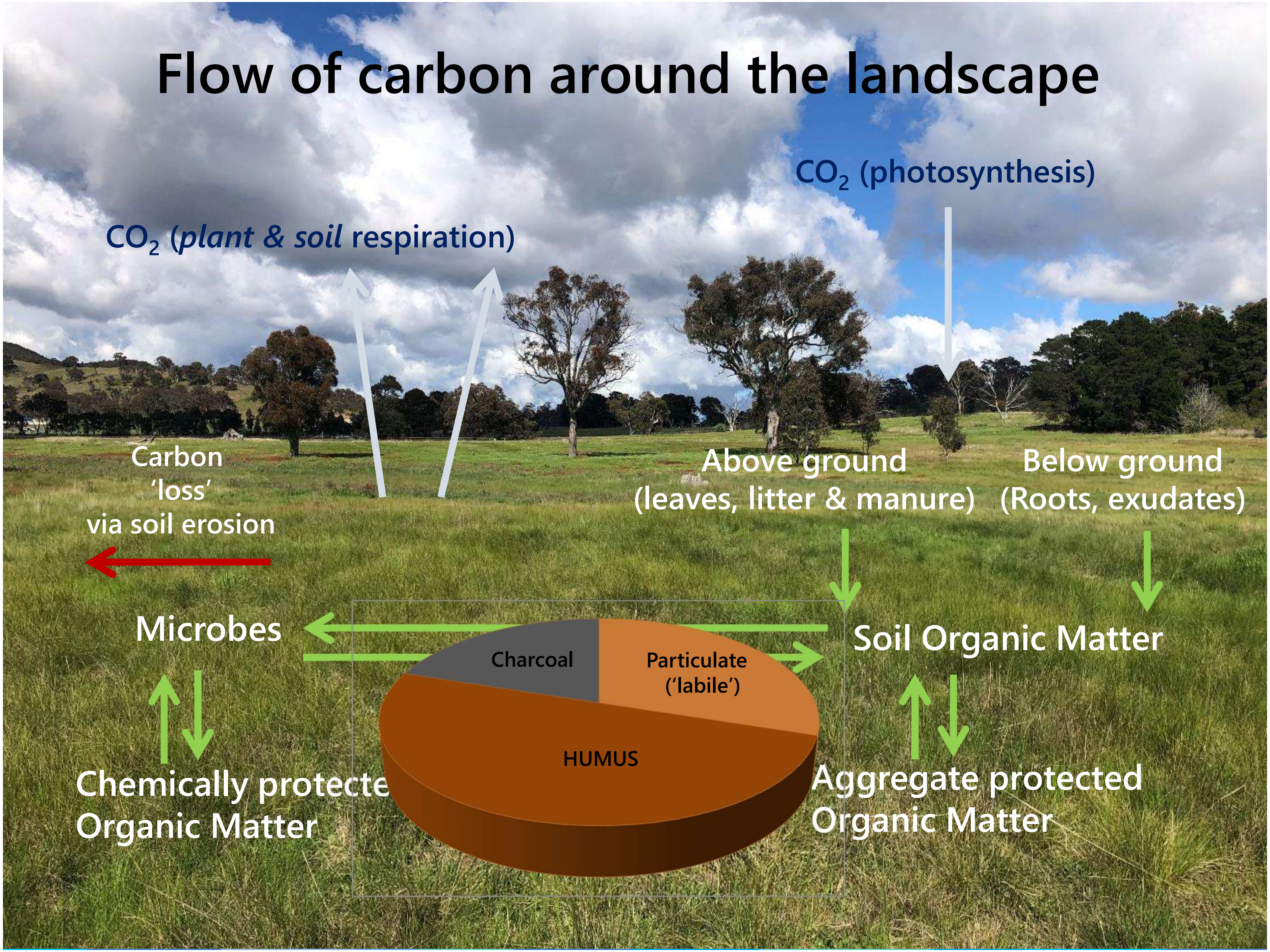
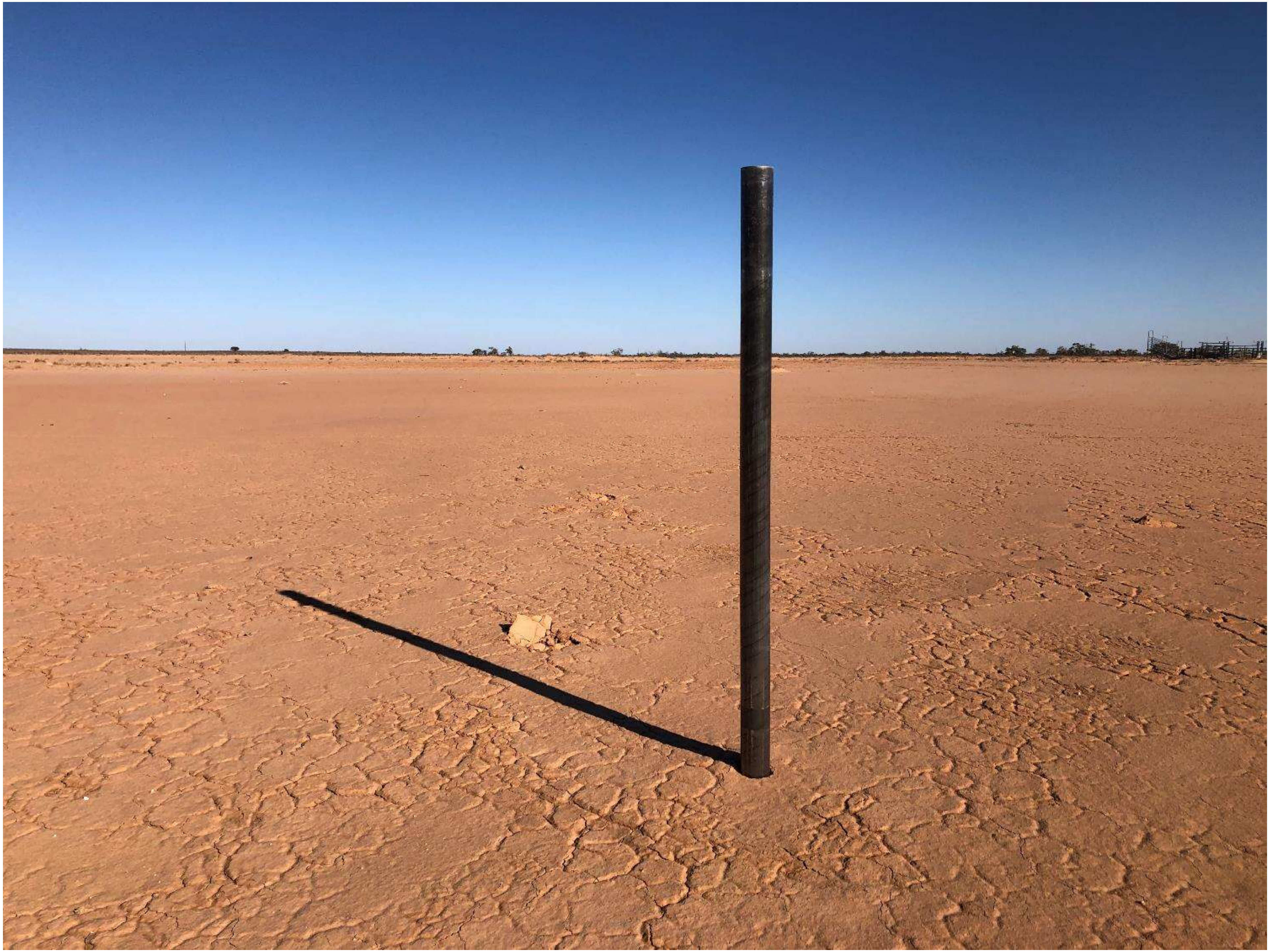
