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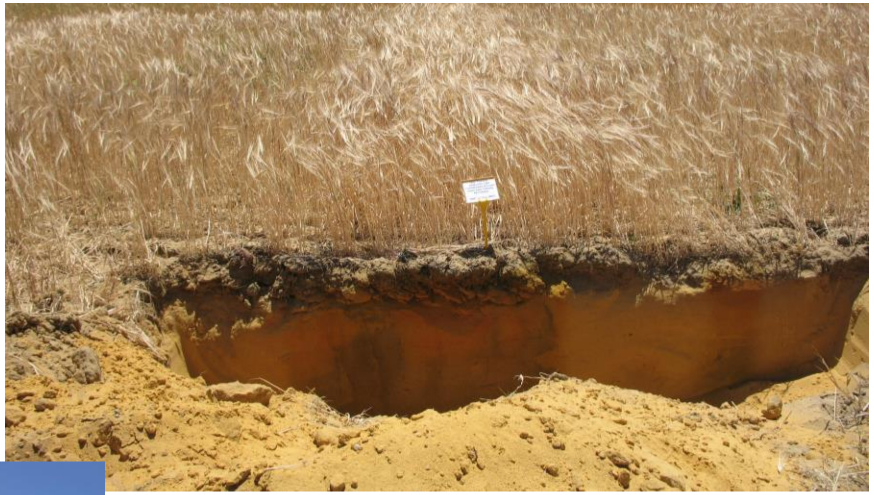
Soil organic carbon stock changes in Western Australian (WA) dryland cropping



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Carbon Accounting: The concept

Farm emissions sources (greenhouse gas emissions)

CH_4
Enteric methane & manure

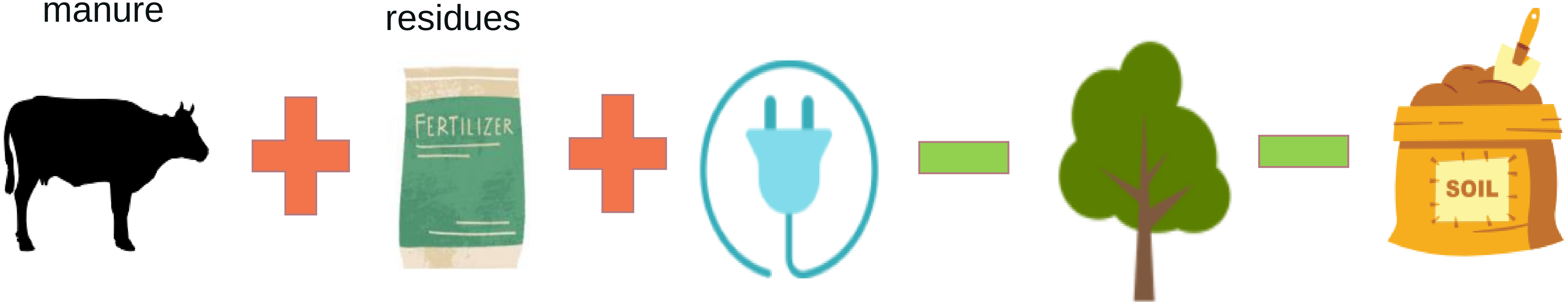
N_2O
Fertiliser, urine and dung, crop residues

CO_2
Energy, lime, urea

Annual change in farm carbon stocks (new sequestration)

Trees

Soil



Source: Agriculture Victoria May 2022

Slide credit: Richard Eckard

Carbon Accounting Tools

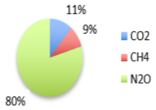
- Greenhouse Gas emissions
  - Sheep & Beef (SB-GAF)
  - Cropping (G-GAF)
  - Dairy (D-GAF/DGAS)
  - Feedlot, Pork, Poultry
  - Buffalo, Deer, Goats
  - Sugar, Cotton, Horticulture

Grains Greenhouse Accounting Tool

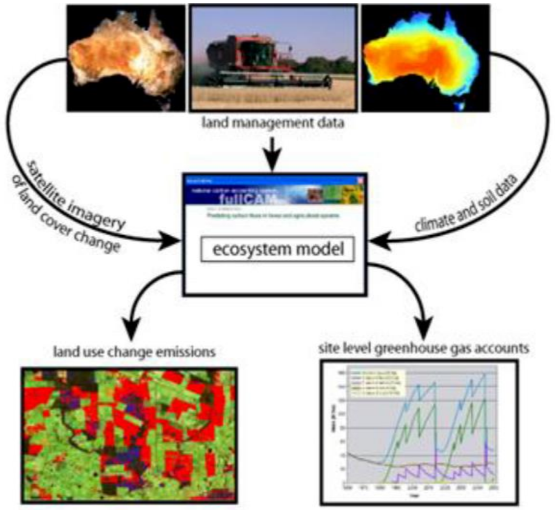
Crop	Wheat	Barley	Pulses	Oilseeds	
Outputs	t CO_2e/farm	t CO_2e/farm	t CO_2e/farm	t CO_2e/farm	total t CO2e/farm
Scope 1 Emissions (on-farm)					
CO_2 - Fuel					7.63
CO_2 - Lime	0.20	0.00	0.20	0.00	0.40
CO_2 - Urea	36.67	0.00	0.00	0.00	36.67
CH_4 - Field burning	99.35	0.00	0.00	0.00	99.35
CH_4 - Fuel					0.02
N_2O - Fertiliser	49.97	35.40	0.00	226.54	311.91
N_2O - Atmospheric Deposition	5.50	3.89	0.00	24.92	34.31
N_2O - Field Burning	36.09	0.00	0.00	0.00	36.09
N_2O - Crop Residues	120.05	18.88	57.92	196.97	393.83
N_2O - Leaching and Runoff	0.00	7.10	15.29	122.36	144.75
N_2O - Fuel					0.05
Scope 1 Total	**348**	**65**	**73**	**571**	**1,065**
Scope 2 Emissions (off-farm)					
Electricity					3.24
Scope 2 Total					**3.24**
Scope 3 Emissions (pre-farm)					
Fertiliser (urea + Superphosphate)					90.83
Herbicides/pesticides					0.29
Electricity					0.36
Fuel					0.40
Lime					0.01
Scope 3 Total					**92**
Carbon Sequestration					
Carbon sequestration in trees	-16.40	-6.84	-1.37	-2.73	-27.34
Net Farm Emissions	**335**	**58**	**72**	**568**	**1,133**
Emissions intensity	**0.11**	**0.02**	**0.04**	**0.19**	**t CO2-e/t crop**

