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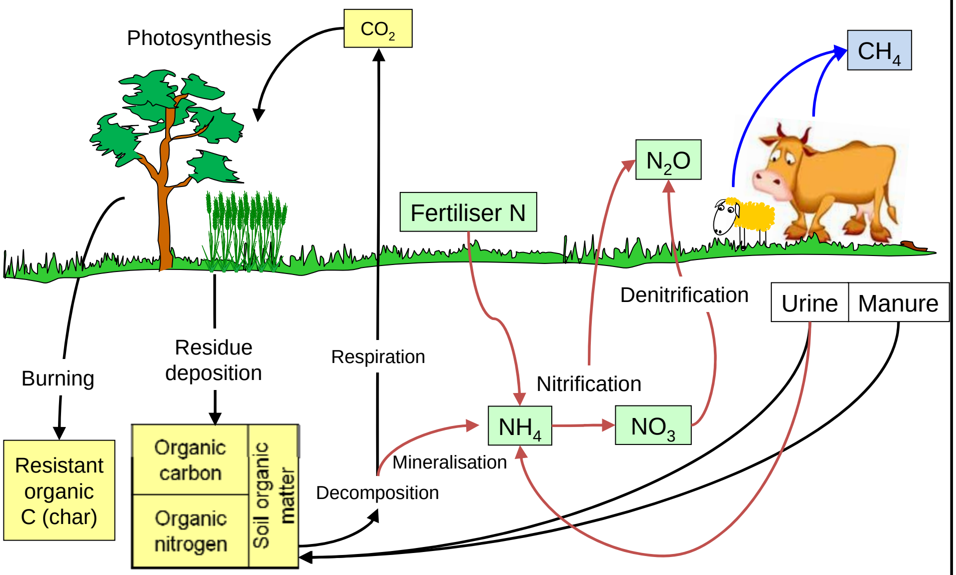
The Carbon Debate: Climate Adaptation

Outline

- Sources of greenhouse gas in livestock enterprises: emissions and stock changes
- Methane: sources and mitigation
- Nitrous oxide: sources and mitigation
- Soil carbon: what is it, how do we measure it, management impacts

Agricultural greenhouse gases

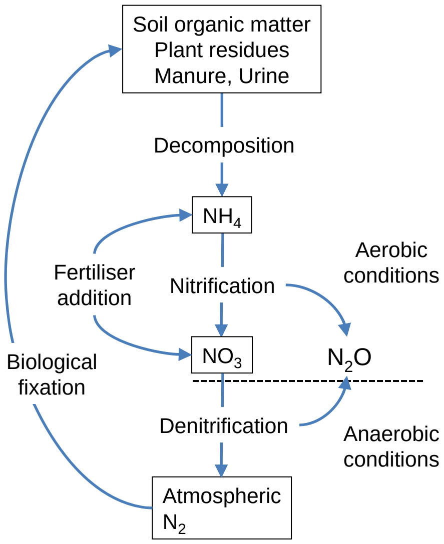


Methane emission from ruminants

- Emissions are related to the duration over which an acceptable LWG is obtained
- Emission mitigation
  - Methane per unit area versus per unit LWG
- Mitigation practices
  - Improved forage/feed quantity and quality
    - Proportion of legumes
    - Rotational/Cell grazing

    } reduces duration of methane emission
  - Feed additives (oils) – 20-30% reduction
  - Improved genetics

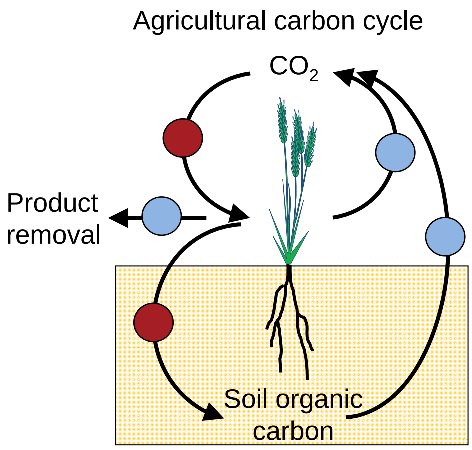
Nitrous Oxide Emission from Soil



- Controlling factors
  - Soil inorganic N status
  - Soil water content
  - Supply of carbon
- Emissions mitigation
  - Match N supply with crop demand
  - Optimum soil structure to reduce saturation
  - Application of process inhibitors
  - Provide adequate C:N feed

Sequestering carbon in agricultural systems

- Agriculture provides both risks and opportunities to soil carbon
  - C capture by plants
  - C removed in products
  - C added to soil
  - Soil C loss



What determines soil organic carbon content?