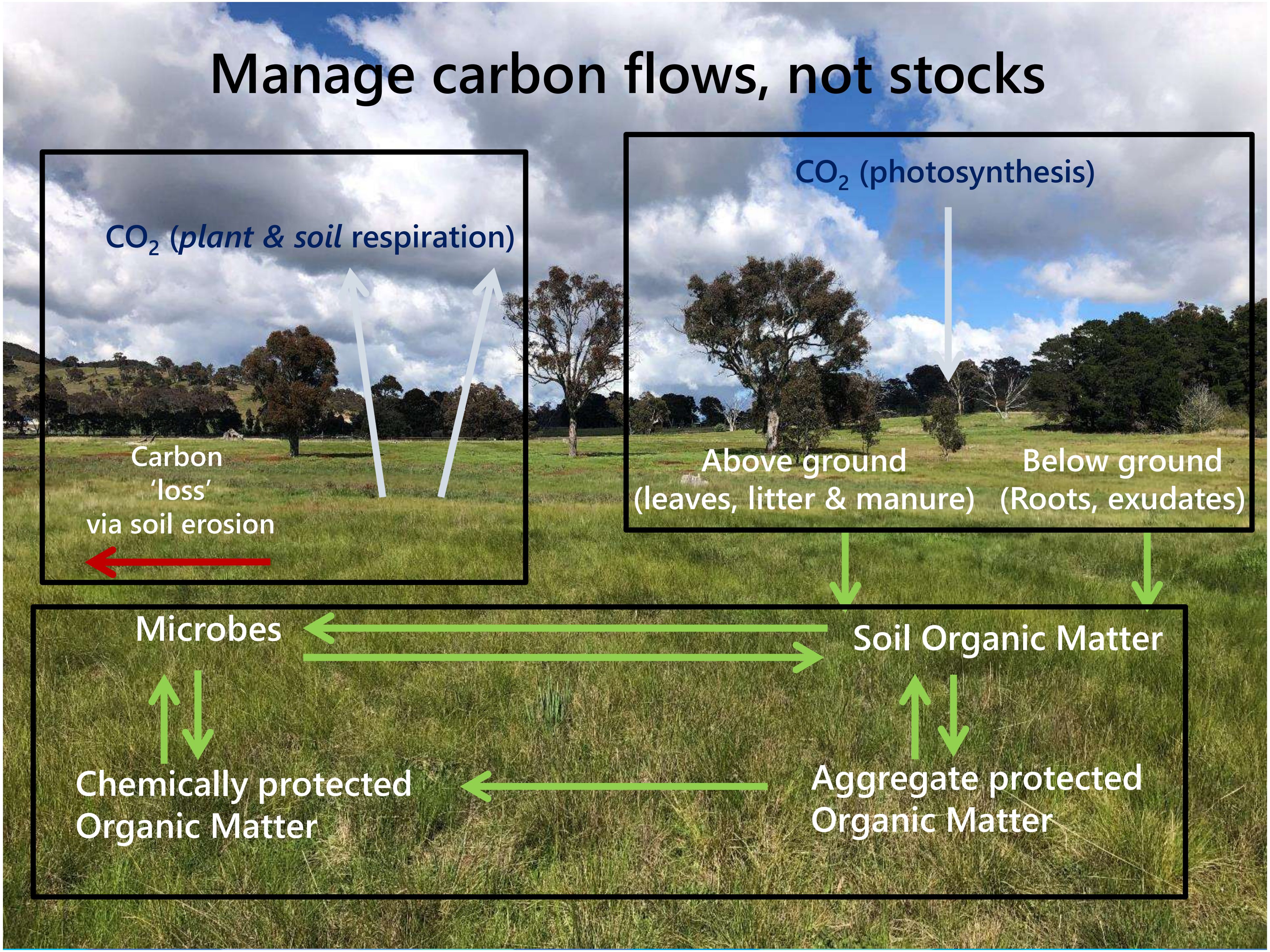