Summary	t CO2e/farm
CO_2	132
CH_4	103
N_2O	921

Breakdown of Scope 1 GHGs



- Carbon stocks and fluxes
  - Direct measurement and/ or
  - An approved model

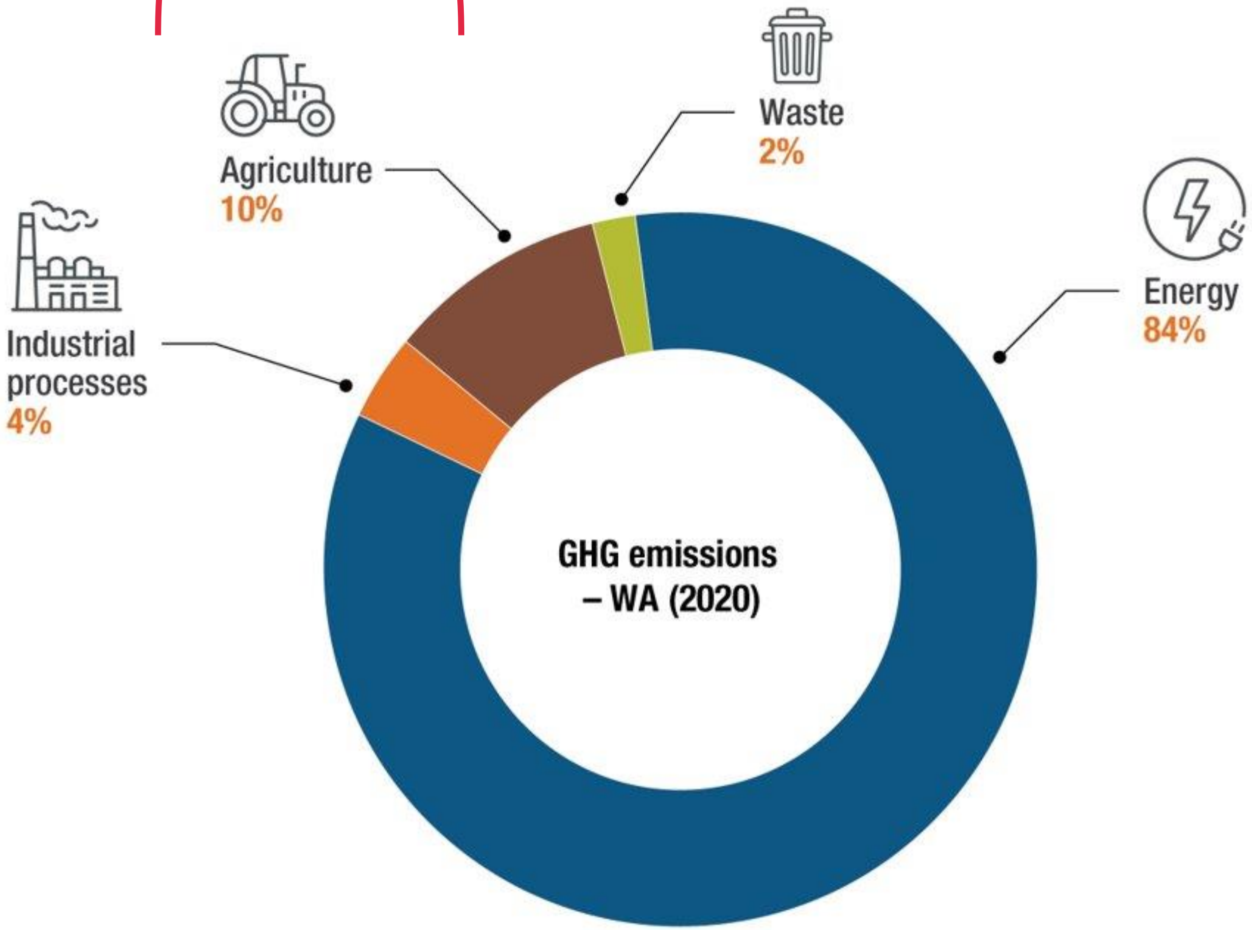


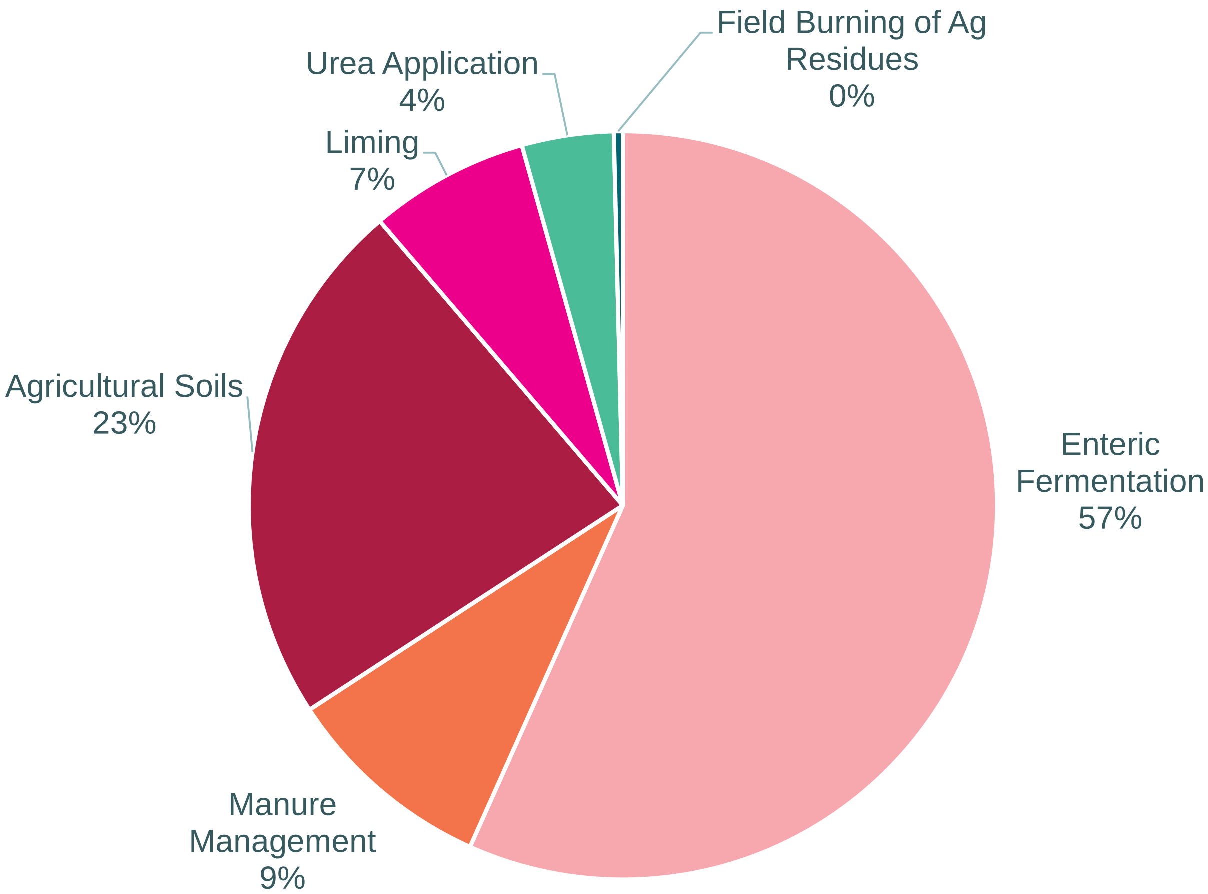
- Greenhouse accounting frameworks
  - Align with Australian National Greenhouse Gas Inventory method – predicts farm GGE
  - Includes scope 1 (e.g. methane, nitrous oxide), Scope 2 (e.g. electricity) and Scope 3(pre-farm) embedded emissions (e.g. urea manufacture)

