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Soil Carbon: A viable offset strategy?

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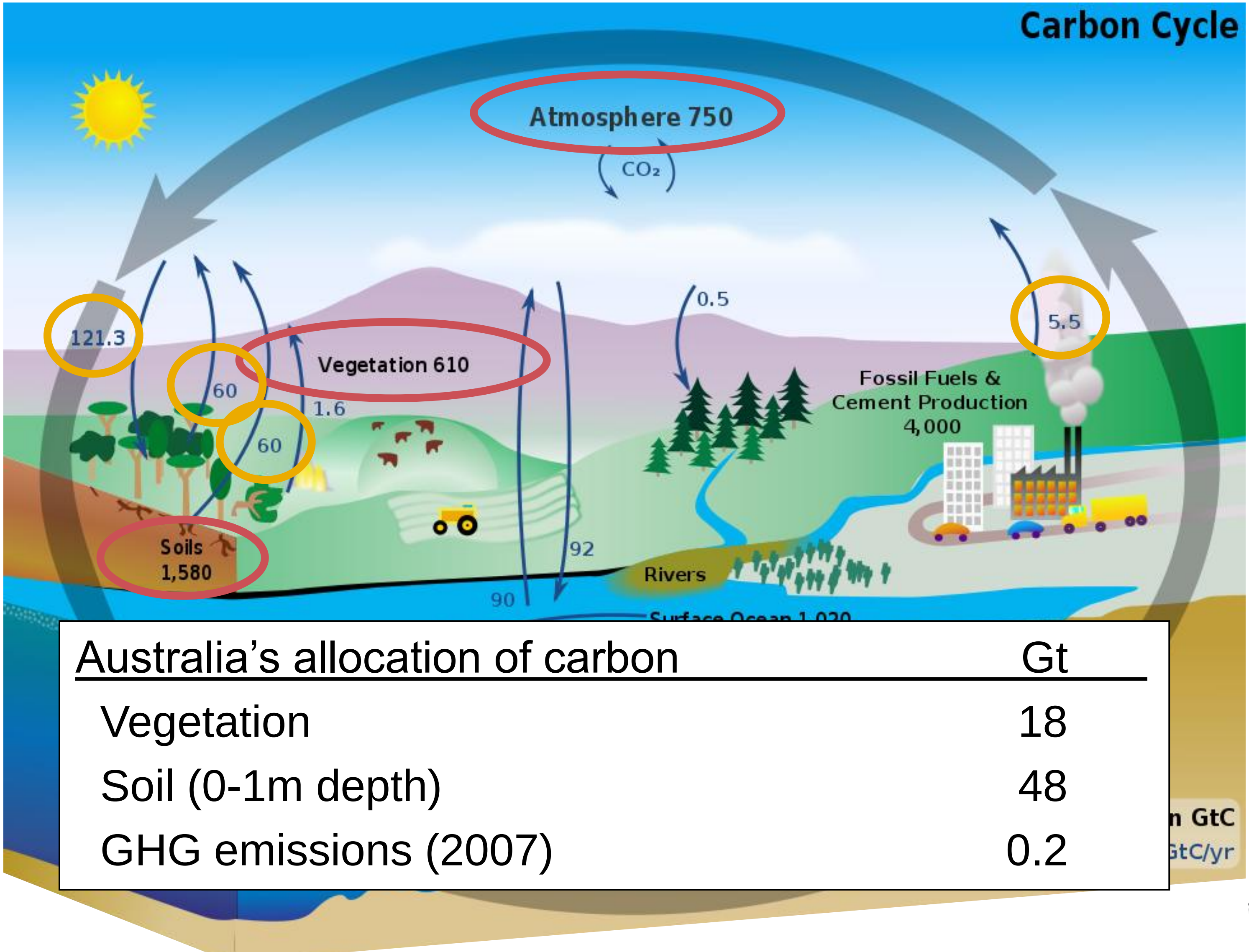
Why Soil Carbon? The carbon cycle



Australia's allocation of carbon	Gt
Vegetation	18
Soil (0-1m depth)	48
GHG emissions (2007)	0.2

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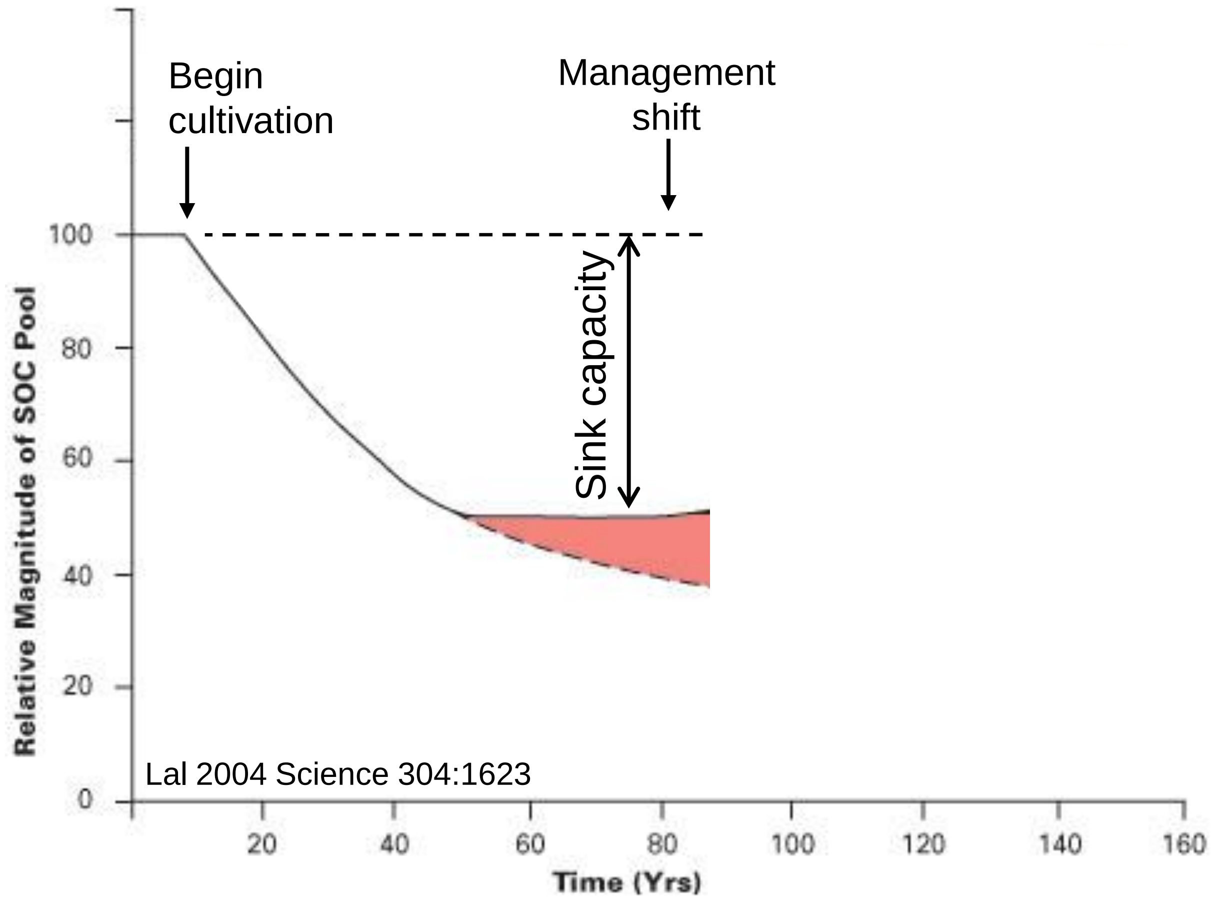
Why Soil Carbon? Sink capacity

