Increasing sensitivity for detecting small changes in soil carbon over highly variable landscapes

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It's not as simple as biomass

Grazing management?

20.5 ± 1.1 t ha^{-1}
SOC (0-10 cm)

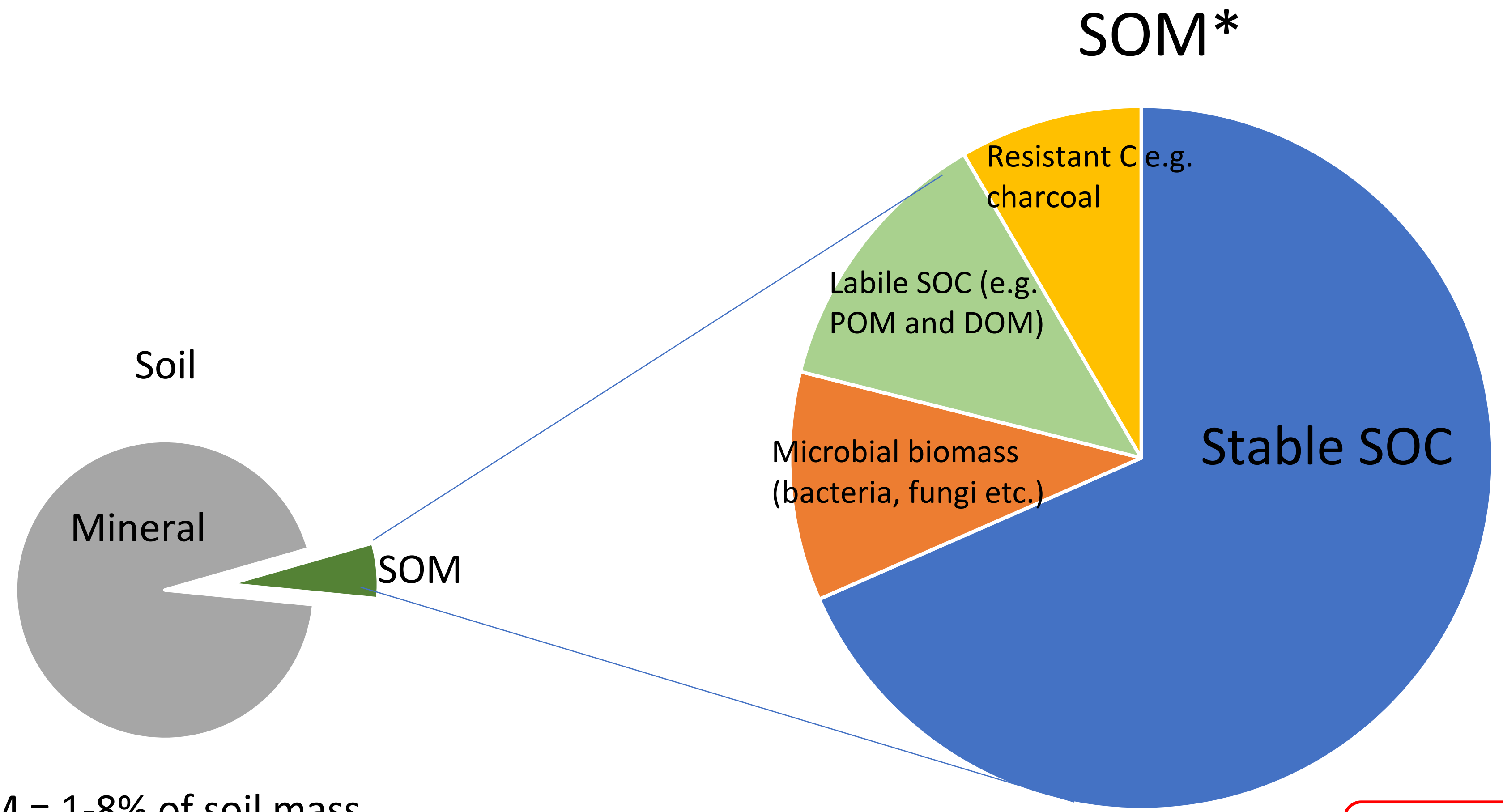
16.6 ± 3.2 t ha^{-1}
SOC (0-10 cm)

Current state of knowledge on soil sequestration science

Reference	System	Study area	Increase/Decrease C	
Schatz (2020)	Intensive rotational vs. conventional	Northern Territory	No significant change	Grazing management
Sanjari (2008)	Time-controlled grazing vs. conventional	SE QLD	1.37 t C/ha/yr*	Grazing management
Allen (2013)	Continuous, rotational, Time-controlled and exclosure	All QLD	Decline in SOC under TCG grazing	Grazing management
Pringle (2011)	Heavy vs. moderate grazing pressure	Charters Towers	No significant change	Grazing management
Badgery (2014)	Cropping to permanent pasture	Central West NSW	0.78 t C ha/yr	Crops to pastures
Chan (2011)	Pasture phase in cropping + P addition	Wagga Wagga	0.5-0.7 t C ha/yr	Crops to pastures
Conrad (2017)	Leucaena *(N fixation)*	Central Queensland	0.28 t C ha/yr	Desmanthus?
Radrizzani (2011)	Leucaena *(N fixation)*	Central Queensland	0.76 t C ha/yr	Desmanthus?

*non-significant

Soil organic matter and soil organic carbon



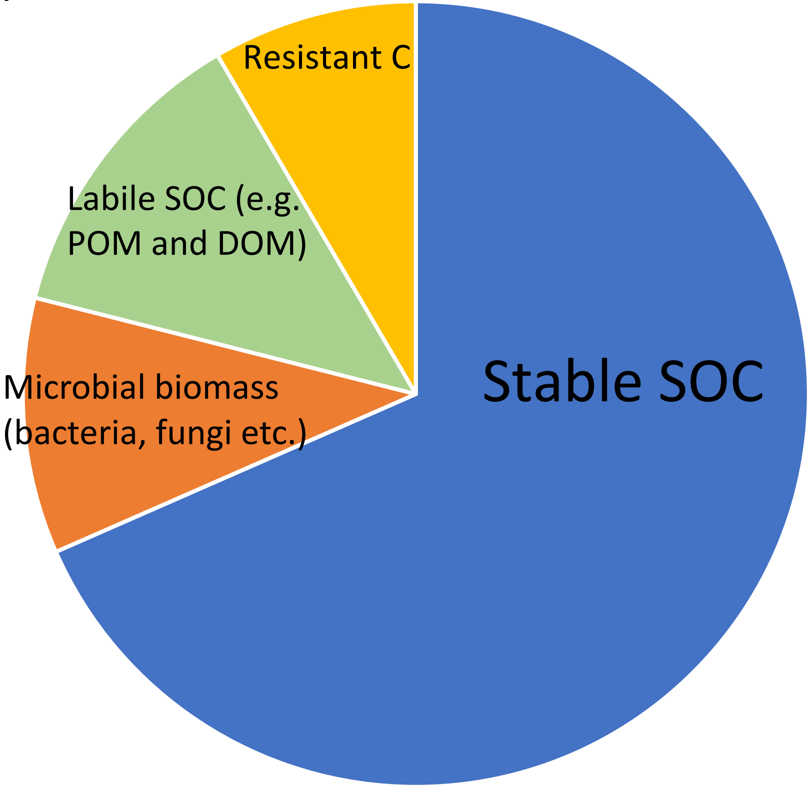
SOM = 1-8% of soil mass

*~58% of SOM = SOC

How much soil carbon can we sequester –*nutrients*

- C sequestration controlled by least limiting factor
- Nitrogen critical for building stable carbon
  - Other nutrients also required P, K, S, Ca

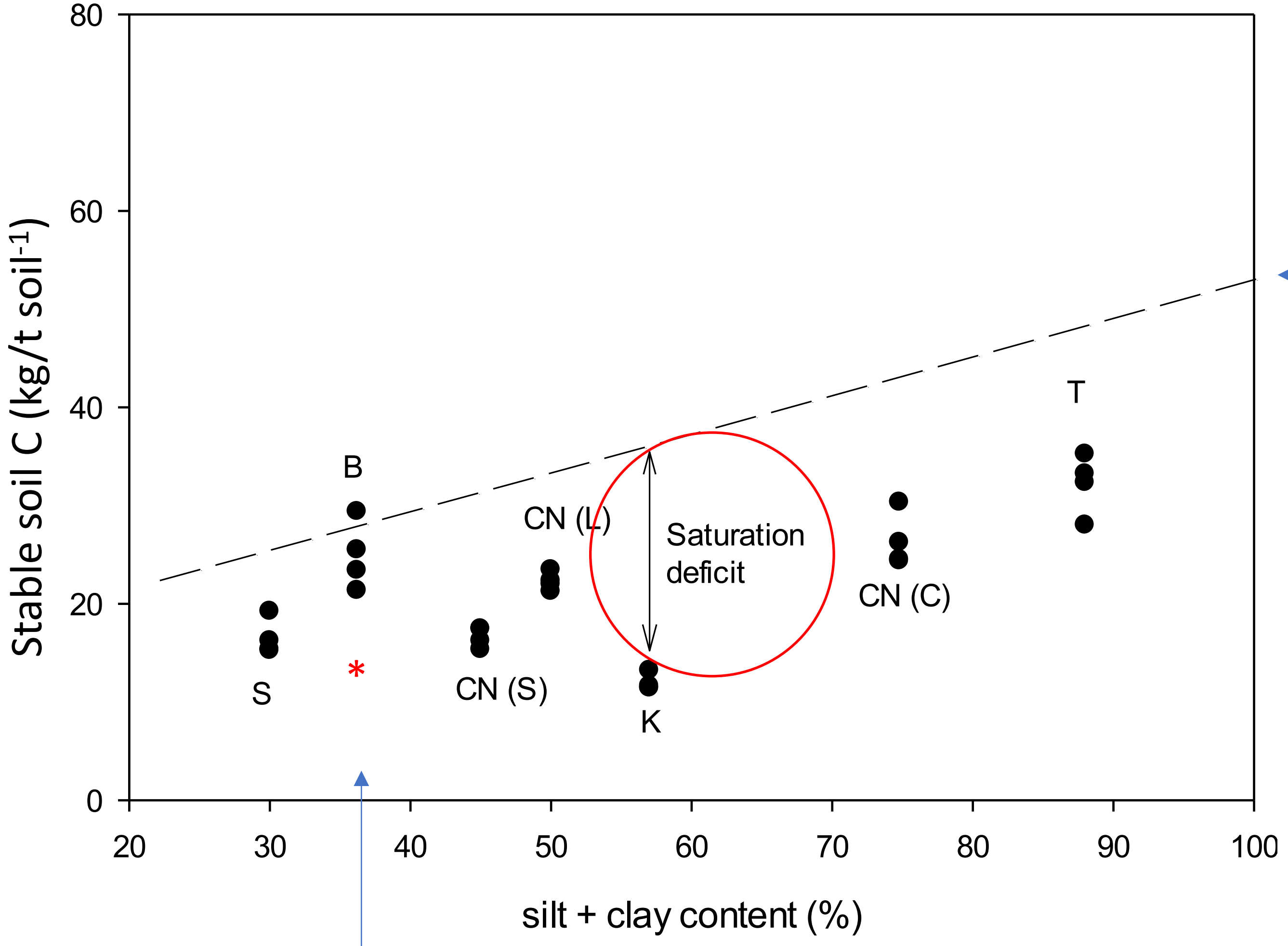
Nitrogen required to build 1 t C ha^{-1}