Slide credit: Richard Eckard

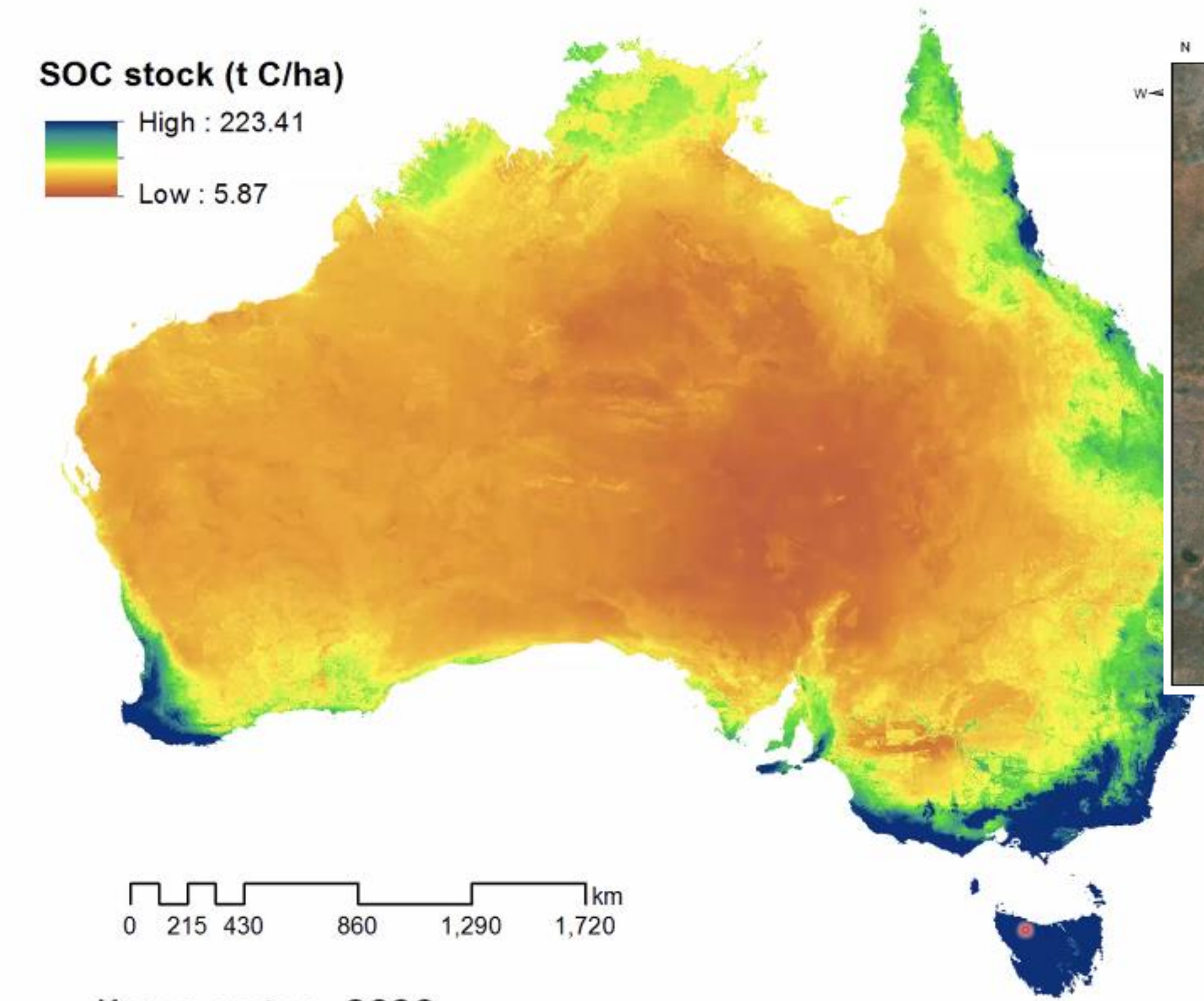
www.piccc.org.au/Tools

WA GHG emissions by national inventory

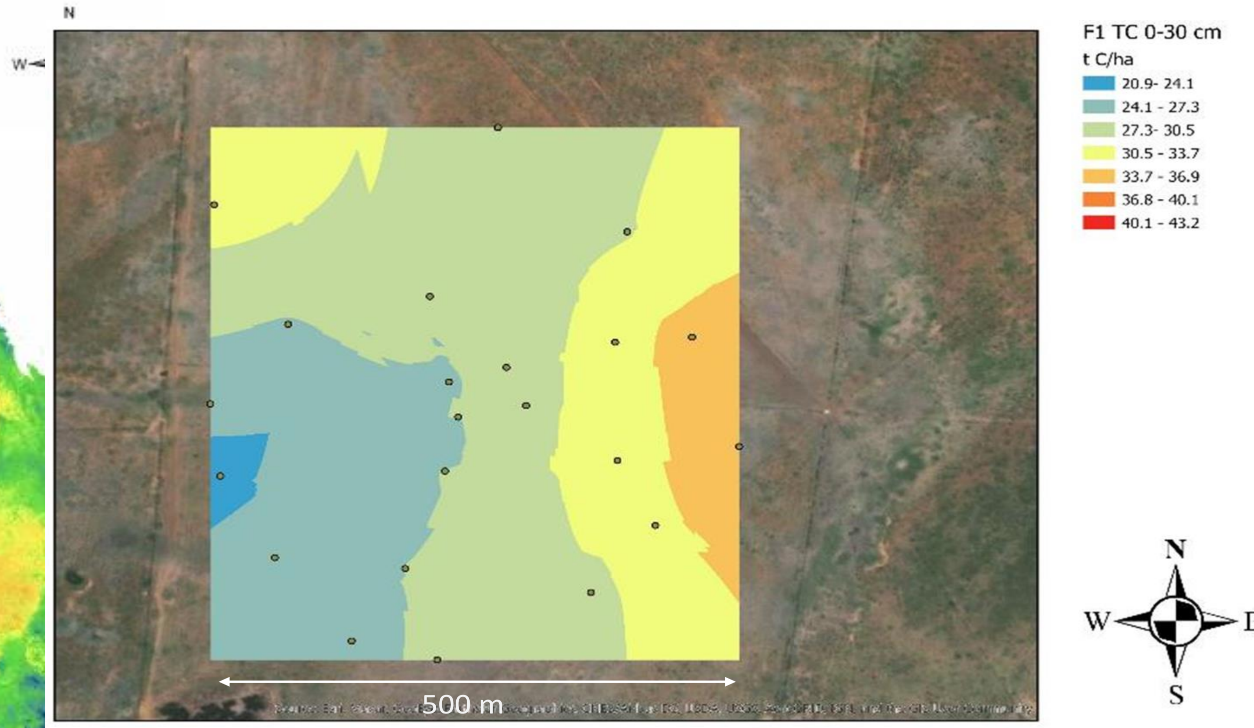




Soil Organic Carbon across Australia



Karunaratne, 2022

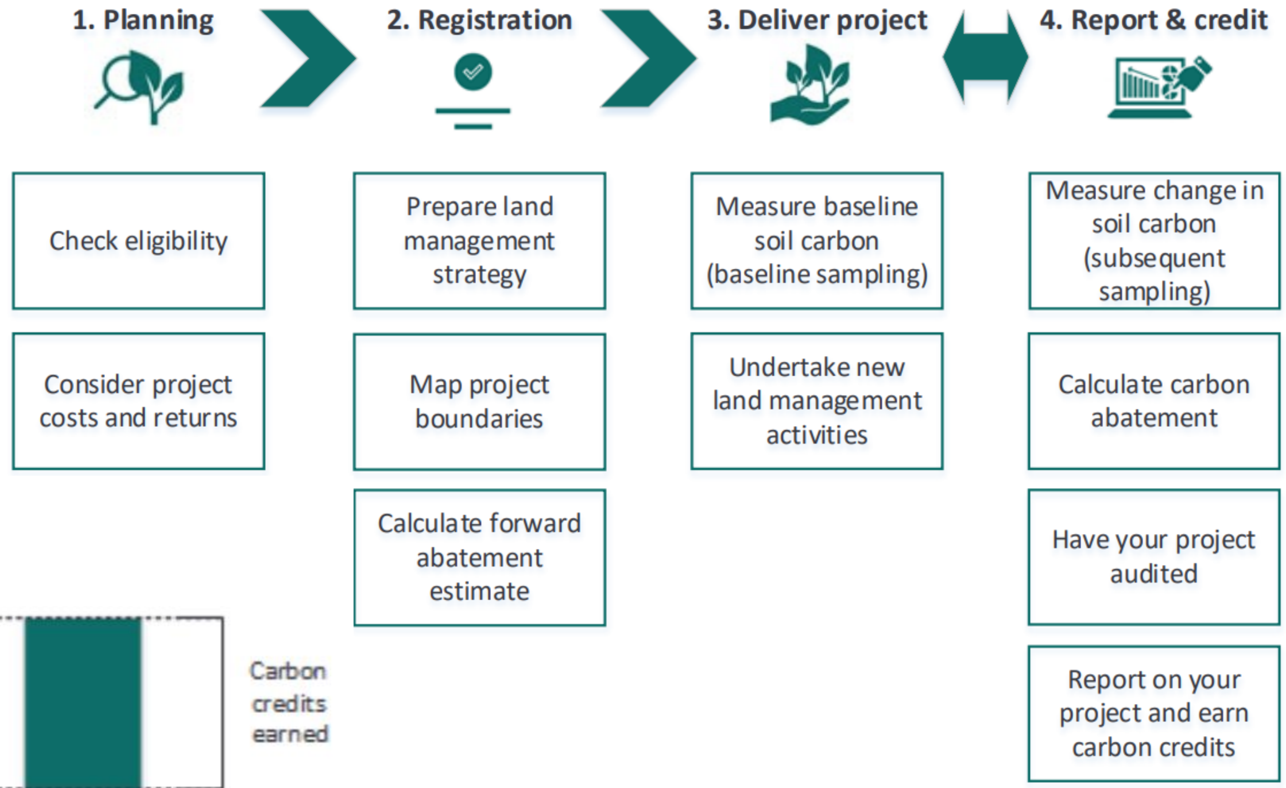


Source: David Rowlings

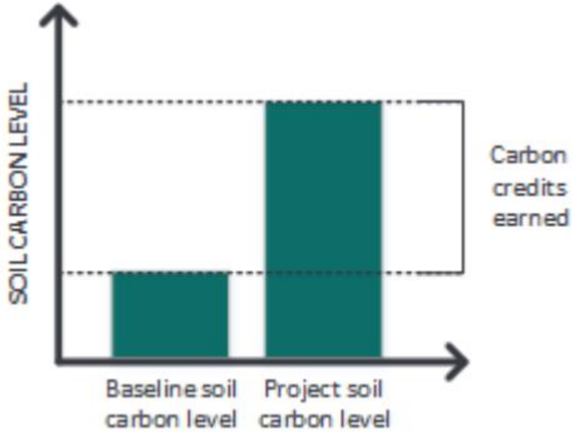
Slide credit: Richard Eckard

Sequestration: Soil Carbon – Offsets

- Two ERF methods
  - Direct Measurement
    - Measure before and after
    - Sampling Protocol – approved by CER
  - Estimated using defaults
    - Lookup table from FullCam
  - Measure model measure



- Crediting period 25 years



- Permanence period
  - 25 or 100 years
  - 25% or 5% ACCU reduction applied

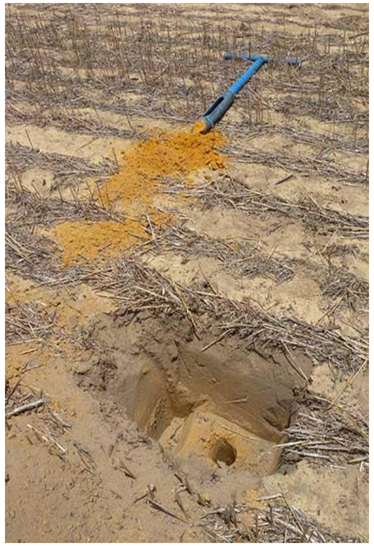
Slide credit: Richard Eckard
piccc.org.au

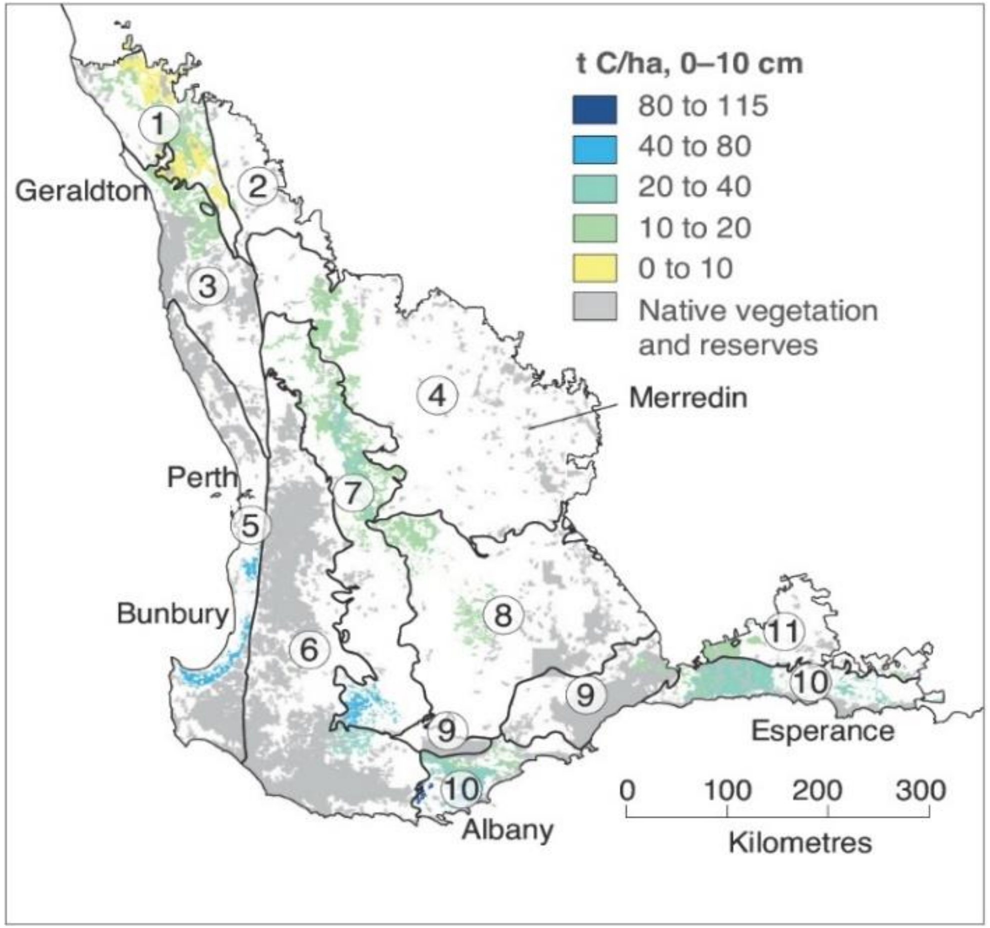
https://www.industry.gov.au/sites/default/files/2020-07/supplement-soil-carbon-agricultural-systems.pdf

WA Soil Carbon Stock Assessment

"Under current management strategies is there any room for movement in carbon storage?"

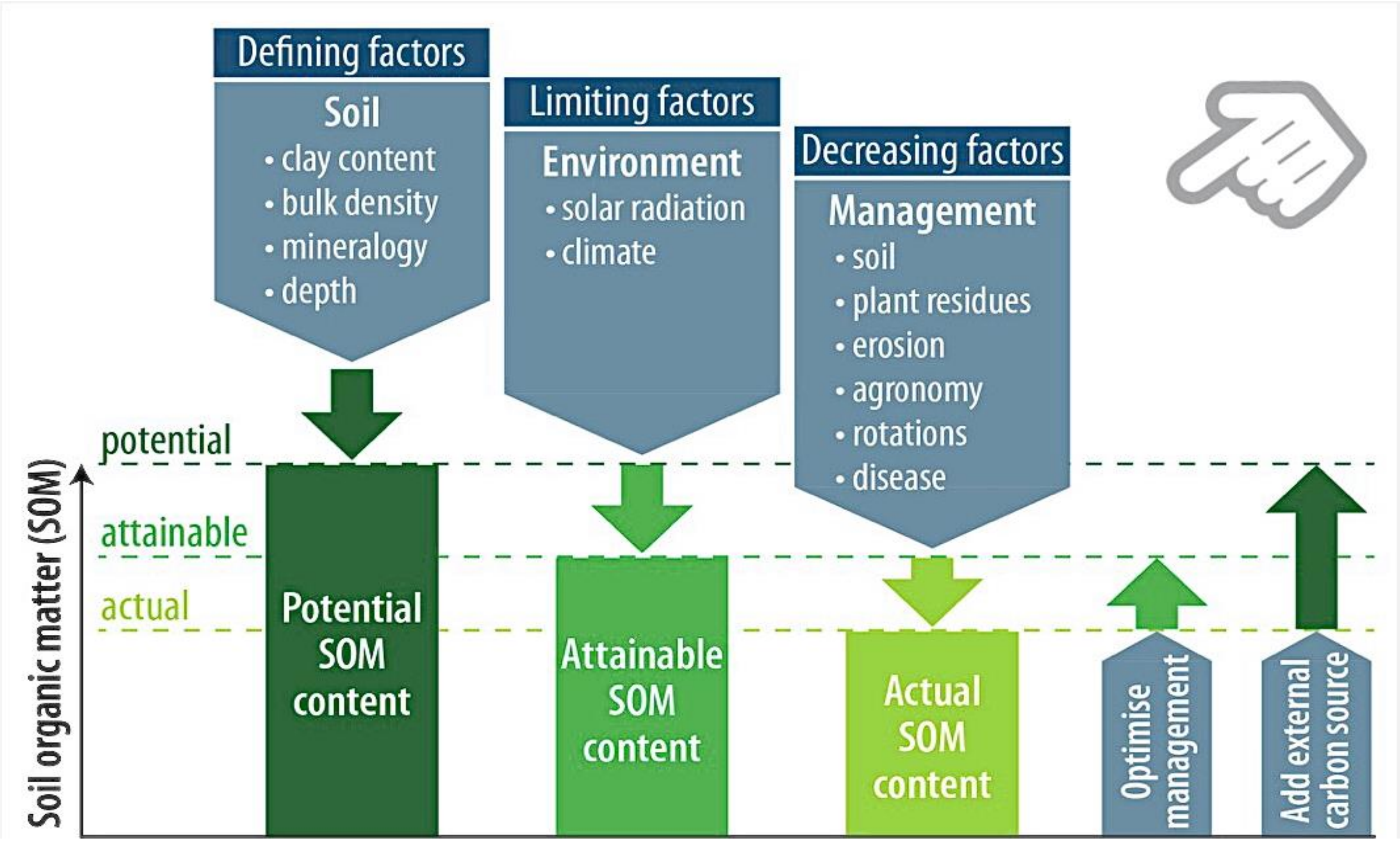
- +1300 sites across Southwest WA
- Seven different systems:
  - Esperance (beef pastures)
  - Young River (cropping and pastures)
  - Kalgan (cropping and pastures)
  - Kojonup (cropping and pastures)
  - Avon (cropping)
  - Geographe (beef and dairy pastures)
  - Mingenew (cropping)
- Target specific soil types (deep sand, sandy duplexes, gravelly duplexes, red loams) and land-uses (n=25).
- Soil variables (0-10, 10-20, 20-30 cm) - C adjusted for equivalent soil mass/stone, climate, management