Globally, agricultural soils emitted ~200 Pg CO_2 to the atmosphere due to loss of soil organic carbon (40 – 60% decline in C stocks)



Why Soil Carbon? Functions in soil

Functions of SOM

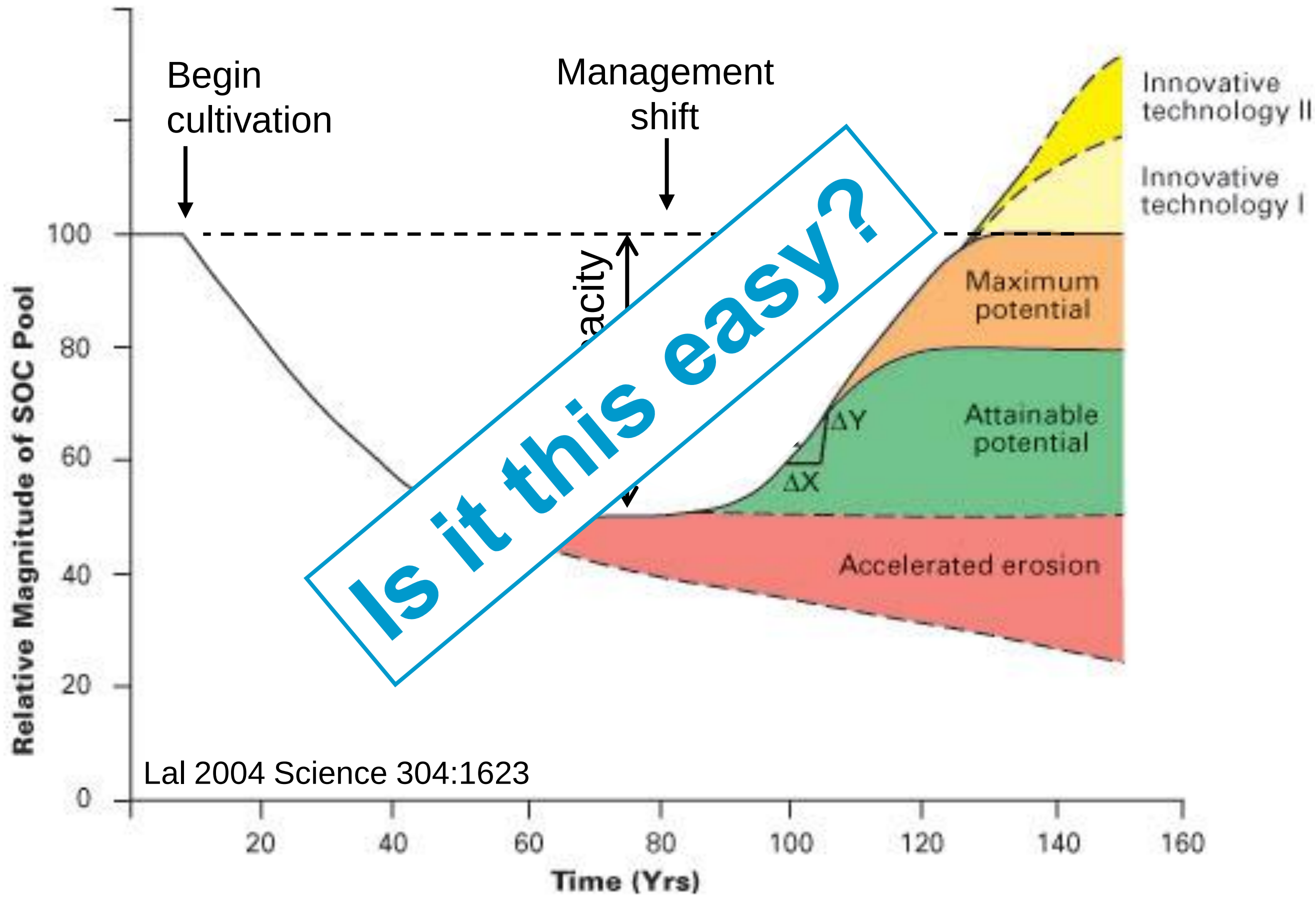
Biological functions
- energy for biological processes
- reservoir of nutrients
- contributes to resilience

Physical functions
- improves structural stability
- influences water retention
- alters soil thermal properties

Chemical functions
- cation exchange capacity
- buffers changes in pH
- complexes cations

Why Soil Carbon: The proverbial "win-win" situation

Building soil carbon stocks can both help mitigate climate change and enhance food security through healthier, more productive soils



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Outline

1. Soil carbon basics
2. Agricultural influence on soil carbon
3. Accounting for changes in soil carbon

What is soil carbon?

Organic Carbon

Inorganic Carbon

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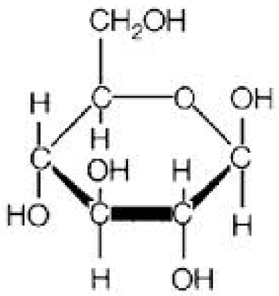
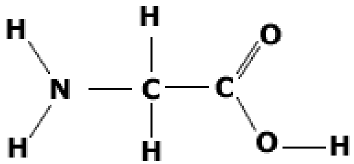
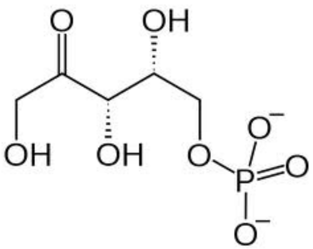
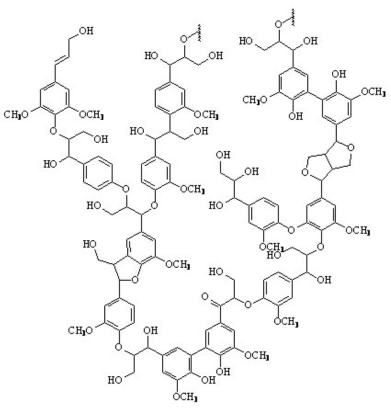
What is soil organic carbon?