Soil organic carbon content = *f* (Inputs of organic carbon , Losses of organic carbon)

Inputs

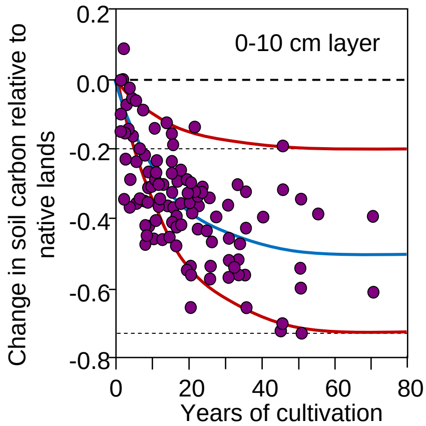
- Net primary productivity (capture by plants and added to soil)
- Addition of organic materials from offsite

Losses

- Conversion of organic C to CO_2
- Protection offered by soil minerals
- Extent of cultivation

Influence of management

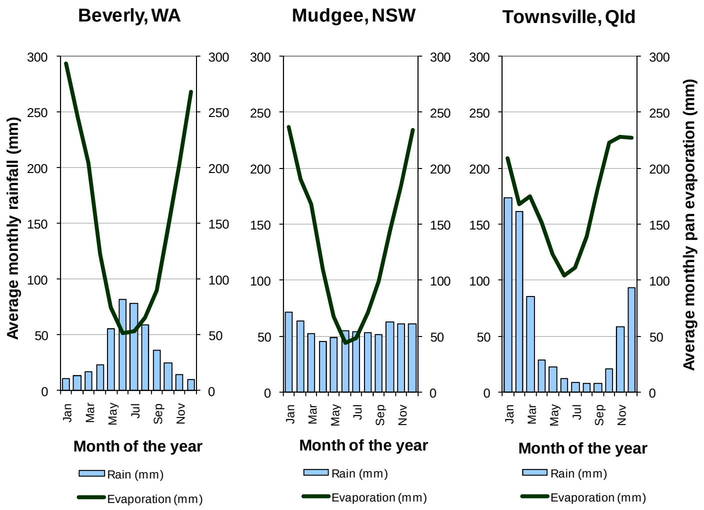
- Historic losses of soil carbon
- Many soils are still loosing soil carbon
- Although a risk, this also provides opportunity
  - 50-60% recovery



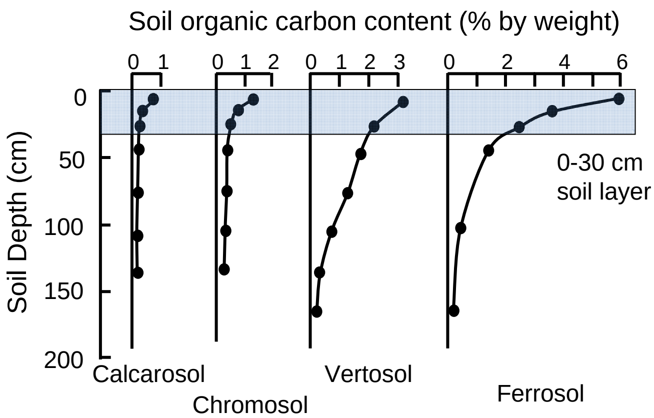
Luo et al. 2010.Geoderma 155:211-223.

