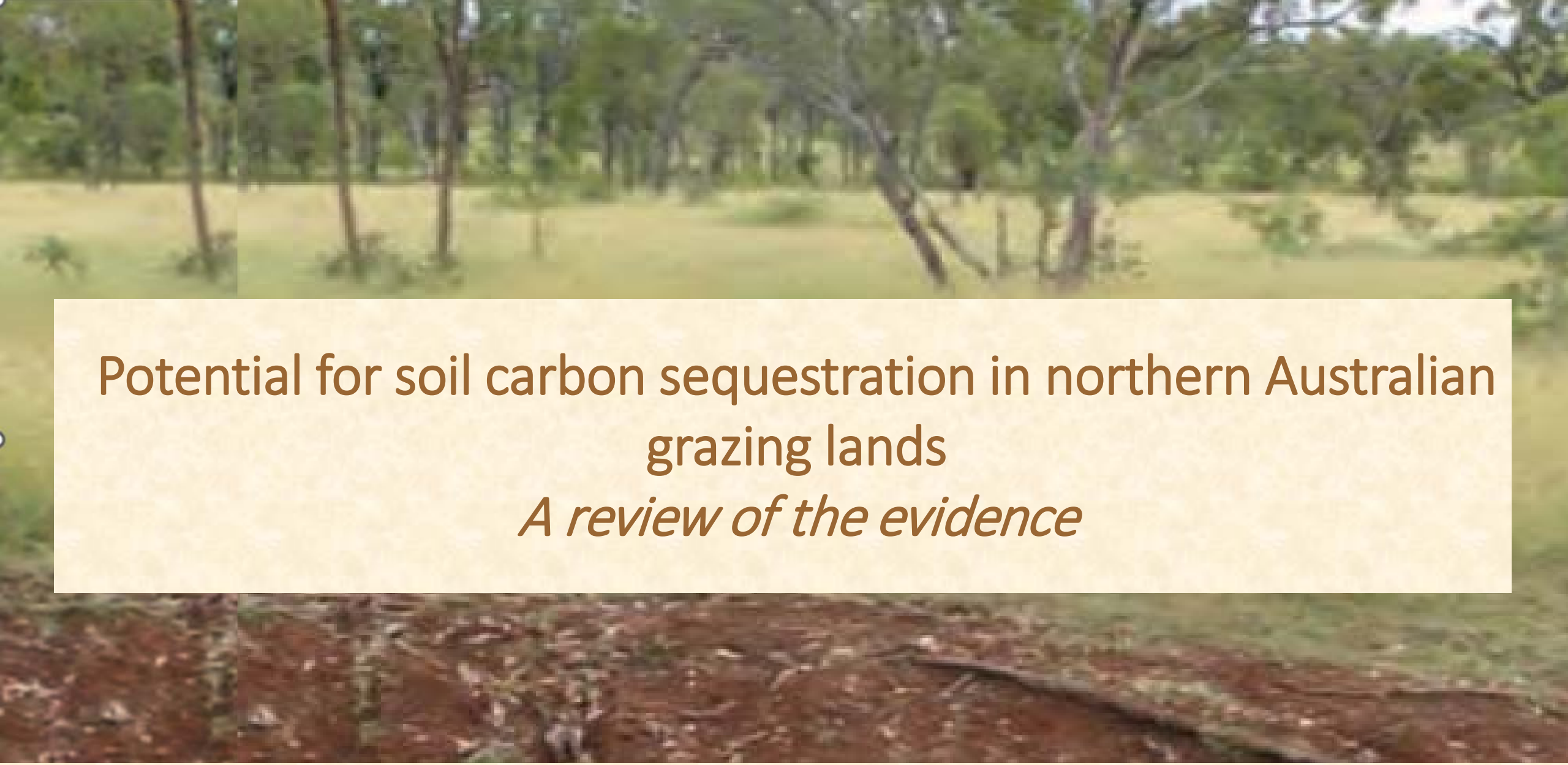

Potential for soil carbon sequestration in northern Australian grazing lands

A review of the evidence

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Potential for soil carbon sequestration: Review overview

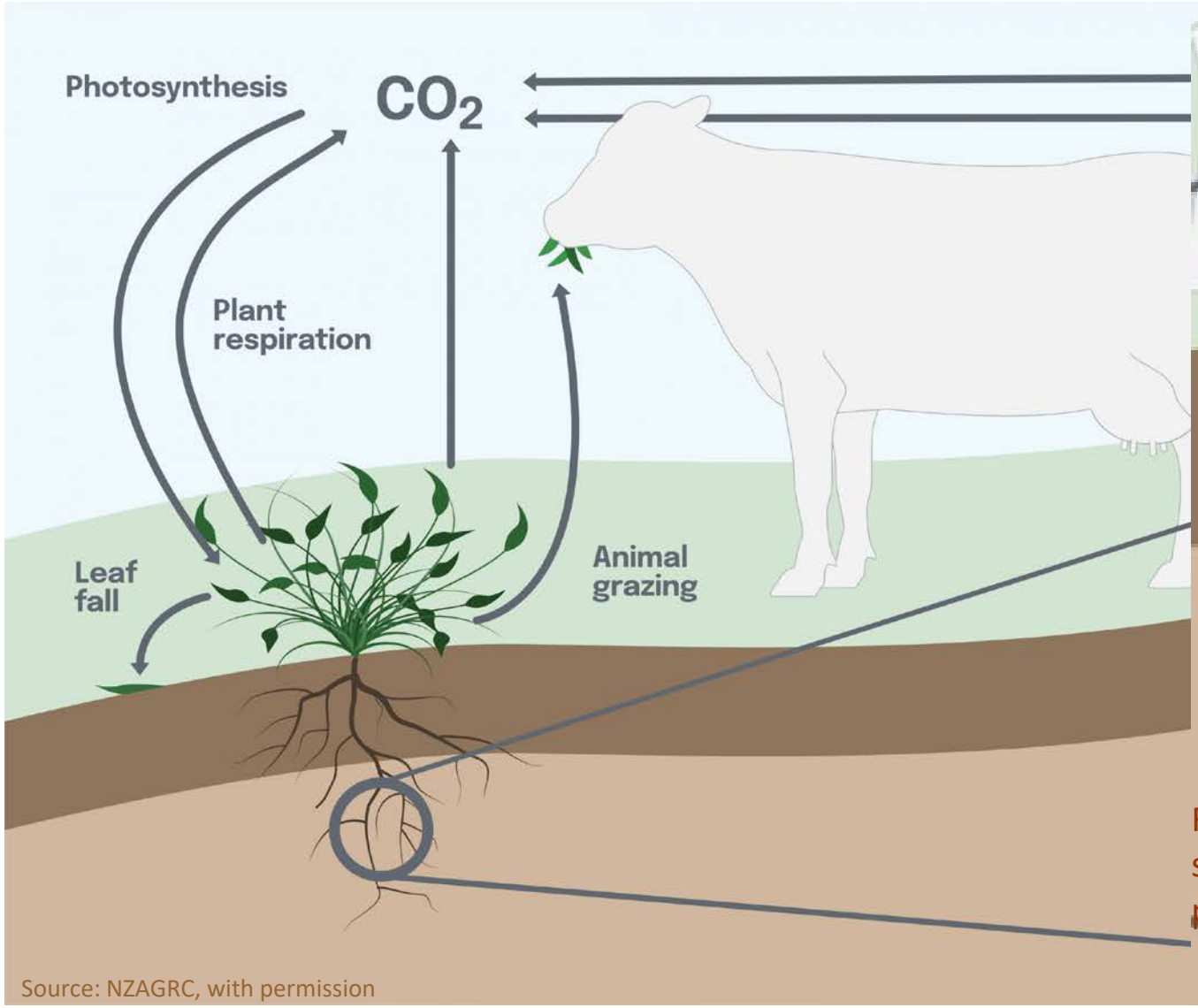
Approach:

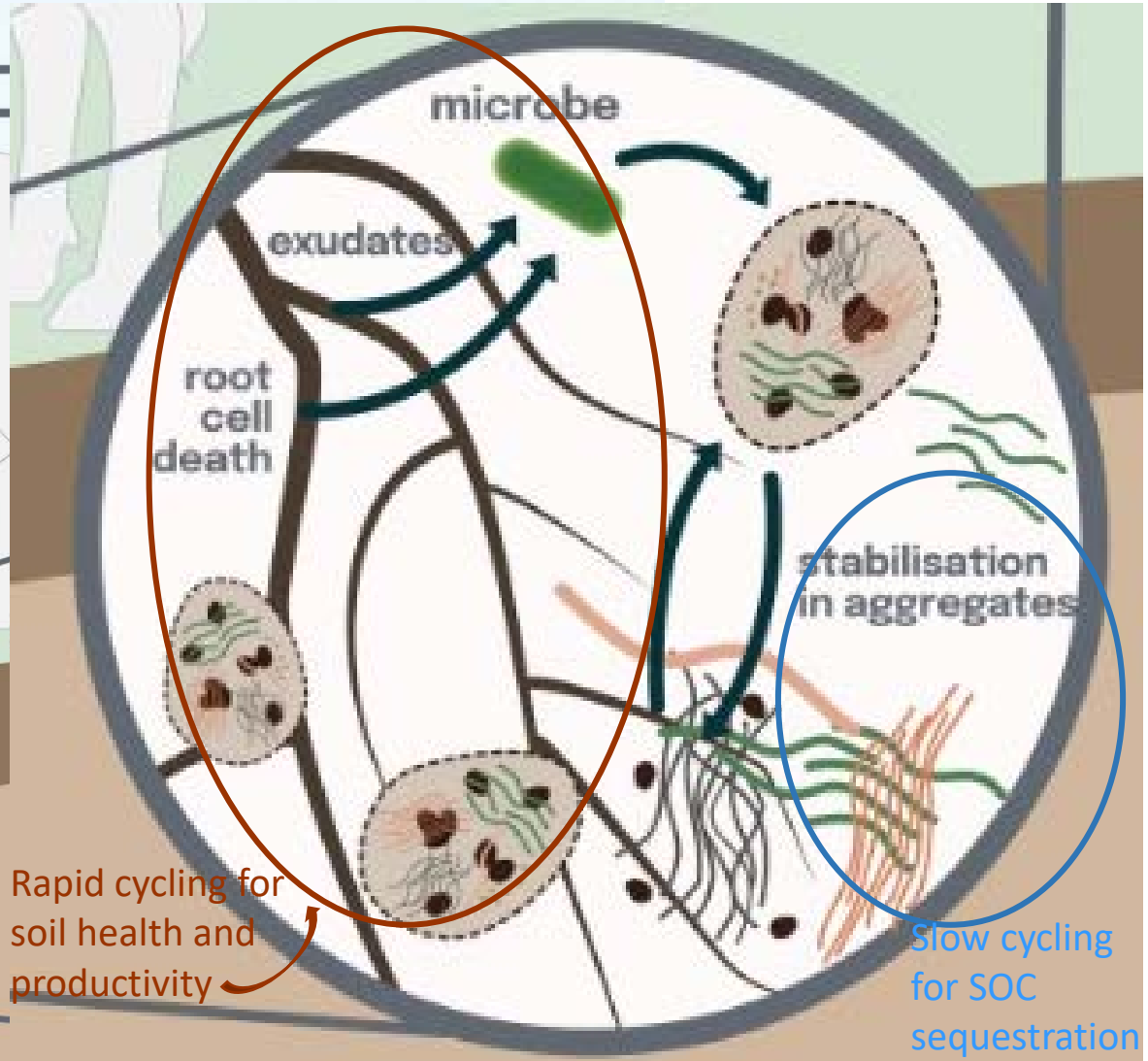
- > 200 papers or reports relevant to northern grazing lands were considered
- 185 were used for either data, understanding or context
- 139 sources of relevant data for soil carbon and management were further evaluated
- 60 had data and methods consistent with quantifying sequestration potential
- Sequestration and management strategies were grouped as (1) grazing; (2) pasture; (3) land conversion

Overall, the literature review found:

- Few long-term studies with high quality data for soil carbon sequestration in N Australia grazing lands
- Results for management impacts on SOC were often inconsistent between studies and locations

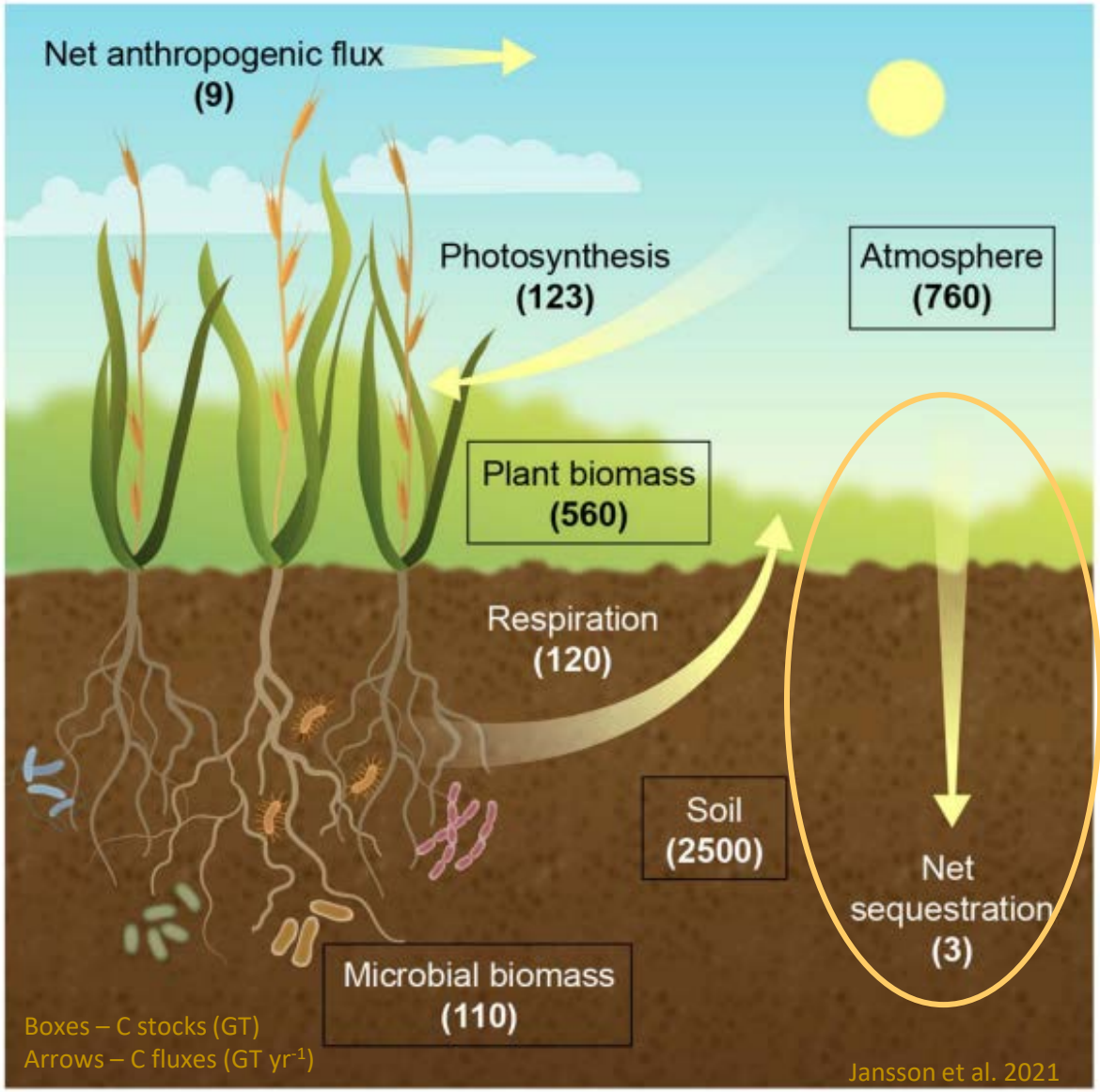
What is soil carbon sequestration?