Flow of carbon around the landscape
CO2 (photosynthesis)
CO2 (plant & soil respiration)
Carbon
'loss'
via soil erosion
Above ground
(leaves, litter & manure)
Below ground
(Roots, exudates)
Microbes
Soil Organic Matter
Charcoal
Particulate
('labile')
HUMUS
Chemically protecte
Organic Matter
Aggregate protected
Organic Matter




Manage carbon flows, not stocks
CO_2 (*plant & soil* respiration)
Carbon
'loss'
via soil erosion
CO_2 (photosynthesis)
Above ground
(leaves, litter & manure)
Below ground
(Roots, exudates)
Microbes
Soil Organic Matter
Chemically protected
Organic Matter
Aggregate protected
Organic Matter

Soil Organic Matter (OM) and Soil Organic Carbon (OC)

Soil Organic Matter

- <2mm partially decomposed organic residues
- microbes
- humus
- charcoal

Carbon is what we *measure;* soil organic matter is ~58% C

The rest is...

O (10 to ~40%)

H (~5%)

N (8 to 10%)

P (0.5 to 2%)

S (1 to 1.5%)

and a range of nutrients and trace elements...

Why are we interested in soil carbon?

Production benefits

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

Ecosystem Services

- Soils support food and fibre production
- Regulate climate, store carbon
- Filter and recycle, water, nutrients and waste
- Regulate floods, droughts, heatwaves, frost penetration
- Habitat
- Genetic resource

Opport.

