Soil carbon sequestration

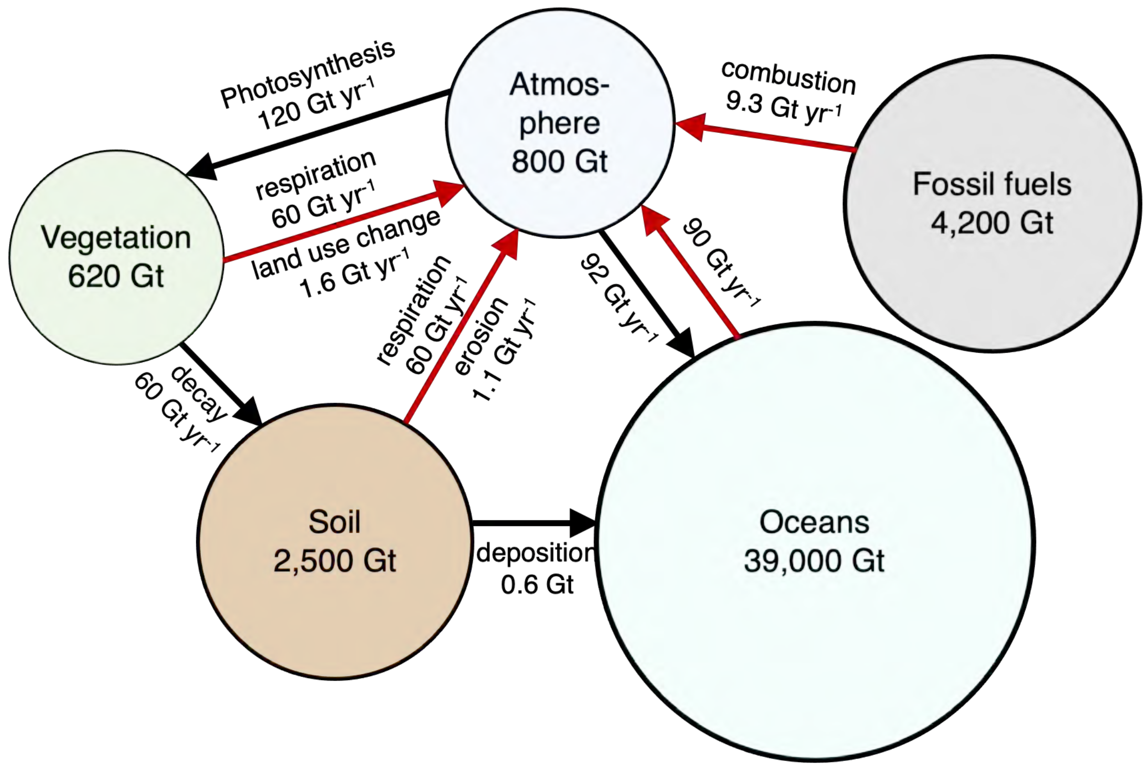
Raphael A. Viscarra Rossel
Soil & Landscape Science

WA Climate Resilience Fund Forum
Muresk Institute, 9 June 2021

Curtin University

Soil and the global carbon cycle

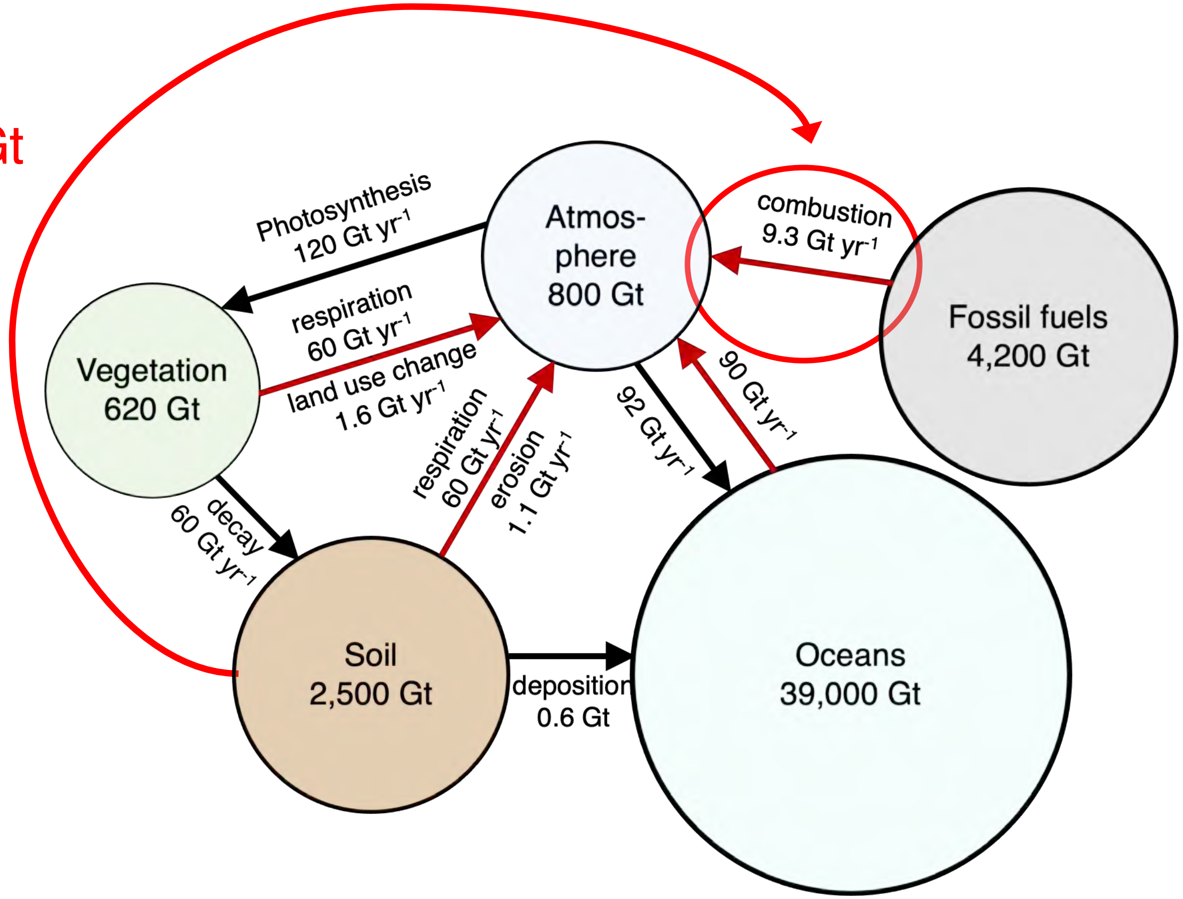
- Soil is the third largest C pool
- Concern over stability of soil C
- Can be a source of C to the atmosphere, enforcing climate change and degradation
- Can be a sink and trap C from the atmosphere: mitigate climate change **and** improve soil health **and** food security



Lal et al. (2017)

Global carbon cycle and the '4 pour mille'