83 - 180
kg N ha^{-1}

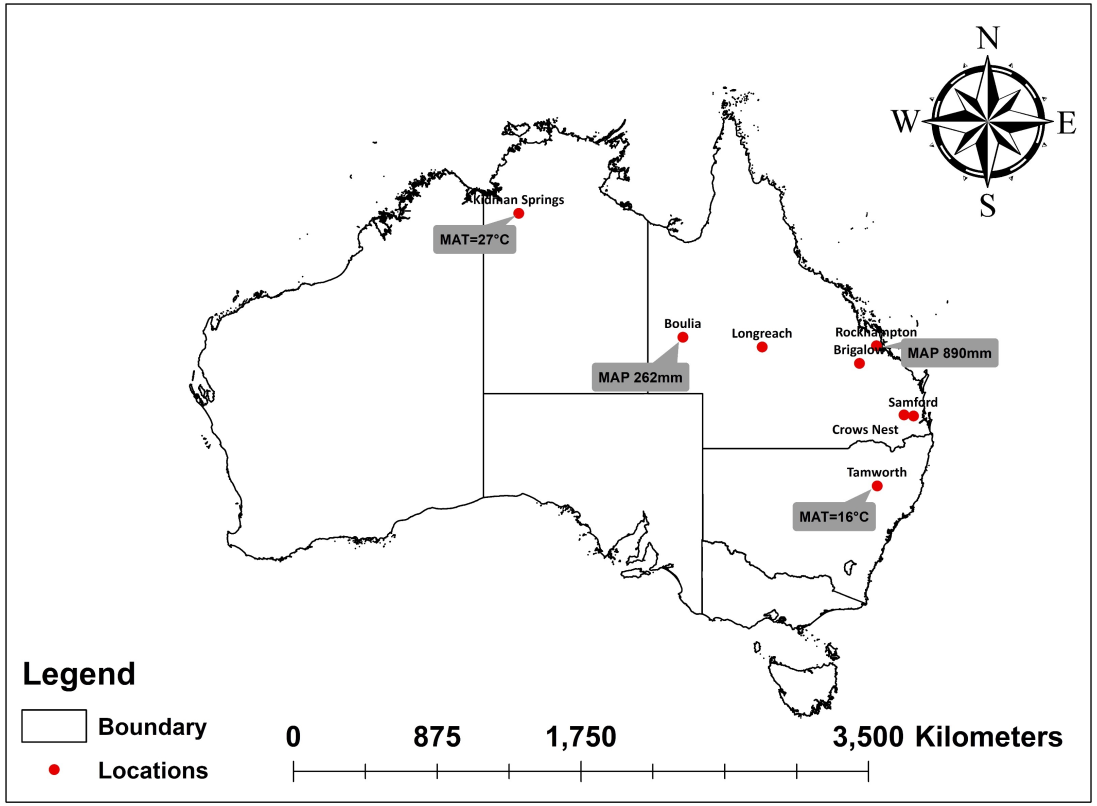
*~58% of SOM = SOC

How much soil carbon can we sequester –*clay content*



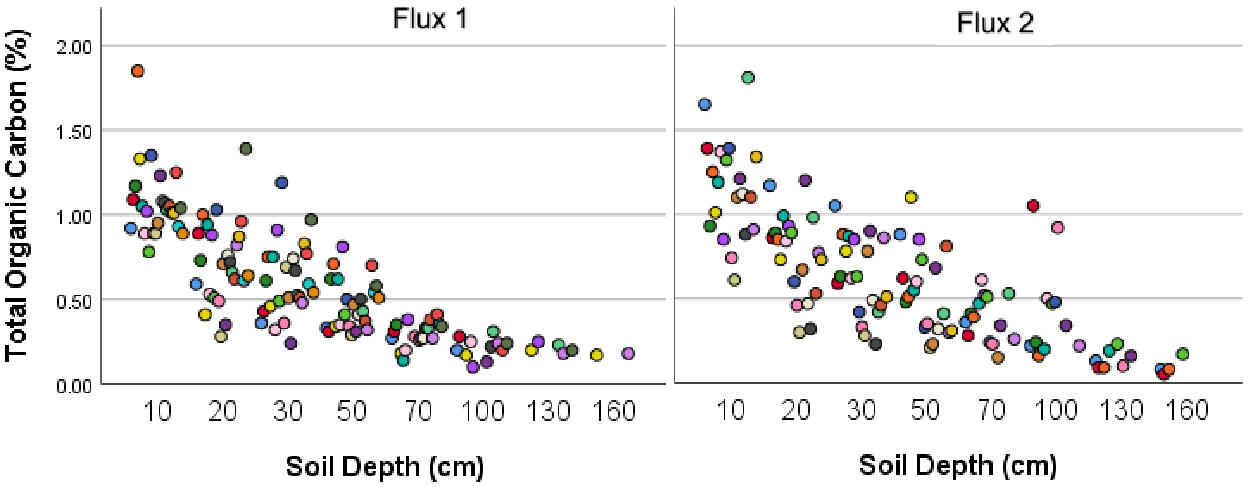
maximum stable C capacity

Cropping



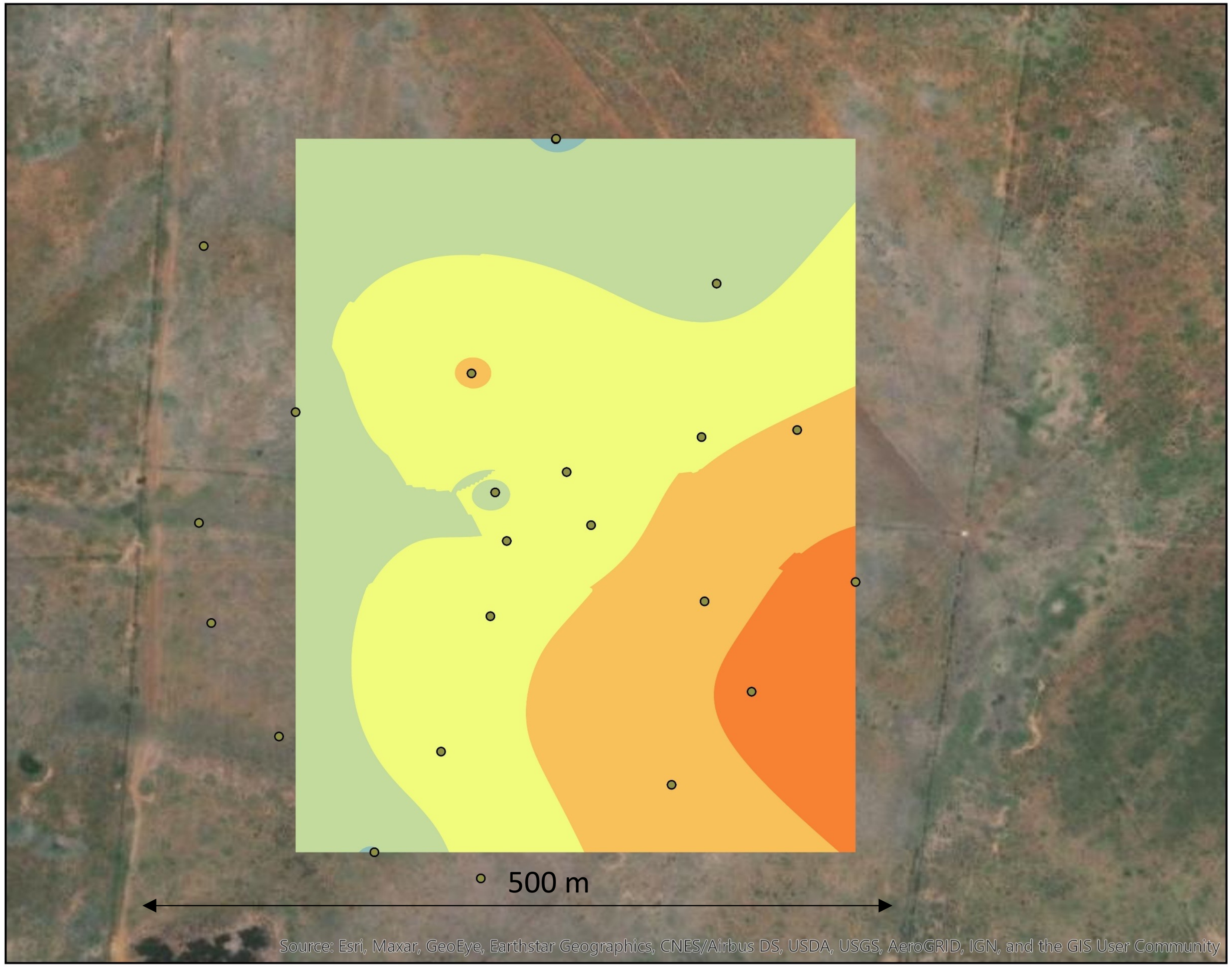
Barriers to soil carbon measurement – *spatial variability*