The influence of climate

Controls rates of carbon capture and loss through impacts on water availability and temperature



The influence of soil type



- Different soils contain different amounts of carbon
- Carbon is typically concentrated near the surface

Composition of soil organic carbon

Crop residues on the soil surface (**SPR**)

Buried crop residues (>2 mm) (**BPR**)

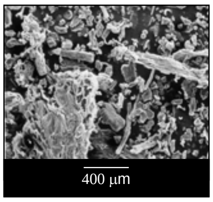
Soil organic carbon:

- Particulate organic carbon (2 mm – 0.05 mm) (**POC**)
- Humus (<0.05 mm) (**HumC**)
- Resistant organic carbon (**ROC**): dominated by charcoal

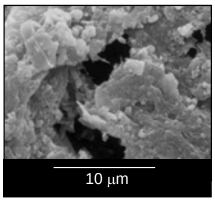
Susceptibility to decomposition decreases

C/N/P ratio decreases (nutrient rich)

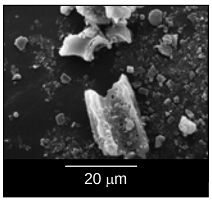
Particulate carbon (2mm – 0.05 mm)



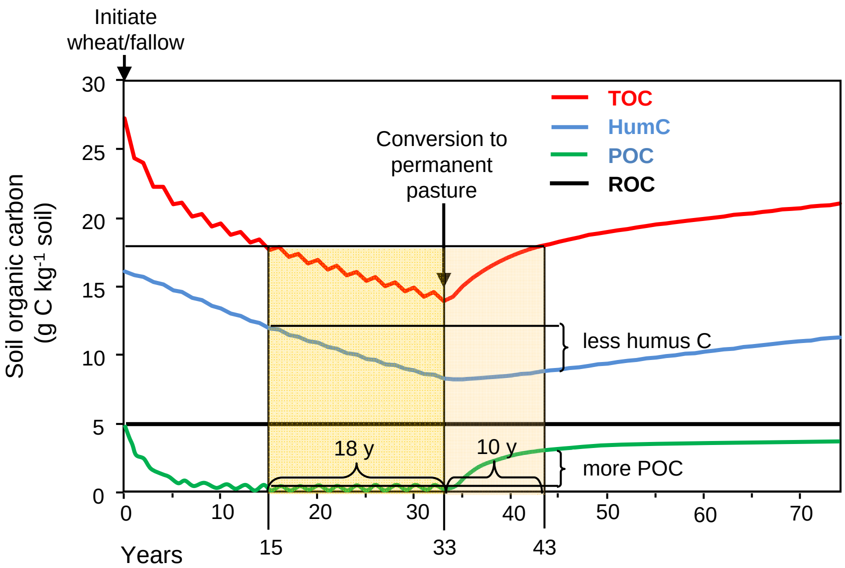
Humus carbon (<0.05mm)



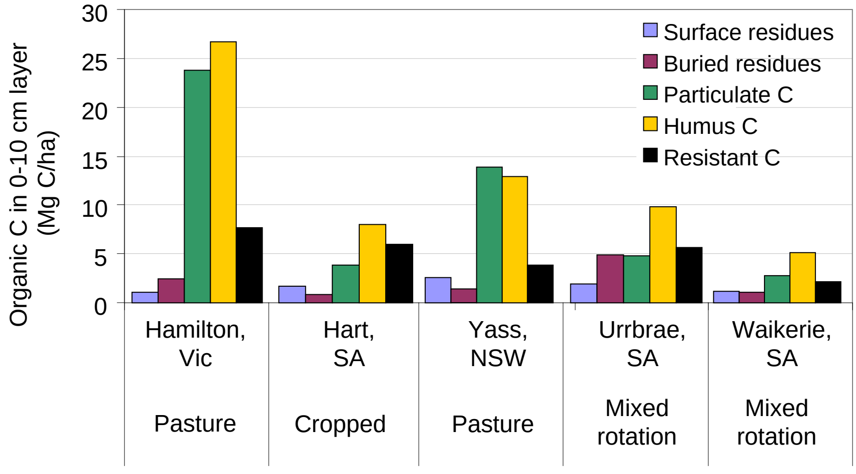
Resistant (charcoal <2mm)



Why define soil carbon fractions?