Carbohydrates	Amino Acids	Phosphates	Lignin









- Carbon is just the backbone of soil organic matter
- Soil OM is composed of1000's of individual and often uncharacterizable compounds
- Large quantities of nitrogen and phosphorous also bound up in OM

What determines the carbon content of a particular soil

- Dynamic balance of inputs and losses

- **Inputs** = plant residues, root exudates, mycorrhizal turnover, manure and composts
  - Net productivity is a function of climate, soil water, nutrients, etc…

- **Losses** = microbial decomposition, erosion, leaching
  - Decomposition rate will be effected climate, soil type and management

- Hot/dry places will have low carbon levels
- Cool/wet places will have high carbon levels

Carbon data reporting

Percentage v. Mass

C mass (tonnes/ha) = Depth x %C x bulk density x gravel correction

% Carbon is usually only measured in the fine fraction

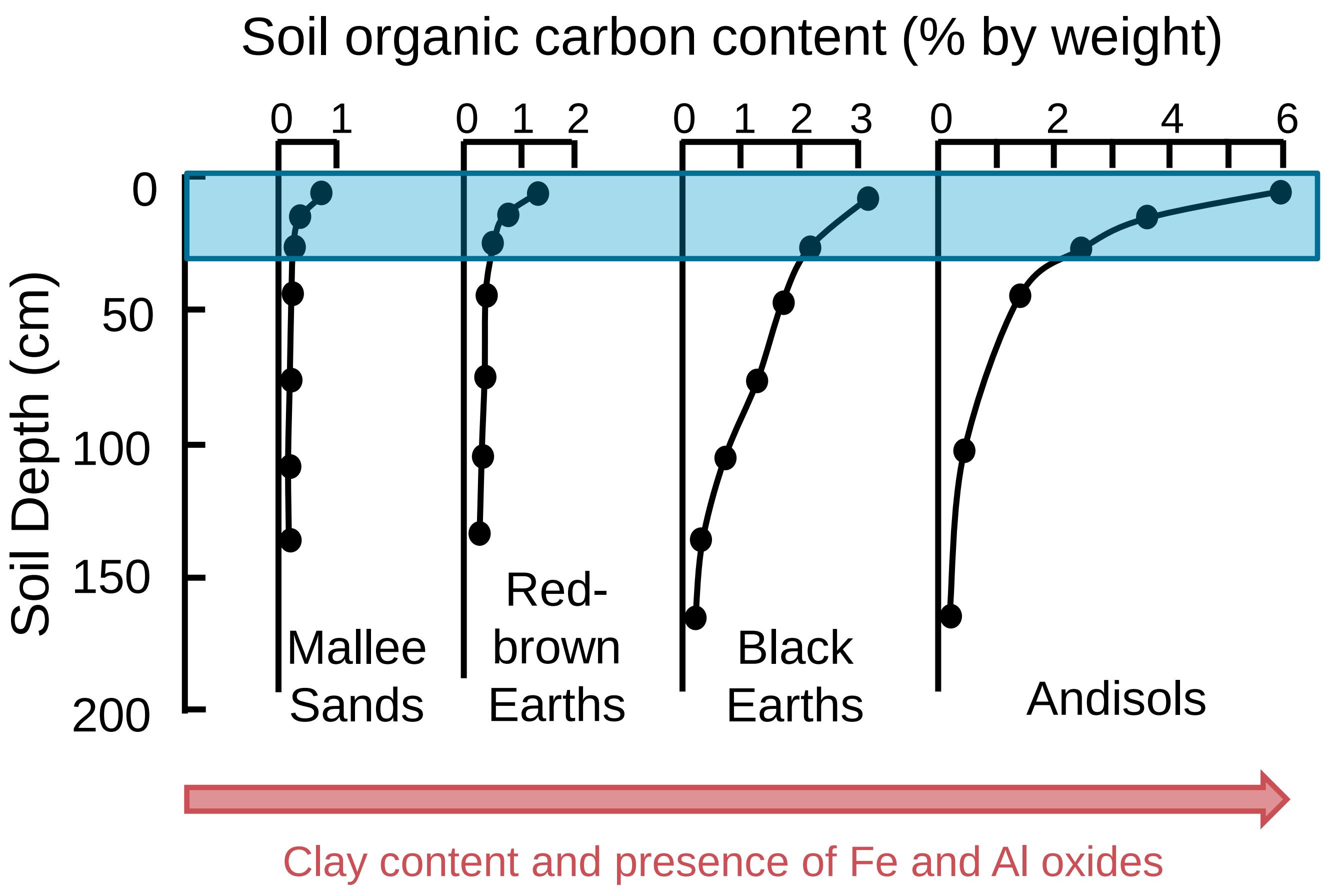
→Actual claim: "*total carbon increased from 0.75 to 2.0% in 1 year in a broad acre cropping enterprise in the Riverina region*"

In C mass terms, assuming a bulk density of 1.2, a 10 cm sampling depth and no gravel, the C mass increased from 9 to 24 tonnes/ha. In other words, 15 tonnes of C has been added to this soil in one year!

Compare to net primary productivity of, at best, 8-10 tC/ha/yr.

→ Be wary when people start saying they can increase soil carbon levels by 1% in a few years time.

Distribution with depth and clay content



Composition of soil organic matter

Crop residues on the soil surface (SPR)

Buried crop residues (>2 mm) (BPR)

Particulate organic matter (2 mm – 0.05 mm) (POC)

Humus (<0.05 mm) (HumC)

Resistant organic matter (ROC)

Extent of decomposition increases

Rate of decomposition decreases

C/N/P ratio decreases (become nutrient rich)