4/1000 x 2500 = 10 Gt

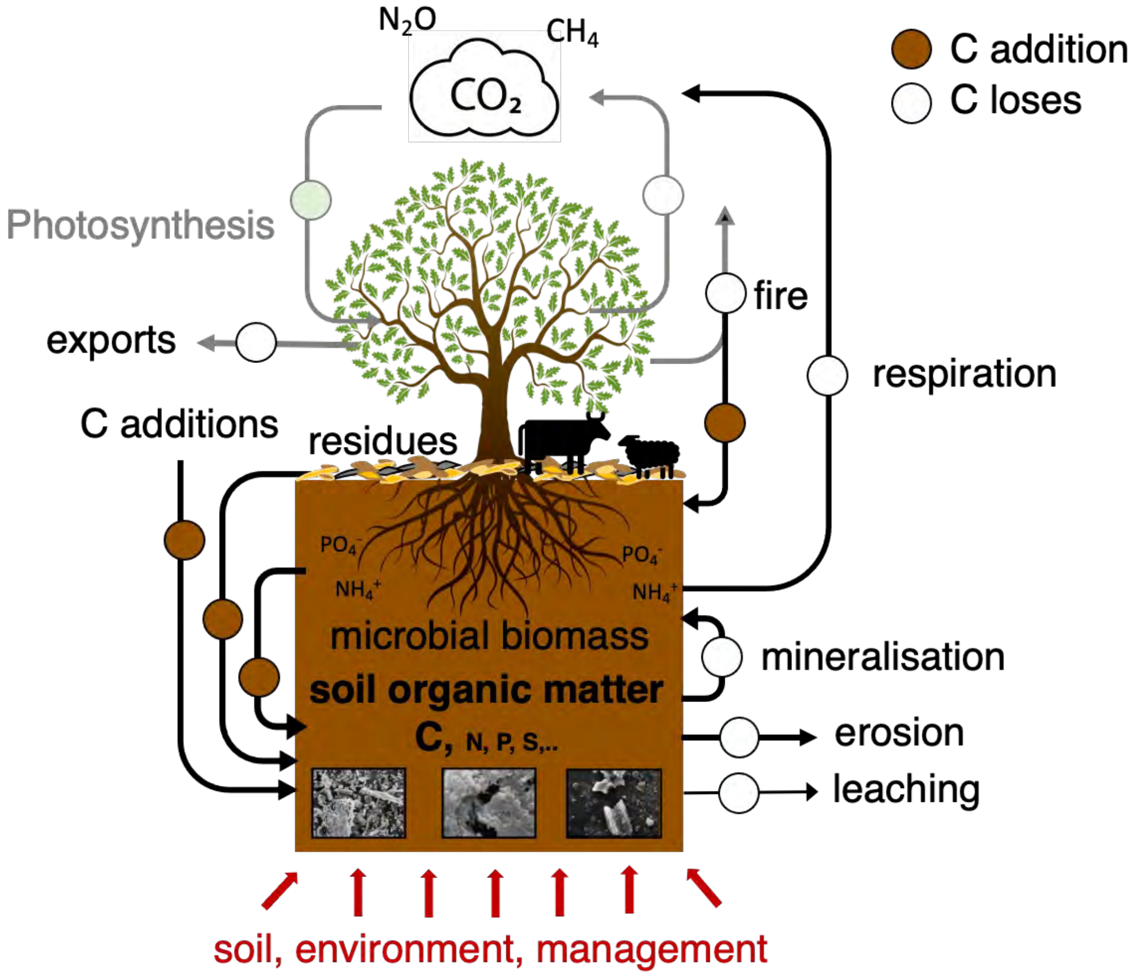


Managing a very small increase (e.g. 0.4%) in the total soil C stock of the planet can compensate for the annual CO_2 emissions from fossil fuels thus contributing to climate change mitigation **and** food security.

Balesdent & Arrouays (1999)

Might not be achievable everywhere, for various reasons, but it isn't a bad aim…

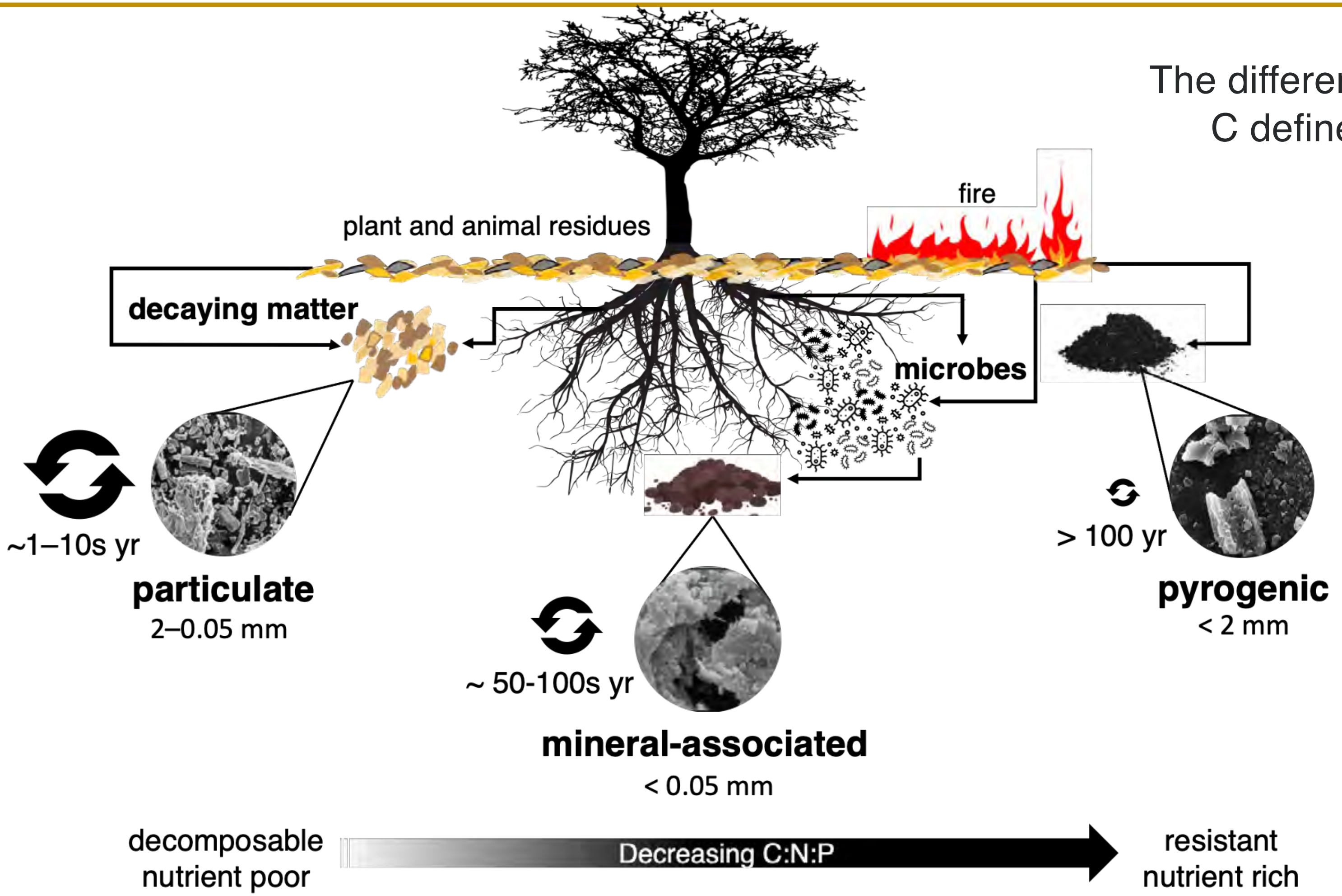
Soil organic matter and organic carbon



- SOM is a complex mixture of molecules and compounds at various stages of decomposition
- Those molecules and compounds enable soil functions and help to provide ecosystem services
- To increase soil C need to manage balance between C additions and losses, considering the local soil, environment and management

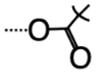
The heterogeneous composition of soil organic carbon

The different types of organic C define soil functions



Six et al. (2002)
Skjemstand et al (2004)
Lehman et al. (2008)
Baldock et al. (2013)
Viscarra Rossel & Hicks (2015)
Poeplau et al. (2018)