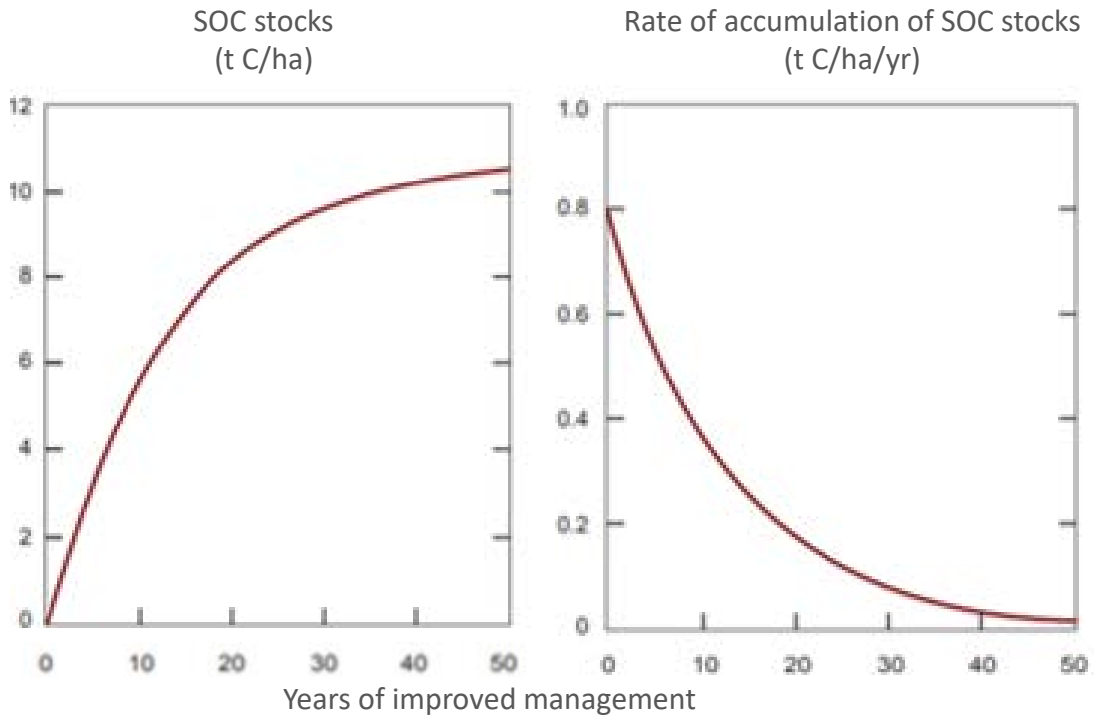




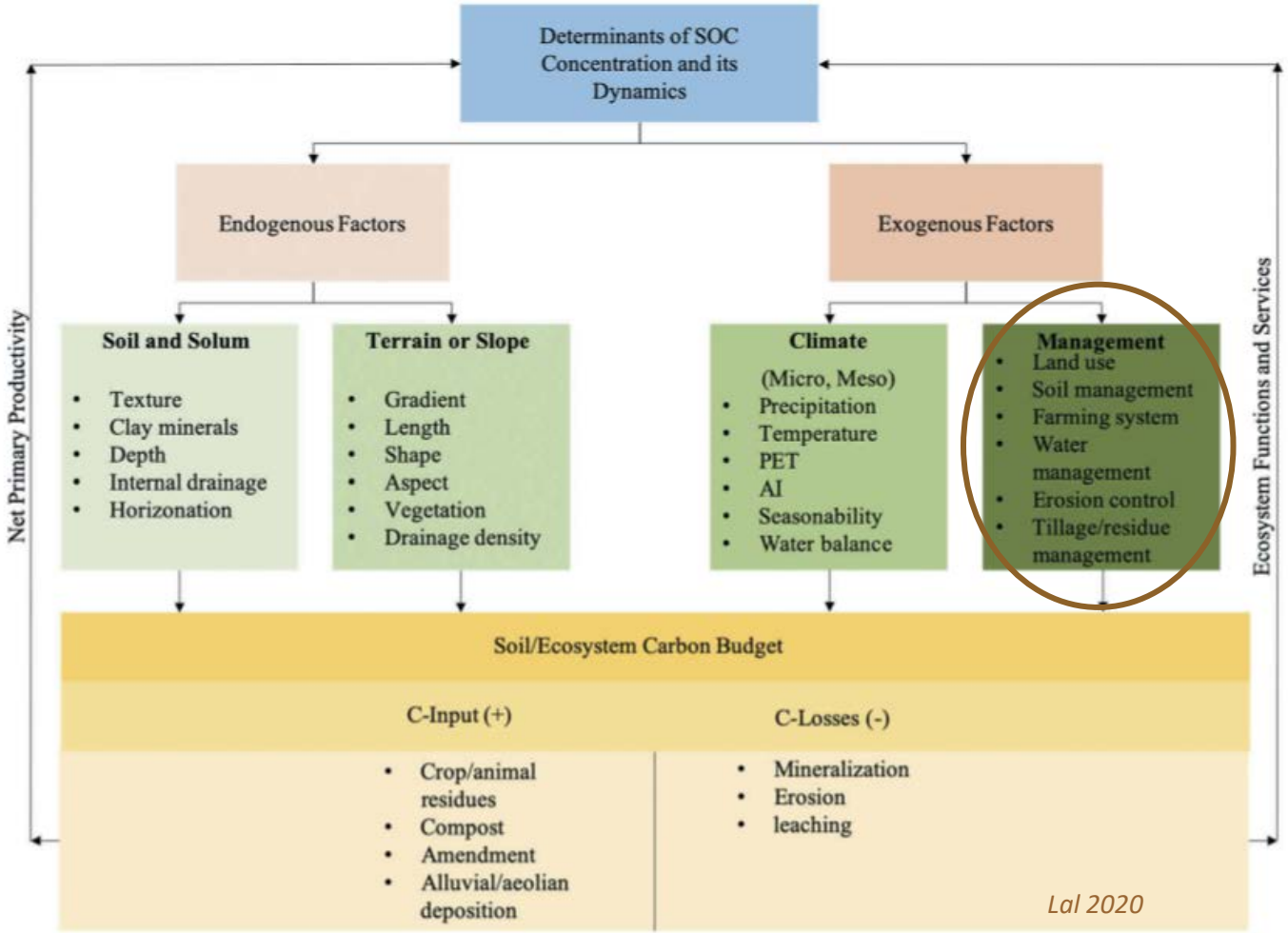
Source: NZAGRC, with permission

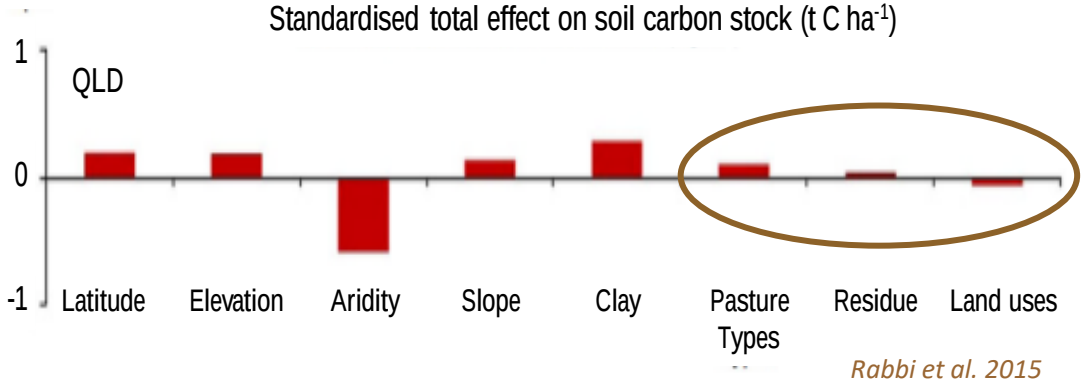
Global potential for soil organic carbon sequestration