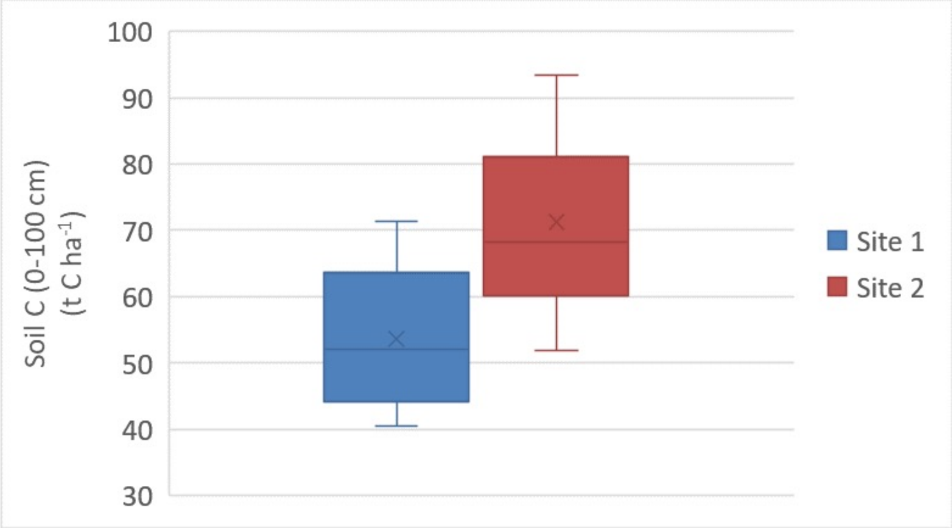
- High spatial variability due to soil type, micro-relief, pasture composition and production and grazing pattern
  - Substantially reduces sensitivity of traditional TOC estimation via soil sampling
  - Leads to high sampling costs to overcome spatial error
  - Reduces carbon sequestration options available to farmers



Variation in total organic carbon (%) per depth for each soil profile (N=23) for the two 10 hectare sampling areas at Goondiwindi.

High spatial variability in grazed pastures



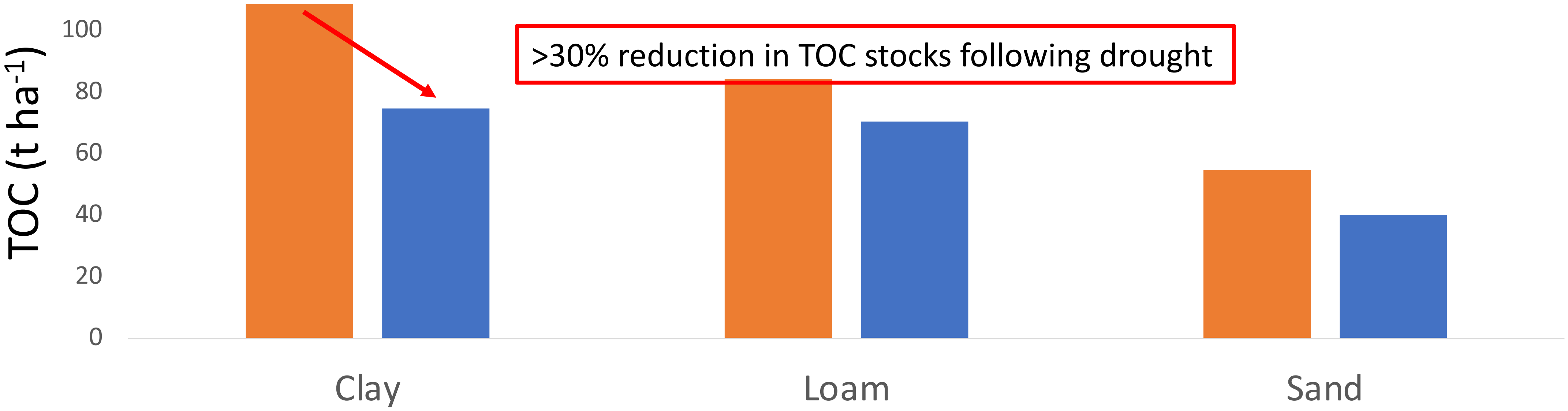


Site 1 = 53 t C ha^{-1} (SD = 10.6) n = 24
Site 2 = 71 t C ha^{-1} (SD = 12.7) n = 20

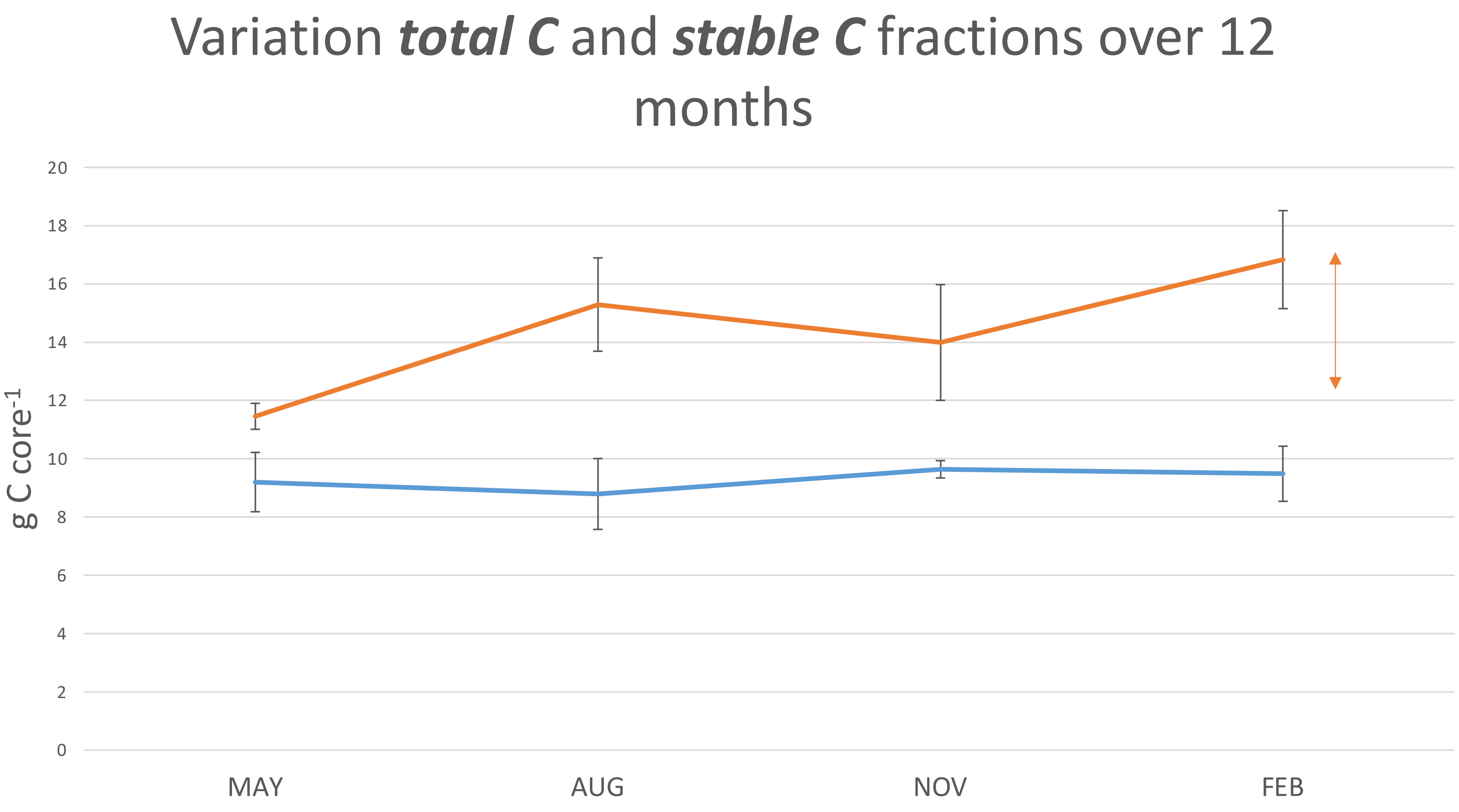
To achieve a statistically significant change in SOC >20-25 t C ha^{-1} required