What impacts soil organic carbon content?

Adapted from Ingram & Fernandez (2001), Agriculture, Ecosystems and Environment 87



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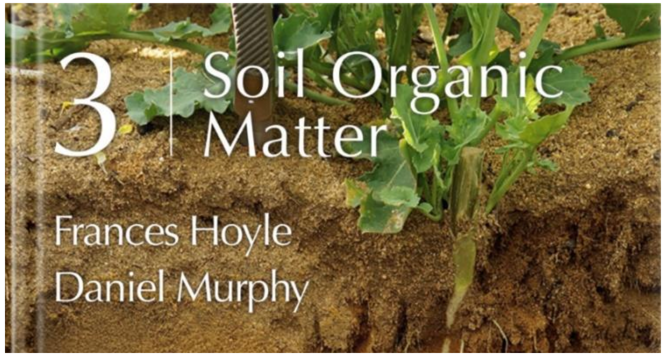
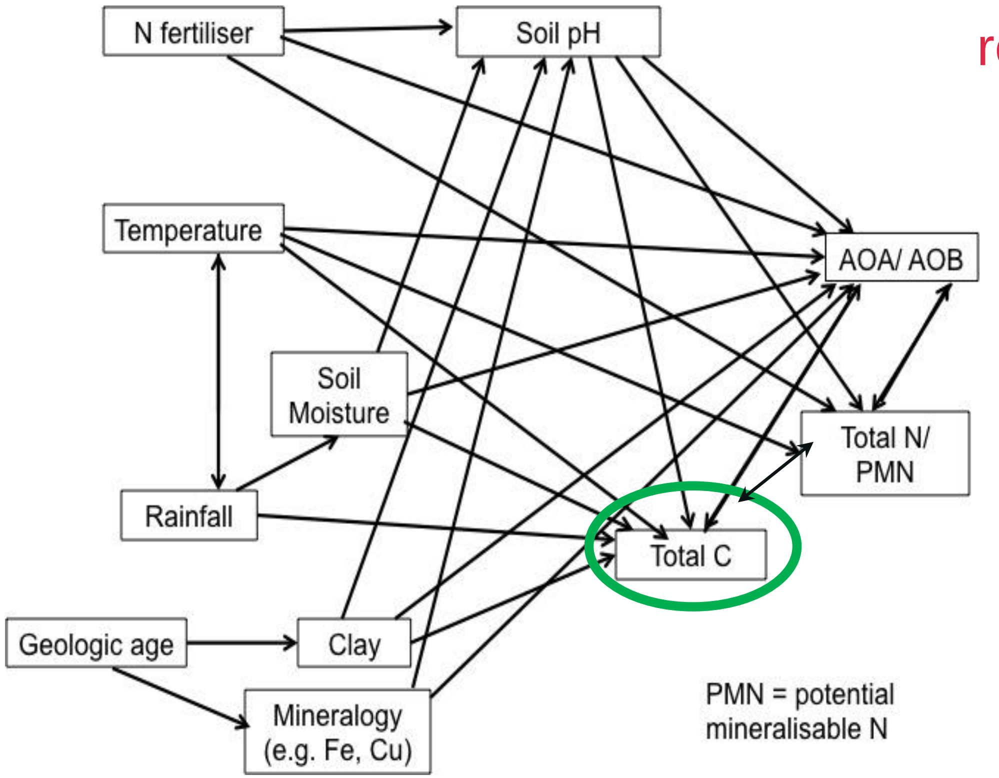
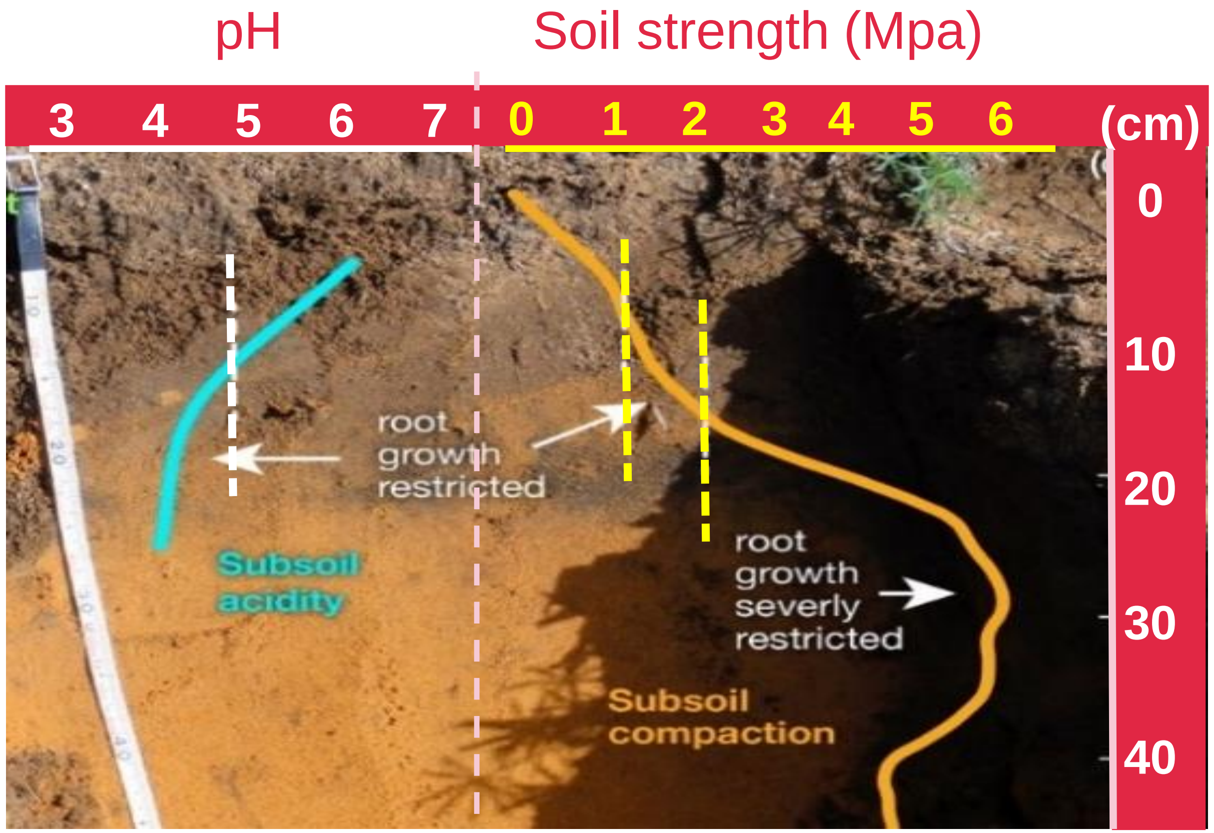


Understanding complexity & management

- Soil properties, environment and management interact
- Focus is to determine how changes in one soil property alter others - derive strategies to manage the risk of negative outcomes