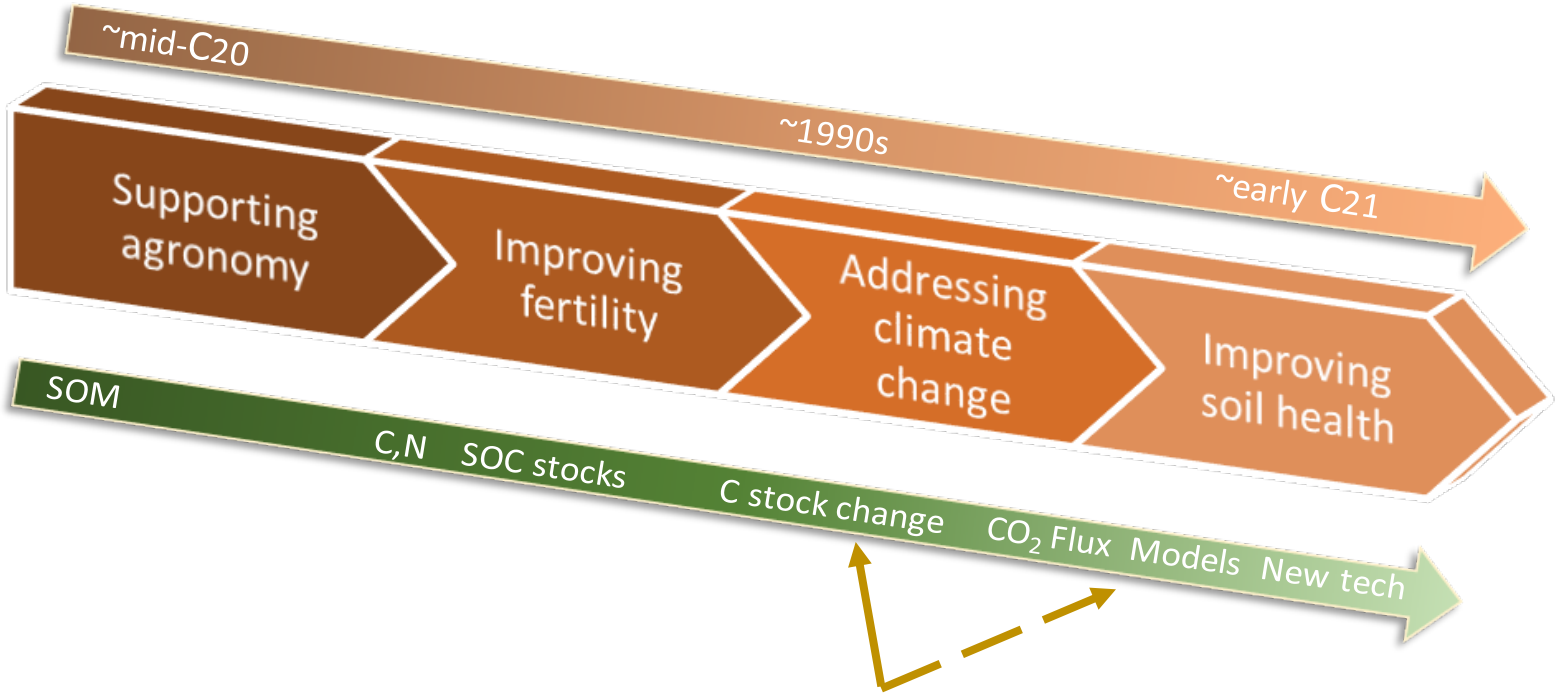
Detecting changes in soil carbon due to management



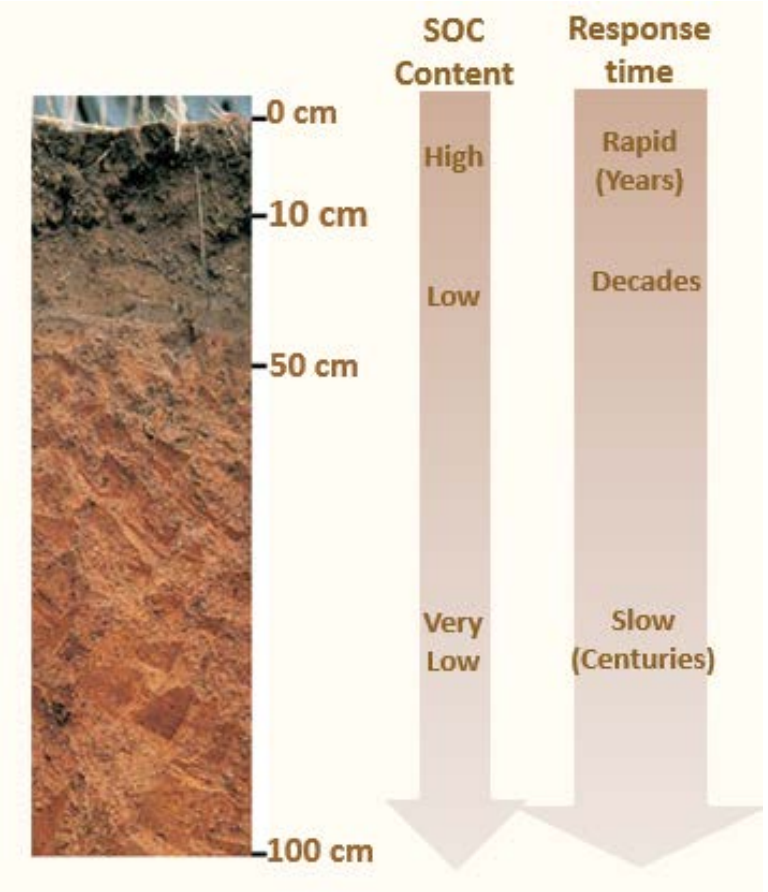


Rabbi et al. 2015

Soil carbon sequestration: Measurement requirements



SOC sequestration (t C/ha/year) is a measure of
long-term change in carbon stocks



Grazing management strategies

1. **Grazing intensity**
   - High grazing pressure/overgrazing is commonly associated with net loss of SOC
   - Low to moderate grazing pressures indicated no significant or consistent effect on SOC stocks
2. **Destocking/exclosure**
   - Small increase in sequestration on average; higher rate of increase for degraded soils
3. **Rotational grazing**
   - No significant impact on soil carbon stocks of various forms of rotational or time-controlled grazing
   - Non-significant or small positive effect on pasture yield

Grazing strategy	SCS average (Range)	Average C stock	Period of observation	Confidence (H,M,L)	Number of studies (sites)
	t C ha^{-1} yr^{-1}	t C ha^{-1}	Years		
Grazing intensity	-0.02 (-0.087 – 0)	NE (20–103)	12-26	L	3
Destocking/exclosure	0.04 (0 – 0.08)	23.7 (16.6 – 32.5)	12 –57	L	3
Rotational strategies vs continuous grazing	0 (-0.01 – 0)	NE (13 – 48)	5 –15	M	6

Pasture management strategies

1. **Pasture improvement**
   - Sowing more productive grasses increased soil carbon stocks in temperate regions; too few data to quantify change in tropical regions
2. **Forage legumes**
   - Planting legumes in grass pastures increased soil carbon stocks; the increase was linked to symbiotic N fixation and deep-rooting properties of legumes