Over 10 years = 2.0 – 2.5 t C ha^{-1} yr^{-1}

Barriers to soil carbon measurement – *drought*



Barriers to soil carbon measurement – *changes over time*



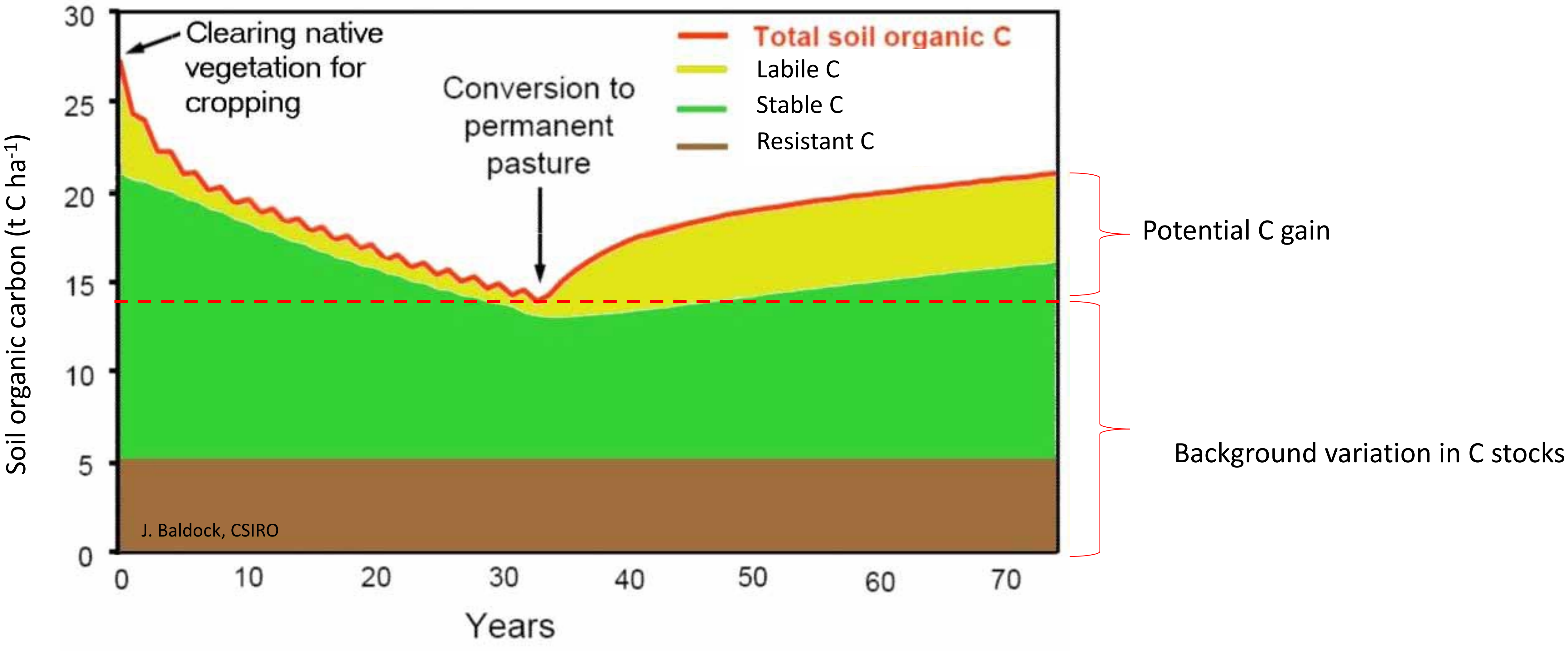
Conventional soil sampling (TOC) - >30% seasonal variation

Stable soil fraction

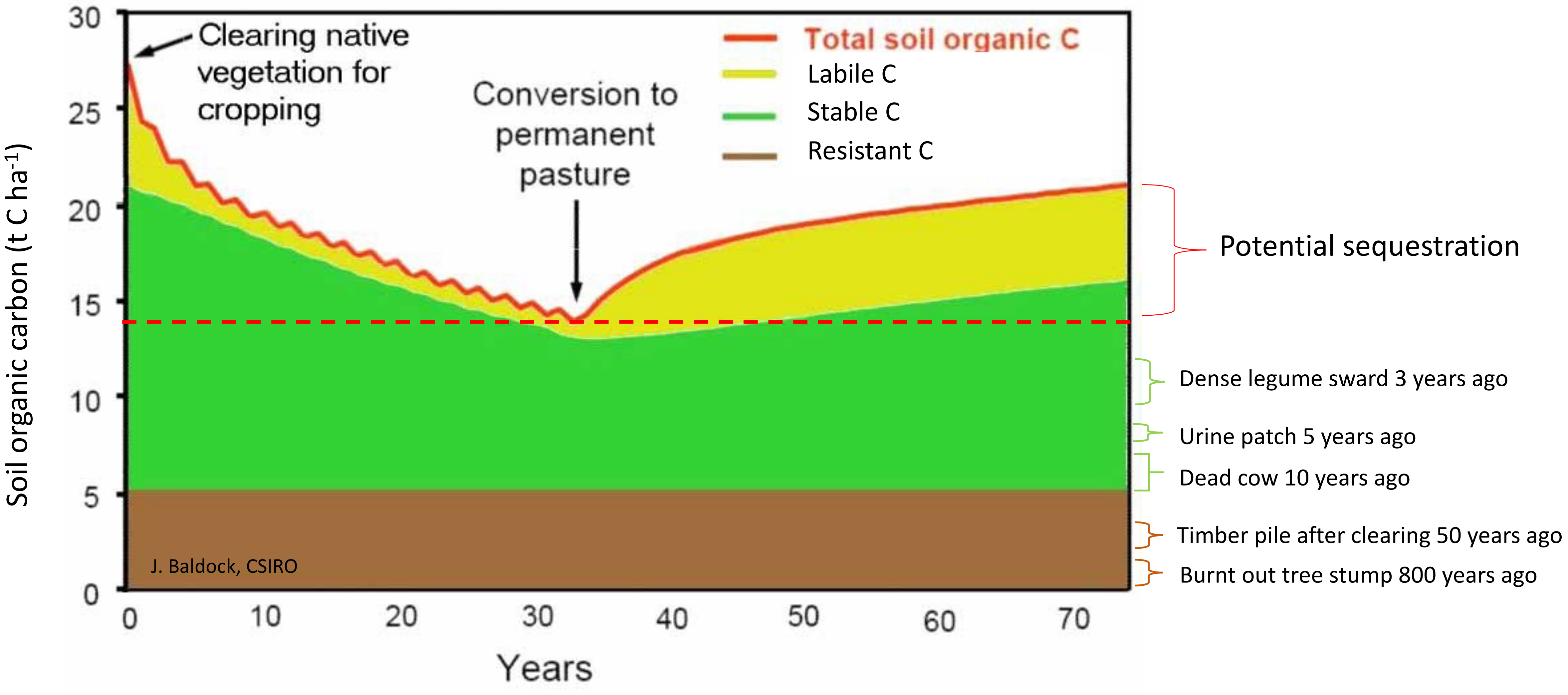
Keeping carbon?

Pasture dieback 2021

Measuring carbon: Stocks vs flows (profit/loss)



Stocks vs flows (profit/loss)



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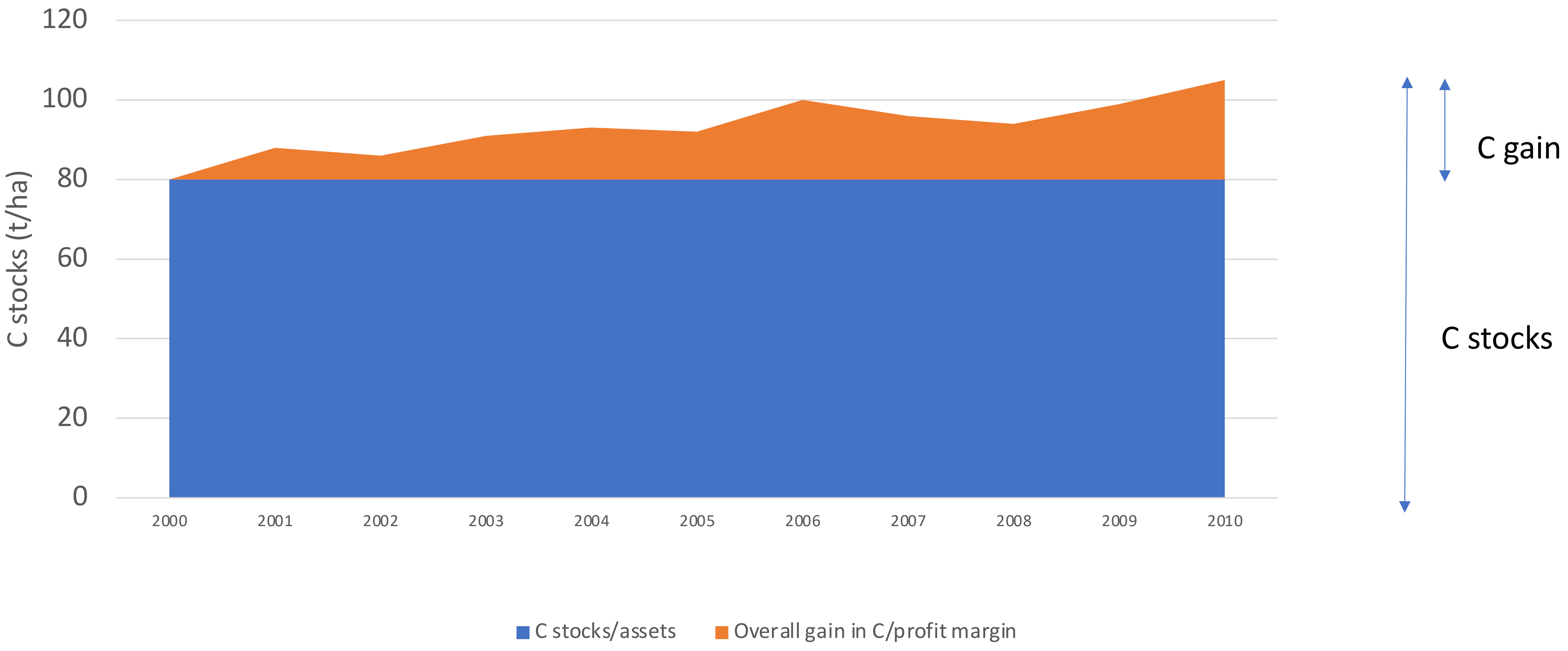