Variation in amount of C associated with soil organic fractions



Minimum requirements for soil carbon for accounting

1. Collect a representative soil sample to a minimum depth of 30 cm
2. An accurate estimate of bulk density
3. An accurate measure of soil organic carbon content
4. Quantification of the confidence in the values derived

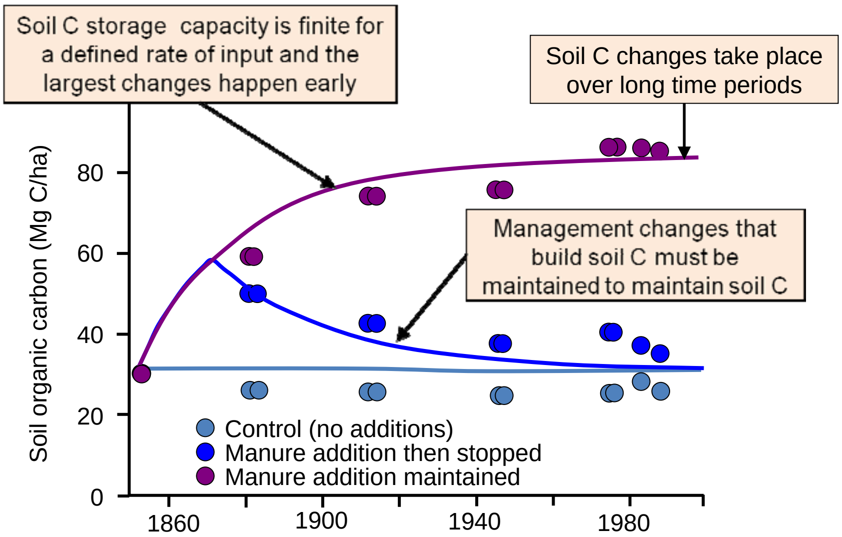
For 0-30 cm soil, a bulk density of 1.0 Mg/m^3 and a carbon content of 1.0%

Mass of Carbon (Mg C/ha) = Depth (cm) x Bulk density (g/cm^3) x Carbon content (%) = 30 Mg C/ha

Need to start defining the confidence associated with soil carbon measurements

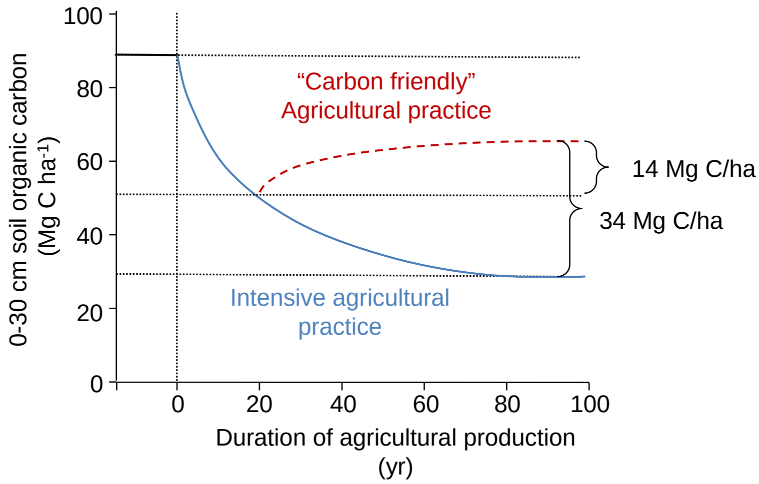
30 ± 5.2 Mg C/ha

Issues of saturation and permanence

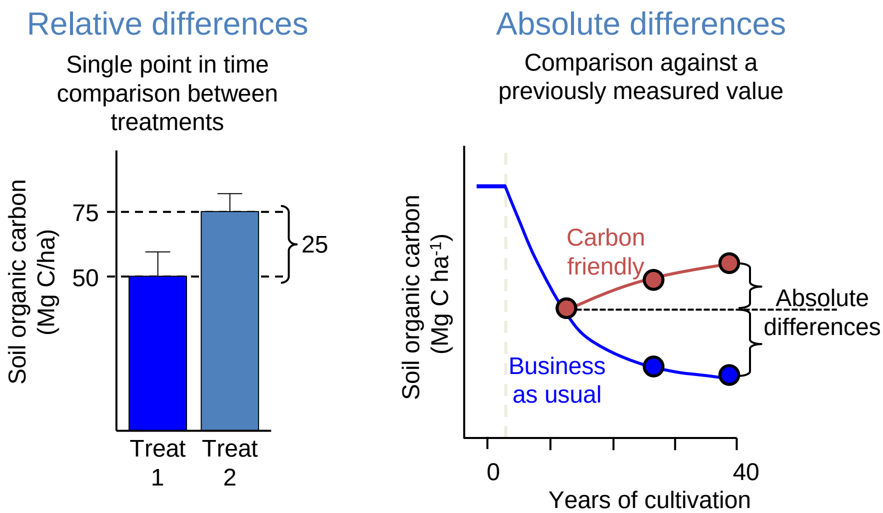


Petersen et al. (2005) Soil Biol Biochem 37: 359

Issues of additionality and business as usual



Relative versus absolute changes



Increasing soil carbon

- Identify soils where carbon capture per unit of available resource is not maximised
- Can resource use efficiency can be enhanced by management