Pasture strategy	SCS average (Range)	Average C stock	Period of observation	Confidence (H,M,L)	Number of studies (sites)
	t C ha^{-1} yr^{-1}	t C ha^{-1}	Years		
Pasture improvement	NE (northern pastures) 0.31 (0–0.6) (temperate)	NR	Various	L	5
Forage legumes	0.32 (0.27–0.45)	NR	20	M	5

Land conversion strategies

1. **Cultivated cropland to permanent pasture**
   - Consistently increased sequestration; opportunities likely limited in N Australia
2. **Forest cover to grassland**
   - No significant increase in sequestration; inconsistent results may reflect differences in baseline condition, time since conversion, sampling depths
3. **Grassland to forest cover**
   - No evidence of significant sequestration following conversion of well-managed grassland to forest cover
   - Small increases in sequestration following tree establishment on degraded grassland

Land use strategy	SCS average (Range) t C ha^{-1} yr^{-1}	Average C stock t C ha^{-1}	Period of observation Years	Confidence (H,M,L)	Number of studies (sites)
Conversion of cropland to grassland	0.40 (0.06 – 0.78)	63 (24 – 102)	4 – 100	M	9
Conversion of forest to grassland	-0.19 (-0.62 – 0.12)	41 (27 – 55)	12 –57	L	5
Conversion of grassland to forest	0 (0 – 0/NS)	35 (35 – 36) (2 sites)	10 – 58	L	4

Fire management strategies

Lower intensity and frequency of burning

- Small increases in soil carbon stocks with reduced frequency and intensity of burning
- In tropical savannas, possible economic trade-offs due to negative impacts on pasture biomass
- Interpretation of the impact of change in fire regime on soil carbon stocks confounded when accompanied by pasture improvement or grazing practice change

Does better land condition indicate higher soil carbon stocks?

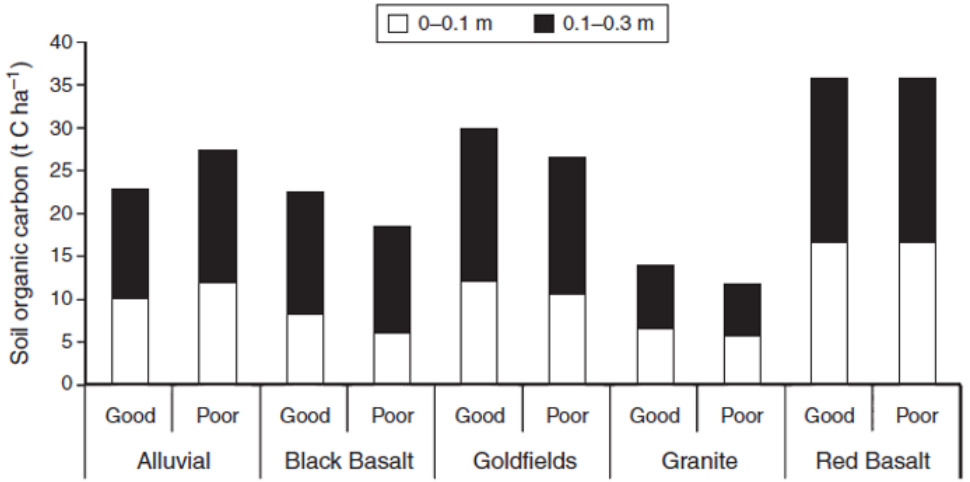
Main findings

- Improved land condition is associated with higher average pasture biomass and higher groundcover
- Paired site studies showed no strong correlation between land condition score and soil organic carbon stocks

Preliminary conclusion

- Land condition score did not appear to provide a reliable indicator of sequestration
- More research is needed to improve understanding of the risks and benefits

B. Land in good condition (left) characterised by perennial grasses and good ground cover and neighbouring site in poor condition (right) with ephemeral species and surface disturbance. (Source: Bray et al. (2010), Georgetown Granite site example)



A. Sampling of paired sites with contrasting land condition classification showed no consistent relationship between condition classification and SOC stocks to 30 cm depth (Source: Bray et al. 2016).

How do the review results compare with other data?

Field studies: av potential for Australia (0-30cm)

Land use	Practices (examples)	Relative gain in SOC
Cropland	No-till+residues; crop rotations	0.2 – 0.3 t C/ha/yr
Grazing land	More productive pasture species	0.1 – 0.3 t C/ha/yr
Land conversion	Cultivation to permanent pasture	0.3 – 0.6 t C/ha/yr

Sanderman et al. 2010

Management	SOC benefit[a]	Conf.[b]	Justification
b. Rotational grazing	+	L	Increased productivity, inc. root turnover and incorporation of residues by trampling but lacking field evidence

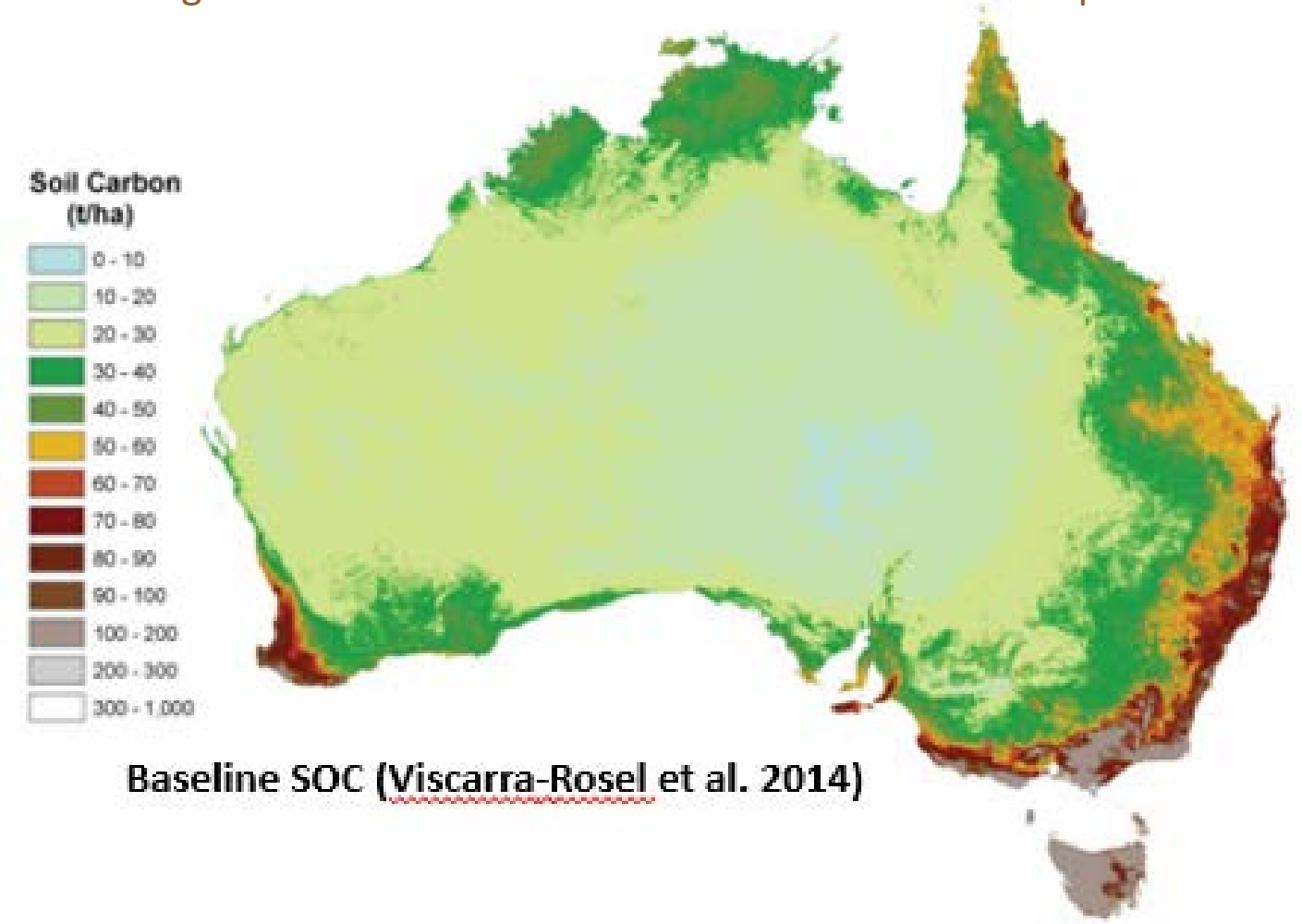
[a,b] Qualitative assessment of sequestration potential and confidence (Sanderman et al. 2010)