Dominated by charcoal with variable properties

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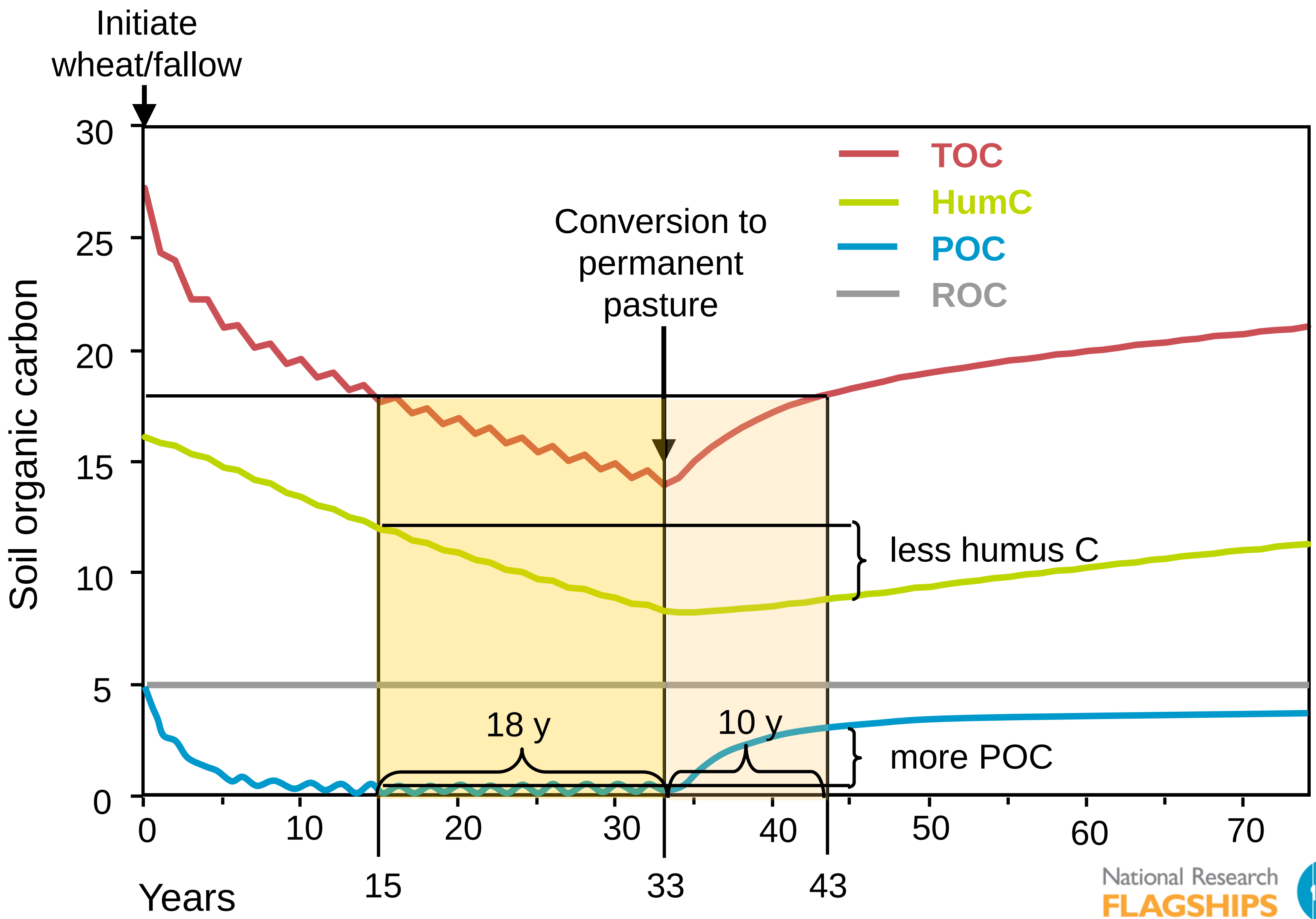
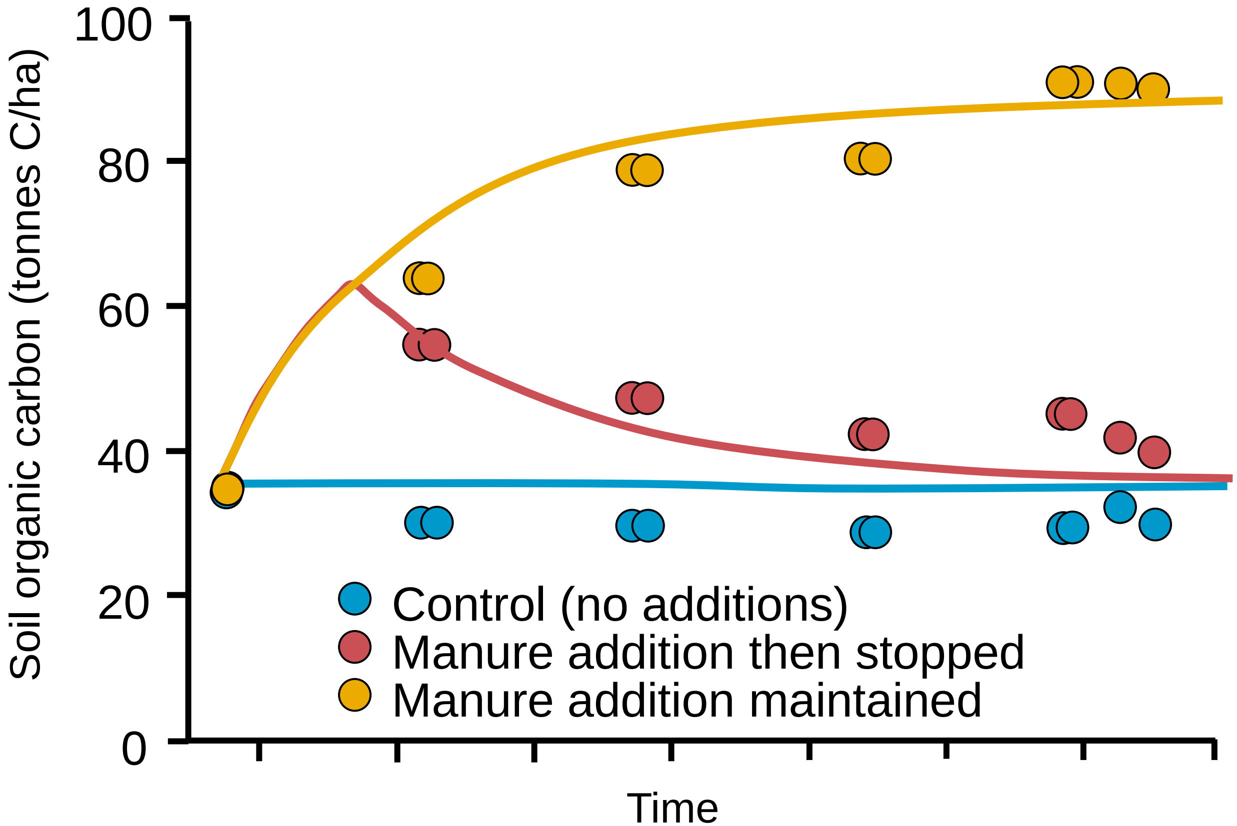
Why do we want to know about soil carbon fractions?



