What does the future look like with carbon farming and what science can be applied to farming?

Dr Mark Farrell

17th February 2022

Acknowledgements

Australian Government
Department of Agriculture, Water and the Environment

National Landcare Programme

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CSIRO

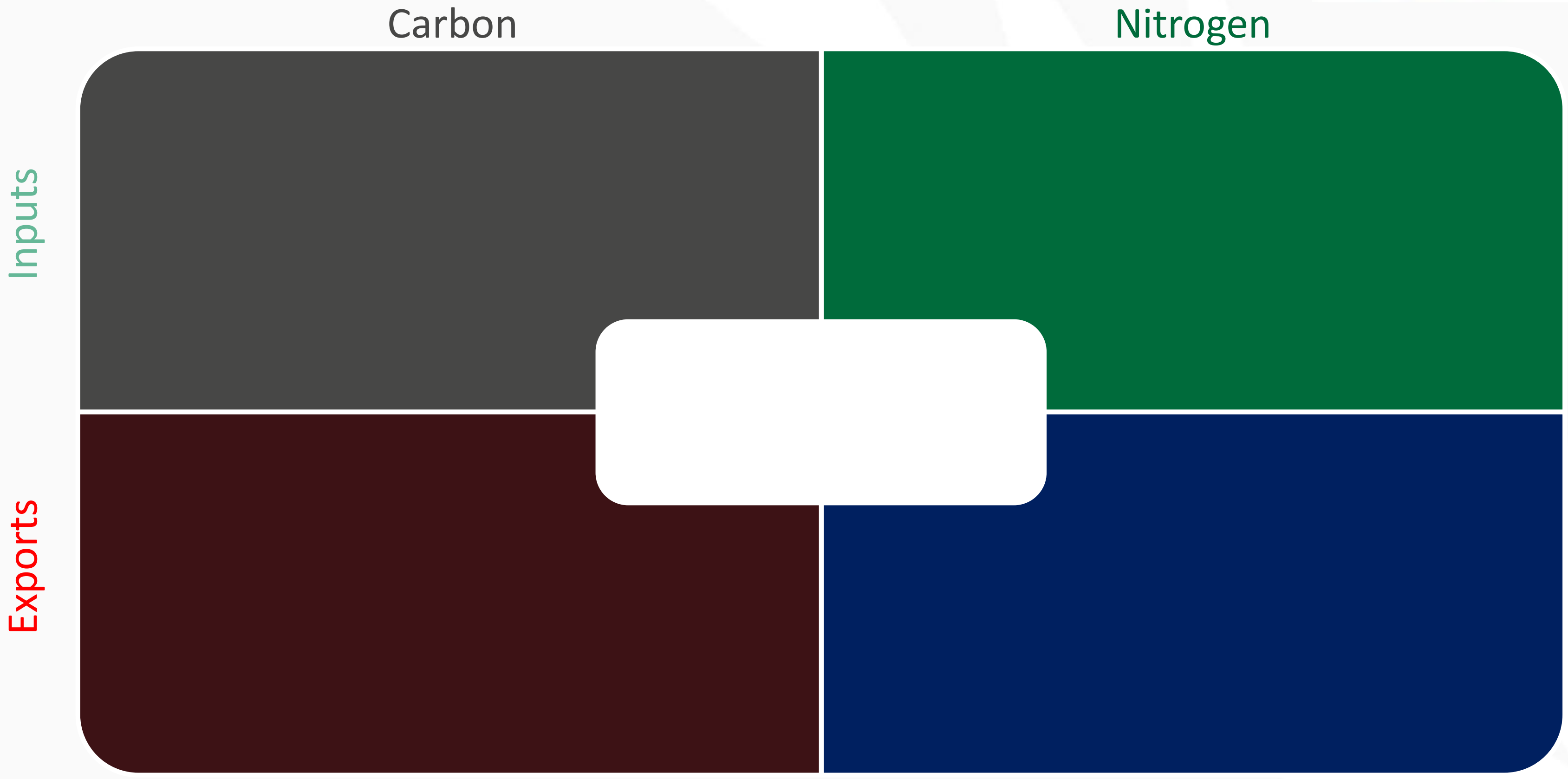


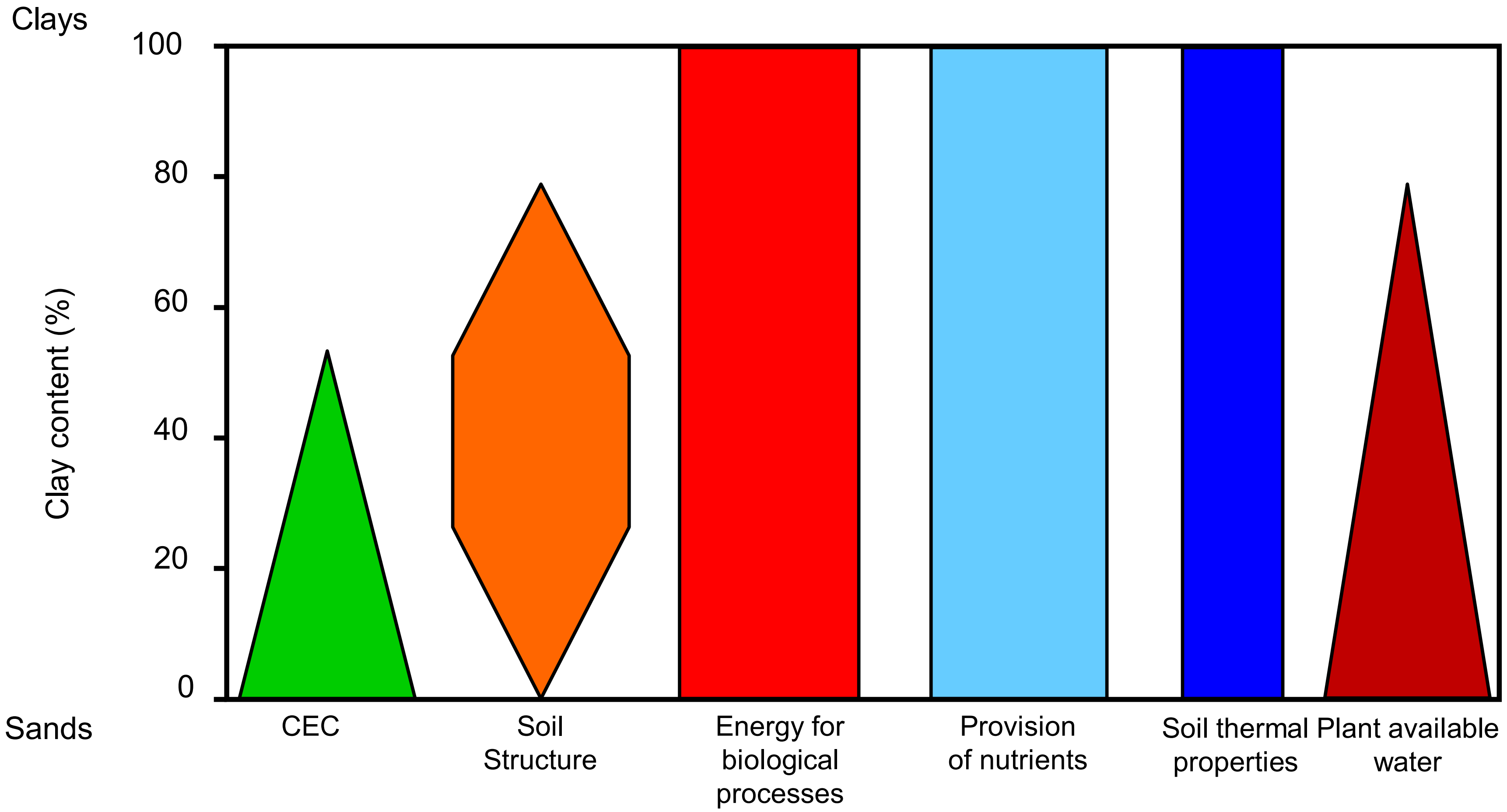


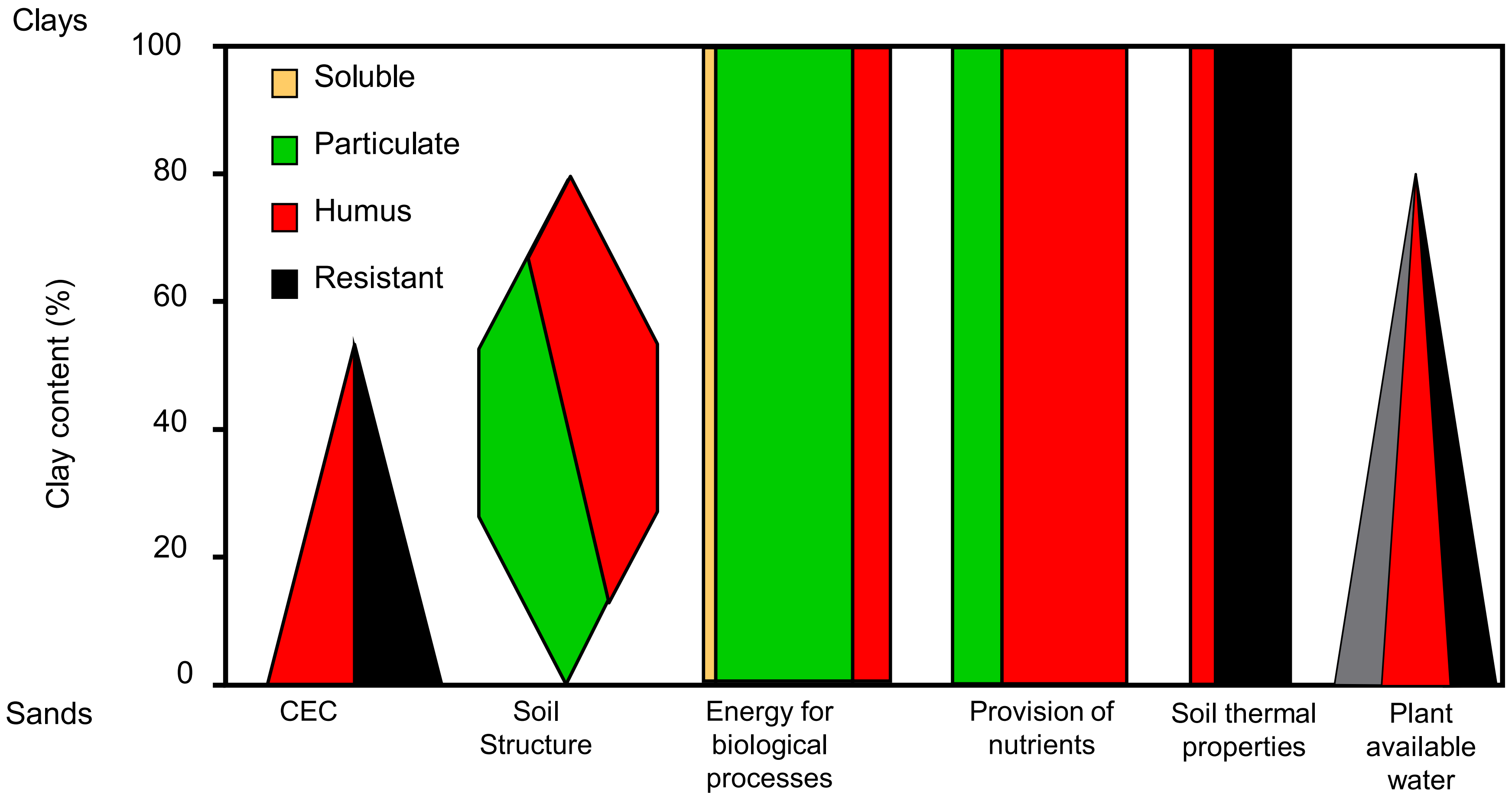



What *is* soil organic carbon?

WHERE DOES IT COME AND GO?




Clays
Sands
Clay content (%)
100
80
60
40
20
0
CEC
Soil Structure
Energy for biological processes
Provision of nutrients
Soil thermal properties
Plant available water


Clays
Sands
Clay content (%)
100
80
60
40
20
0
Soluble
Particulate
Humus
Resistant
CEC
Soil Structure
Energy for biological processes
Provision of nutrients
Soil thermal properties
Plant available water

Carbon fractions

"Oils ain't oils, soils ain't soils"

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

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

Soil organic carbon

Particulate organic carbon (2 mm – 0.05 mm) (**POC**)

Humus-like organic carbon (<0.05 mm) (**HOC**)

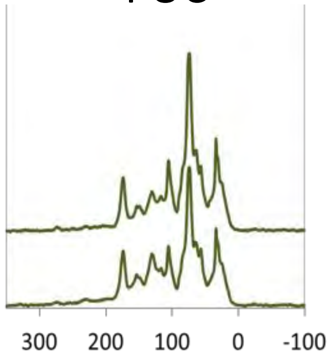
Resistant organic carbon (**ROC**): dominated by charcoal