Increase productivity
Diversify farm income, access new markets
Reduce risk, or reverse land degradation
Improve resilience, lessen impact of climate variability

Essential functions of SOC

Energy for biological processes
↑ SOC = ↑ Microbial Activity
↑ SOC = ↑ Soil Function

Soil Organic Matter
- ✓ Nutrient cycling
- ✓ Water infiltration and storage
- ✓ Plant growth & quality

↑ SOC = ↑ CEC
Cation Exchange Capacity
SOC = 25 to 90% of CEC
(depends on soil type, management, soil pH, OM type)

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

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

Does increasing SOM pay?

Where water is limiting, yes it does.

- Increased pasture production associated with higher SOM on average valued \$26 to \$95/ha/yr
  - ➢ low rainfall zone - increased plant available water
  - ➢ high rainfall zone N (\$85–\$105/ha) (Meyer et al 2015)
- Riverina soils - estimated that a 1 % increase in SOC (e.g. from 1 to 2%) increased gross margins by >\$100/ha/yr (Ringrose Voase et al 1997)
- Carbon trading offers the ability to diversify farm income
- Clear <u>economic</u> and <u>environmental</u> reasons to increase in SOM on our farms

Soils vary in their capacity to sequester and 'protect' carbon

SOC % is dependant on:

Carbon (OM) supply

Biomass grown or (carbon) amendment added e.g. compost

AND

Carbon loss

Decomposition and erosion

This is modified by the...

- Type of OM
- Soils capacity to store SOC

(clay%, mineralogy, depth, structure)

Soil, vegetation and climate factors influence carbon sequestration

- These factors drive productivity
- Some *can* be changed (plant type, structure)
- Some *cannot* be changed (clay, soil depth)

Soil Organic Matter (OM) and Soil Organic Carbon (OC)

- SOC% = total organic carbon in soil, g of C per 100 g soil

- Soil C stocks = t C/ha generally to 0-30cm

(Soil C stocks (t C/ha) = SOC g/100g x depth (cm) x BD)

- CO_2-e 1 t of C = 3.66 t CO_2

(Carbon dioxide equivalent)

SOC sequestration rates from selection of studies

Location	Management practice	Depth (m)	SOC seq rate (Mg ha^{-1} year^{-1})	Study
Global				
	Best management practice in managed agricultural land (most 5–30 years)	most <0.3	0.2–0.5	Minasny et al. (2017)
	Cropping conservation farming (most <30 years)	most <0.5	0.2–0.5	Page et al. (2020)
	Improved crop management (20 years)	0.3	0.56–1.15	Zomer et al. (2017)
Australia				
	Improved land management (10–40 years)	most <0.3	0.1–0.4	Minasny et al. (2017)
	Improved crop management (most <40 years)	most <0.5	0.2–0.3	Sanderman et al. (2010)
NSW				
Central West	Conversion crop to pasture (5 years)	0.3	1.2	Badgery et al. (2020)
Liverpool Plains	Perennial pastures (lucerne) (8 years)	0.2	0.33	Young et al. (2009)
Southern NSW	Management of grazing pressure (8 years)	0.3	1.04	Orgill et al. (2017); Waters et al. (2016)
Southern NSW	Including pasture phases in crop rotations (18 years)	0.2	0.23	Helyar et al. (1997)
	As above (10 years)	0.3	0.02–0.26	Chan et al. (2011)
NSW wheatbelt	Incorporation of wheat stubble (20 years)	0.3	up to 0.2	Liu et al. (2014)
Southeastern NSW	Nutrient and grazing management (20 years)	0.6	0.60	Coonan et al. (2019)

Gray, J. M., Wang, B., Waters, C. M., Orgill, S. E., Cowie, A. L., & Ng, E. L. (2022). Digital mapping of soil carbon sequestration potential with enhanced vegetation cover over New South Wales, Australia. Soil Use and Management, 38, 229– 247.