Soil carbon levels tend towards equilibrium



1. Sink capacity is finite
2. Most rapid changes in first 10-20 years
3. Sink is reversible if management is not maintained

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

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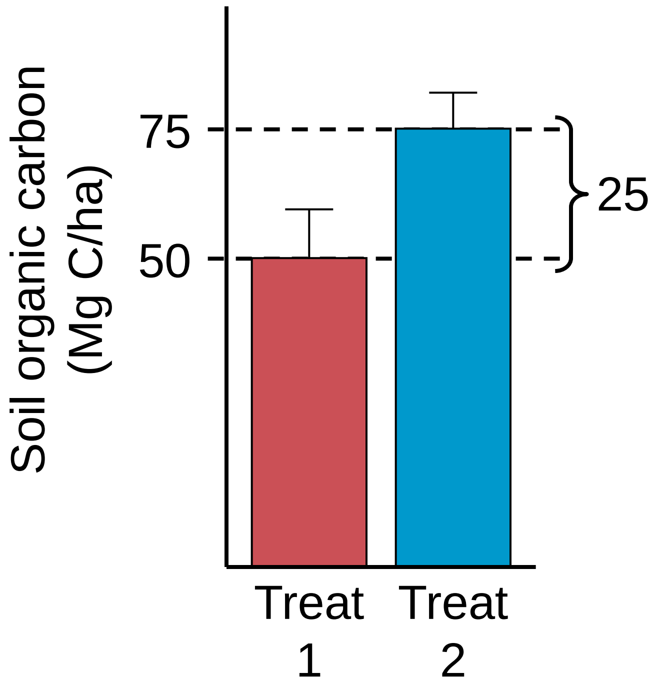
Evidence for changes in soil carbon

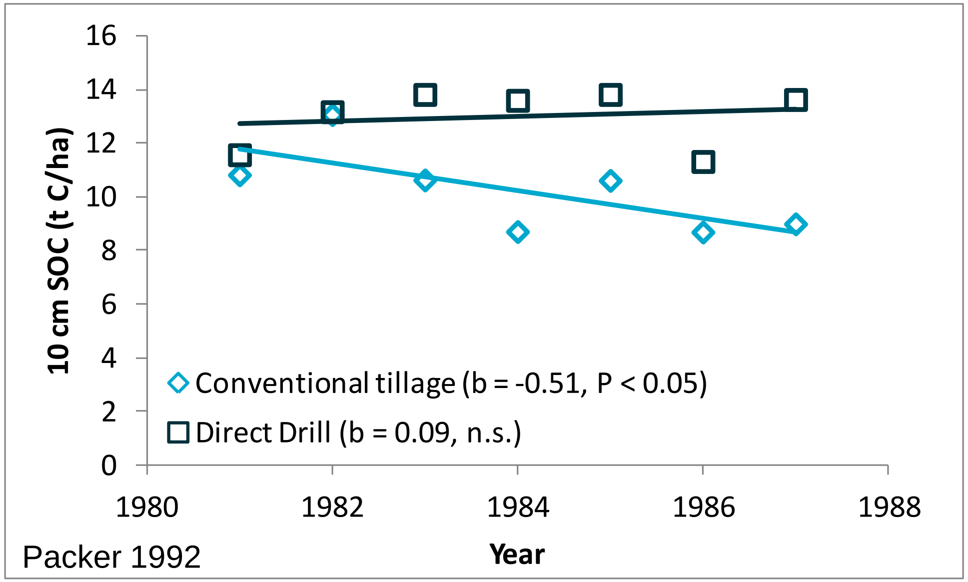
Relative differences

Single point in time comparison between treatments

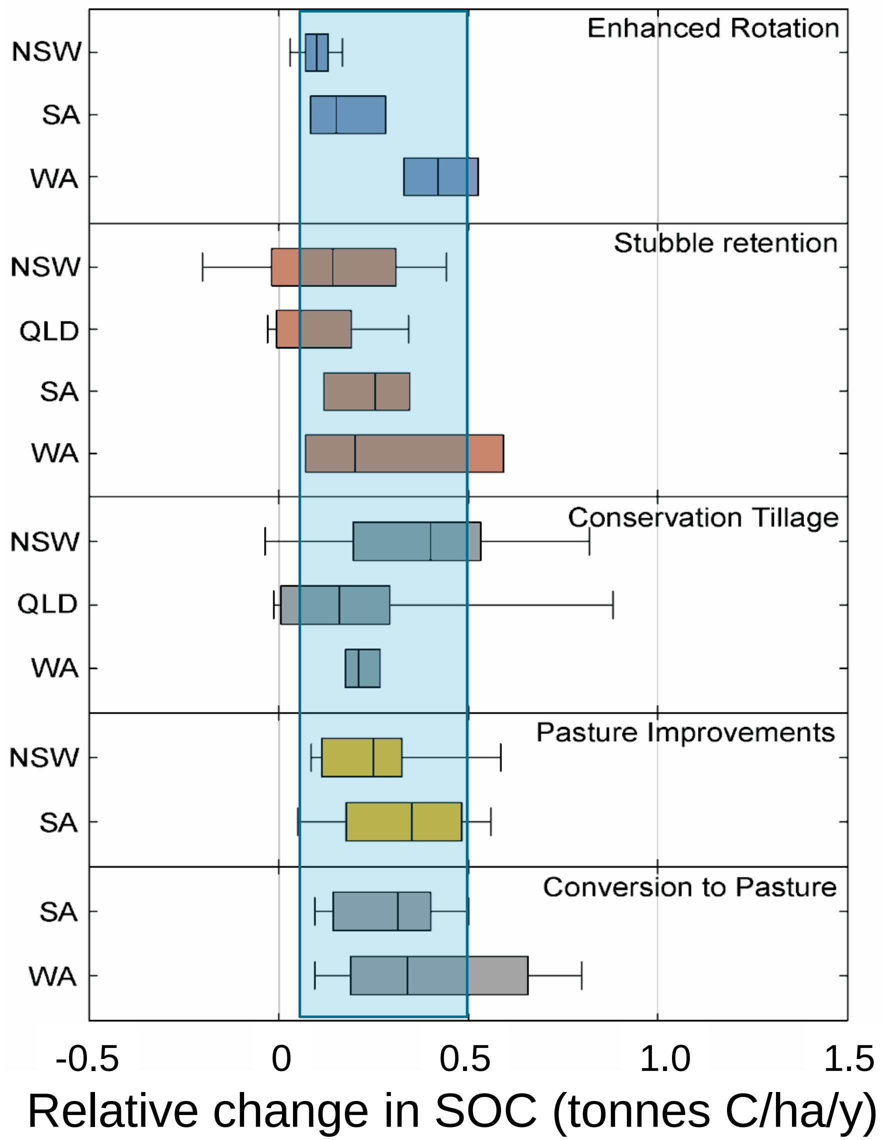


Absolute difference

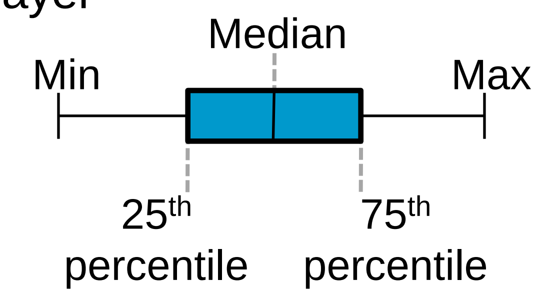
Repeat measurements through time



Impact of Australian agriculture on soil carbon: relative and absolute rates of change