CH_2O decreases

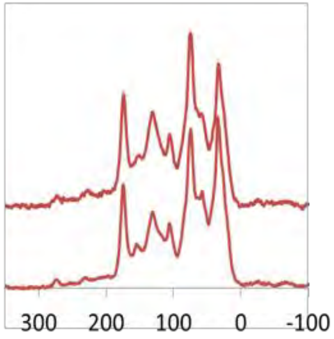
C/N/P decreases

Resistant to decomposition increases

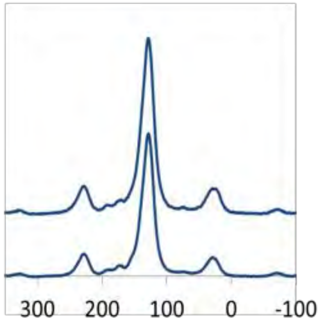
POC



HOC

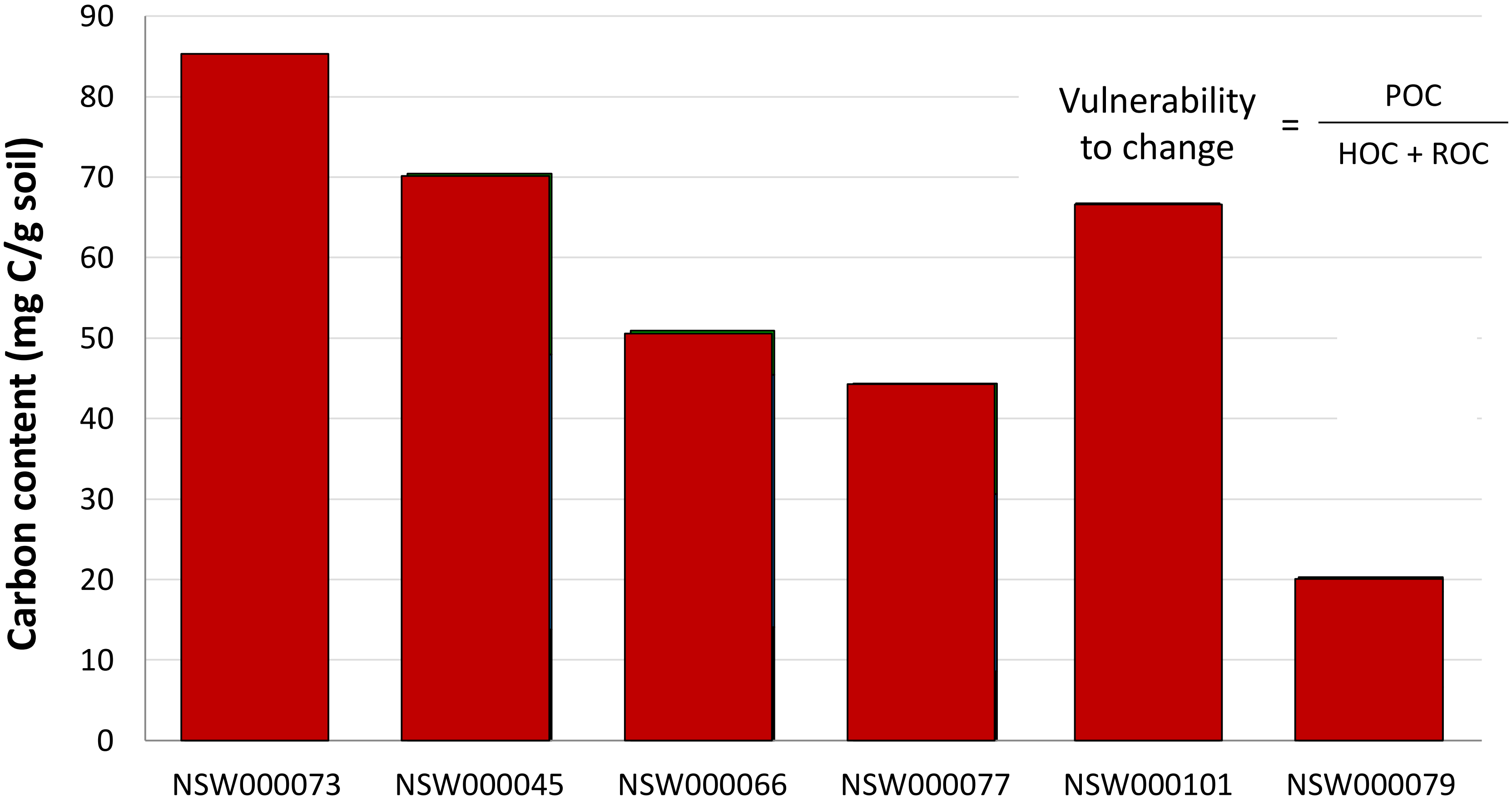


ROC



Carbon fractions

"Oils ain't oils, soils ain't soils"



Measurement and uncertainty

Calculating SOC stocks - volumetrically

$$\underset{(\text{Mg C/ha})}{\text{Soil carbon stocks}} = \left[\underset{(\text{g C/kg AD soil})}{\text{Carbon concentration}} \times (1 + \theta_m)\right] \times \underset{(\text{cm})}{\text{Depth}} \times \underset{(\text{Mg/m}^3)}{\text{Bulk density}} \times \left[1 - \underset{(>2\text{mm})}{\text{Proportion of gravel}}\right] \times 0.10$$

Carbon stocks do not depend on just measurements of C concentration

	Actual	Measured
OC (g OC/kg soil)	25.4	25.4
θ_m (g water/g soil)	0.12	0.14
Depth (cm)	30.0	30.2
Bulk density (Mg soil/m^3 soil)	1.25	1.30
Gravel (g gravel/g soil)	0.12	0.10

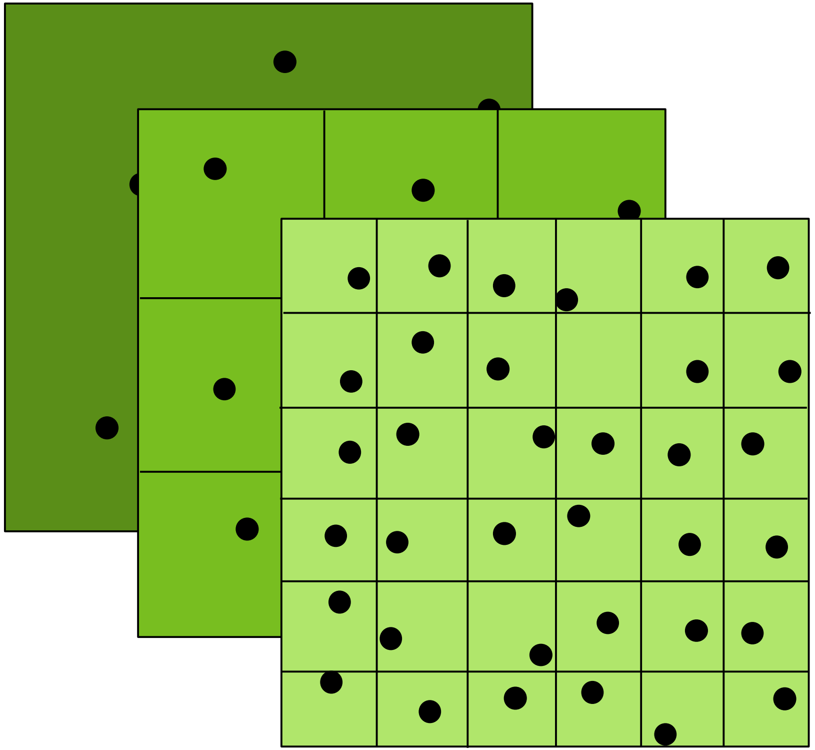
Soil carbon stock (Mg C/ha) 92.9 102.3

Error of approximately 10%

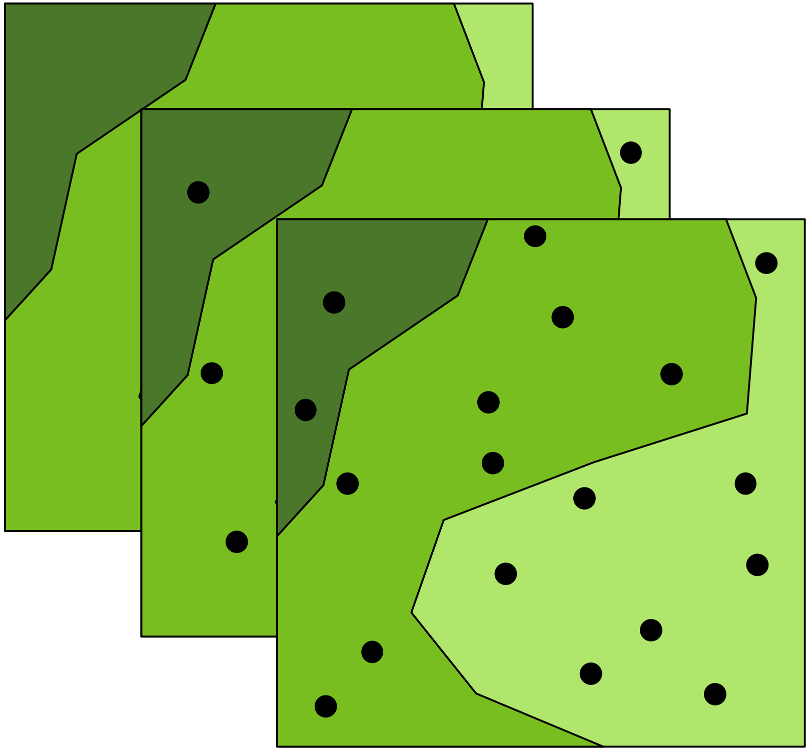
The manner in which soil samples are collected and processed is very important

Sampling strategies

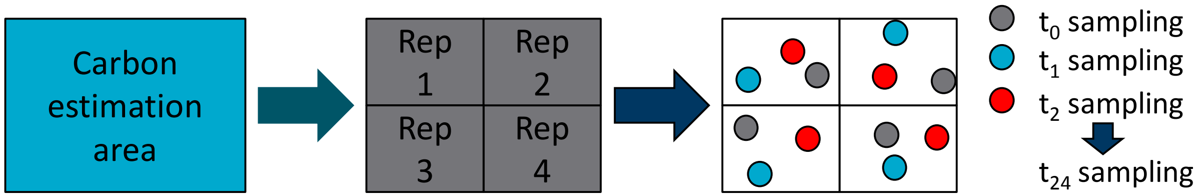
No prior information

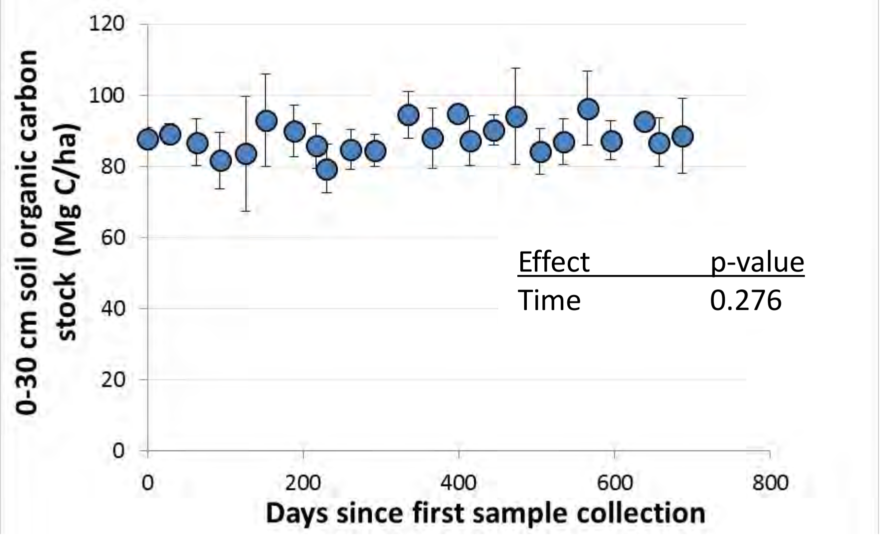


Spatial distribution known



Temporal changes in 0-30 cm soil organic carbon stock at Armidale (grazed tall fescue pasture)