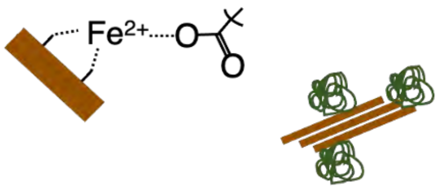
Processes of soil carbon stabilisation

 = organic matter  = functional group  = clay minerals  = mineral surface

1

Complexation & adsorption

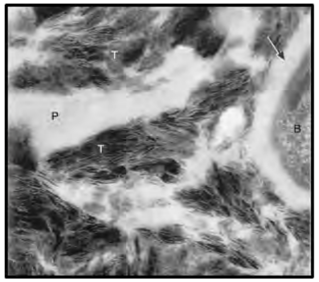
of organic molecules with clay minerals and oxides



2

Physical protection

of organic molecules and accessibility by microbes (for decomposition)

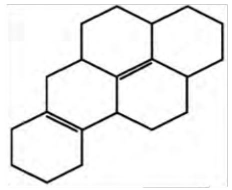


Keil & Meyer (2014)

3

Recalcitrance

is only relevant for pyrogenic carbon

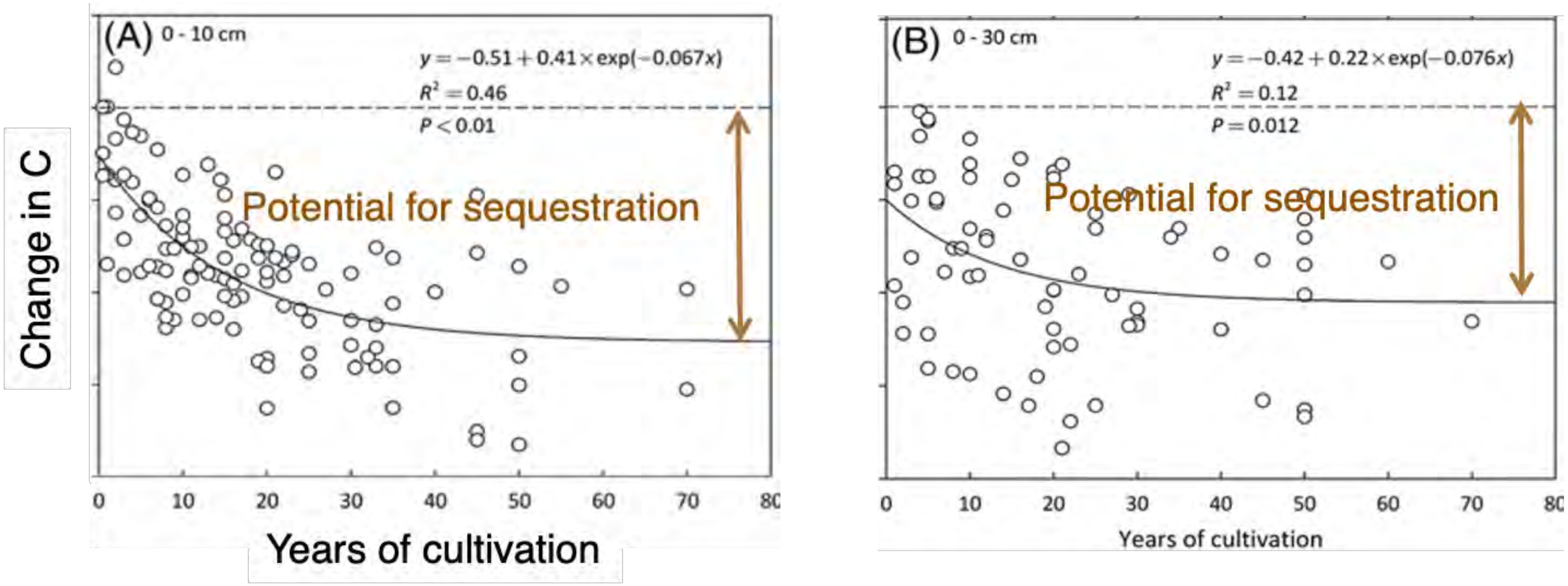


Soil C persistence is an ecosystem property rather than any one process taking place

Six et al., (2002); Lehmann & Kleber (2015); Kogel-Knabner (2017)

Soil organic C storage: is there potential?

- Historic loss of soil C said to provide the opportunity for re-capture and storage.

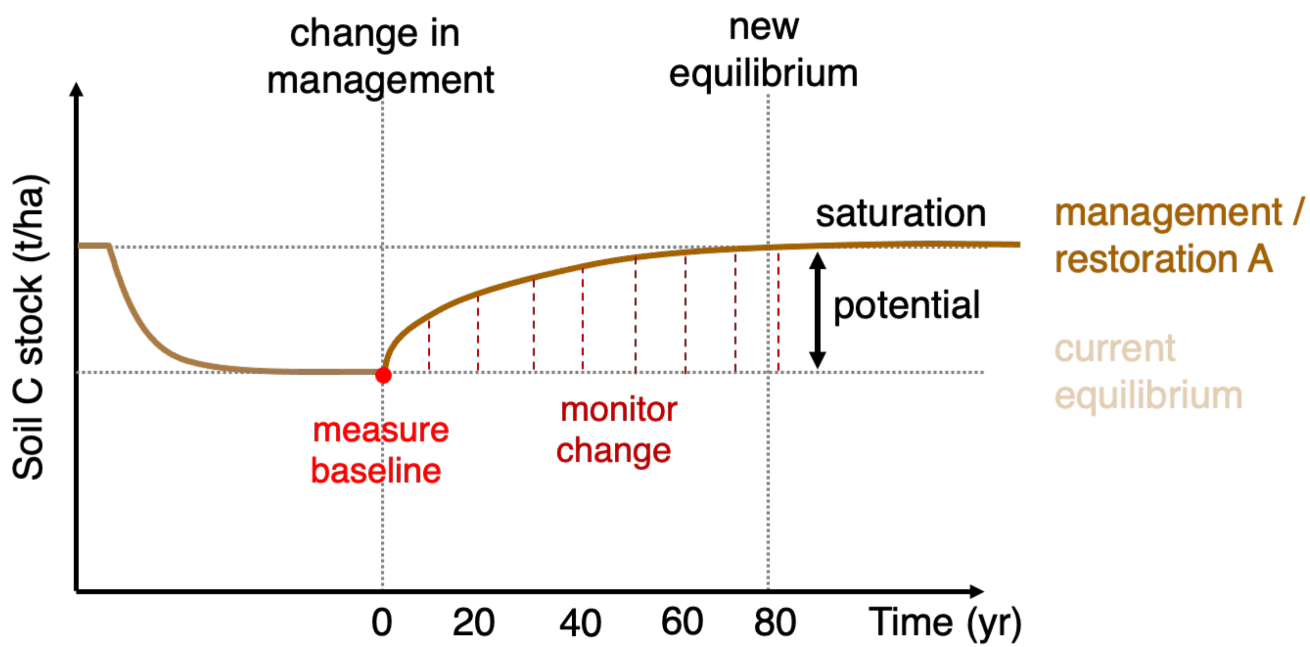


- In Australia 40 to 80% lost from pre-clearing levels

Luo et al. (2010)

Soil organic C storage – important to note:

Soil organic carbon storage: how long and how much?