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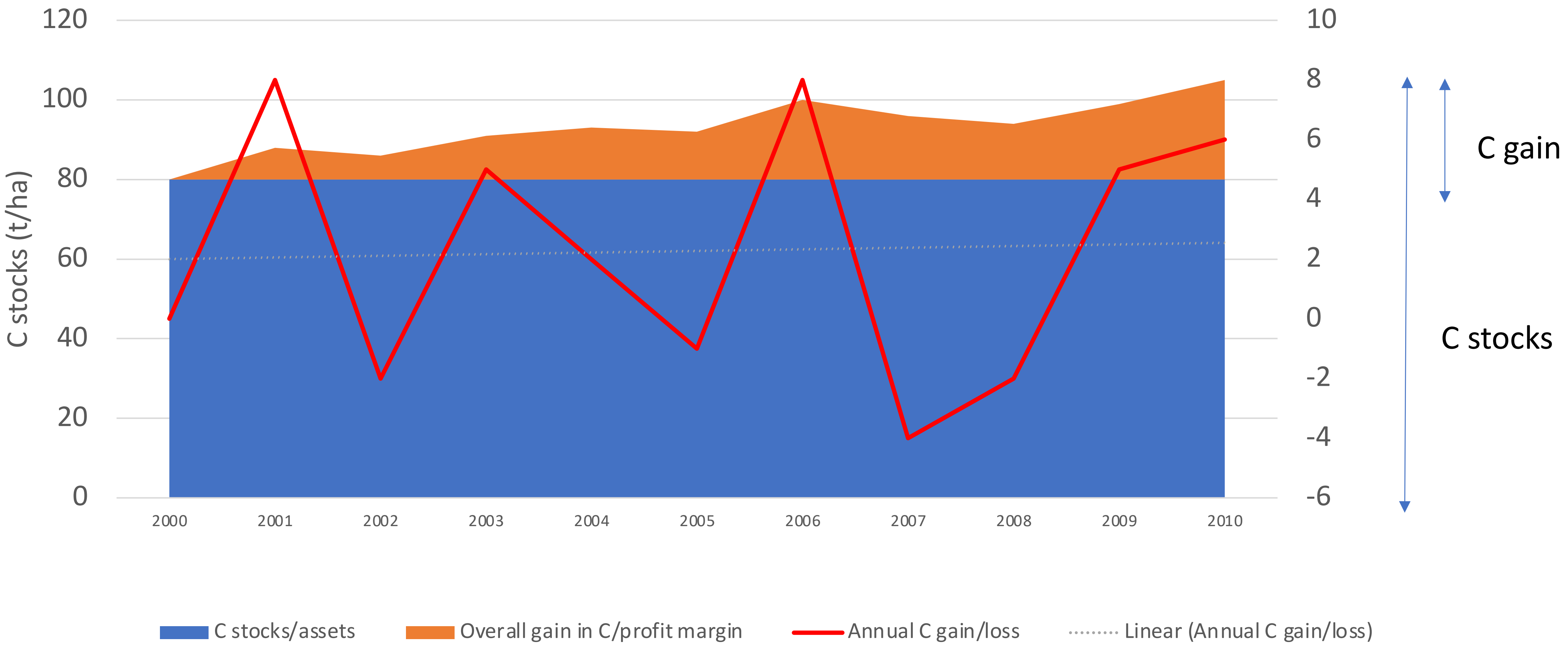
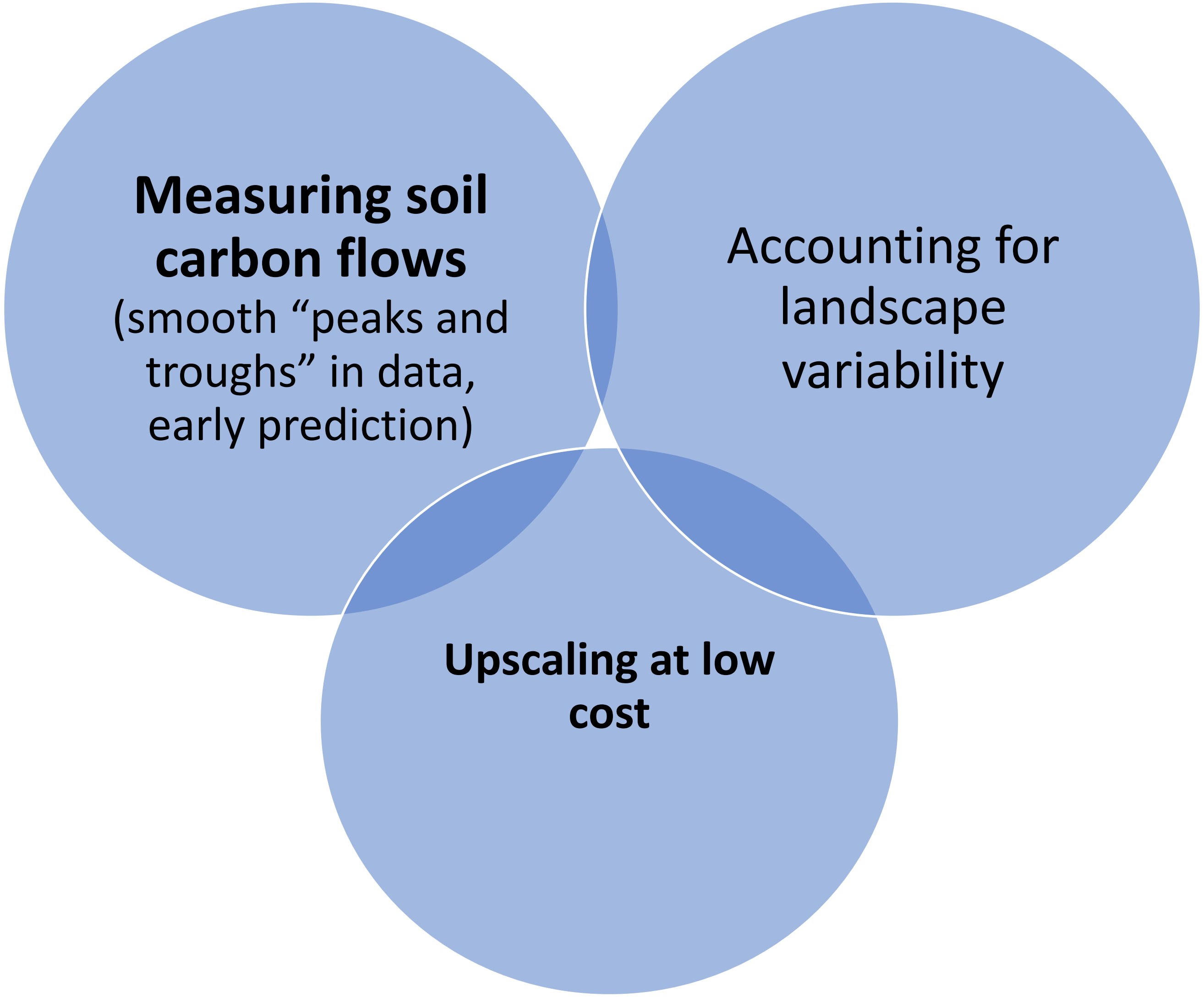


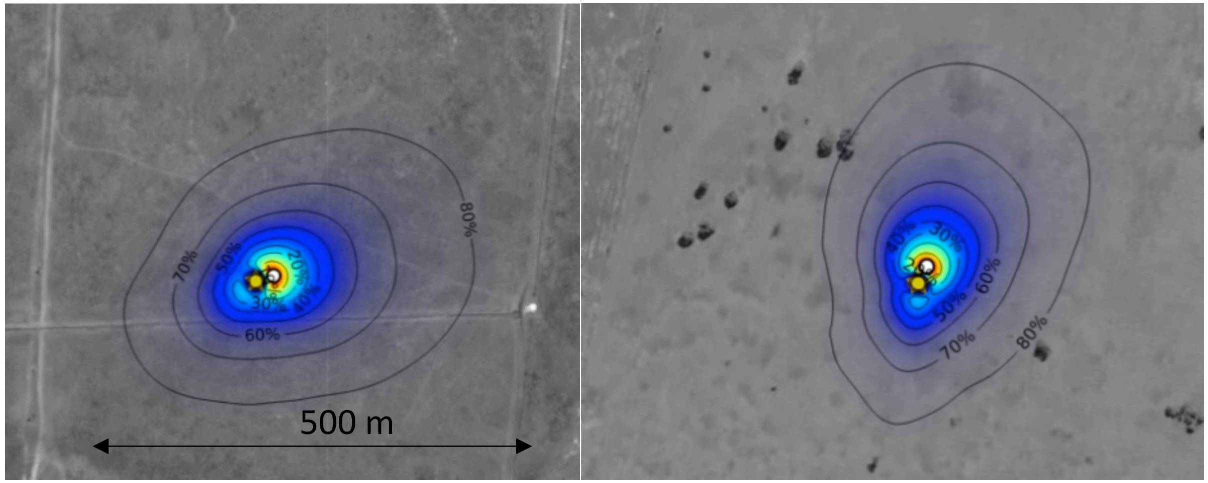
Future directions - 3 tiered approach to measuring SOC



Technology suite:

- Flux towers
- Process models
- Remote sensing

CO_2 Flux towers



Sample area of the flux towers

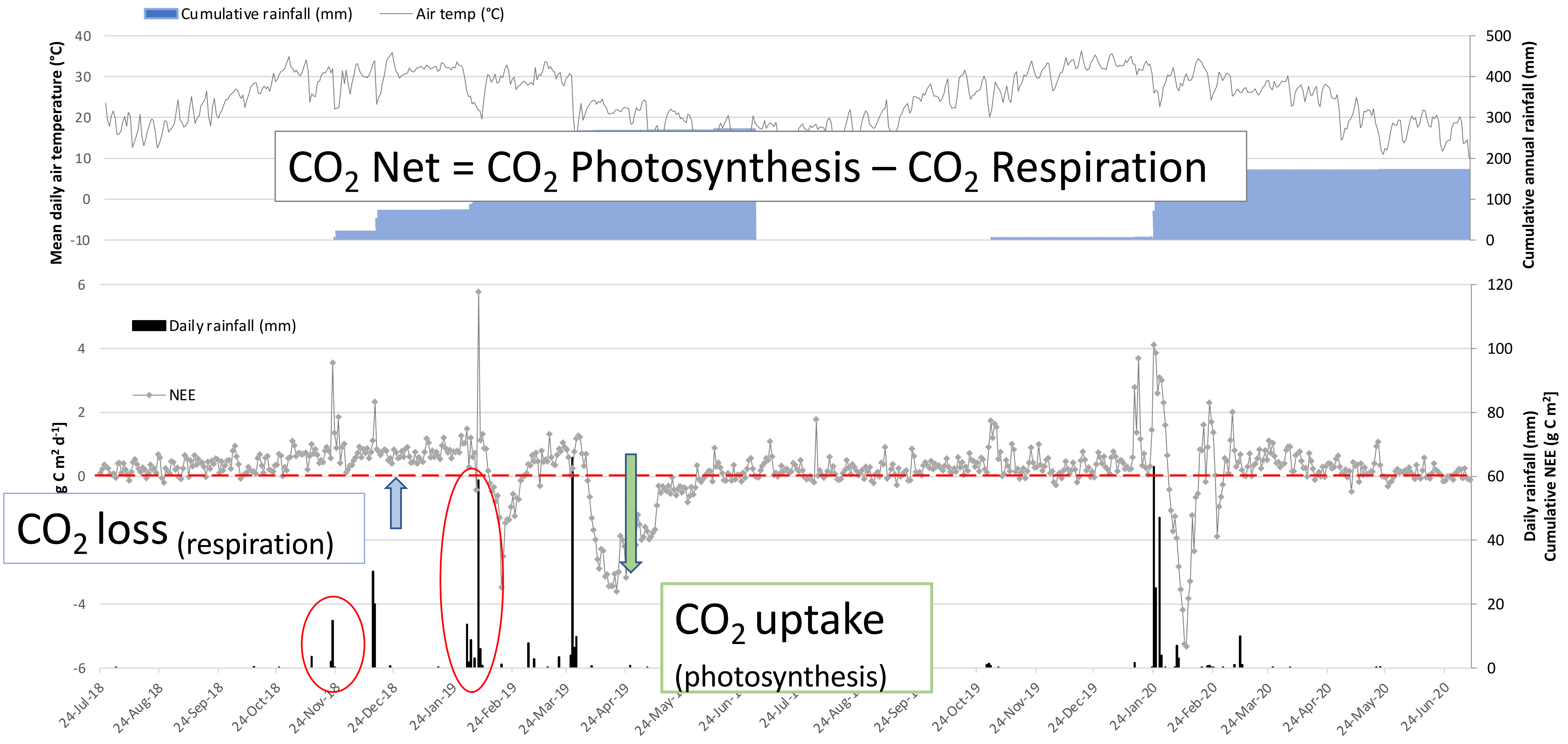
- Measure high-resolution CO_2, water and energy (radiation) fluxes
- Provides
  - accurate actual (not potential) evapotranspiration → Water Use Efficiency
  - Carbon uptake and release
  - Albedo (reflectance) – indicator of pasture palatability and digestibility
  - Combine with time-lapse camera (plant phenology) and soil moisture probes
- Integrate over large areas (10-50 ha)
- Reliable, robust, remote, low maintenance and cost (relative)