There are multiple strategies to build SOC

Pastures

- Grazing management is KING! Think time and timing
- Legumes and nutrients from microbes

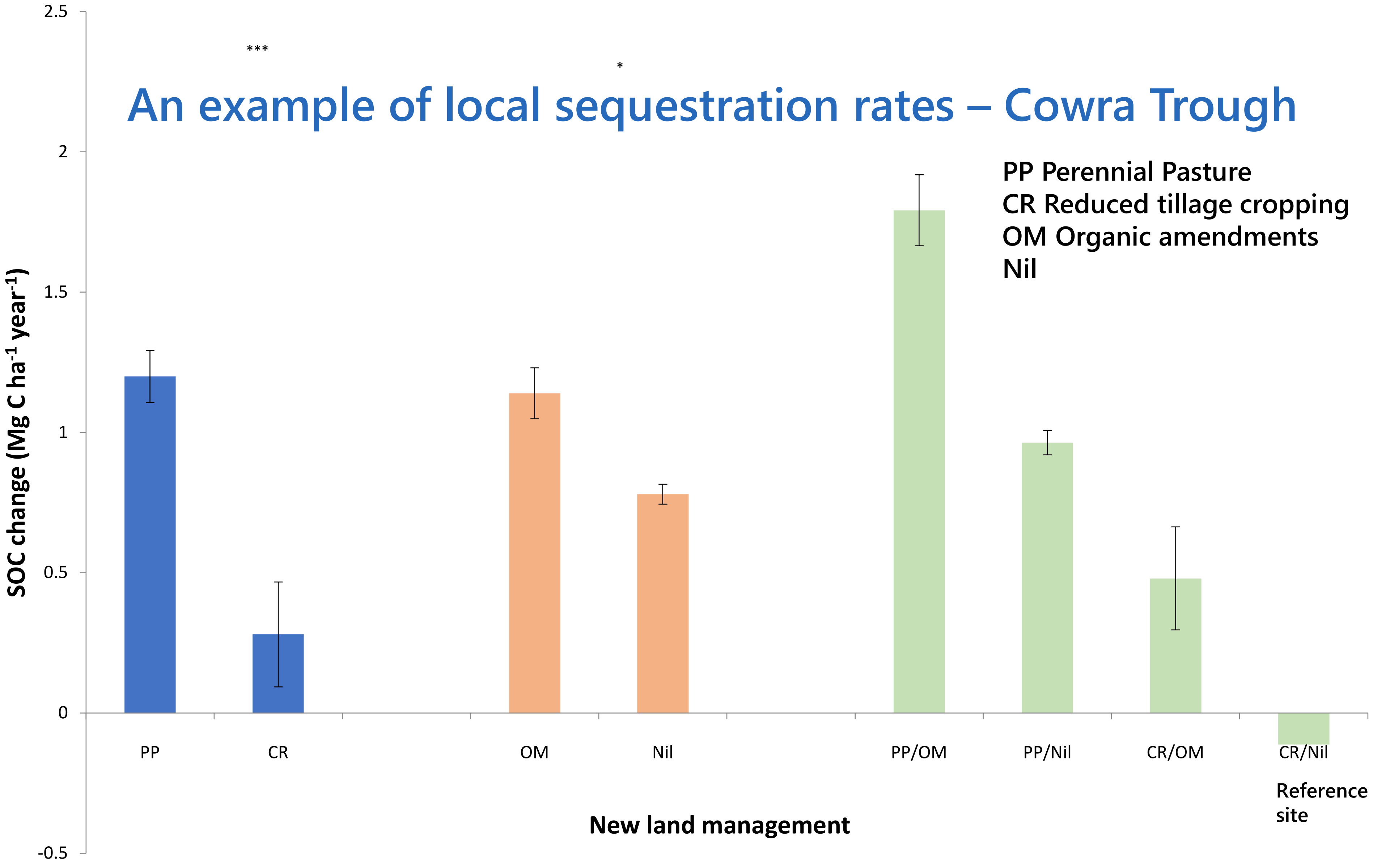
Crops

- 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

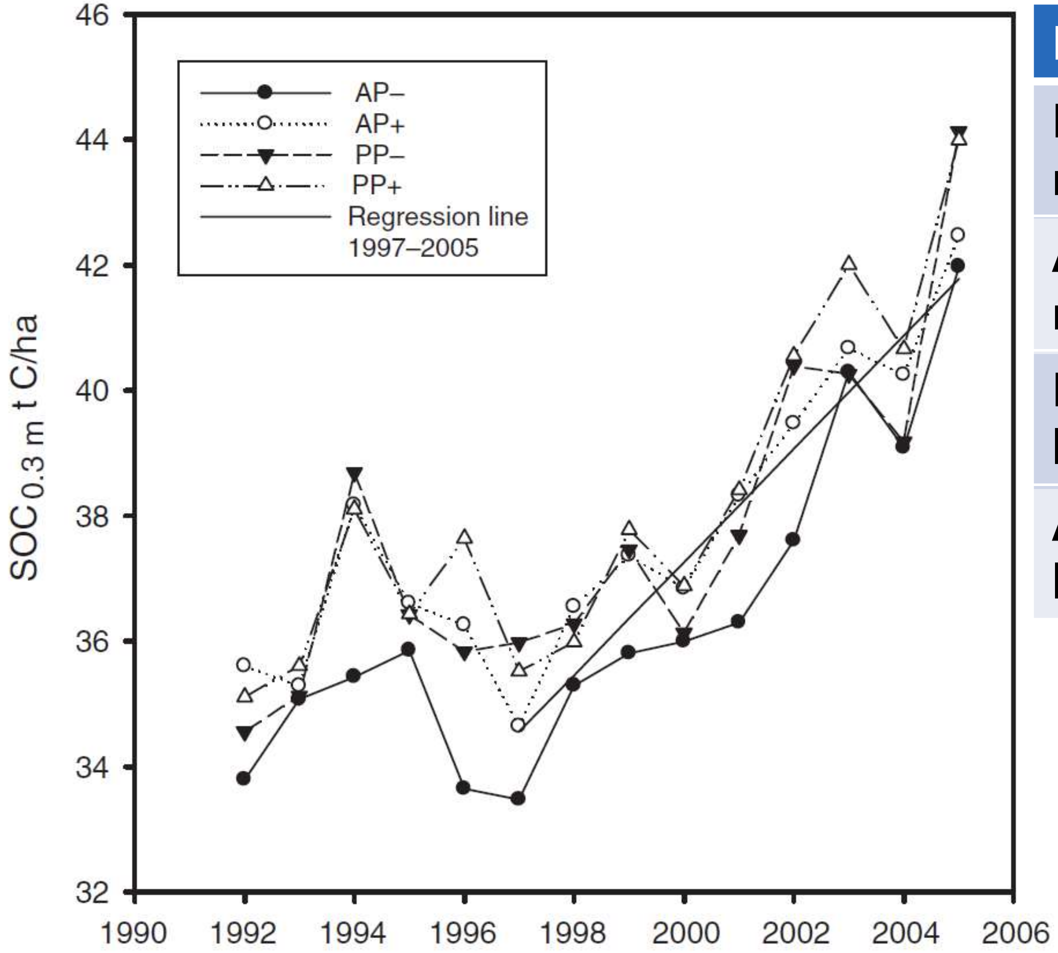
- Nutrients for plants and microbes (build humus)
- Liming to overcome acidic soil constraints
- Gypsum to overcome sodicity, compaction or surface sealing
- Changing practice or land use on degraded soils
- Adding carbon-rich materials (e.g. composts and manures)
- Mixed species plantings
- Biostimulants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

An example of local sequestration rates – Cowra Trough



Badgery, W, Murphy, B, Cowie, A, Orgill, S, Rawson, A, Simmons, A, Crean, J (2021) Soil carbon market-based instrument pilot - the sequestration of soil organic carbon for the purpose of obtaining carbon credits. *Soil Research* **59**, 12-23.

Maintain higher levels of OM input to build SOC and protect it



Source: Chan et al (2011) Soil Research

Rotation	SOC t/C/ha/yr
Perennial pasture – no lime	+ 0.499
Annual pasture – no lime	+ 0.496
Perennial pasture – lime	+ 0.552
Annual pasture – lime	+ 0.462

What works


Plant nutrition


Grazing management


Pastures in rotation


Crop nutrient & residue management


Organic amendments

Rate of sequestration depends on

- Starting SOC%
- Soil type
- Climate
- Management

In some systems, why doesn't SOC increase?

- Large background SOC levels
- Spatial variability
- Soil type and climate (drivers of production and OM turnover)
- Plant nutrition
- Drought
- Ecological equilibrium

Is SOC the right indicator? (It shouldn't be the only one)

Basic principles to increase SOC

- ✓ Increase above- and below-ground OM inputs to soil
- ✓ Increase protection of OM - surface soil protection and enhancing soil aggregation
- ✓ Influence conversion of fresh OM to more stable (e.g. humus) forms of SOM through plant diversity, nutrients and microbial processes
- ✓ Influence the location of OM in the soil profile

In Summary...

- Carbon is cycling on your farm already

.... To change it and sequester <u>more</u> SOC you may need to change practice

So what is your biggest lever?

- There may be some soil and climate factors that limit carbon sequestration
- Benefits of SOM to soil fertility and structure are from carbon cycling – microscopic livestock are key!
- To increase SOC on your farm consider:

right practice, right place, right time

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