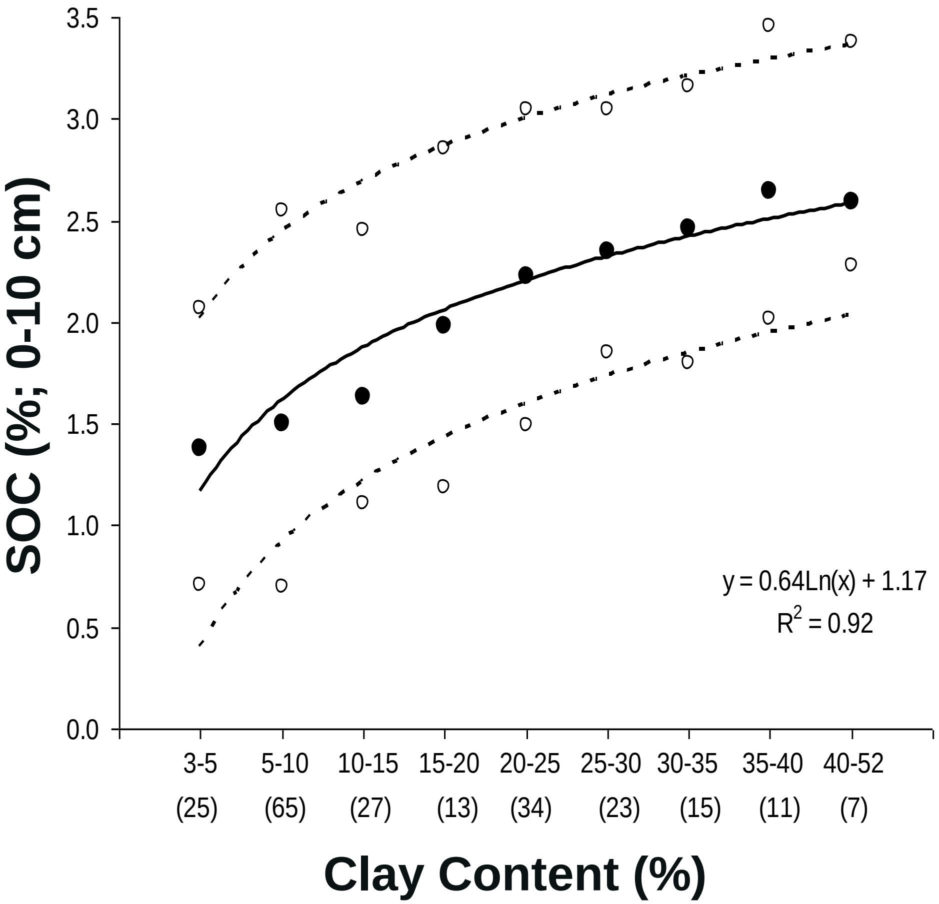


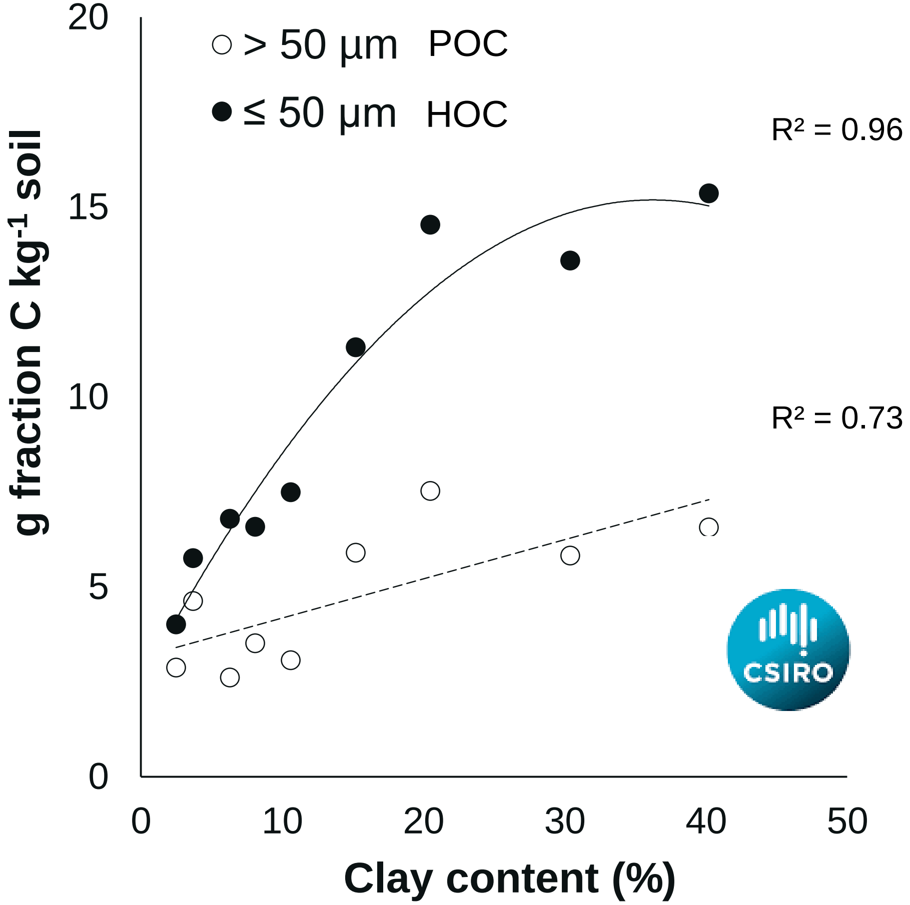
Water repellence 4.3



Clay content defines potential SOC

Influence of clay content on SOC in a 10-hectare area under cereal-legume rotation in WA



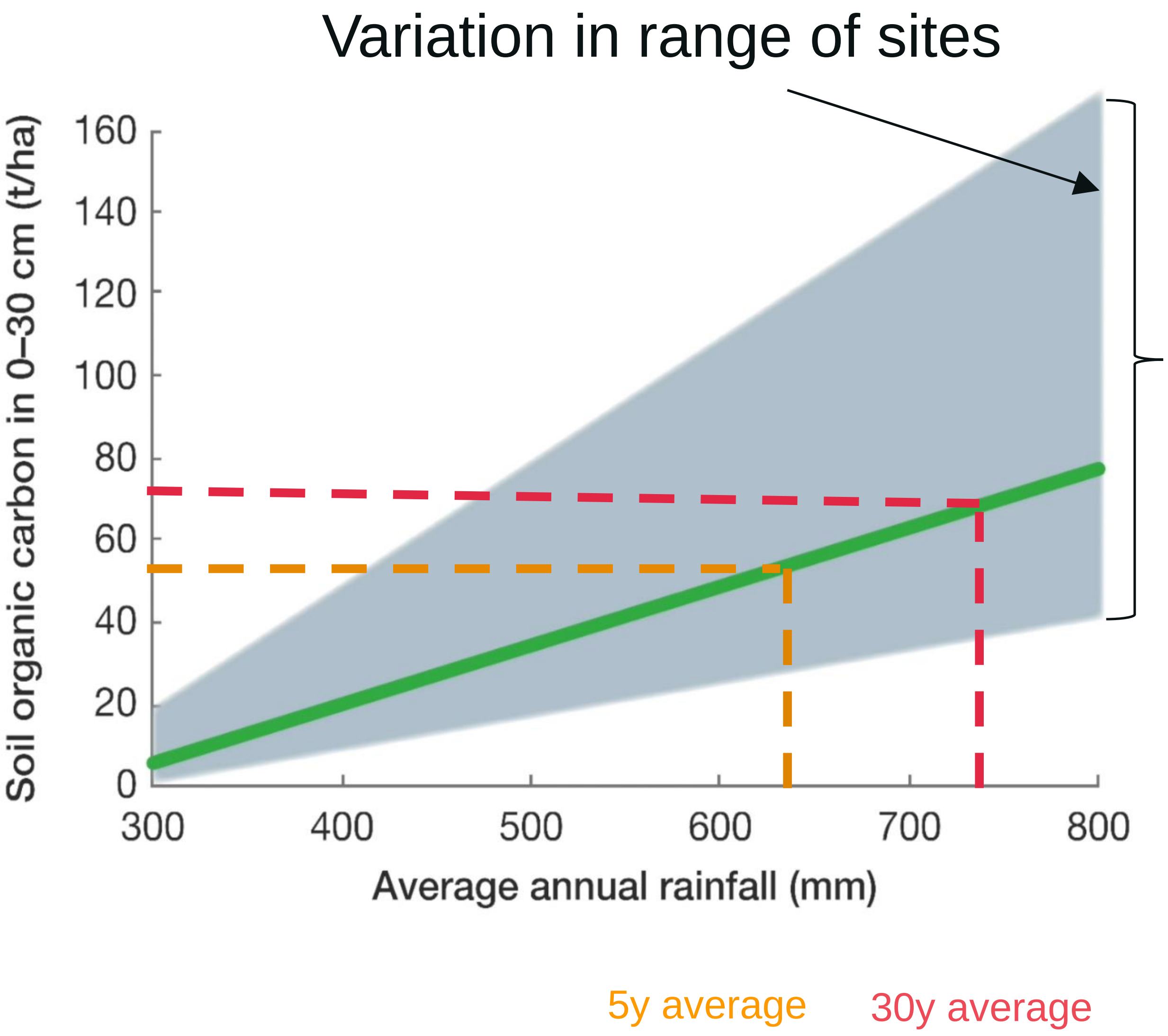


Hoyle FC, Baldock J, Murphy DV (2011). Rainfed Farming Systems

Creamer et al. (2016) Soil Biology & Biochemistry

WA Climate Influence

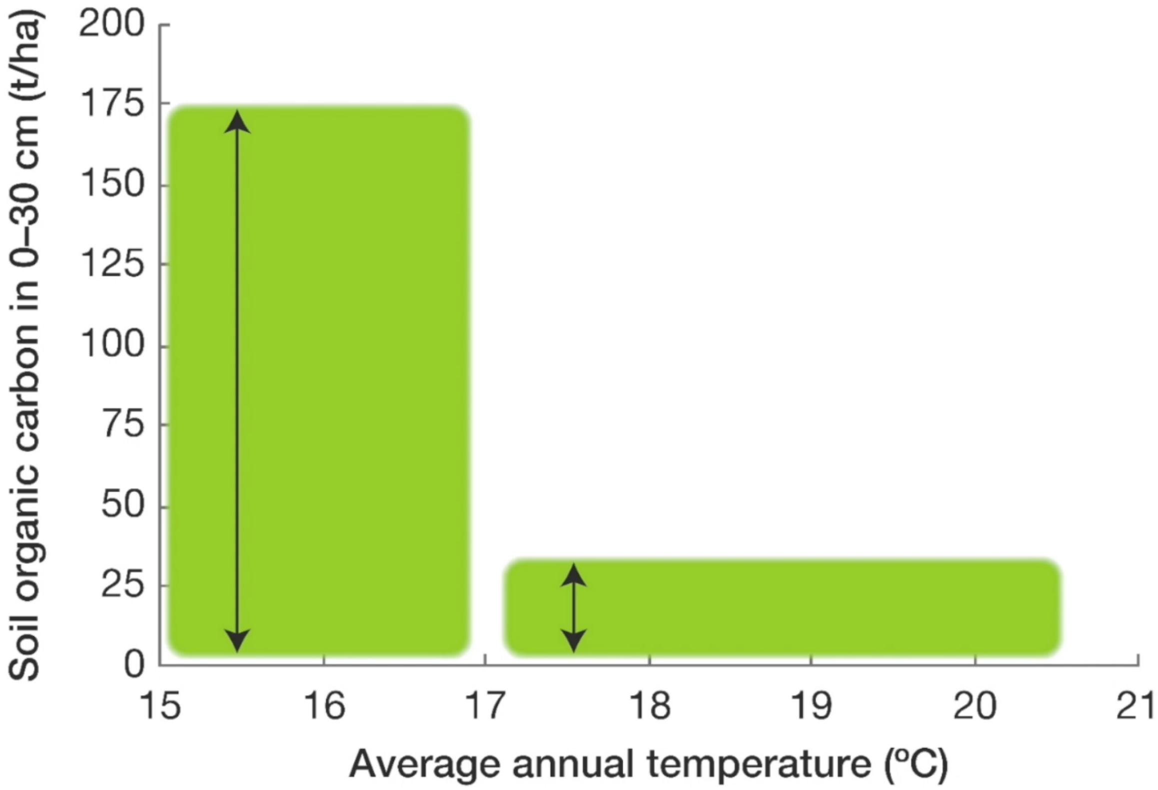
- Rainfall drives plant growth (inputs) and decomposition (losses).
- Large variation in SOC stock with soil type and management.
- Potential to optimise management and soil to accumulate SOC increases.
- Drying climates may indicate future potential changes in carbon storage.
- Increasing summer rainfall may accelerate losses.