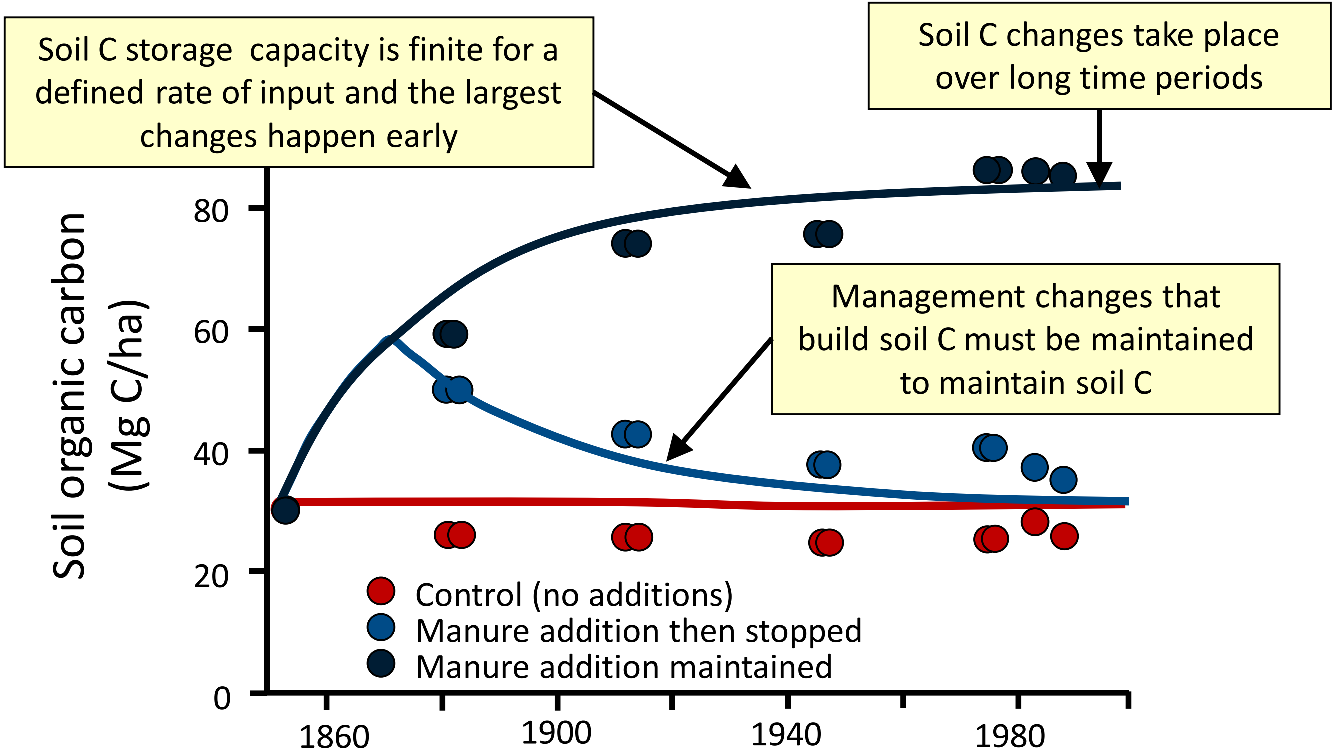




Potential sources of variation

- Spatial
- Temporal
- Sampling
- Preparation
- Analytical

Permanence of changes in soil carbon stocks

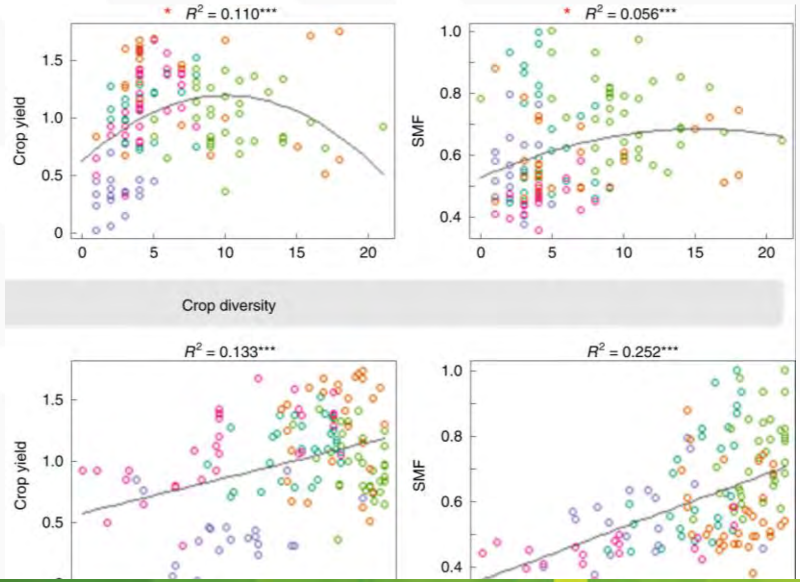


Petersen et al. (2005) Soil Biol Biochem 37: 359

Links between productivity and soil carbon

GROW MORE, GROW MORE THINGS

- Simply achieving a greater percentage of plant cover over a year means more C is being added to the soil
- Currently exploring efficacy of single- and mixed-species cover crops in the southern region
- 20 demo sites
- Soil water, fertility, SOC, mic activity
- Major research this coming season, reporting later this year



Project Proponents

Project Funders

https://research.csiro.au
/mixedcovercrops/

YOUR CARBON BUDGET….

1) $\Delta_{ABC} = \left(\Delta_{yield}/_{HI}\right) \times CC$

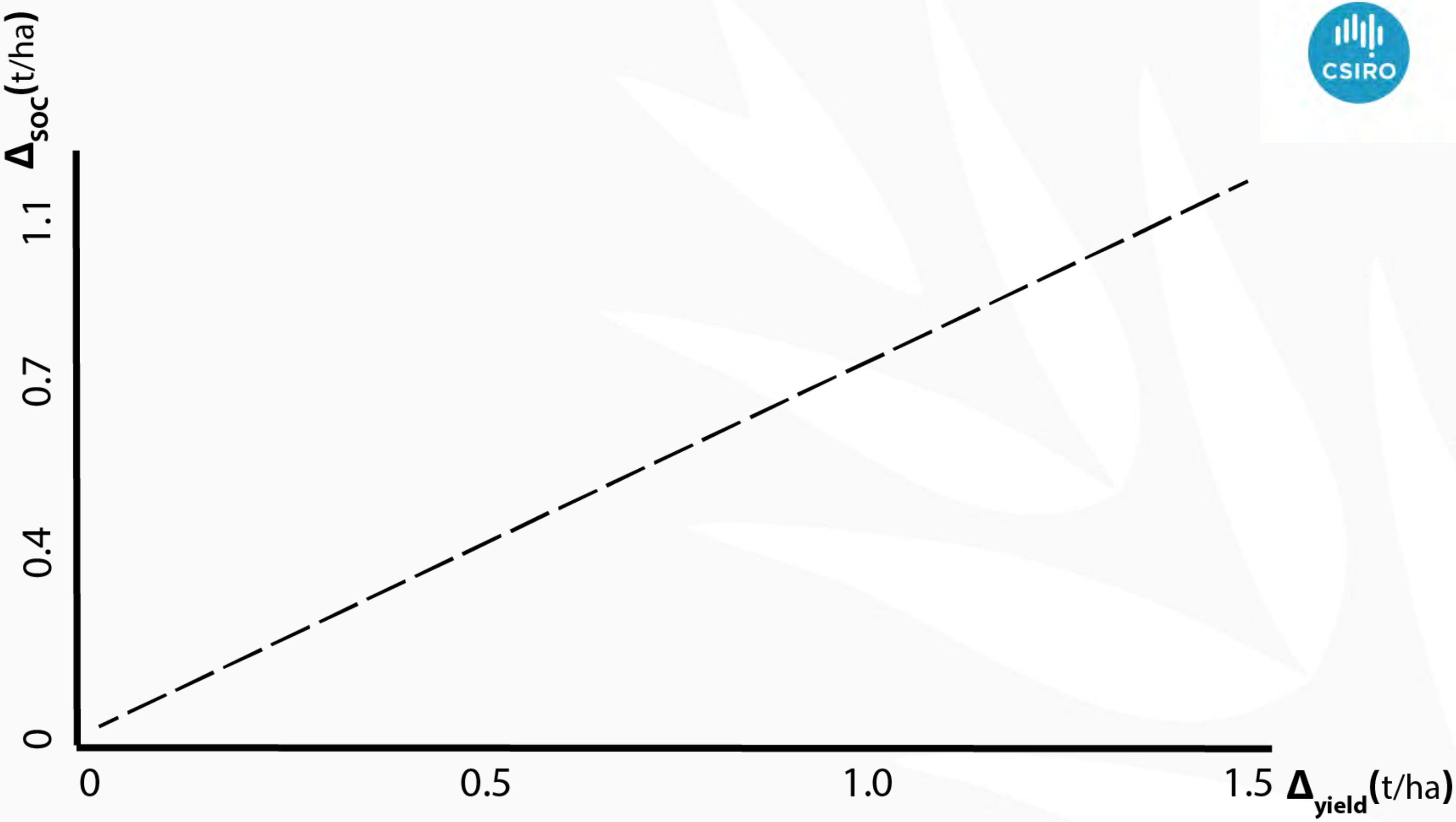
2) $\Delta_{BBC} = \Delta_{ABC} \times RS$