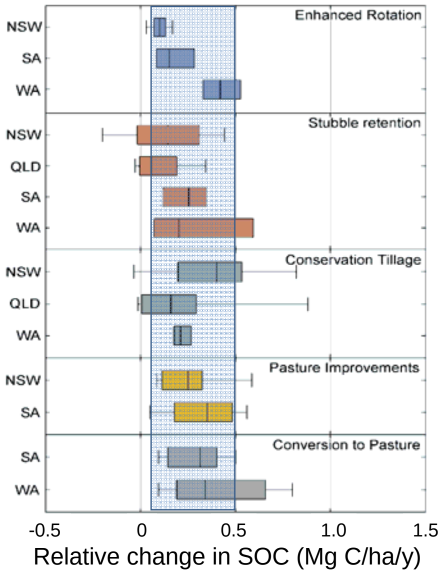
Maintain current production system

- Maximise resource use efficiency (e.g. carbon capture per mm water or per kg nutrient)
- Maximise carbon retention and return to the soil
- Examples – liming, fertilisation, rotational grazing

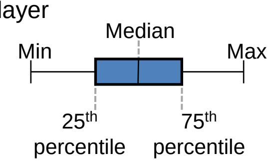
Shift to alternative production systems

- Introduction of perennial vegetation where appropriate
- Alternative crops - lower harvest index
- Alternative pasture species – increased below ground allocation
- Set aside areas with low margins

Impact of agriculture on soil carbon



All data normalised to the 0-15 cm soil layer



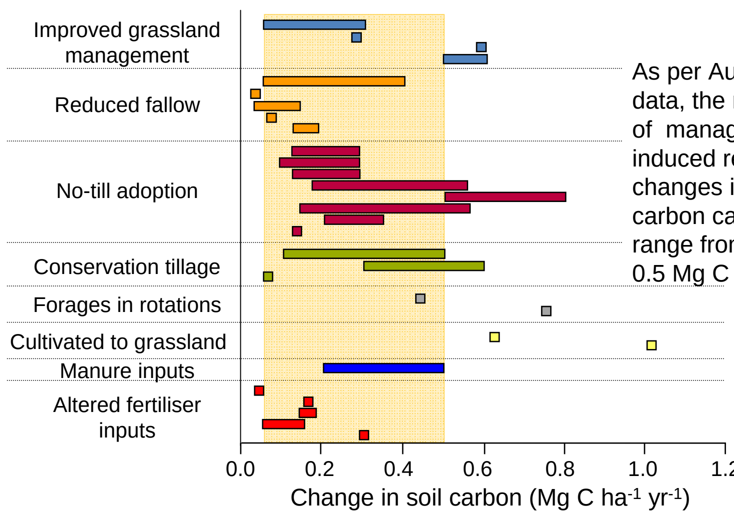
Absolute rates of soil C change were found to be less than relative values

1) Cropping systems
- **-0.1 to -0.3 Mg C ha^{-1} yr^{-1}**

2) Conversion from crop to pasture
- **+0.3 Mg C ha^{-1} yr^{-1}**

Sanderman et al. 2010. Soil Carbon Sequestration Potential: A review for Australian agriculture. CSIRO Technical report

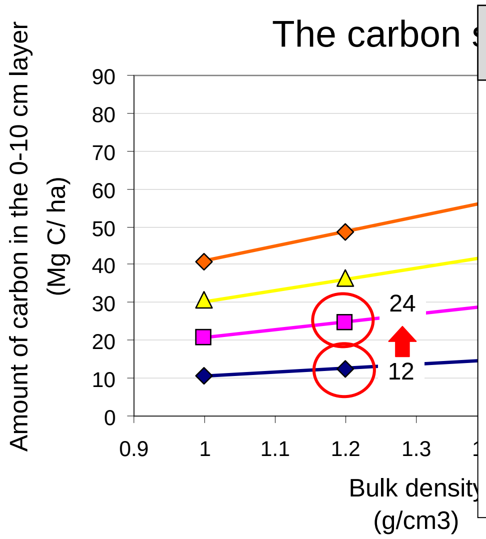
Agricultural impacts: International data