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

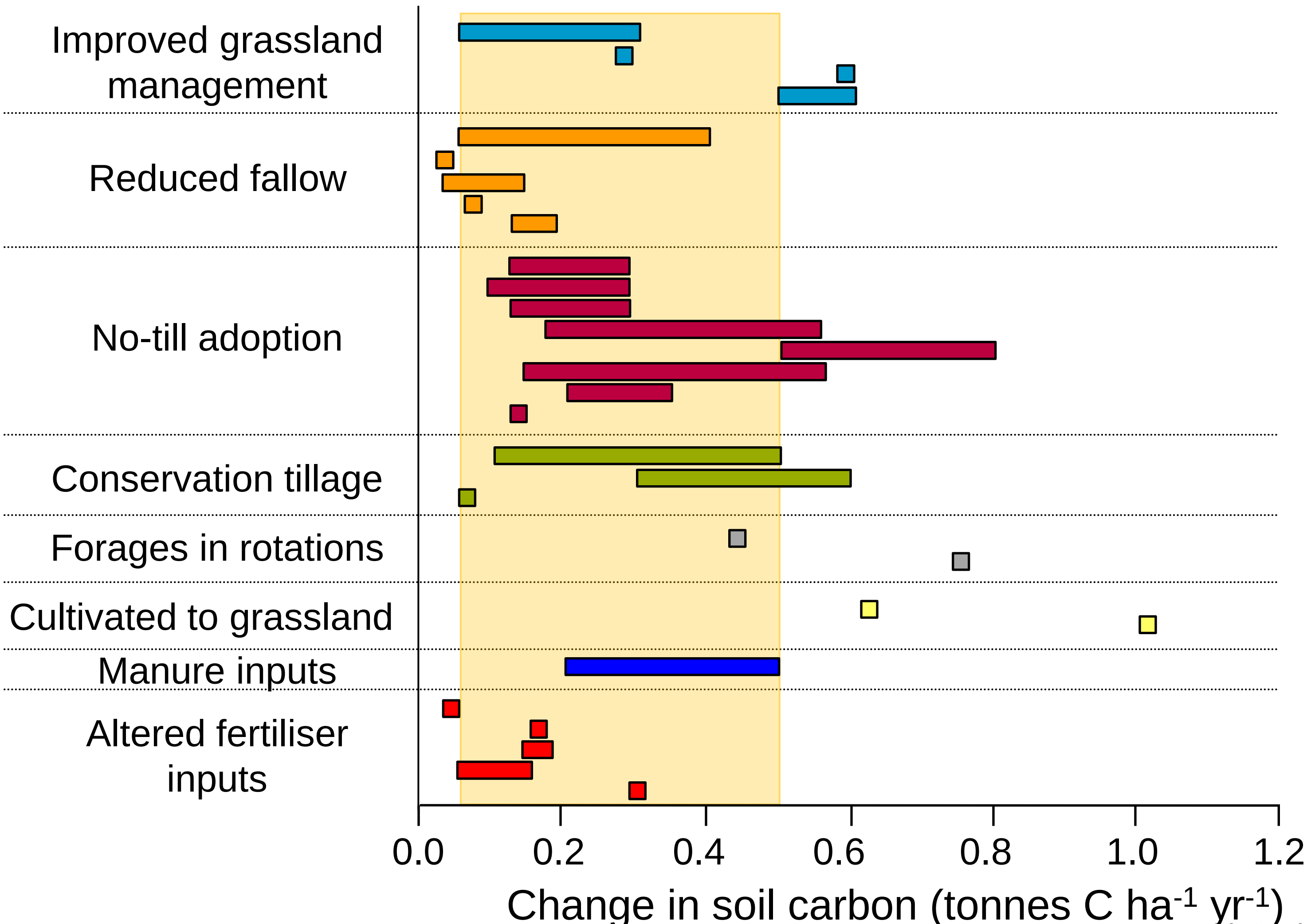
- **-0.1 to -0.3 Mg C ha^{-1} yr^{-1}**

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

Relative impacts of agricultural practice on soil carbon: International evidence



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

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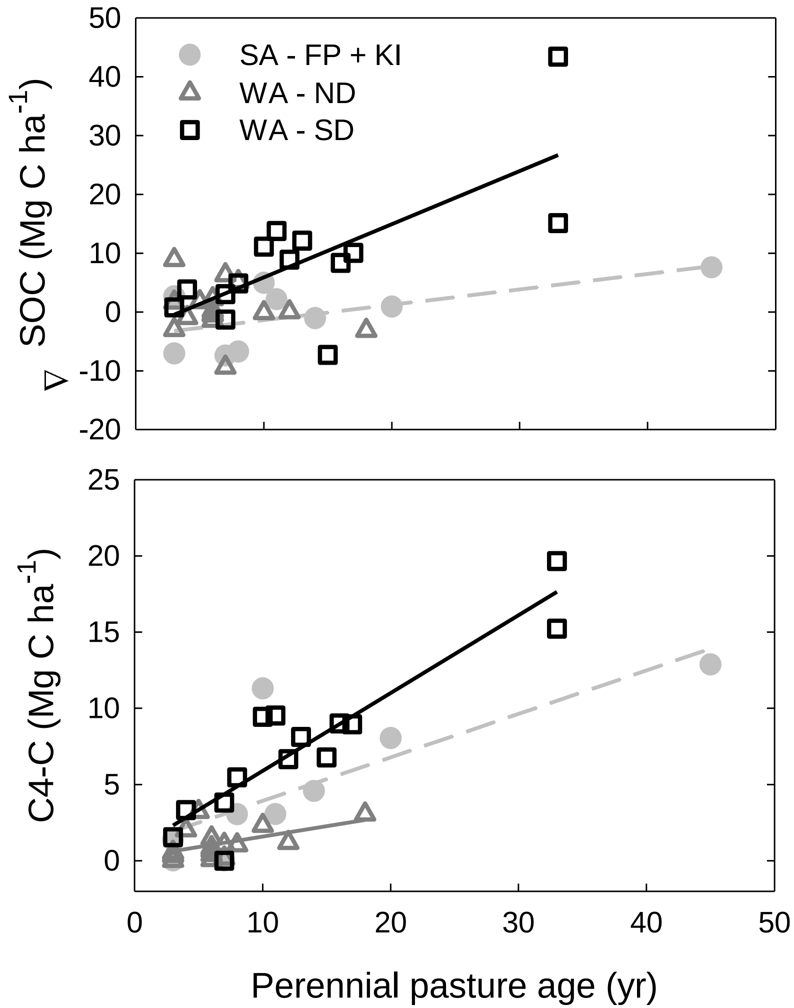
Perennials in grazing systems