3) $\Delta_{RC} = \Delta_{BBC} \times RR$

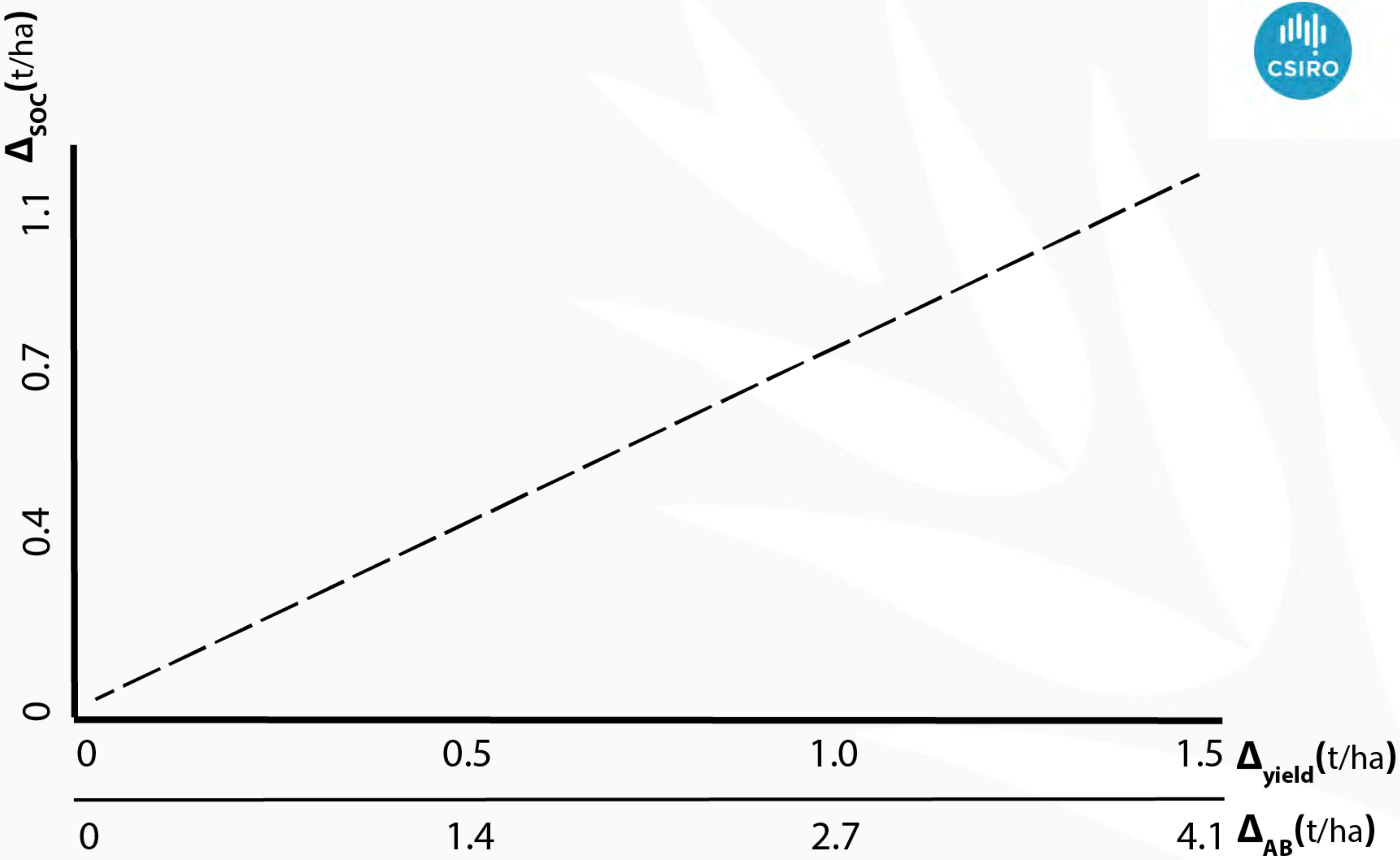
4) $\Delta_{SOC} = \left((\Delta_{ABC} + \Delta_{BBC})RF^{b}\right) + (\Delta_{RC} \times RF^{r})$

Harvest Index (cereal)	0.37
Root:shoot ratio (cereal)	0.50
%C biomass (cereal)	44%
Retention Factor	0.30
Exudate-C (prop root biomass)	0.50
Retention Factor rhizodeposits	0.57

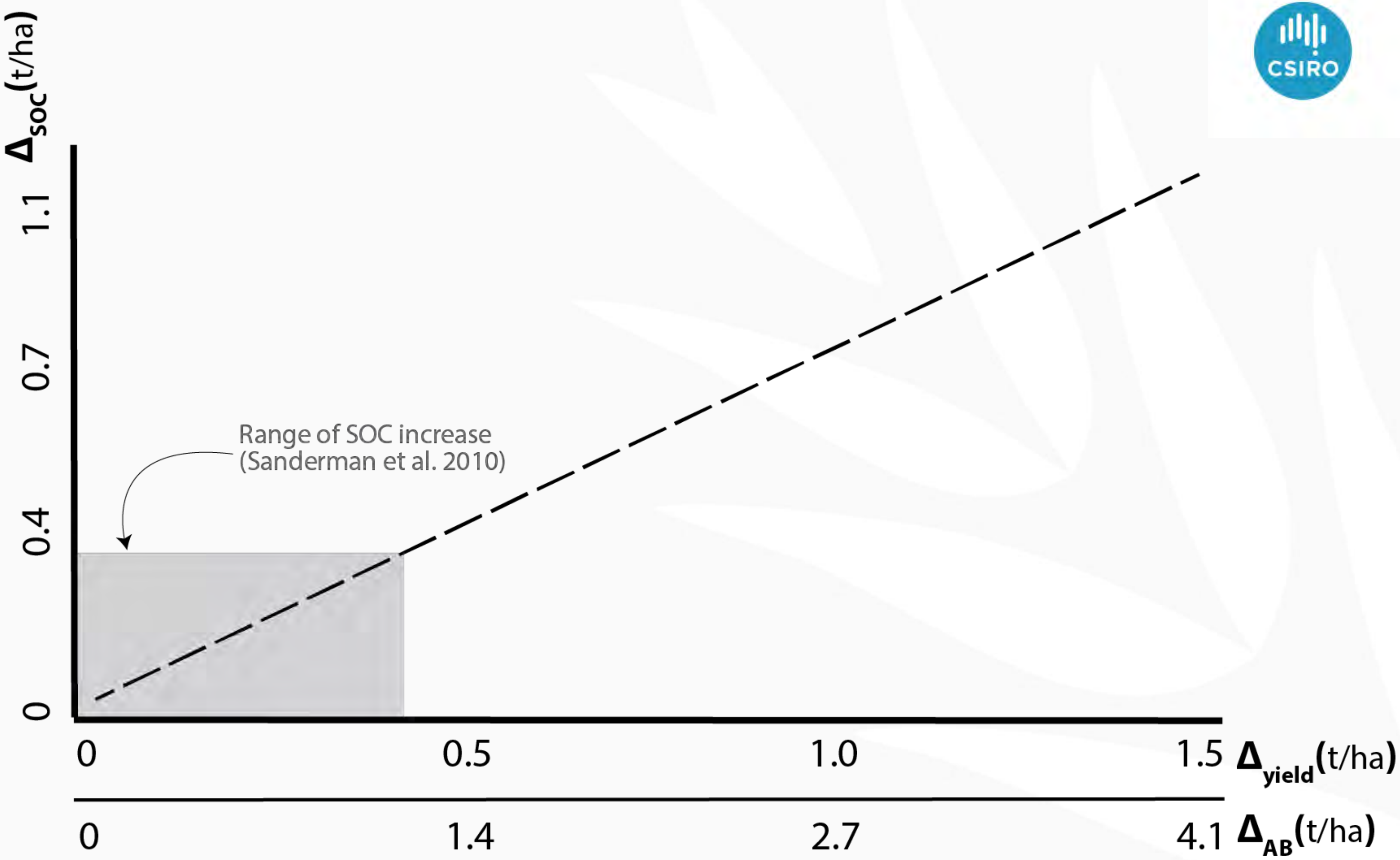
Macdonald et al. 2020, Farrell et al. 2021, 2022