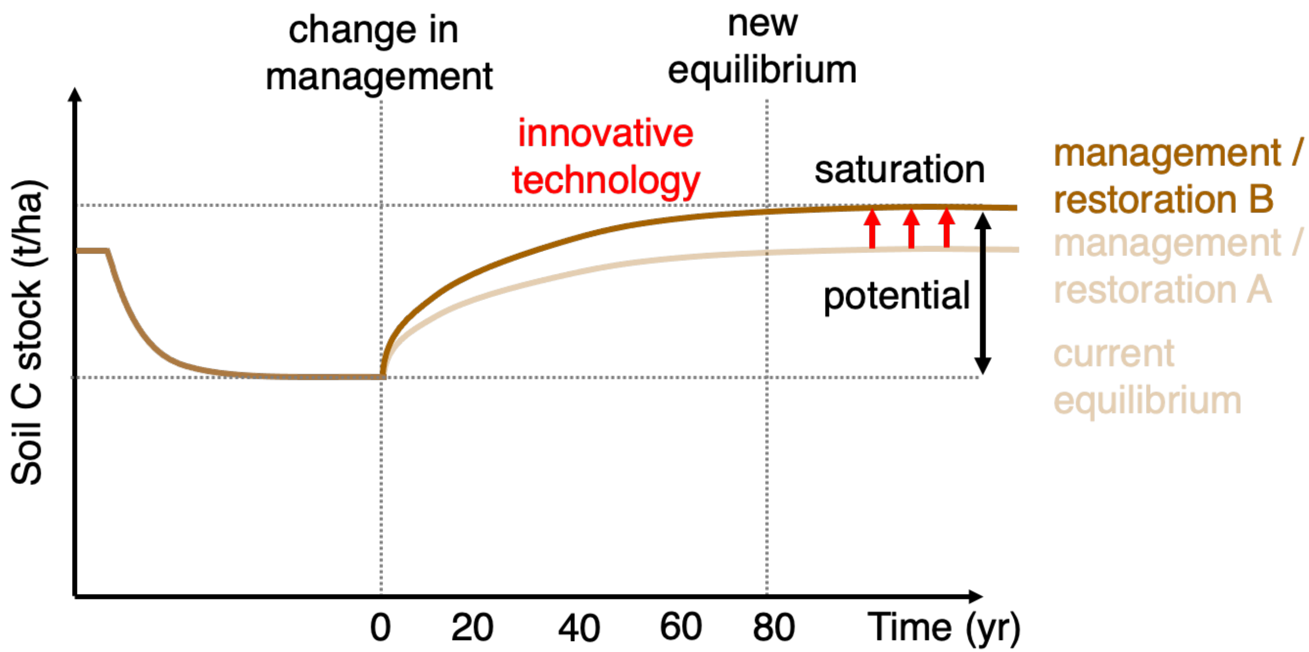


C storage:

1. is slow
2. is not linear (it saturates)
3. <u>measurement, monitoring, reporting and verification</u>

MRV is crucial and in Australia we have world-leading scientifically robust methods for doing so!

Soil organic carbon storage: limited capacity

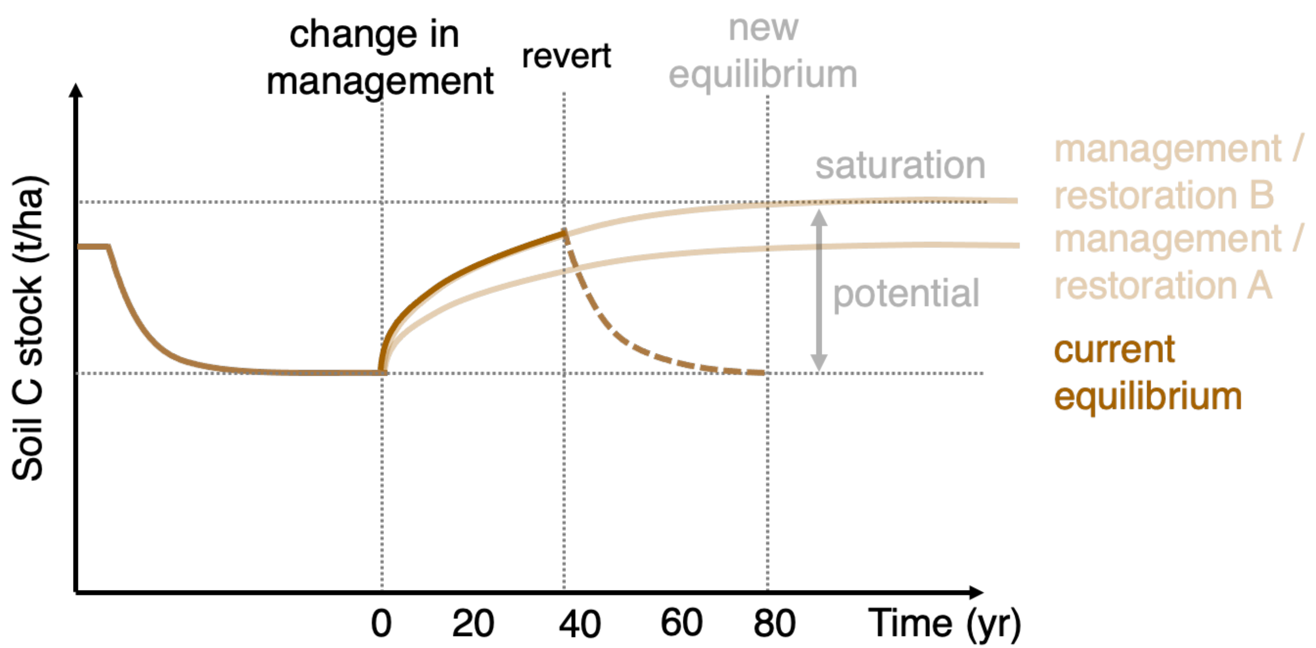


C storage:

1. is slow
2. is not linear (it saturates)
3. measurement, monitoring, reporting and verification
4. depends on management
5. has limited capacity

Activities with good potential: reduce erosion; cover cropping; pasture phase; increase biodiversity; improve water use efficiency; (cell) grazing management; reduce soil disturbance; stubble retention…

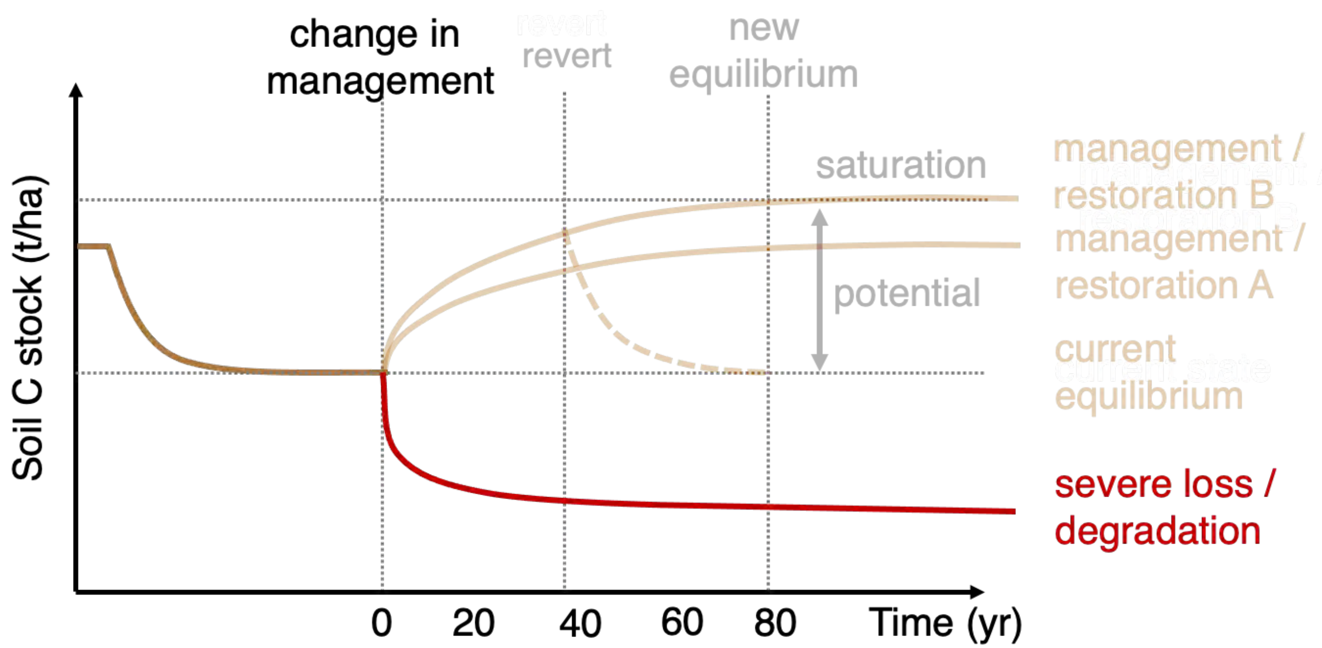
Soil organic carbon storage: it is reversible