+ = low, ++ = moderate, +++ = high

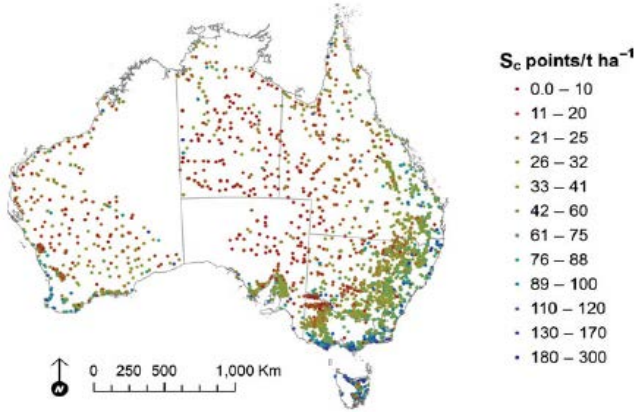
L = low, M = medium, H = high

The potential for sequestration: Baseline SOC stocks

Organic carbon stocks in Australian soils to 30 cm depth

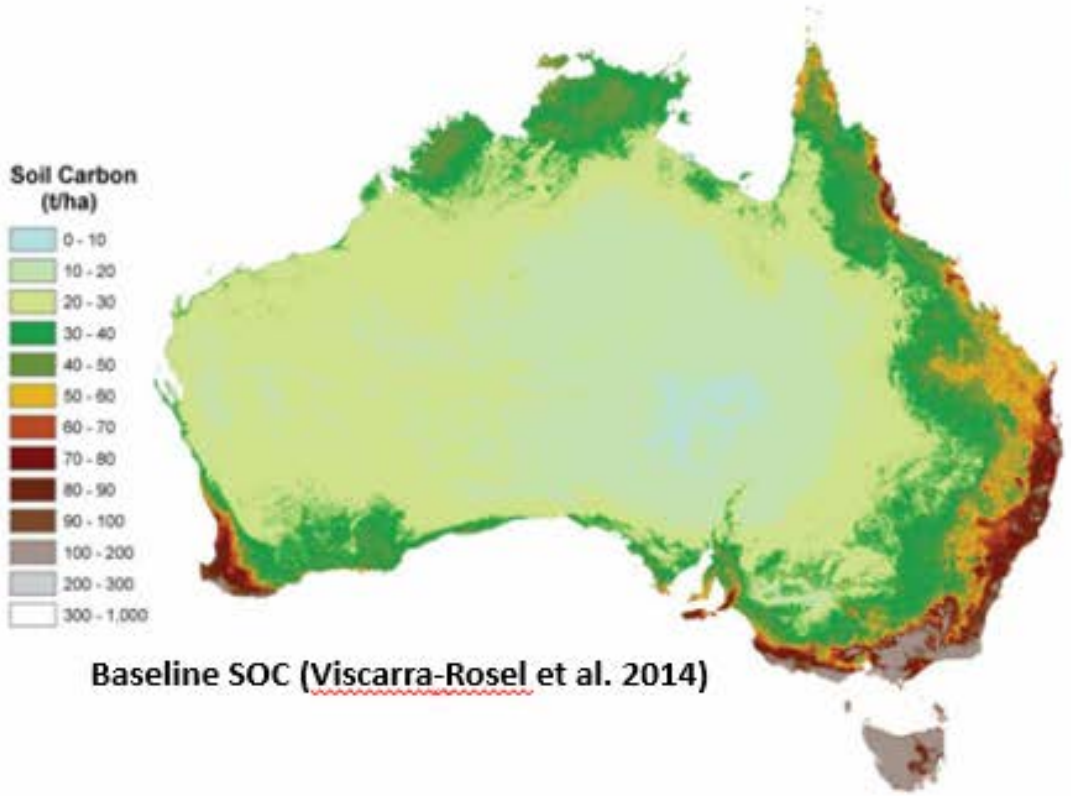


Baseline SOC (Viscarra-Rosel et al. 2014)

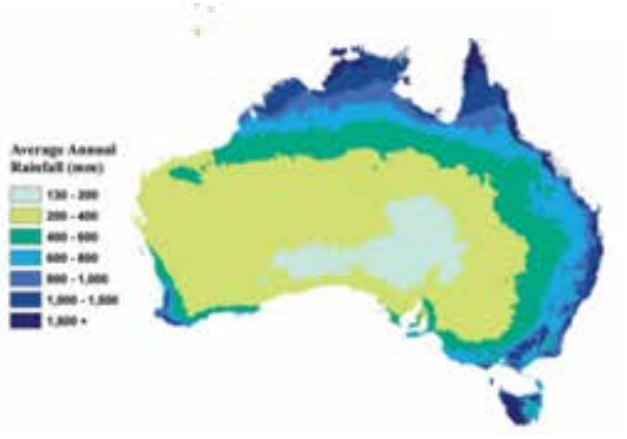


SOC sampling points

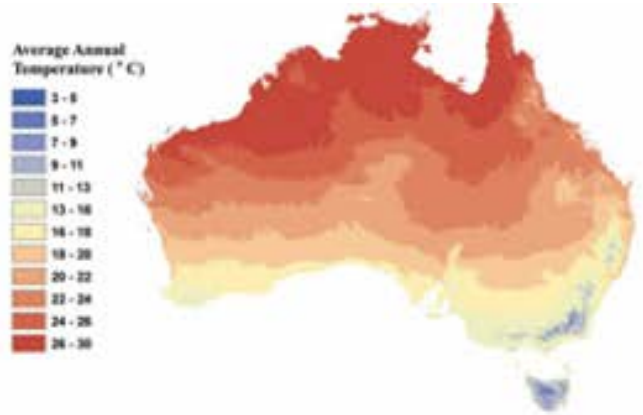
The potential for sequestration: Major drivers



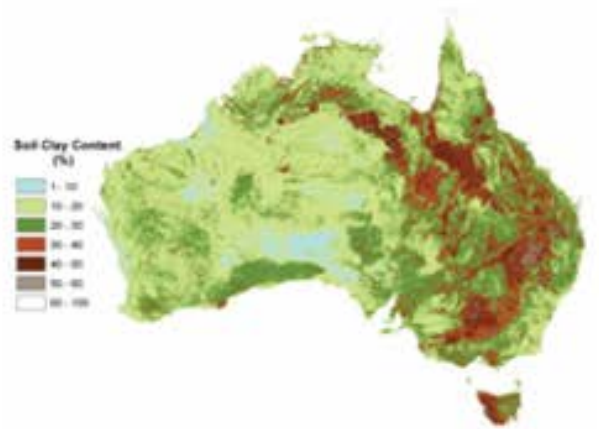
Baseline SOC (Viscarra-Rosel et al. 2014)