Flux tower at Goondiwindi

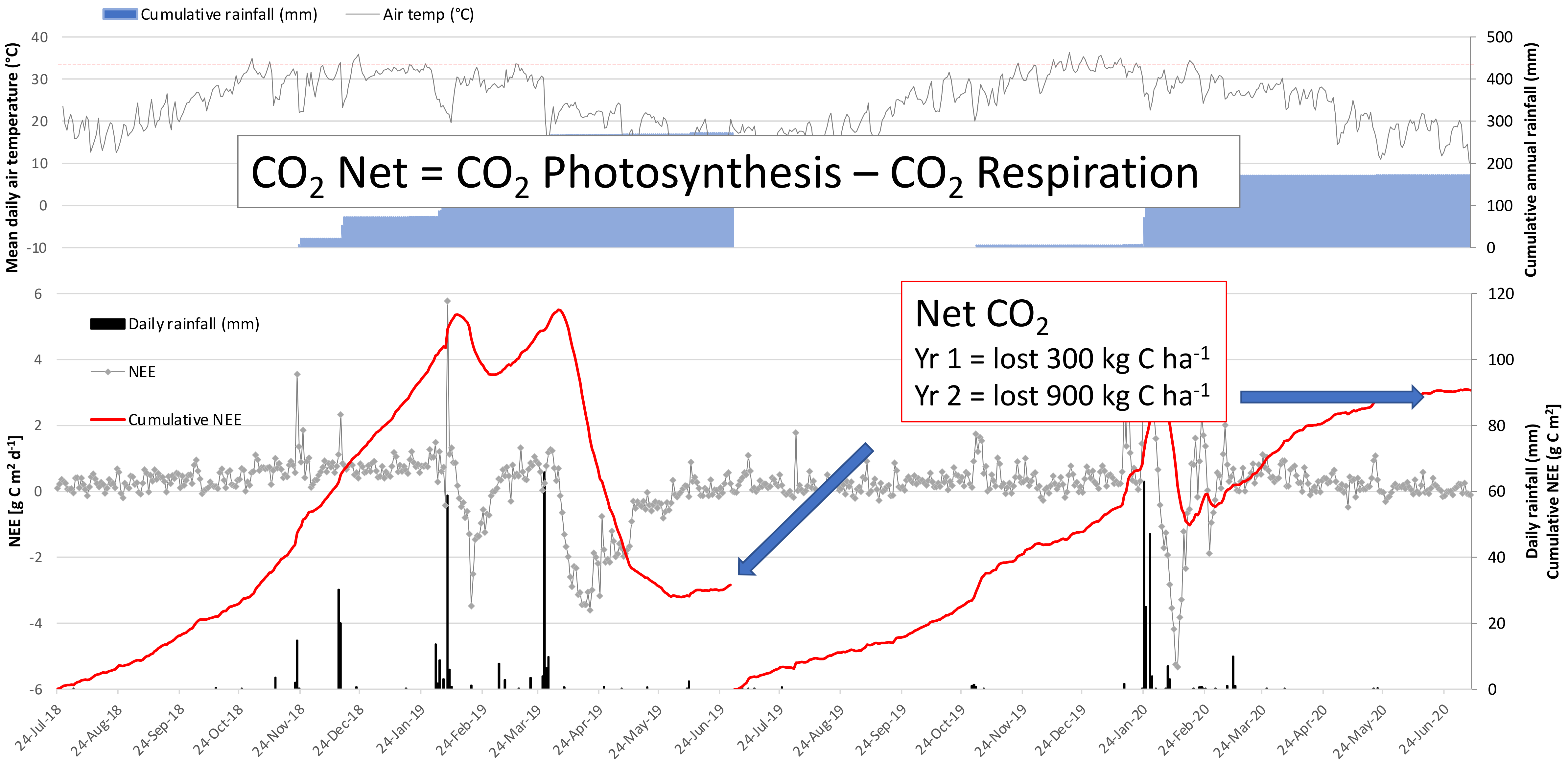
Australian Flux Networks

TERN
OzFlux
Land-Atmosphere Observatory

Flux towers: Climate and Carbon at Longreach

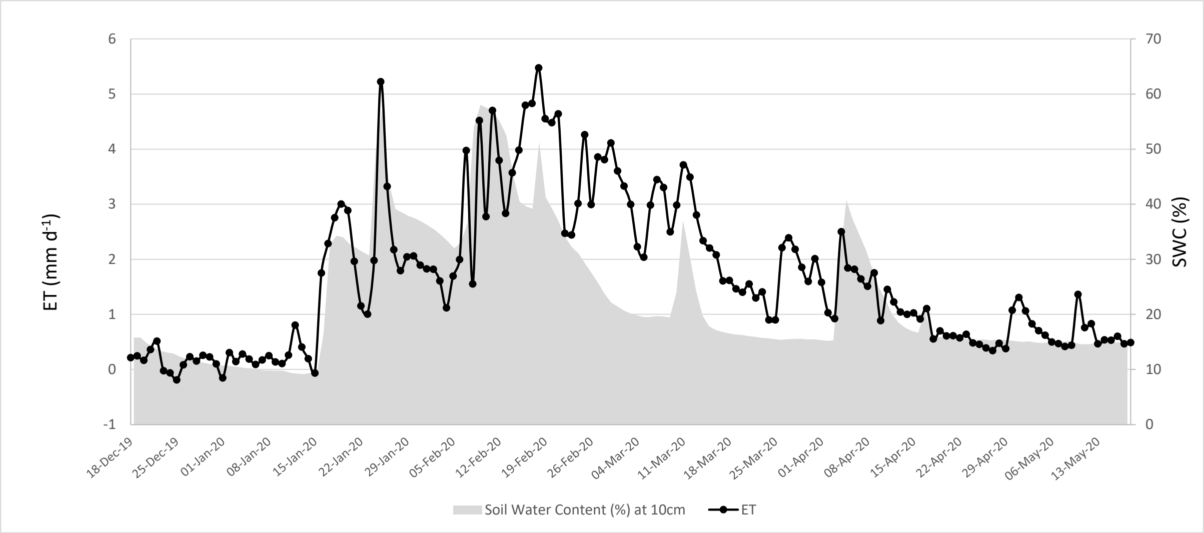


Flux towers: Climate and Carbon at Longreach

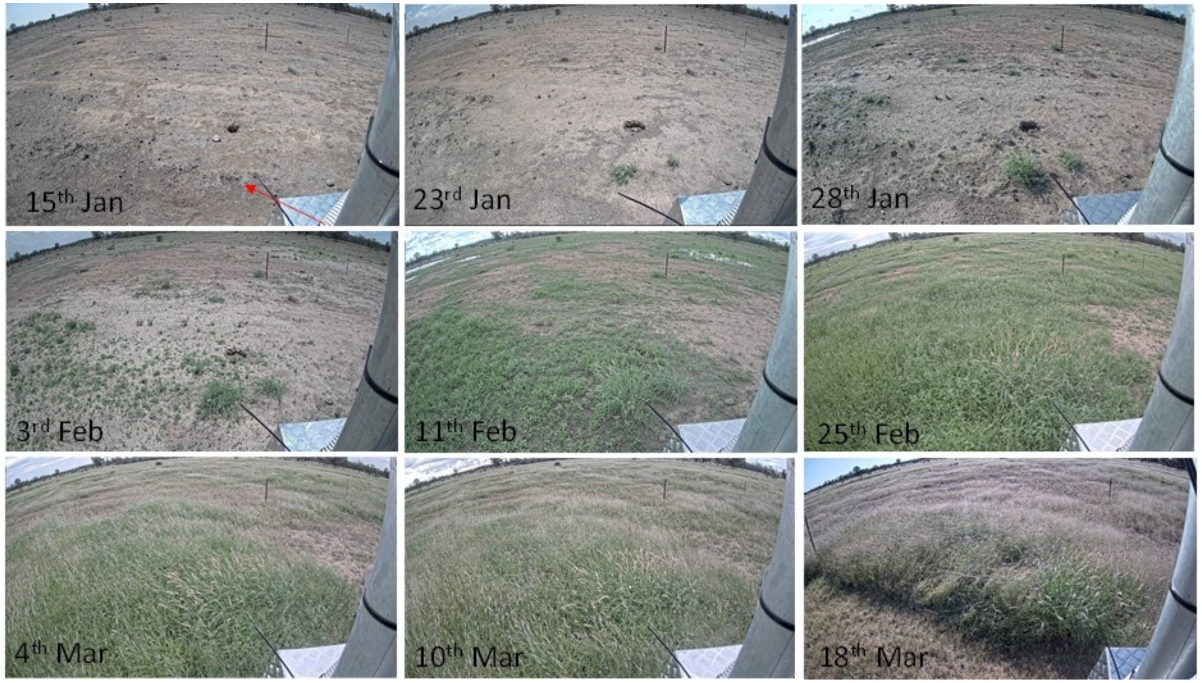


Flux towers: Understanding of *how* we sequester soil carbon

- Combine with management and pasture growth information to understand sequestration mechanisms – i.e. reduced water-use efficiency from overgrazing



https://www.youtube.com/watch?v=C-5bBPVJ-1k&feature=youtu.be

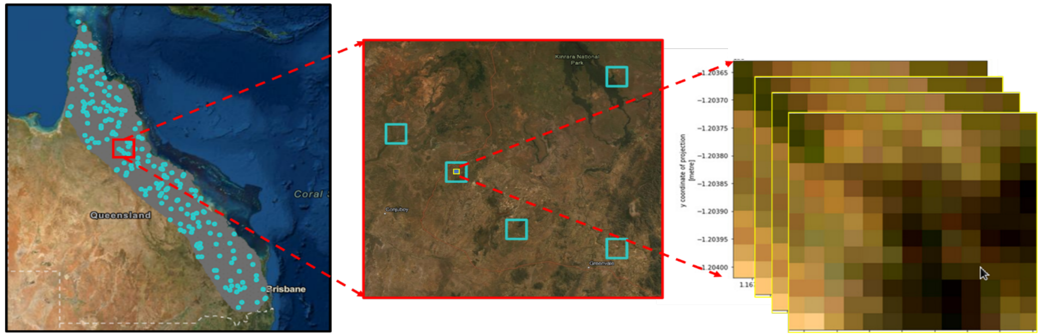


Phenocam time-lapse images of pasture response to rain from overgrazed paddock at Goondiwindi. 19 mm of rain fell on the 16th January, with an additional 210 mm falling over the remainder of the displayed period. Red arrow highlights the surviving (just) Buffel tussock, remaining (Qld Bluegrass) germinated from seed.

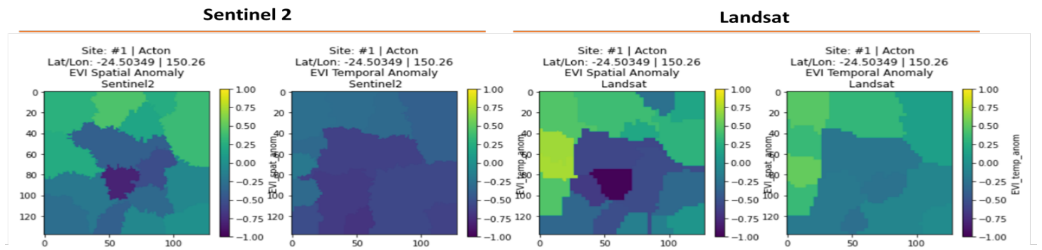
The tussock was able to respond substantially faster to the rainfall, reaching flowering before the Bluegrass had established full ground cover (11th Feb). Over the same period 60 mm of evapotranspiration was measured (figure on left), equating to ~40% of total seasonal rainfall being lost before any pasture production could occur.

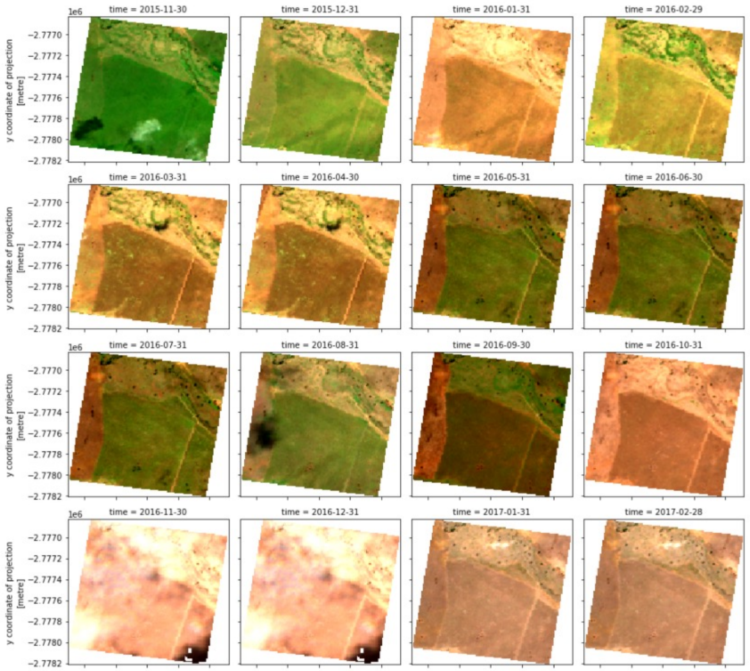
Remote sensing: *Upscaling* from paddock scale to property