C storage:

1. is slow
2. is not linear (it saturates)
3. measurement, monitoring, reporting and verification
4. depends on management
5. has limited capacity
6. is reversible

Soil organic carbon storage: loss can be large and rapid

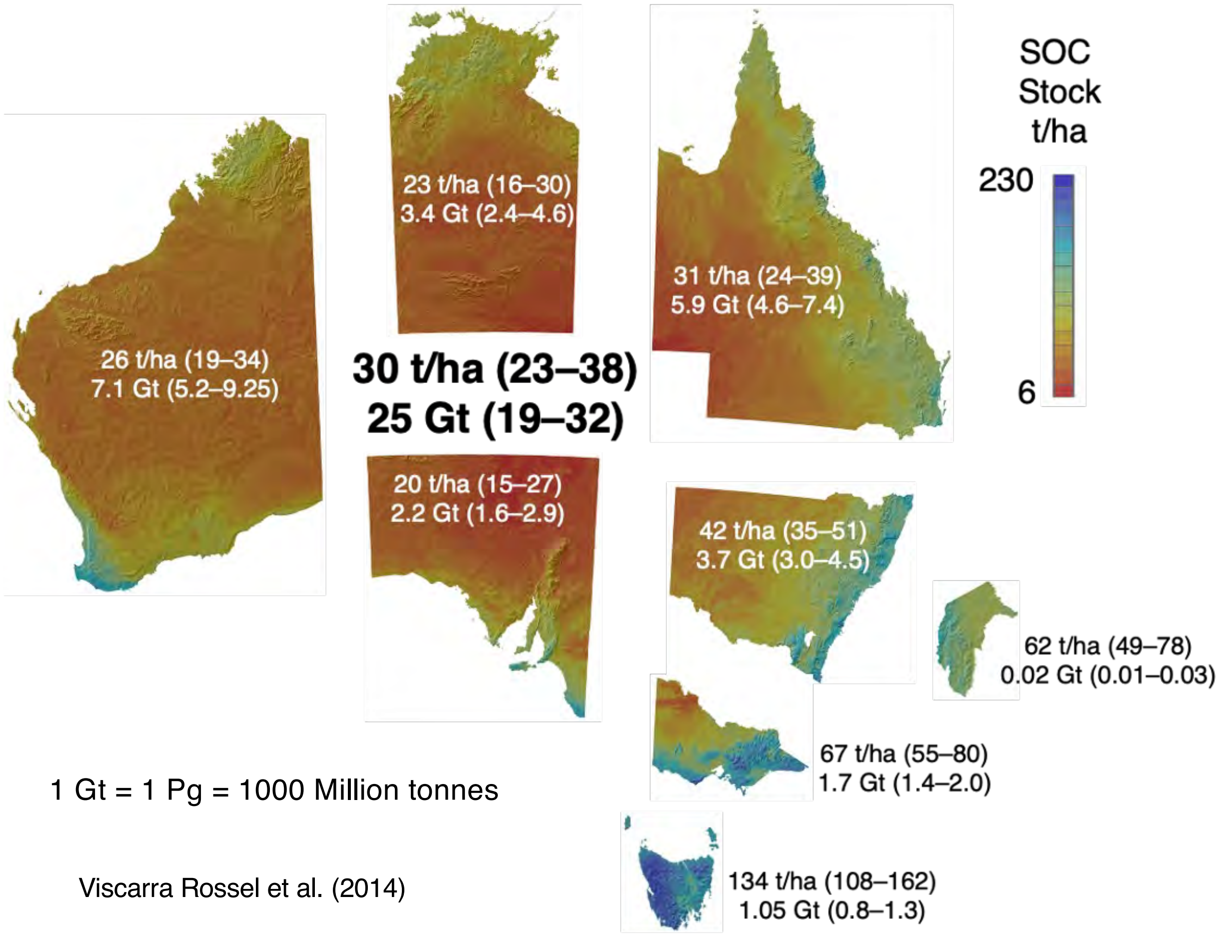


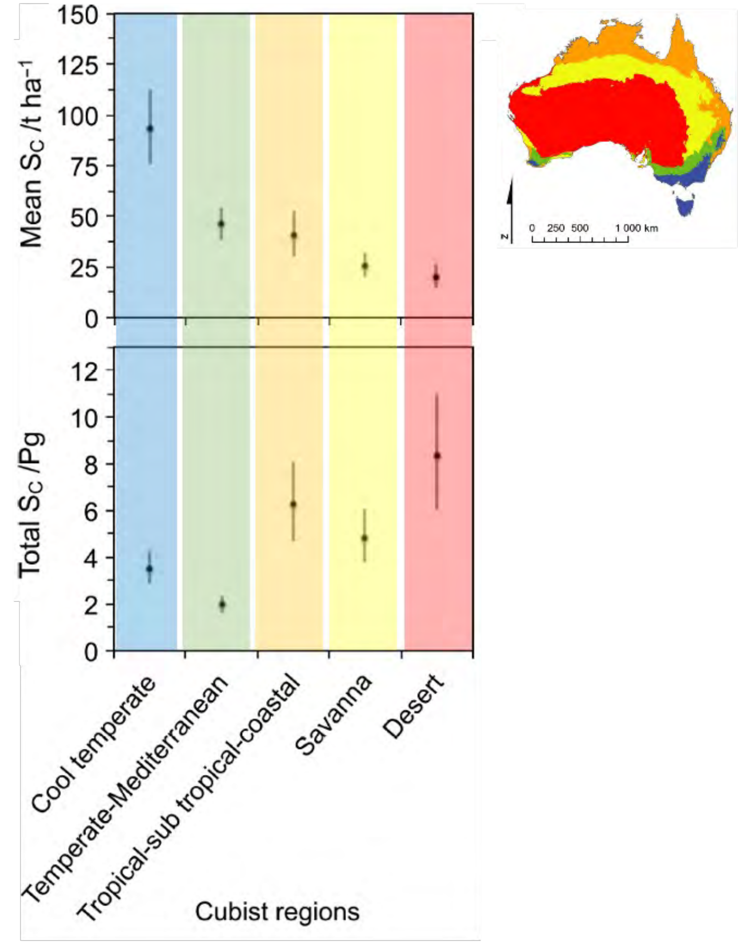
C storage:

1. is slow
2. is not linear (it saturates)
3. <u>measurement, monitoring, reporting and verification</u>
4. depends on management
5. has limited capacity
6. is reversible
7. loss can be large and rapid