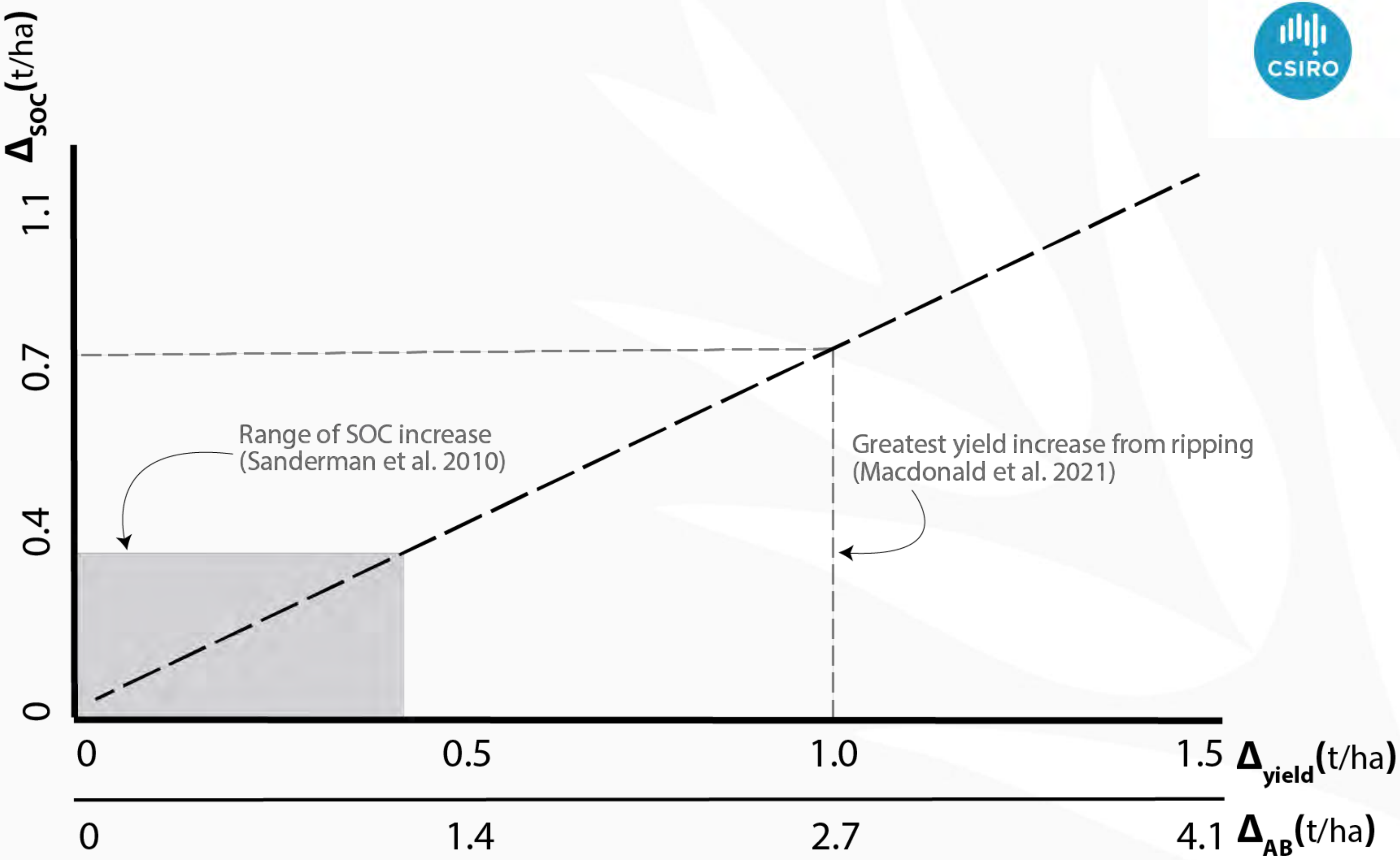
Macdonald et al. 2020, Farrell et al. 2021



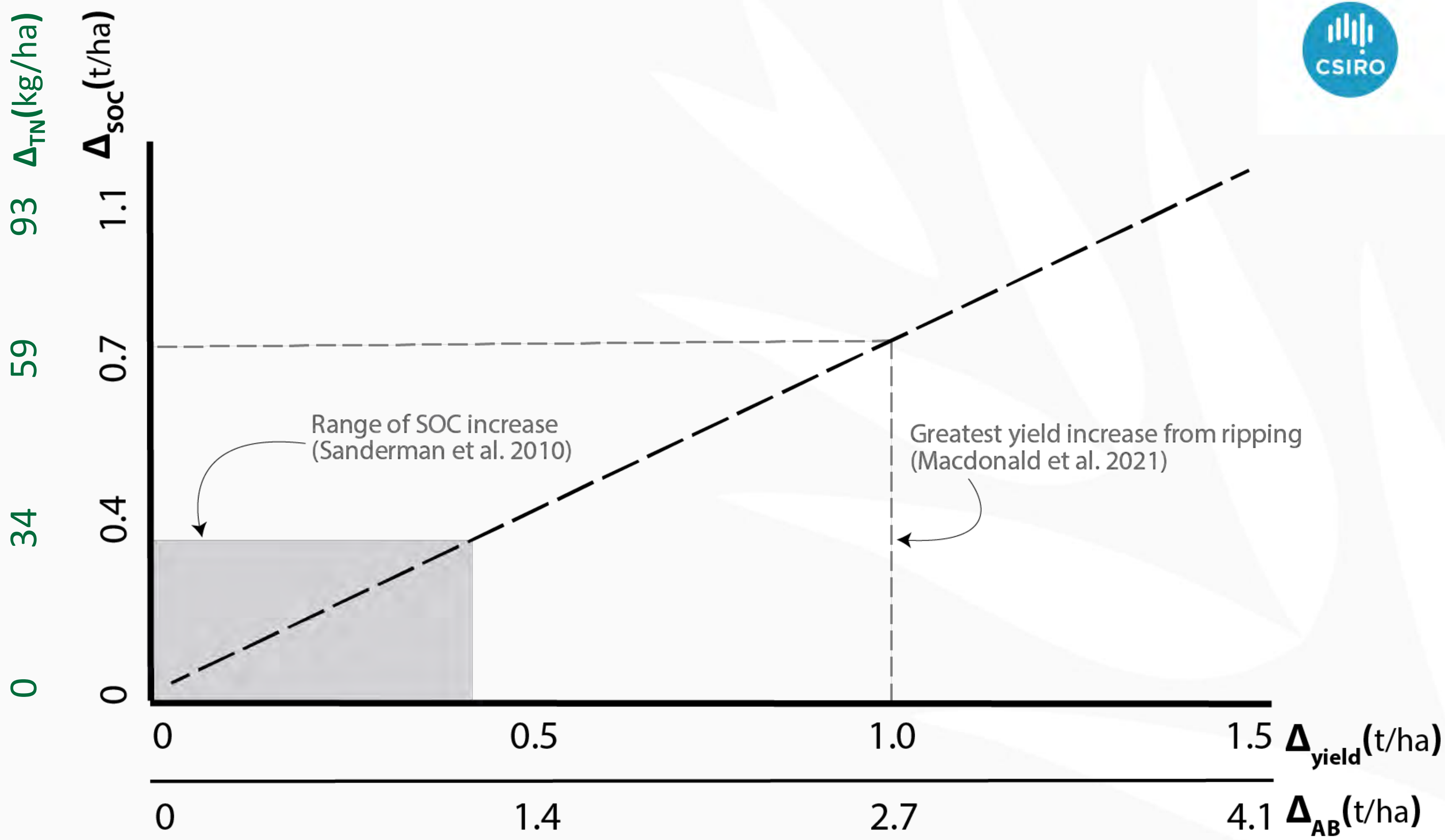
Macdonald et al. 2020, Farrell et al. 2021