As per Australian data, the majority of management induced relative changes in soil carbon capture range from 0.1-0.5 Mg C ha^{-1} y^{-1}

Hutchinson et. al. (2007) Agric. For. Meteorol. 142: 288-302

Requirements to increase soil carbon



Changing soil carbon from 1% to 2% over 5 years

Amount of C required:
12 Mg C/ha
25 Mg Dry matter (DM)/ha

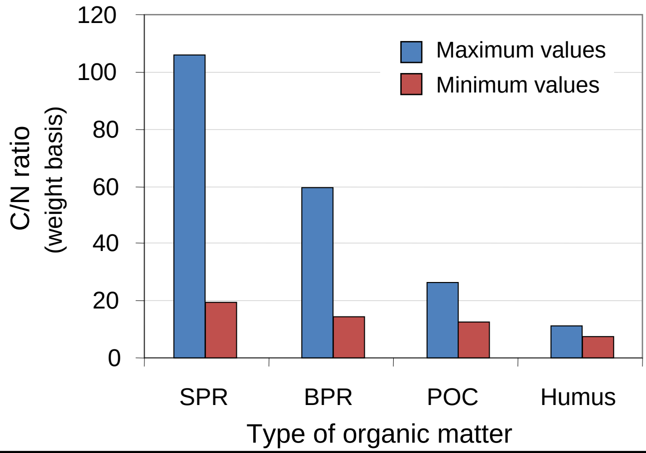
Rate per year
5 Mg DM/ha/y (no losss)
10 Mg DM/ha/y (50% loss)
50% allocation below ground
5 Mg shoot DM/ha/y

Additional C capture required by photosynthesis

4.8 Mg C/ha/y

Variation in C/N ratio of different fractions of soil organic carbon

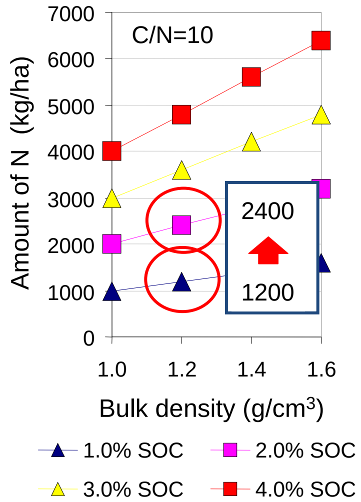
29 soils from southern Australia with total organic carbon contents ranging from 0.8% to 5.7%



	Min	Max
SPR	19	105
BPR	14	60
POC	13	20
Humus	6	10

Requirements to increase soil carbon

The nitrogen story



Changing soil carbon from 1% to 2% SOC requires 1200 kg of N

Annual requirement over a 5 year period = 240 kg N/ha/y @ a C/N ratio of 10

Even if C/N = 20, the annual requirement to build SOC would be 120 kg N/ha/y

Summary

- Methane (emission reduction)
  - Carbon accounts will be defined on an land area basis. Enhanced efficiency for LWG are unlikely to be rewarded if stocking rates are increased
  - Management options exist to decrease methane intensity
- Nitrous oxide (emission reduction)
  - Goal should be to minimise excess inorganic N
  - Better match supply to crop demand
  - Enhanced N use efficiency will result in decreased emissions

Summary

- Soil carbon
  - Australian soils do have a place in C accounting
    - Capacity is finite and largest changes occur early
    - Relative increases <0.5 Mg C/ha/y
    - Absolute increases - negative for cropping systems and <0.5 Mg C/ha/y for conversion to grasslands
  - Opportunities exist where:
    - Inefficiencies in current production systems can be removed or reduced
    - Alternative systems with higher carbon capture per increment of resource use are available

Summary

- Soil carbon
  - There will not be one solution – solutions need to be adapted to specific soil and climate conditions
  - Constraints
    - Farmers are paid to remove carbon in products
    - Future liabilities and implications on land values
    - Uncertainty in value of carbon and agricultural products
    - Measurement – spatial variability and degree of confidence