- …and there are also other biophysical, technical, cultural, economic constraints

Carbon stocks in Australian soil (0–30 cm)

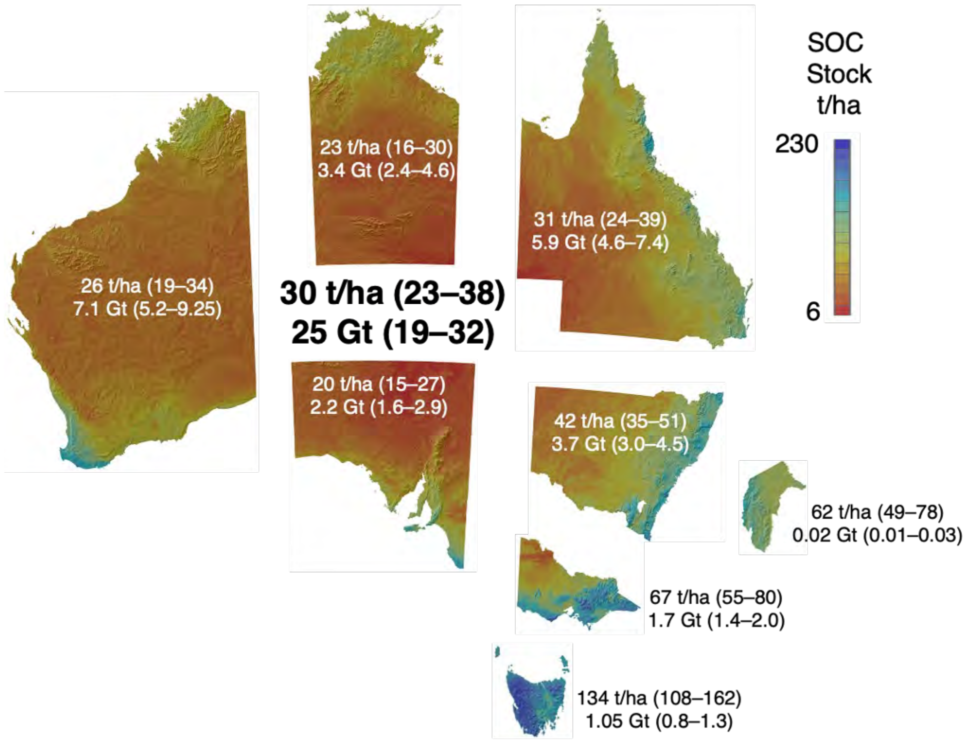


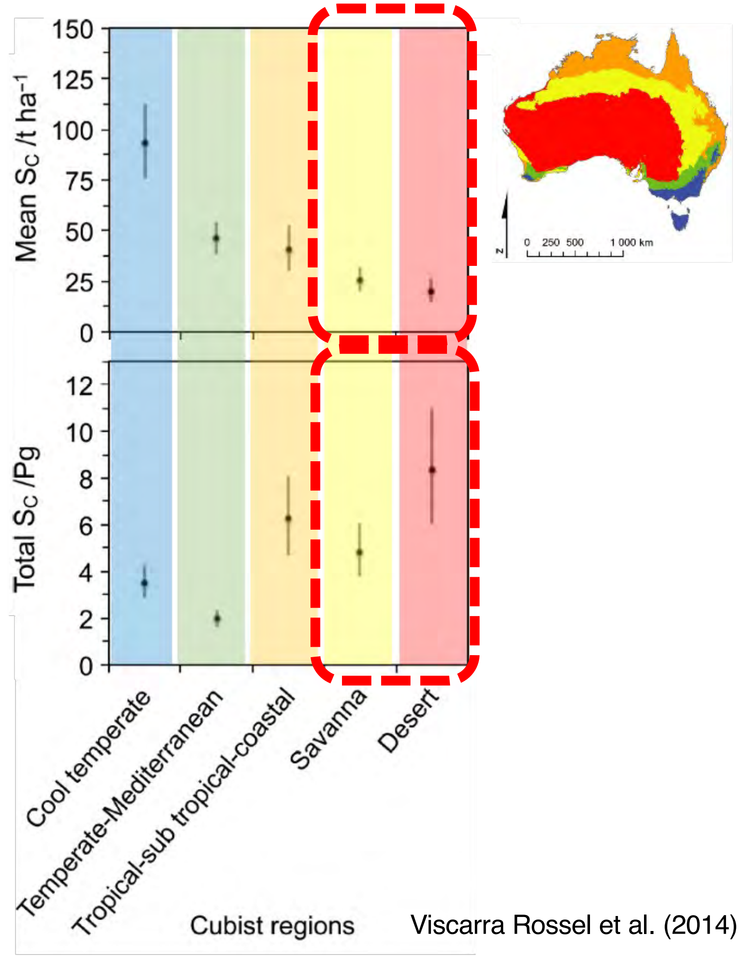


1 Gt = 1 Pg = 1000 Million tonnes

Viscarra Rossel et al. (2014)

Carbon stocks in Australian soil (0–30 cm)