Macdonald et al. 2020, Farrell et al. 2021



Macdonald et al. 2020, Farrell et al. 2021



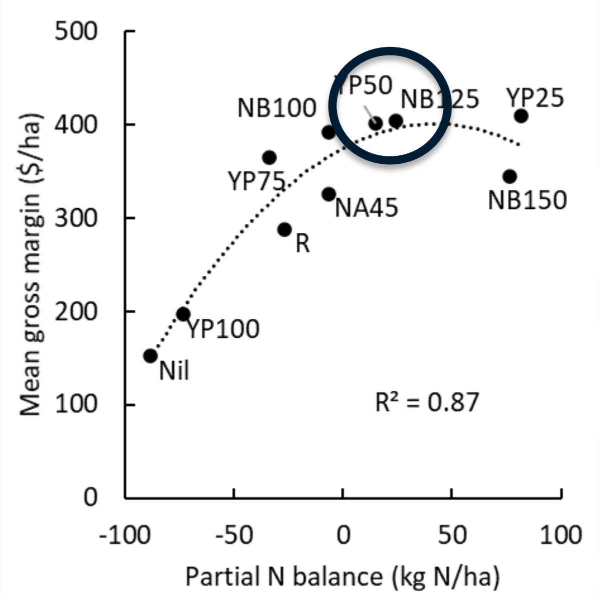
Macdonald et al. 2020, Farrell et al. 2021

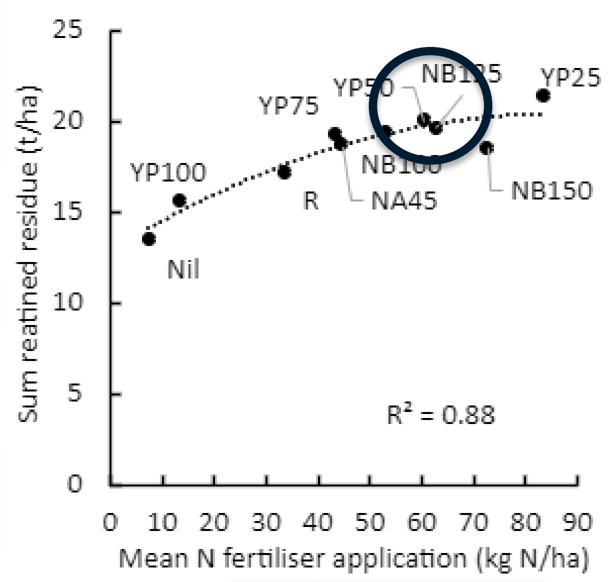
OVERCOME CONSTRAINTS

The single largest driver of failure to meet WLYP is lack of available N

Can more N be applied?

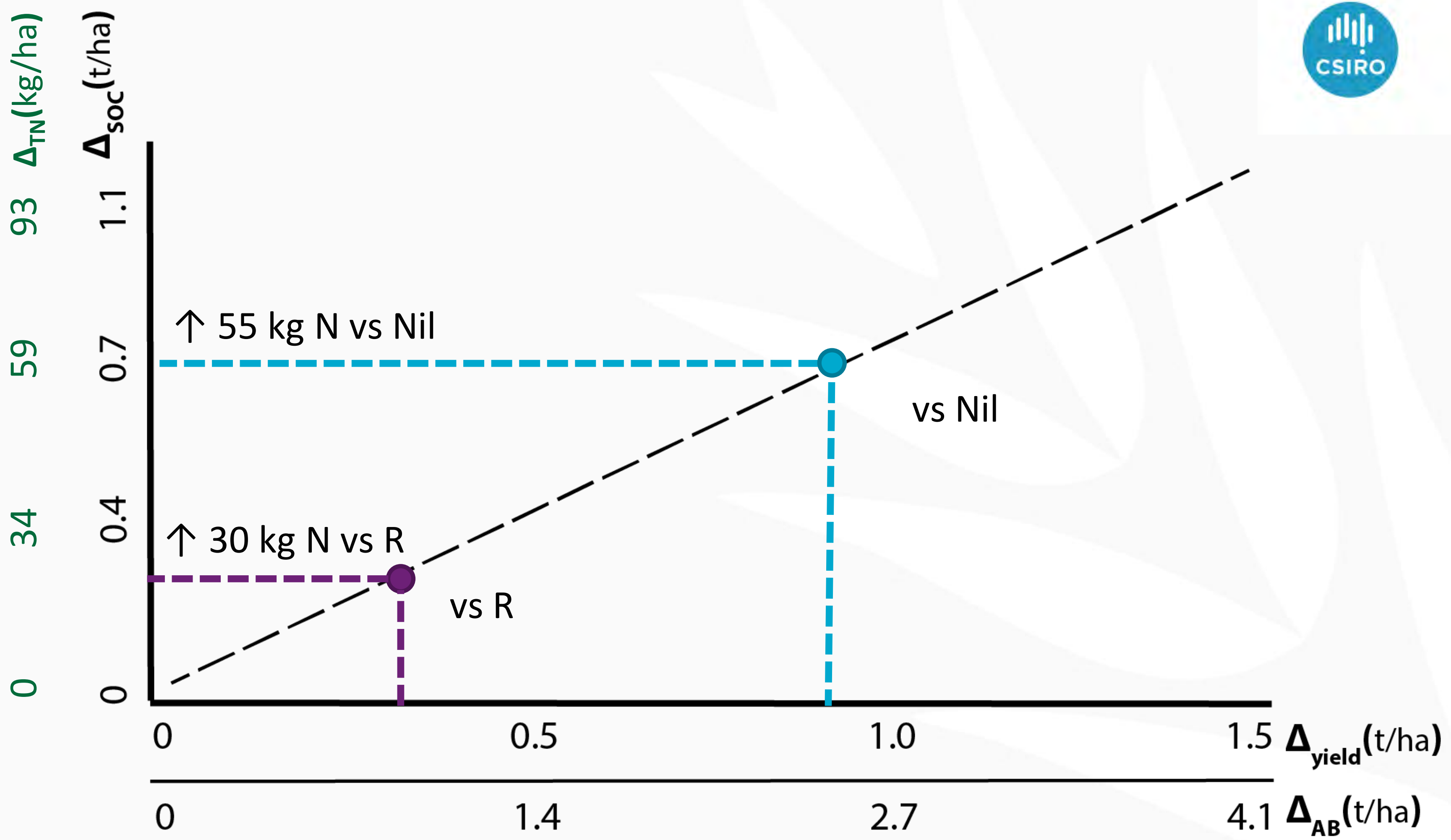
- What are the risks?
  Haying off, lower rainfall, volatilisation
- Environmental concerns?
  Leaching, N_2O
- Impact on bottom line