Study of subtropical grasses (kikuyu, panic and Rhodes) in improved pastures:

- Kikuyu responsive but response depends on soil type/region
- 0.3 to 0.6 tC/ha/yr increase in SOC

New studies starting July 2012:

- Rotational grazing to restore native perennial grasses (CSIRO)
- Use of perennial fodder shrubs in grazing systems (Future Farming CRC, Rural Solutions SA)

Summary of management impacts on soil carbon

Cropping systems

Agronomic Improvements

Elimination of Tillage

Stubble Retention

Cover crops instead of bare fallows

More pasture phases in rotation

Organic matter additions

Retirement and restoration of degraded land

Increasing sequestration potential

Grazing systems

Agronomic Improvements

Improved grazing (cell grazing)

Shift to perennial grasses

Inclusion of perennial shrubs

Summary of management impacts on soil carbon

- ✓ Many agricultural soils have the capacity to store more carbon
- ✓ Local climatic and soil conditions will always factor into the ability of a particular area to sequester carbon
- ✓ Despite a general lack of good scientific evidence:

Many management shifts within existing production systems appear only capable of halting the decline in carbon stocks

Higher sequestration rates will likely be seen for more drastic shifts in management

What about claims of much higher rates?

Pasture cropping, biological amendments, biochar, etc…

The jury is still out.

1. Near complete lack of data
2. Short-term changes can be misleading
3. Theoretical reasons to both support and refute claims

Image courtesy: www.winona.net.au

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Carbon integrity standards

1. Can you **measure** and **verify** the change?
2. Is the practice **additional**?
3. Will the carbon be stored **permanently**?
4. Will there be any **leakage**?

Applying these principles to soil carbon is much more difficult than for many other mitigation strategies

Emissions avoidance versus sequestration

- Numerous recent papers arguing that emissions avoidance is almost always a better deal than sequestration projects

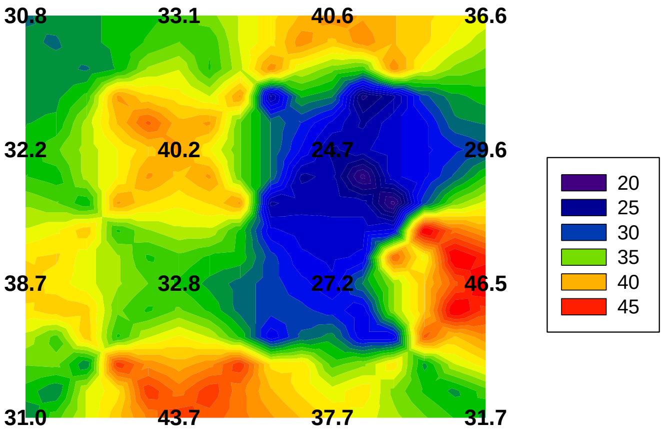
Example: Landfills emit methane (business-as-usual)

- Flare the methane to CO_2 and you have reduced the GHG potential 23 times

- It is **Additional** *(no incentive to do it otherwise)*, **Permanent** *(the CH_4 is not emitted)*, easily **Verified** *(inspection/remote sensing)* and there are no **Leakage** issues *(more CH_4 isn't going to be emitted elsewhere due to this project)*

Measuring and verifying soil carbon change

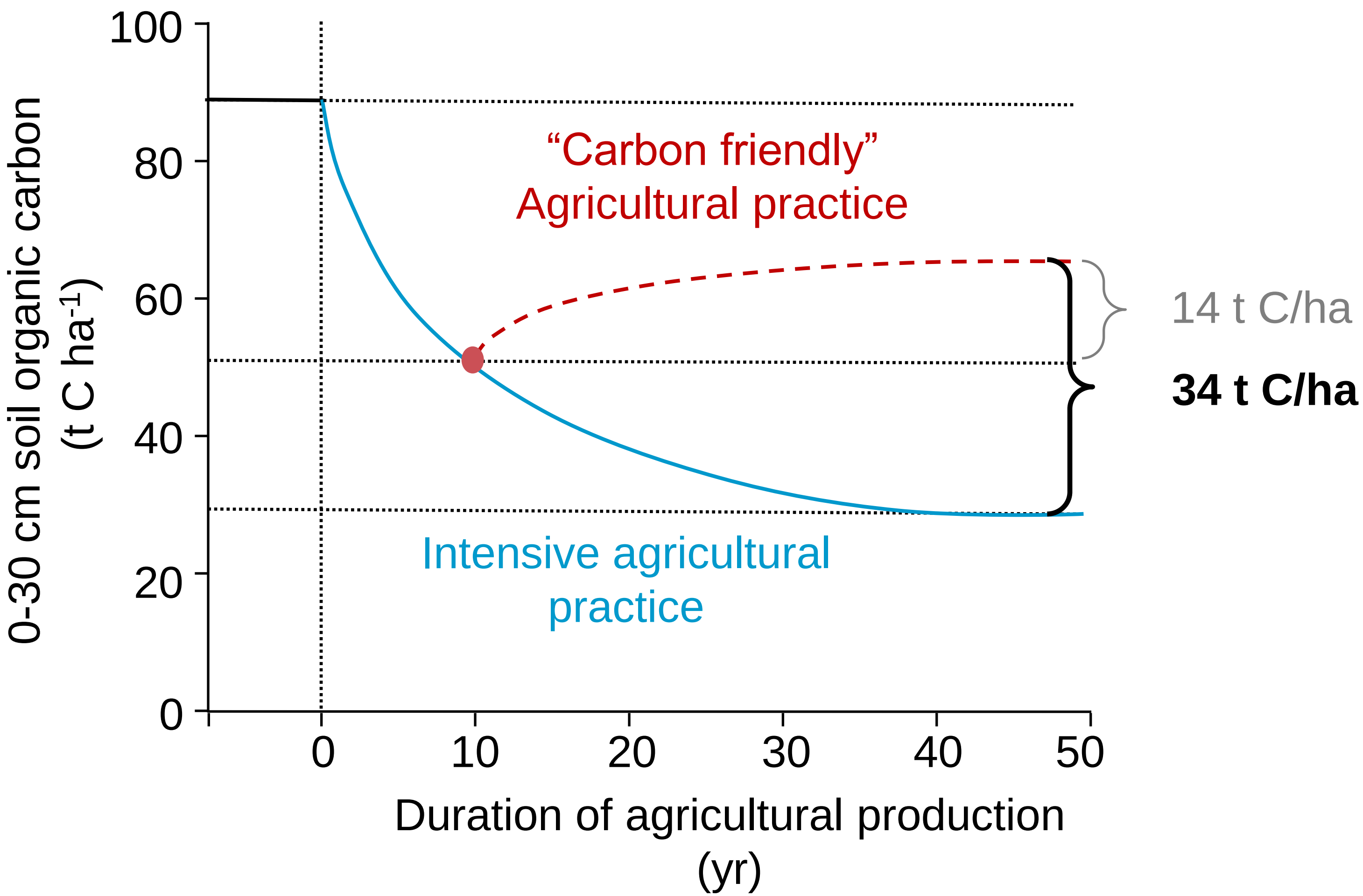
- Soil carbon is naturally variable and rates of change are small relative to this natural variability