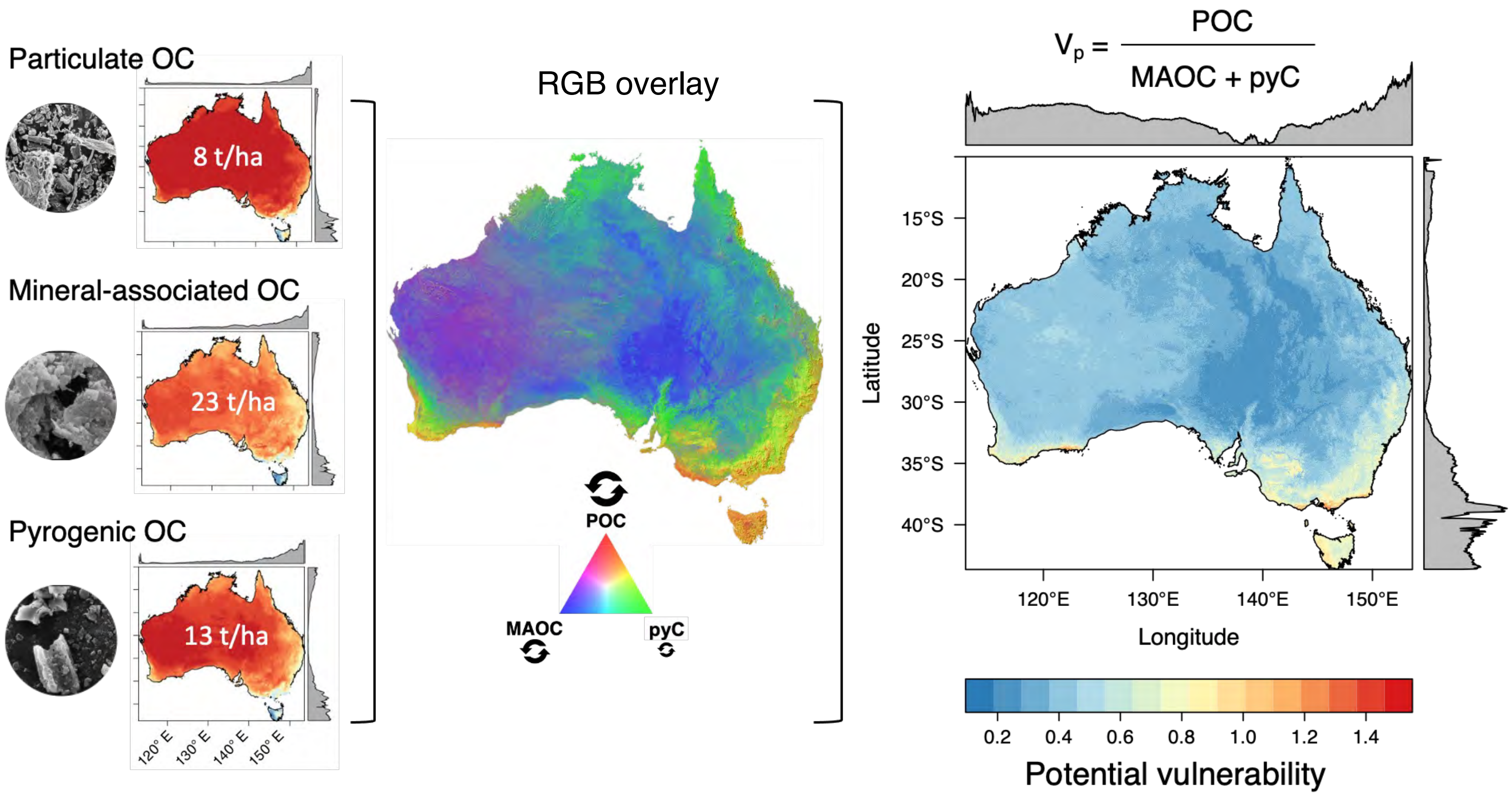




Viscarra Rossel et al. (2014)

…even a small increase in organic C stocks across vast areas of land, could sequester a significant amount

Carbon composition of Australian soil (0–30 cm)



Viscarra Rossel et al. (2019)

- Need to preserve OC in soils that are more vulnerable
- Need to better understand the potential for C capture in soils that are more less vulnerable – more stable

ERF methods to quantify changes in soil C

Based on measurements
Measurement of soil C sequestration in agricultural systems

ΔC t/ha yr^{-1} = $(Ct_n - Ct_0)/(t_n - t_0)$

- Can use prior information for geo-stratification of CEA and random sampling across strata and use of sensors to measure the C stocks (e.g. vis–NIR; γ-attenuation)
- Cost for sampling and measurements but provides more confidence

England & Viscarra Rossel (2018)

2021 Update: A hybrid method

Based on modelling
Estimating sequestration of carbon in soil using default values method

ΔC t/ha yr^{-1} = $\Delta C_{Gain} - \Delta C_{Loss}$

- Simulates changes using default values for different management actions derived from the FullCAM (Full Carbon Accounting Model).
- No sampling or laboratory analysis, small cost but also less confidence in the magnitude of change – conservative estimates

Lee & Viscarra Rossel (2019)

Urgent need to develop robust and practical systems for their implementation

Final remarks

- Soil C has multiple benefits: soil resilience (adaptation to climate change); soil and ecosystem health --- not just climate change mitigation or economics.
- Assessments of potential C capture and benefits of soil C need to be site-specific considering local soil, environmental, management, socioeconomic conditions
- Although we have the methods for measuring soil C change, there is an urgent need for developing practical tools for measurement, monitoring and verification
- Science and innovation are essential, supported by government initiatives and policies
- Soil C is not a ‘silver bullet’ --- but must be part of the solution.

Thank you.