Hunt et al. 2022

Yield @ NB125 ↑ 53% vs Nil and ↑ 13% vs R



Macdonald et al. 2020, Farrell et al. 2021, 2022, Hunt et al. 2022

Conclusions

- The main input of C to soil is from plant growth
- SOC is more than *just* C
- Quantification of stocks to detect change is challenging
- To build more C, more plant inputs are needed
- Overcoming constraints to production at the systems level is required
- Gains likely to be modest

Thank you

Dr Mark Farrell
CSIRO Agriculture and Food
Waite Campus, Urrbrae, SA
mark.farrell@csiro.au
08 8303 8664

Acknowledgements:
Jeff Baldock & SCaRP team

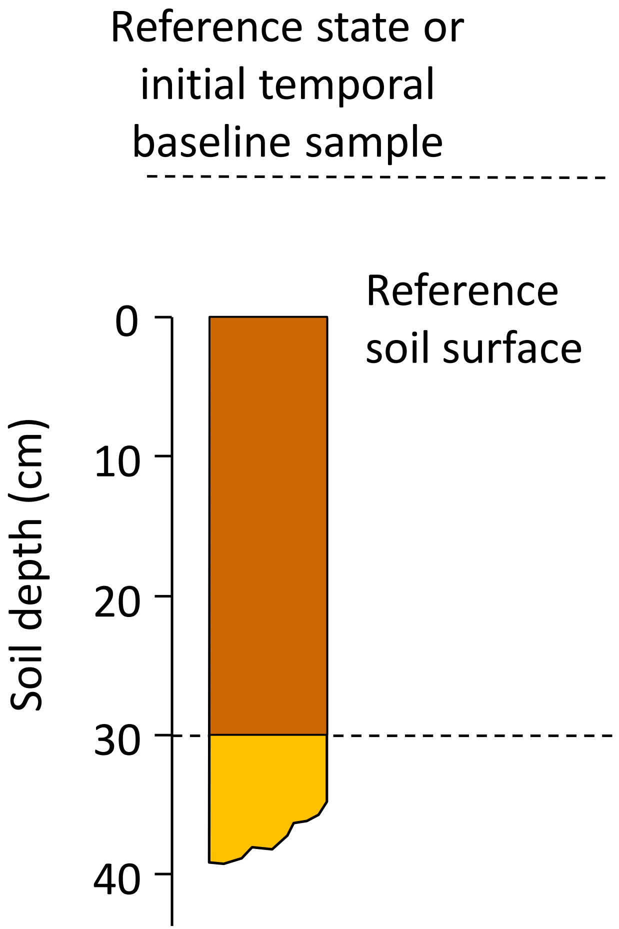
Australian Government
Department of Agriculture, Water and the Environment

Australian Government
Department of Industry, Science, Energy and Resources

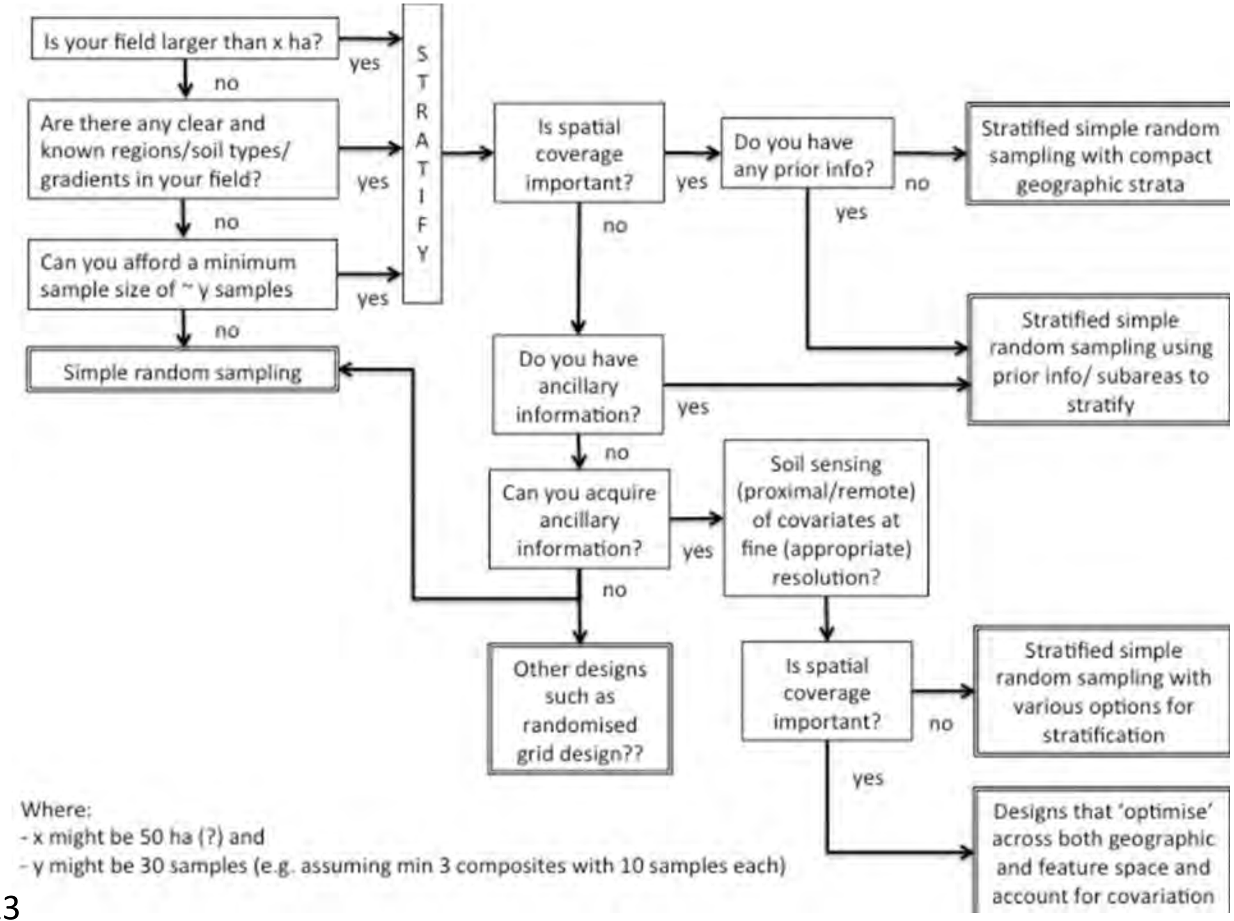
GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Australia's National Science Agency

Equivalent soil mass



What strategy is appropriate?

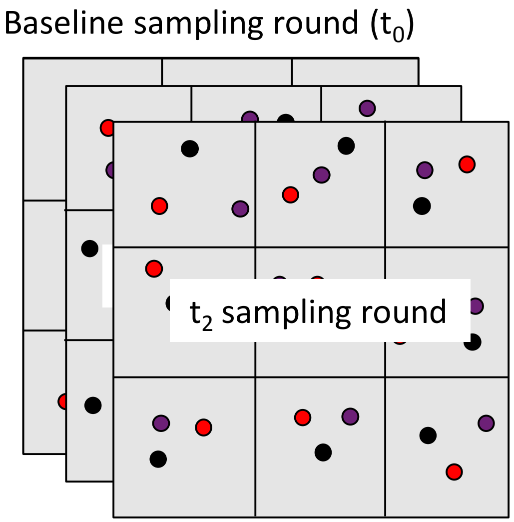


Chappell *et al*. 2013

Direct measurement soil carbon ERF methodology

Method prerequisites:

- based on direct measurement,
- must be at least 30 cm,
- allow two depth layers (one must be reported at 0-30 cm), and
- conservative in its estimate of stock change



- Stratified random sampling within equal area strata / unequal area strata
- Create composite samples by acquiring a soil core from each stratum
- Each composite sample encompasses spatial variability / single core samples with a stratum
- Variability between samples sent for analysis is reduced
- Improved ability to detect temporal change

Quantifying the temporal change in ESM soil carbon stock

Statistics	t_0	t_1	t_2	t_3	t_4
Project duration (y)	0.00	2.98	5.98	9.02	11.99
Average (Mg C/ha/y)	75.01	85.94	95.96	99.12	110.15
Stdev (Mg C/ha/y)	1.84	2.61	2.15	2.52	1.17
Sample size (n)	4	4	4	4	4