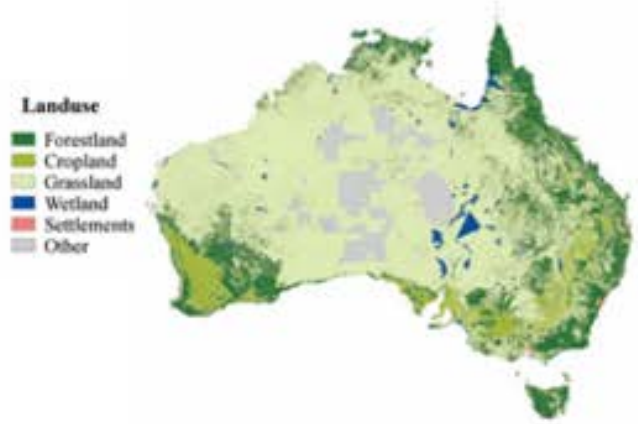
Long-term average annual rainfall



Long-term average annual temperature



Australian three-dimensional soil grid (Clay)
(Viscarra-Rossel, 2015)



Australian land use (2016)

The potential for sequestration: Opportunities

- More productive grasses or incorporating legumes in pasture and avoiding high grazing pressure showed the highest potential for soil carbon sequestration
- Managing agricultural soils to increase or maintain organic matter content generally benefits productivity and resilience
- Possibility of increasing soil organic carbon in degraded lands may have wider benefits
- Increasing soil organic carbon can provide co-benefits for soil health, biodiversity, soil nutrient cycling, water status… More research is needed to fully understand co-benefits and trade-offs
- Carbon crediting schemes such as the ERF may create opportunities for land managers to earn income or offset their on-farm emissions

The potential for sequestration: Impediments and risks

Real or perceived barriers and risks may include:

Uncertain potential for sequestration *and uncertainty in achievable sequestration*

- Potential for increasing soil carbon is context-specific due to factors such as climate, soil, baseline
- Trusted sources of reliable information and knowledge on how to start is limited

Possibility of trade-offs

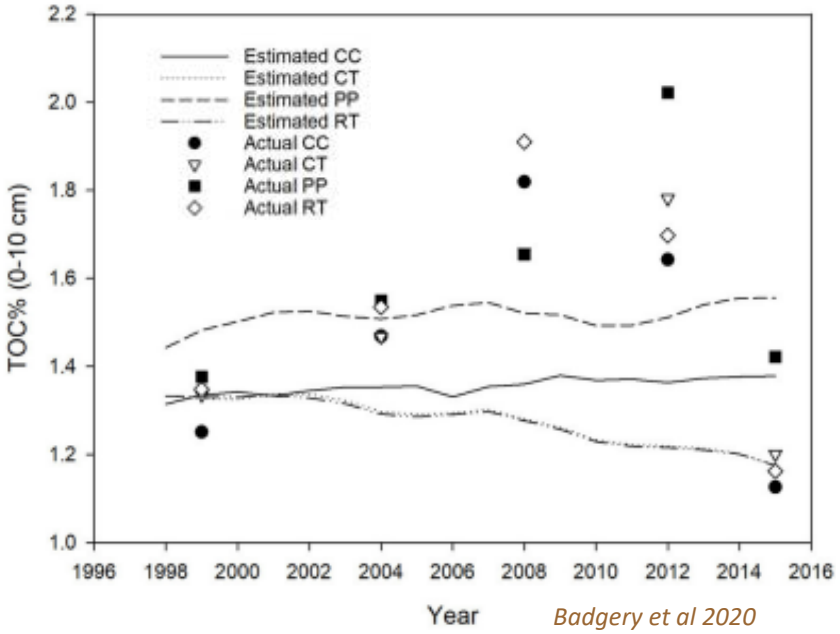
- Management strategy may involve significant up-front costs (e.g. sowing legumes)
- Management strategies with most potential must fit into property management planning and personal goals
- Changing management to strategies is a big commitment

Carbon credits?

- If engaging in carbon credit projects there may be additional impediments, e.g. additionality, permanency obligation, reporting, engaging a carbon service provider