- Direct measurement is time consuming and expensive
- Need for bulk density measurements
- Rapid and cost-effective tools are being developed

- Need for modelling

Comparison against business as usual – reason for modelling



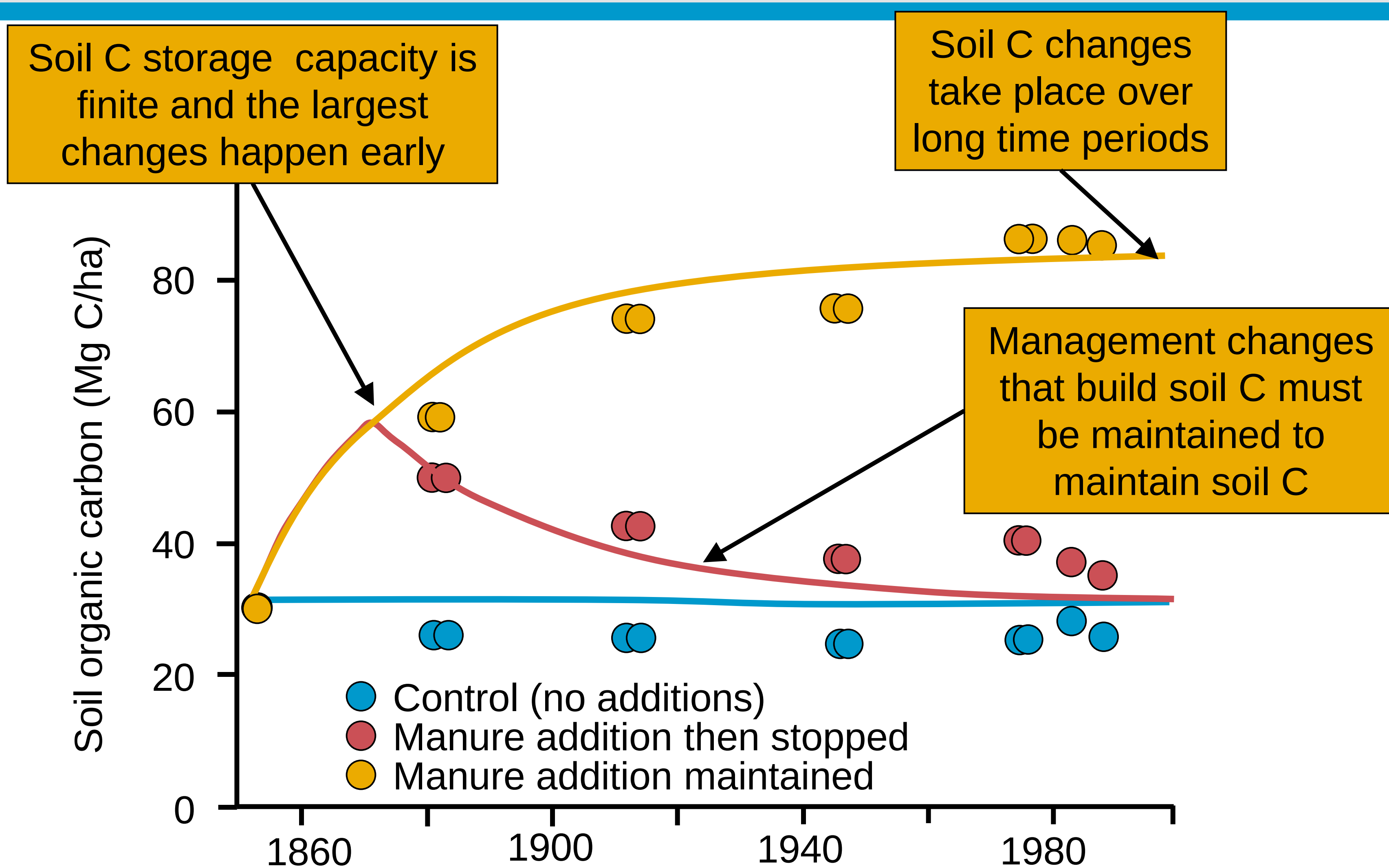
Additionality of soil carbon projects

- Most management options to increase soil carbon will increase productivity (and hopefully profitability), thus it is arguable that soil carbon would ever meet the **additionality** requirement.

- It comes down to how the Australian government wants to interpret additionality. The latest from the CFI website:

"The *financial additionality test* has been removed from the legislation. Instead, abatement activities that are <u>not common practice</u> in an industry or under specific regional conditions will be deemed to meet the additionality test."

Permanence of soil carbon



From Petersen et al 2005

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

Carbon Leakage

- **Example 1**: Soil carbon is enhanced by increasing use of nitrogen fertilizer, but there would be an increase in nitrous oxide emissions.
- **Example 2**: A humic acid extracted from coal to build soil carbon levels, but there are emissions involved in the mining and extracting phases.
- **Example 3**: If all Australian wheat growers shifted to permanent pastures, an equal amount of land elsewhere in the world would likely be brought into wheat production to meet the demand.
- It will be interesting how leakage plays out in the CFI.

Political versus atmospheric reality

Depending on how these integrity standards are applied, there is a real risk that carbon offsets may be generated that have no actual impact upon atmospheric CO_2 levels.

Summary

- Soil carbon levels are a result of a dynamic balance between inputs and losses
- Modest gains in soil carbon appear attainable across much of the agricultural sector
- Details of how we account of soil carbon in a trading scheme still need to be finalised

Soil carbon will likely be part of the solution, not *the* solution

Finally… Why biospheric offsets in the first place?

Stopgap measure to buy us a few decades of time to transition away from a fossil fuel based economy.

Currently, this seems to have been completely forgotten

Otherwise, we just have an expensive program to promote environmental sustainability.

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Thank you

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