R.A. Viscarra Rossel

Professor Soil & Landscape Science

Curtin University

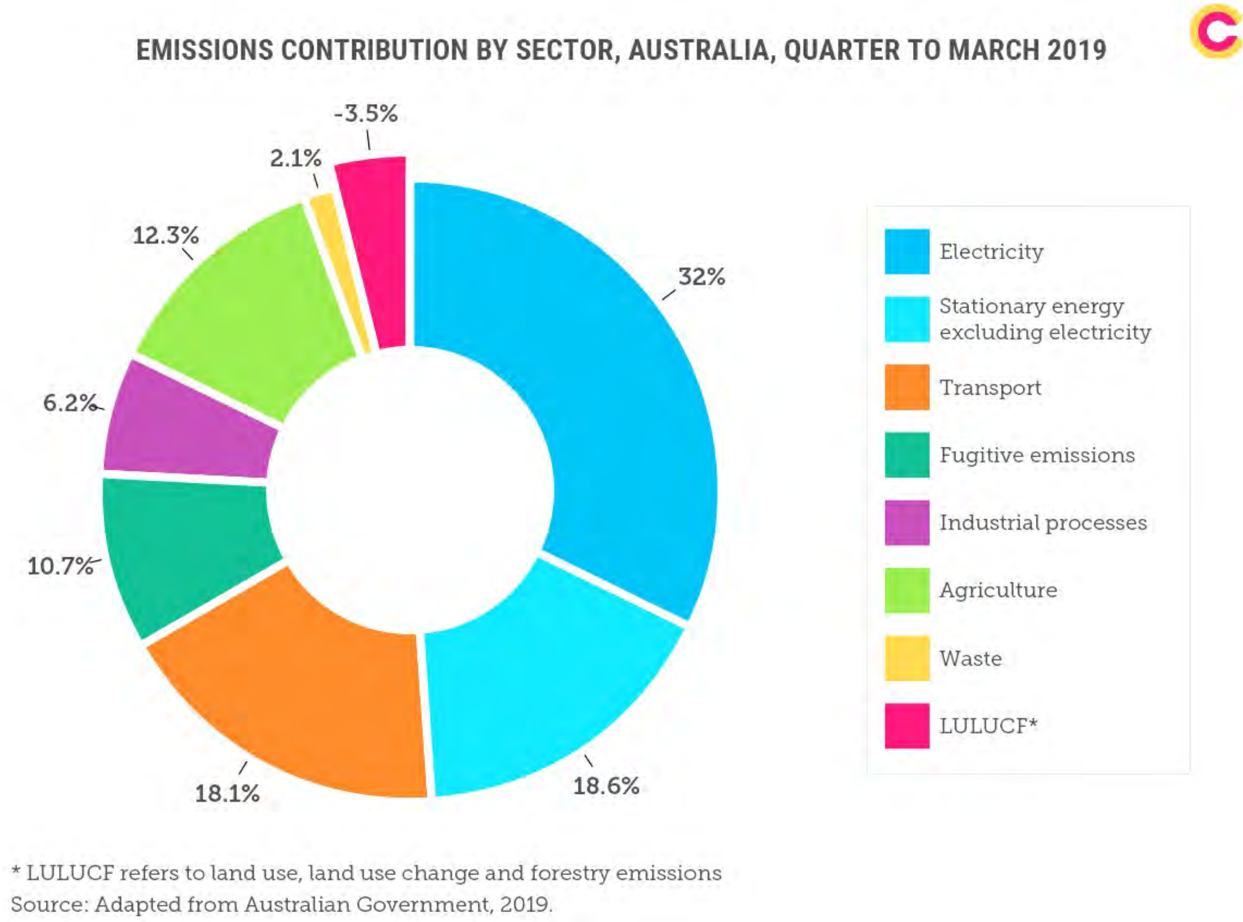
r.viscarra-rossel@curtin.edu.au

http://curtin.edu/soil-landscape-sci

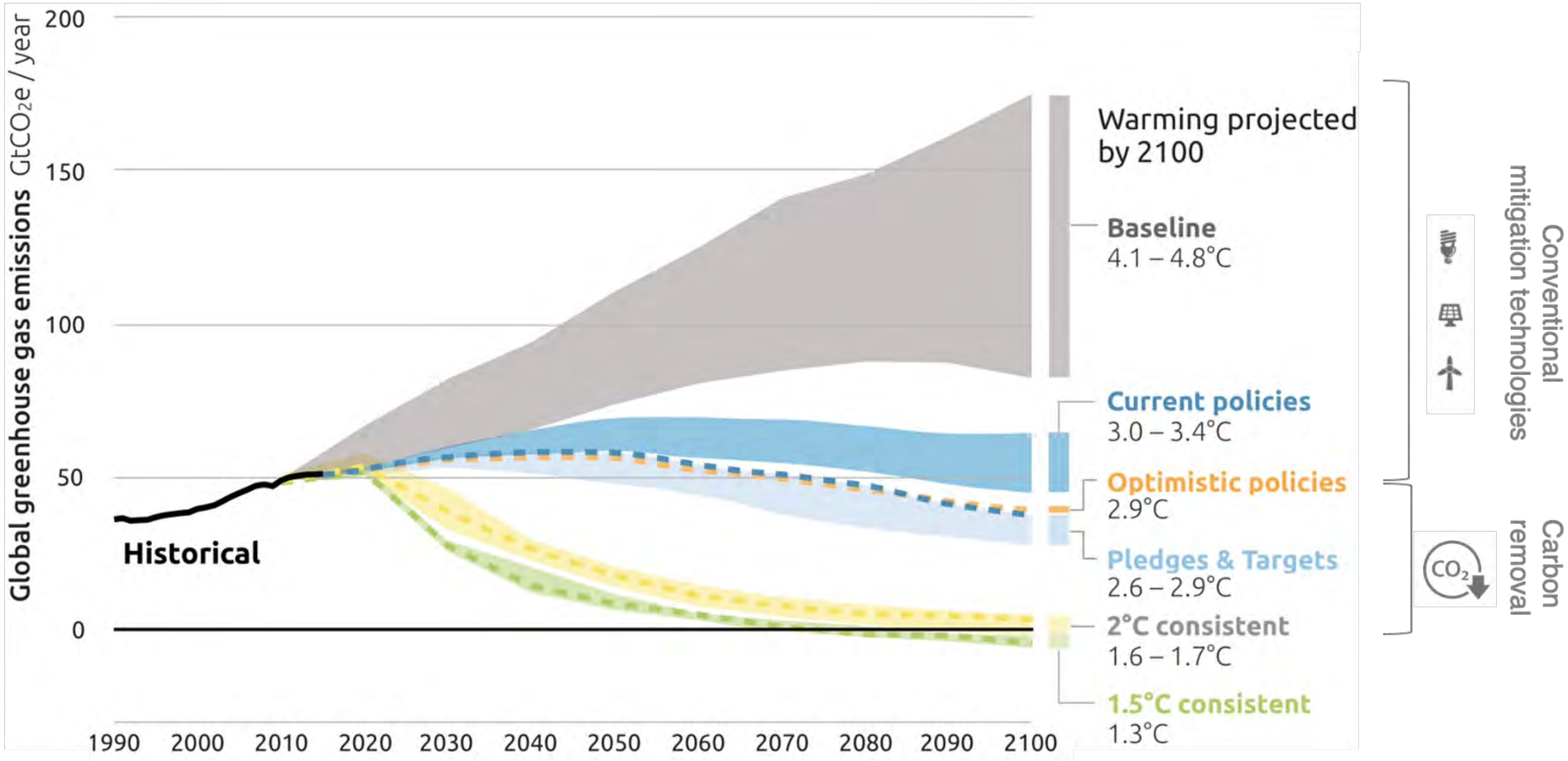
Curtin University

Australia's GHG emissions by sector

- 2019 Total net emissions 539 Mt CO_2-e yr^{-1}
- 12.3% or 66 Mt CO_2-e yr^{-1} from agriculture
- Potential to generate emissions reductions in agriculture

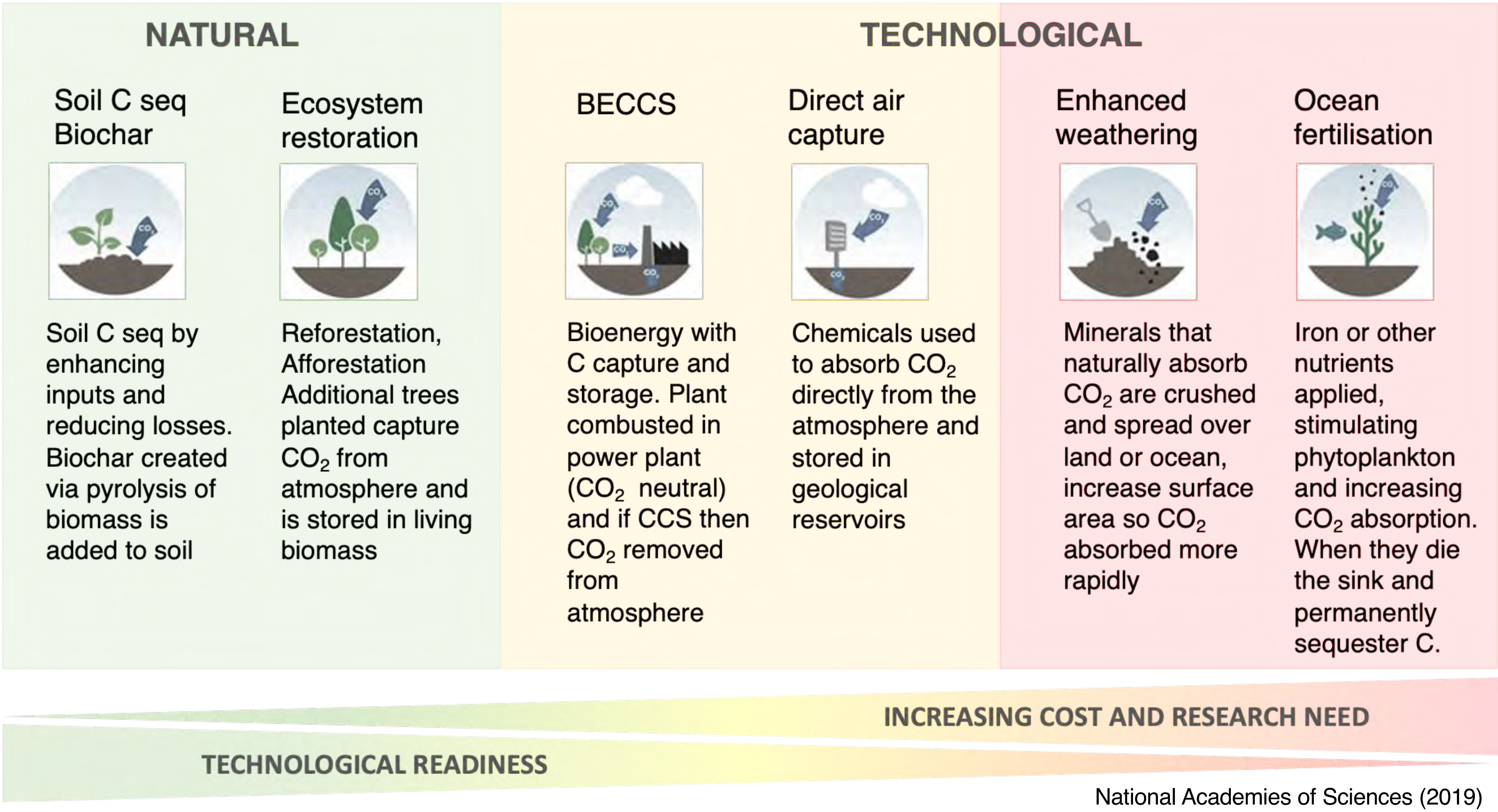


Global emissions and the need for C removal



Climate Action Tracker (2019)

Negative emissions technologies



National Academies of Sciences (2019)