Step 1: model calibration at flux tower sites



Step 2: New property broken into precision CEA's

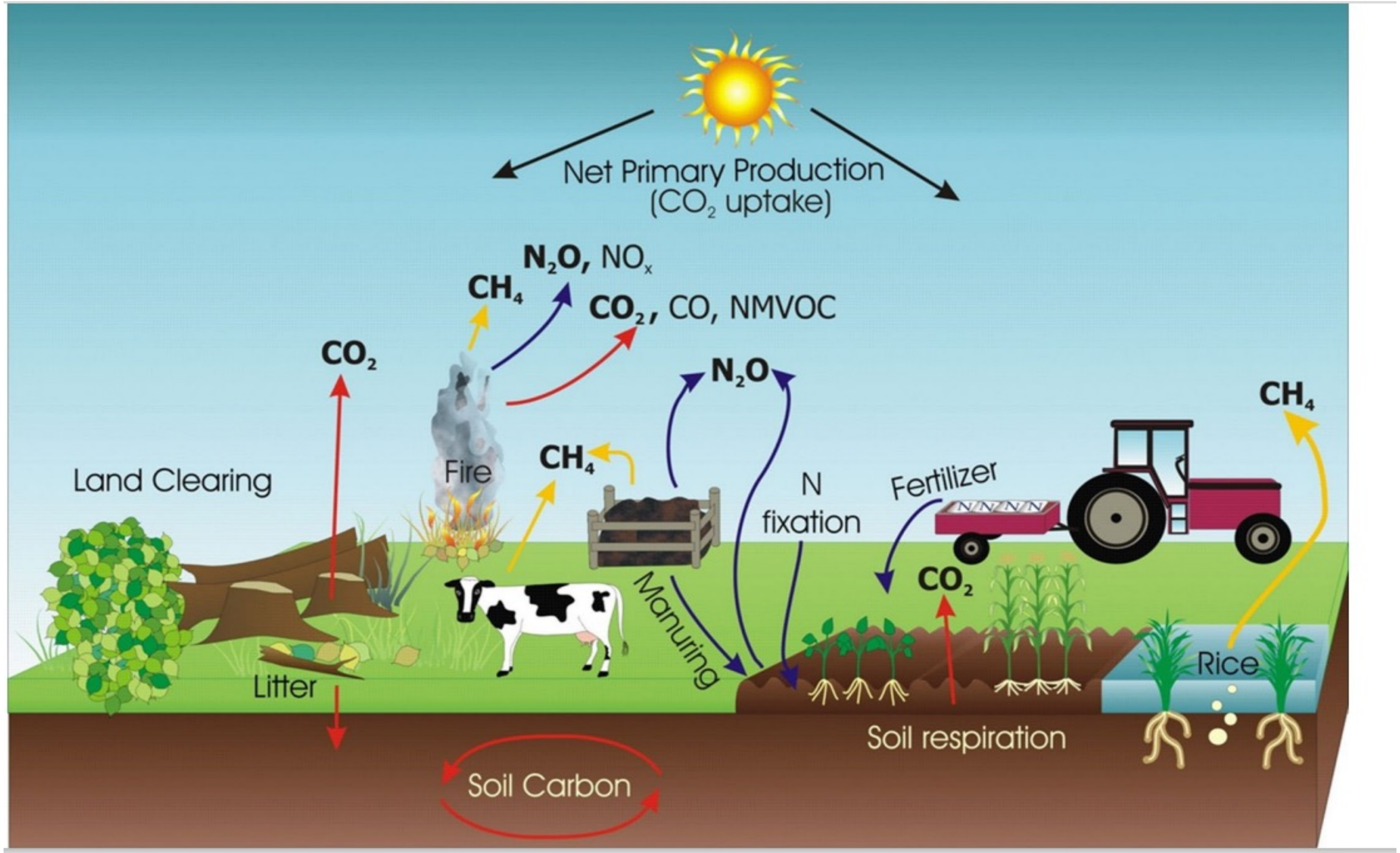




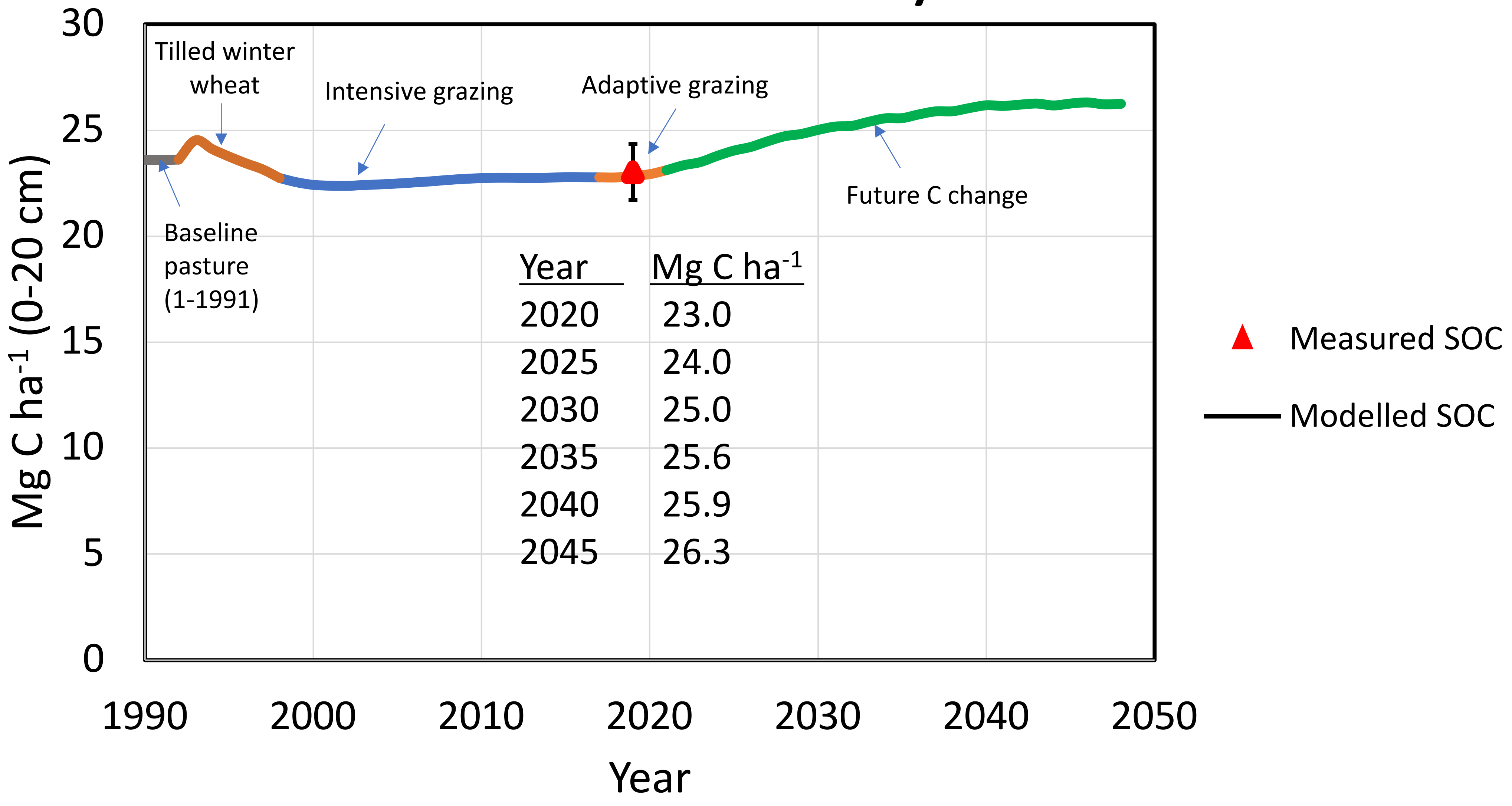
Step 3 – model updated with monthly biomass quantity and quality per CEA

Step 4 – Short-term validation with portable flux towers

Modelling: Accounting for *trade-offs*

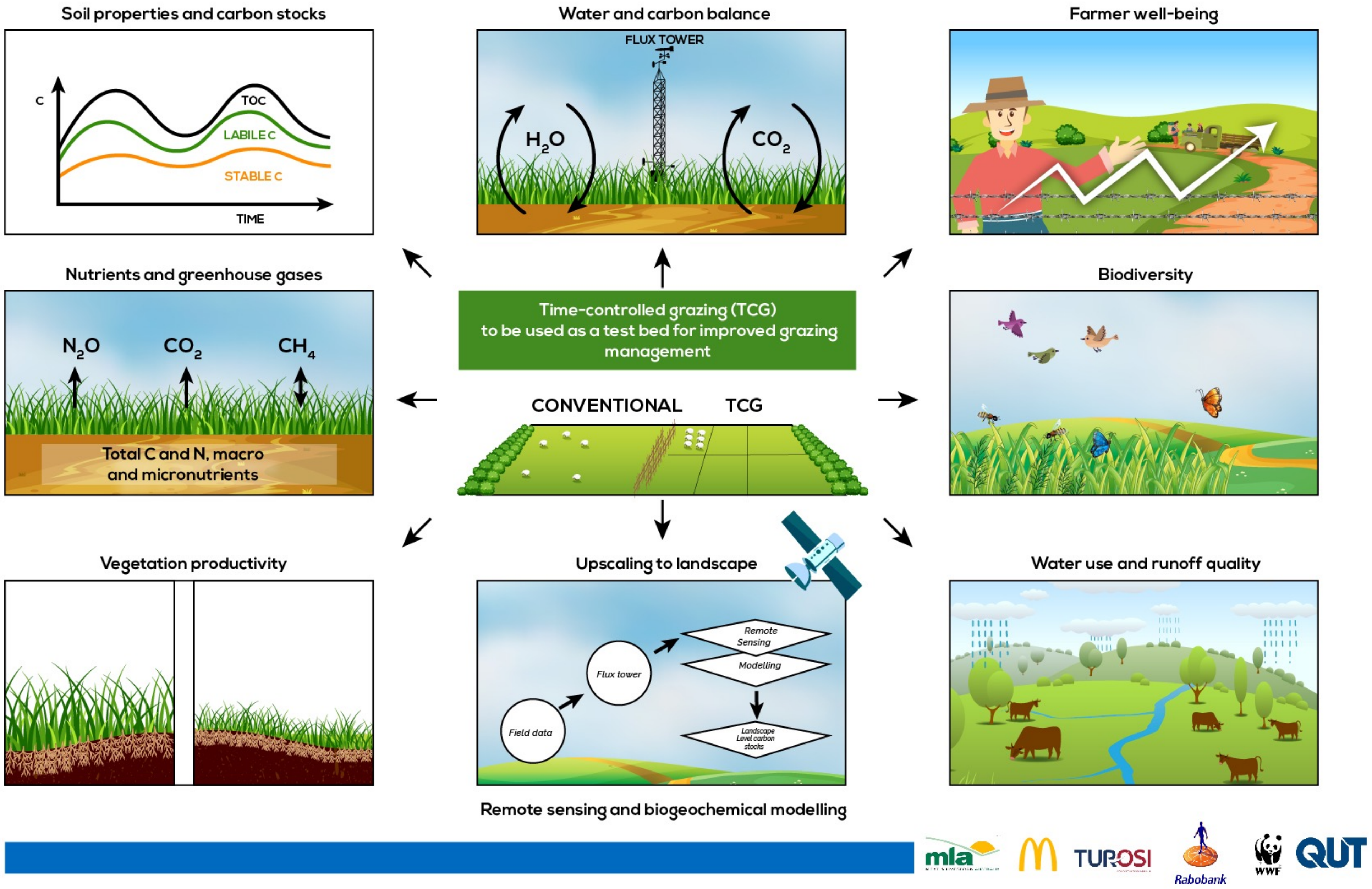


Flux Site - Soil Carbon Dynamics



- More flux sites are needed for calibration to capture the variability among landscapes.
- Models can be used anywhere once calibrated with multiple flux sites.

Project aim: To determine if innovative grazing management can increase soil carbon stocks and the sustainability of Australian beef



Summary

- Current knowledge – YES opportunities but future focus?
- Drivers of sequestration – limiting factor
- Barriers to soil carbon measurement – spatial variability
- Barriers to soil carbon measurement – temporal variability
- Measuring carbon: Stocks vs flows (profit/loss)
- Model Measure method
  - Flux towers
  - Remote sensing
  - Modelling