The potential for sequestration: *Risks and uncertainty*

Climate variability risk



Badgery et al 2020

Climate change risk

Roxburgh et al 2020

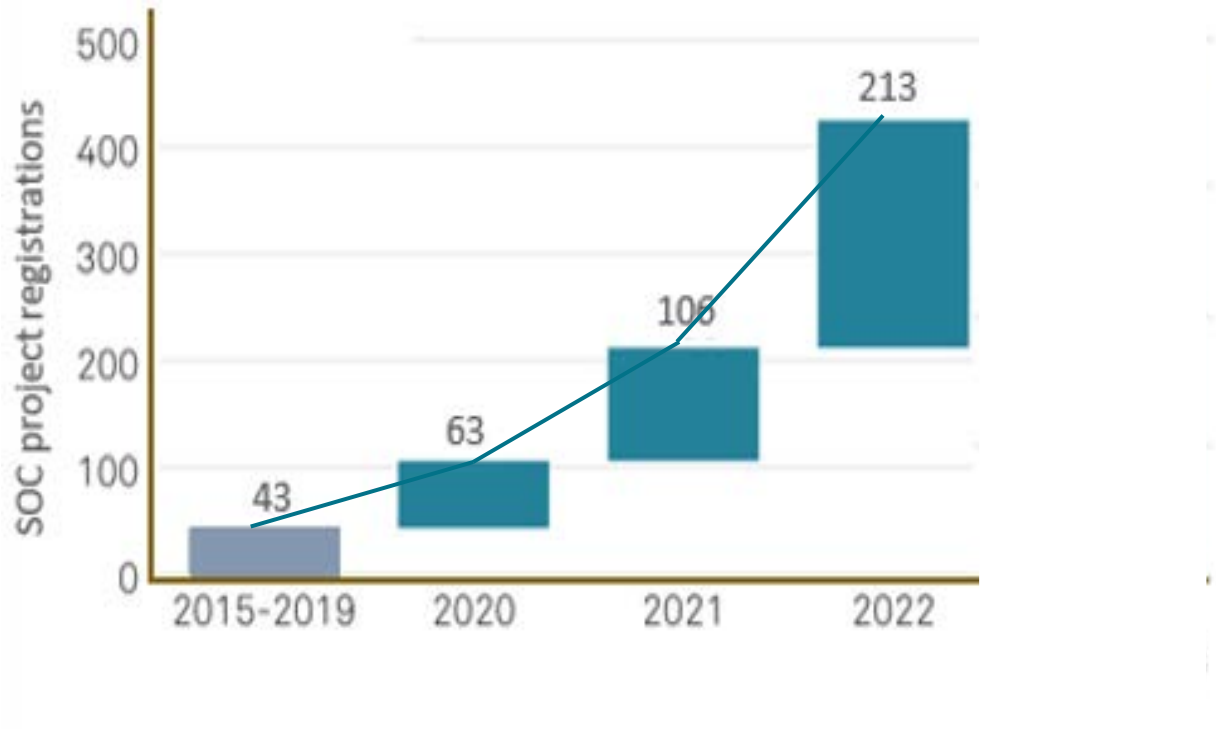
Soil carbon sequestration: ERF projects

Emissions Reduction Fund soil carbon methods

Model method (2015) Estimating sequestration of C in soil using default values

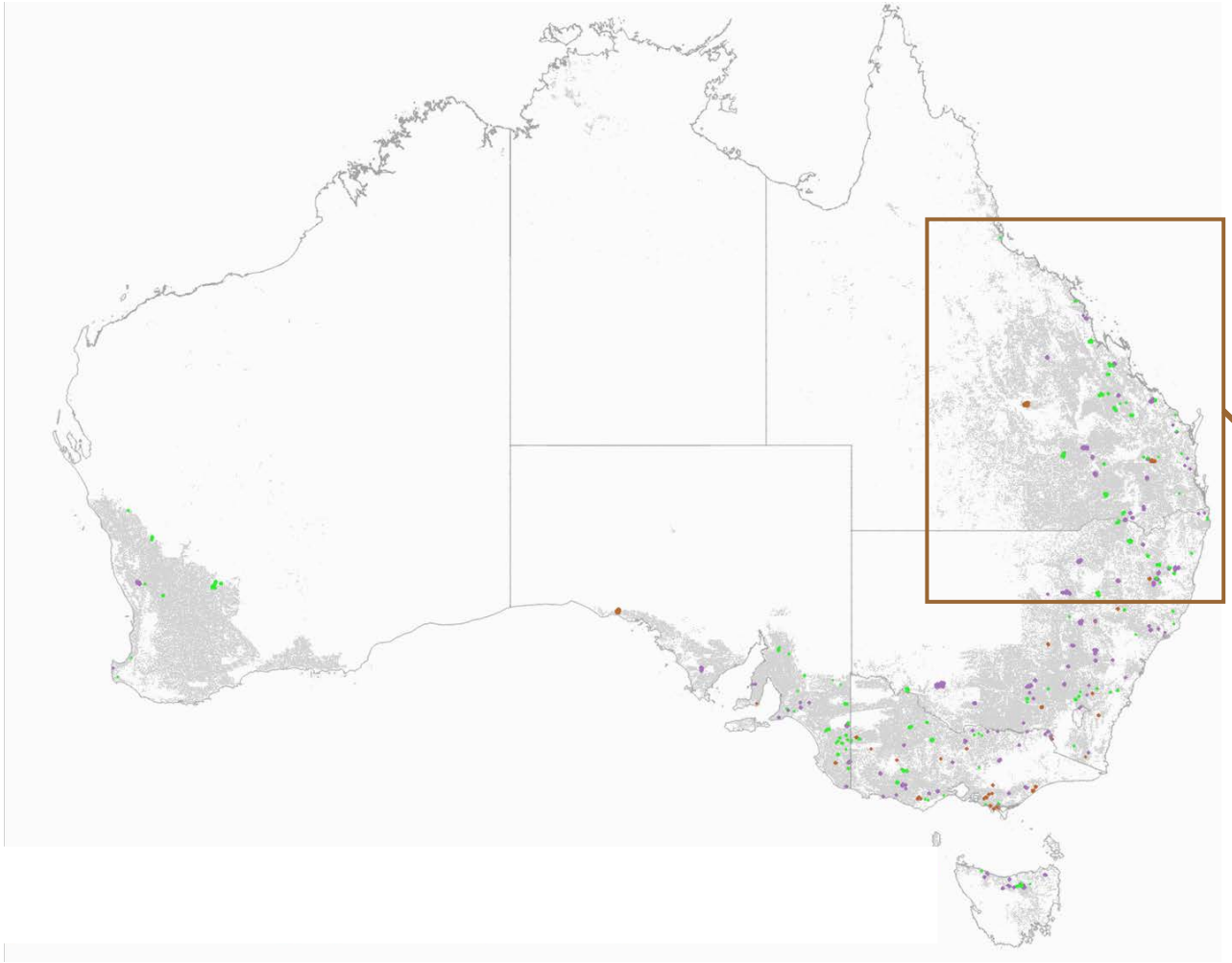
Measure – Model method (2021) SOC sequestration in agricultural systems using measurement and models

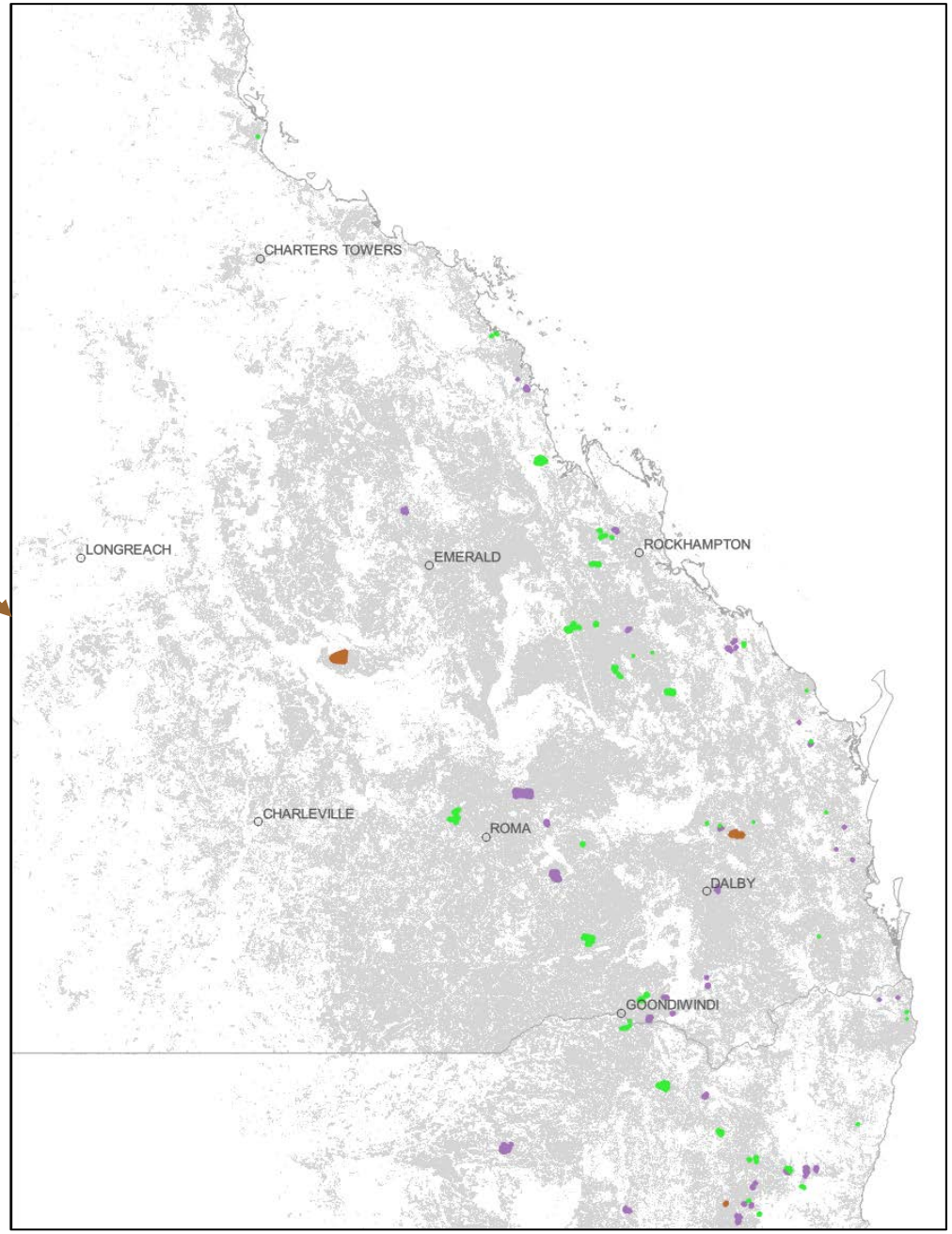
New ERF soil carbon project registrations



Data source: Clean Energy Regulator QCMR Mar 2023

ERF soil carbon projects in the north





Estimation of Soil Carbon Sequestration and models 2021
Measurement of Soil Carbon Sequestration in Agricultural Systems 2018
Sequestering Carbon in Soils in Grazing Systems 2014

Source of data: CER Feb 2023

Review recommendations

To build evidence and understanding of the potential for soil carbon sequestration in northern Australia:

1. ***Enhance and expand SOC data and predictive capability for northern Australia***

   - Maintain and continue monitoring long-term studies in northern Australia
   - Seek to expand high quality data (Evaluate (a) re-measuring archived soil samples; (b) well-designed surveys)

2. ***Improve confidence in management strategies with potential for soil carbon sequestration***

   - Investigate causes of inconsistencies in reported soil carbon changes for practical management strategies
   - Investigate links between soil carbon stocks, productivity, land condition score in grazing lands

3. ***Develop information materials on the potential for SOC sequestration***

   - Develop and maintain an accessible SOC database as a resource for stakeholders
   - Develop and regularly update online explanatory material

Thank you for your attention

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