Hoyle et al. 2016 Scientific Reports 6

WA Climate Influence

- In WA is temperature a critical limit for SOC storage potential?
- Climates getting hotter and drier.



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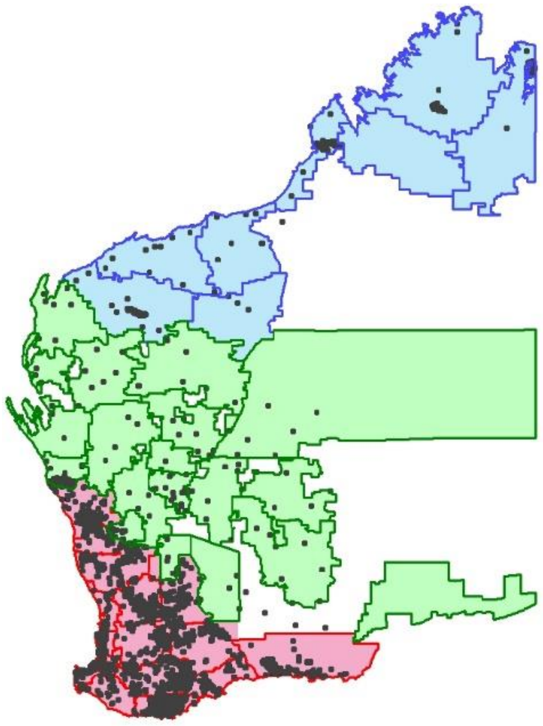
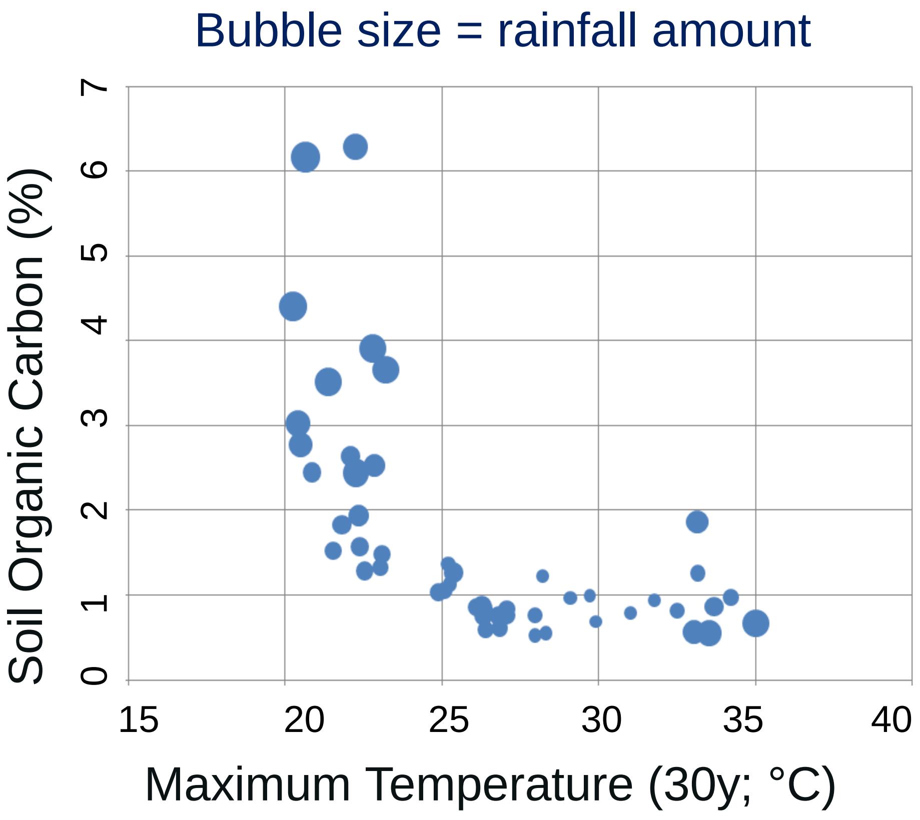
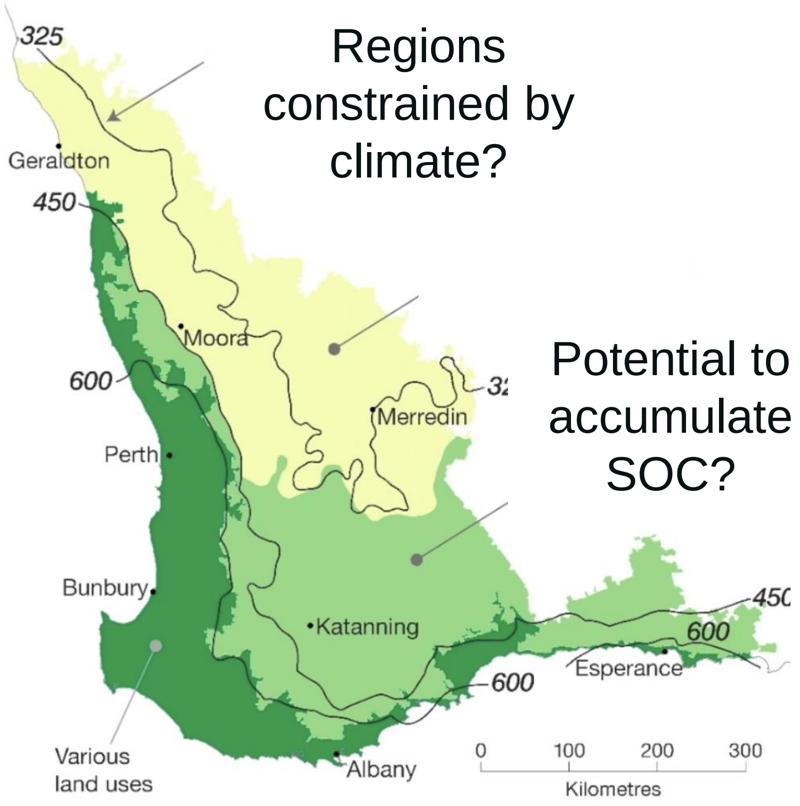
WA Climate Influence

- Interaction between temperature and rainfall influence SOC.
- Predictors useful to identify environments in which SOC accumulation is possible





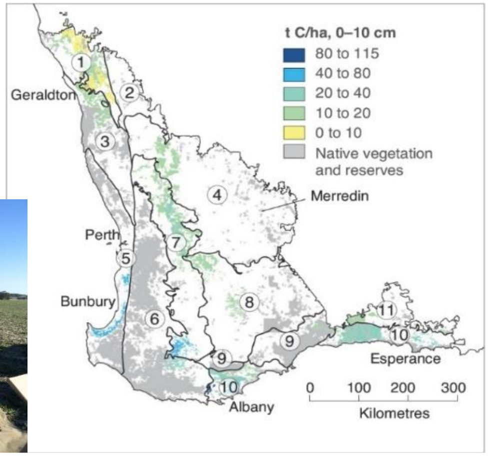


Griffin DPIRD (Source TERN, ASRIS)

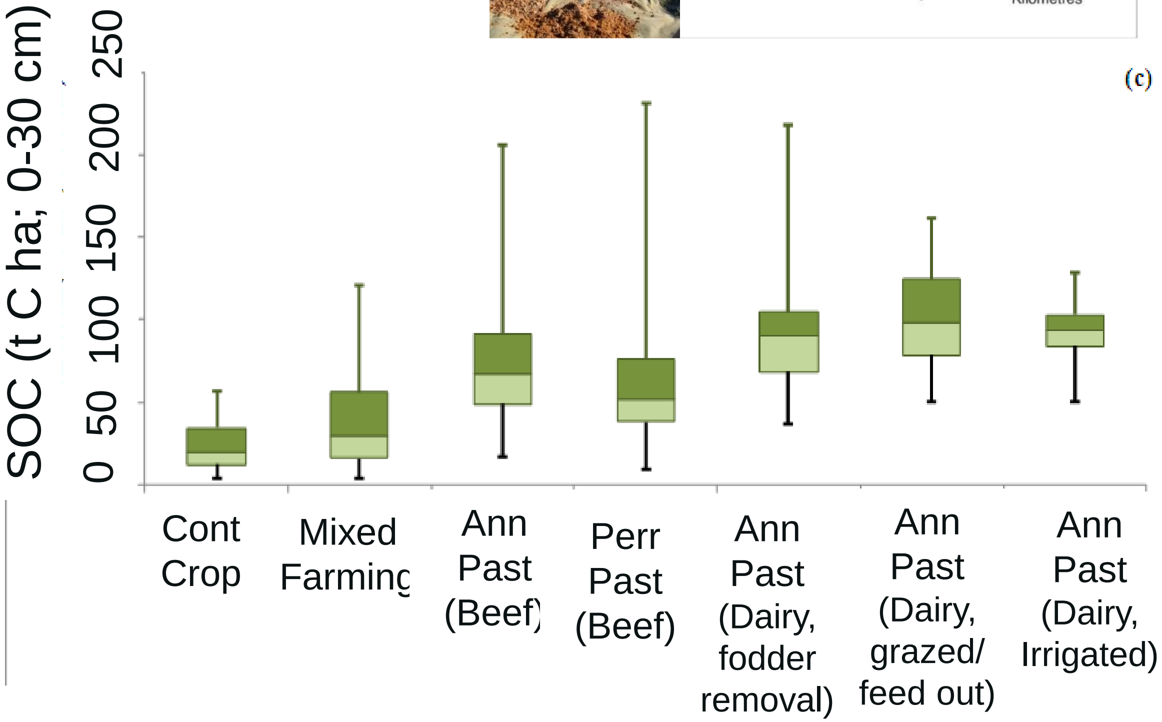
Hoyle FC, O'Leary RA and Murphy DV (2016)

WA Land use influence

- Separation in mean SOC stock evident when grouped by land use
- SOC stocks (0-30 cm) ranged from 3 t C ha^{-1} to 231 t C ha^{-1}
- Wide range variability



Continuous crop	= 25 t C ha^{-1}
Mixed farming	= 36 t C ha^{-1}
Beef production: Annual pasture	= 70 t C ha^{-1}
Beef production: Perennial pasture	= 61 t C ha^{-1}
Dairy (Fodder removal): Annual pasture	= 93 t C ha^{-1}
Dairy (Irrigated): Annual pasture	= 92 t C ha^{-1}
Dairy (Grazed feed out): Annual pasture	= 101 t C ha^{-1}

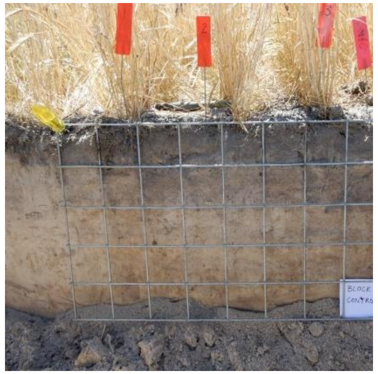


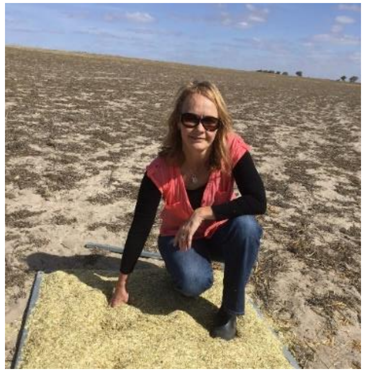
Hoyle et al. 2016 Scientific Reports 6

WA Management Influence

Management change in SOC (0-0.3 m) compared to relative ‘standard practice’

- Stubble retention 0 - 0.1 t C ha^{-1}
- Reduced tillage 0 - 0.1 t C ha^{-1}
- Clay addition to sandy soil : 0 - 0.2 t C ha^{-1}
- Imported plant residue (high load, > 20 t OM ha^{-1}): 0.6 t C ha^{-1}
- Organic amendments rate dependent (high inputs needed)
- Pasture phase frequency, cover, biomass, length
- Often no consistent effect of management measurable above landscape variability

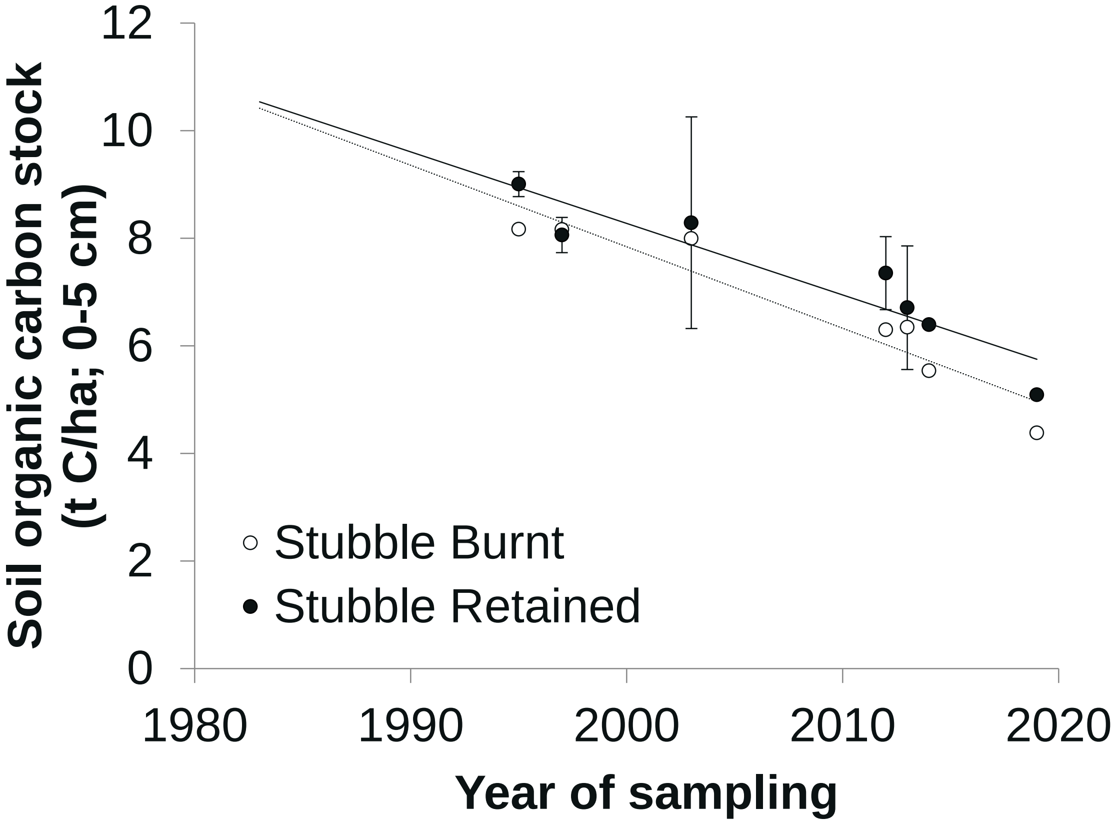




WA Management Influence

Merredin (low rainfall, clay loam), 315 mm (+30 y)

Stubble retained vs. burnt treatments



- Retention of plant residues is not always sufficient to maintain SOC
- Agricultural systems often still losing SOC

Treatment	SOC (%)	POC (mg kg^{-1} soil)	Microbial Biomass C (mg kg^{-1} soil)
Burnt	1.2	139	142
Retained	1.3	182	211
	NS	*** (31%)	***(49%)

Hoyle and Murphy (2007)

Albany Sand Plain

Department of Primary Industries and Regional Development
GOVERNMENT OF WESTERN AUSTRALIA

Four paddock management systems:

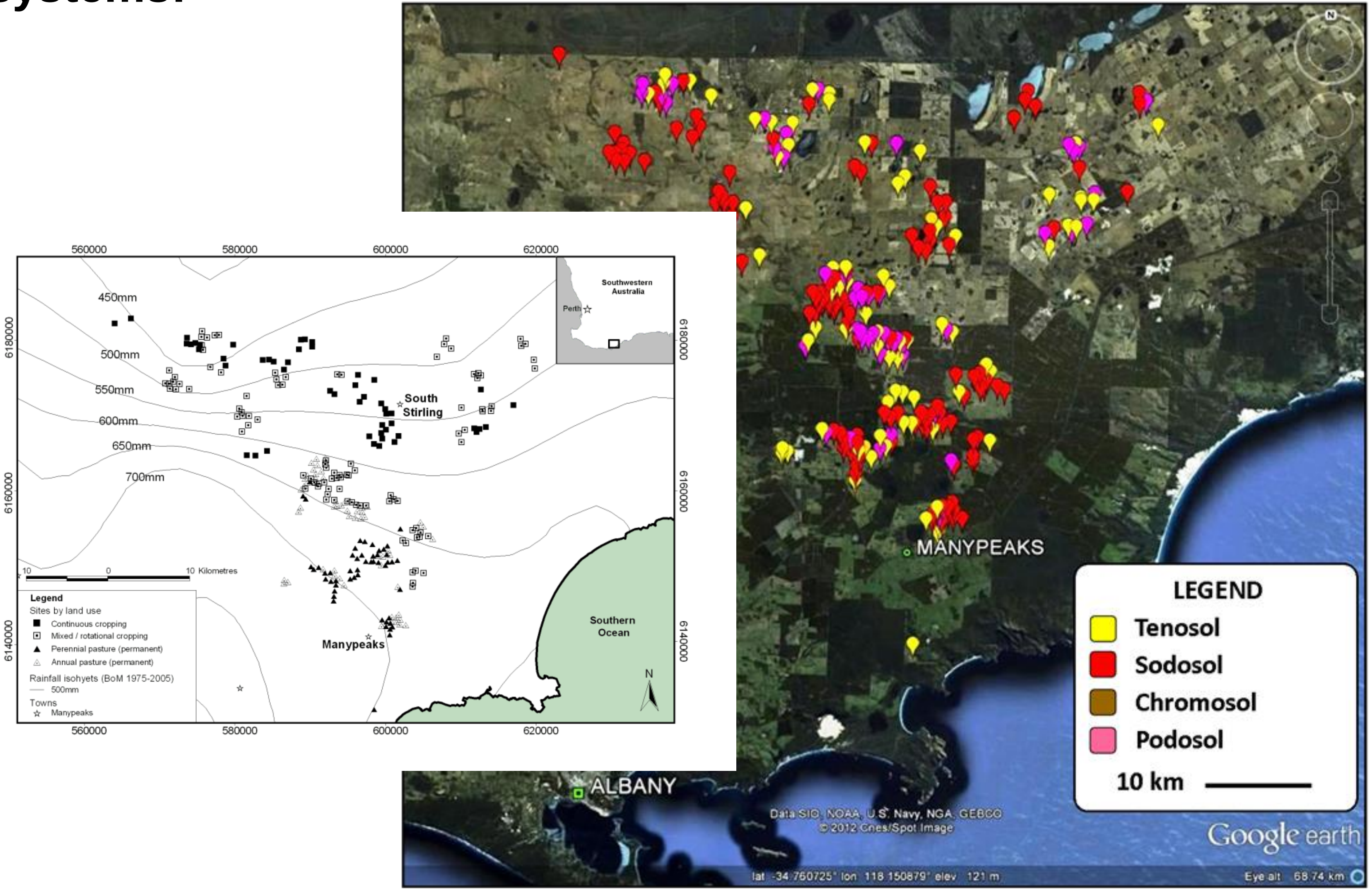
- Continuous cropping.
- Mixed cropping.
- Annual pastures.
- Perennial pastures.

Three soil types:

- Deep Sand.
- Sandy Duplex.
- Loamy Duplex.

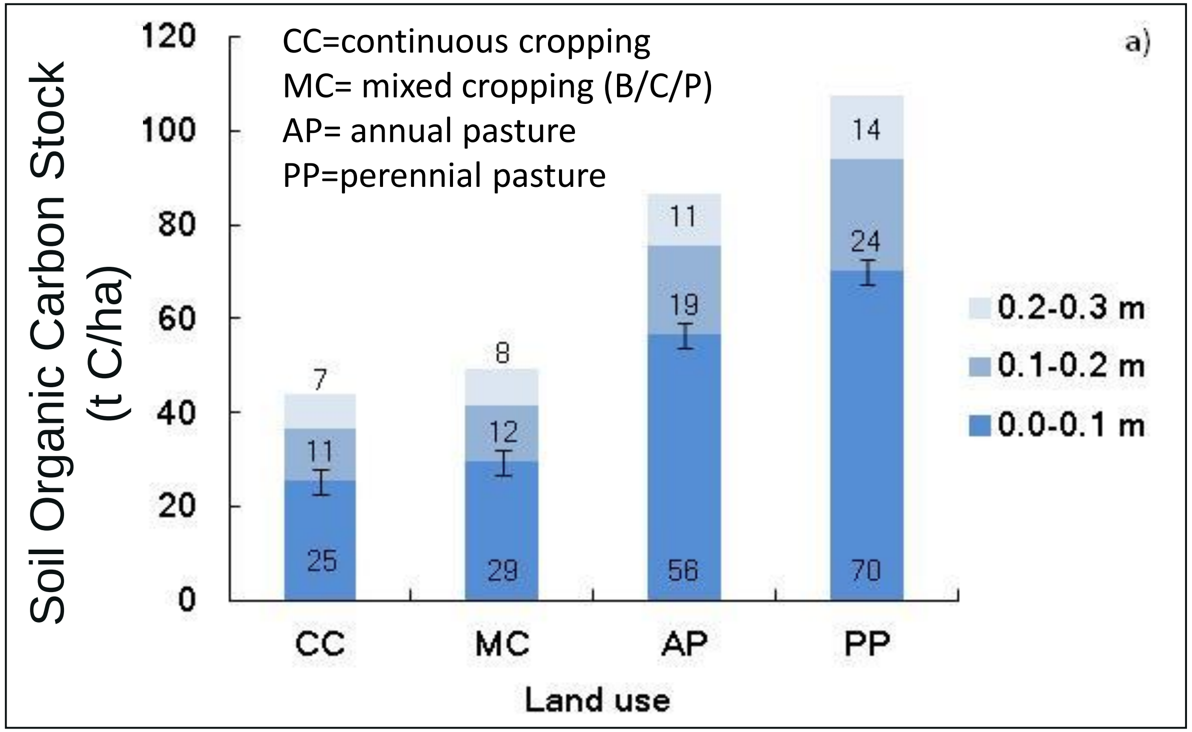
Other features:

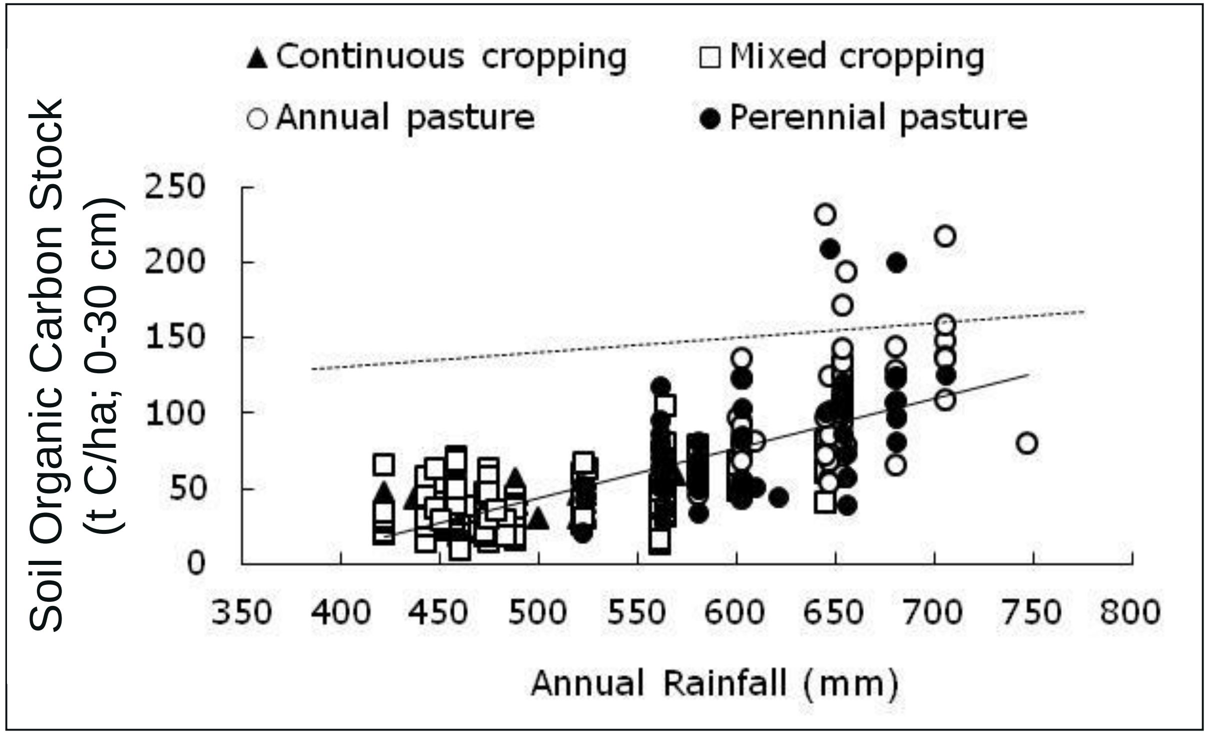
- Tight rainfall gradient.
- Water repellence.



Hoyle et al. (2013) Soil Research

Albany Sand Plain – Measured & Modelled





What does this suggest?

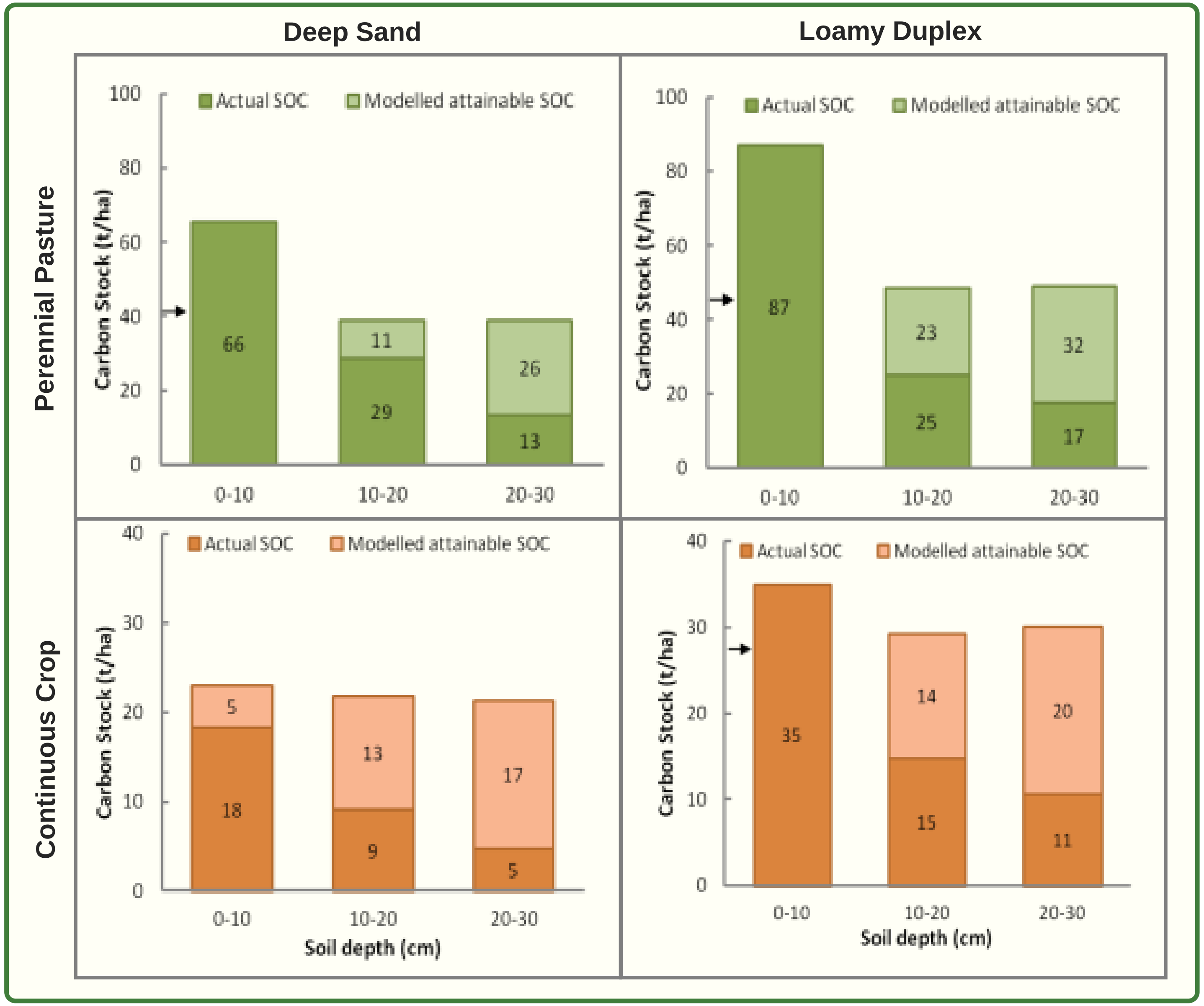
- Perennial > annual pasture > cropping.
- 0-0.1 m soil layer contained 63% of measured SOC within the top 0.3 m of the soil.

Hoyle et al. (2013) Soil Research

What does this suggest?

- Rainfall drives net primary productivity.
- High rainfall near potential; wider range.
- Modelled capacity shows increased C – constraints?

Measured & Modelled



Hoyle et al. (2013)

Modelled SOC Capacity

1. Perennial pasture > cropping (higher rainfall).
2. Soils with more clay have greater capacity to store SOC.
3. Capacity for storage in topsoil is limited ('full')
4. Building carbon at depth our best strategy: 60% 'remaining'

How do we increase carbon at depth?

Challenges and Solutions for WA

Challenge	Solution
Carbon storage capacity limited in sandy soils. Majority of ‘new’ carbon in particulate fraction (permanence??).	Maintain higher inputs & protect your topsoil. Loamy soils and cooler environments can increase SOC accumulation.
Topsoils theoretically ‘full’.	Management solutions need to focus on getting carbon into soil at depth.
Convert rainfall into plant biomass.	Improving WUE - large changes needed.
Increasing % of year receiving organic inputs.	Sustained inputs required. Management to retain more soil moisture.
Measuring change against large background/temporal patterns.	Long term outlook. Measure through time. Evidence builds confidence.
‘Improved’ management may still show declines in SOC stock over time.	Temporal measurement is critical to understanding long term outcomes.

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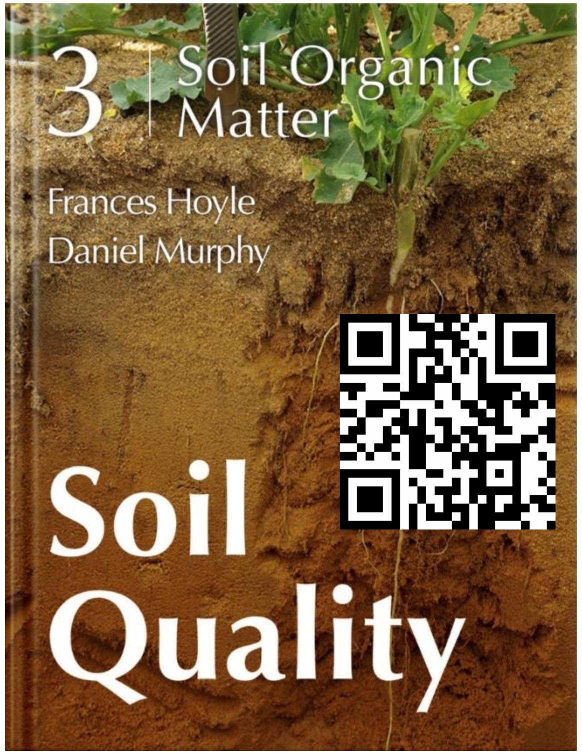

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