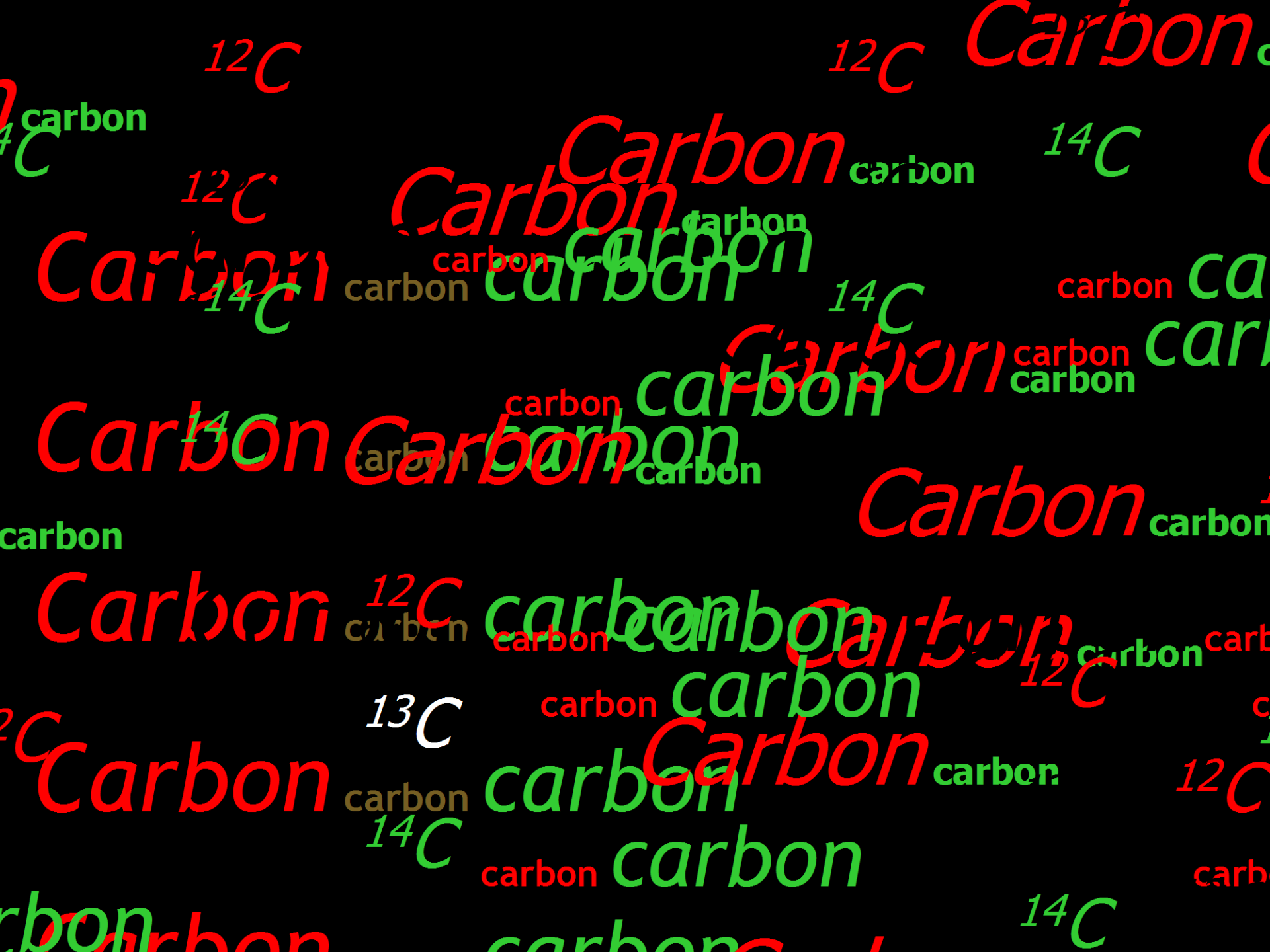

12C
Carbon
carbon
14C
13C

THE UNIVERSITY OF SYDNEY

Towards more efficient soil carbon measurement and monitoring [A very brief overview]

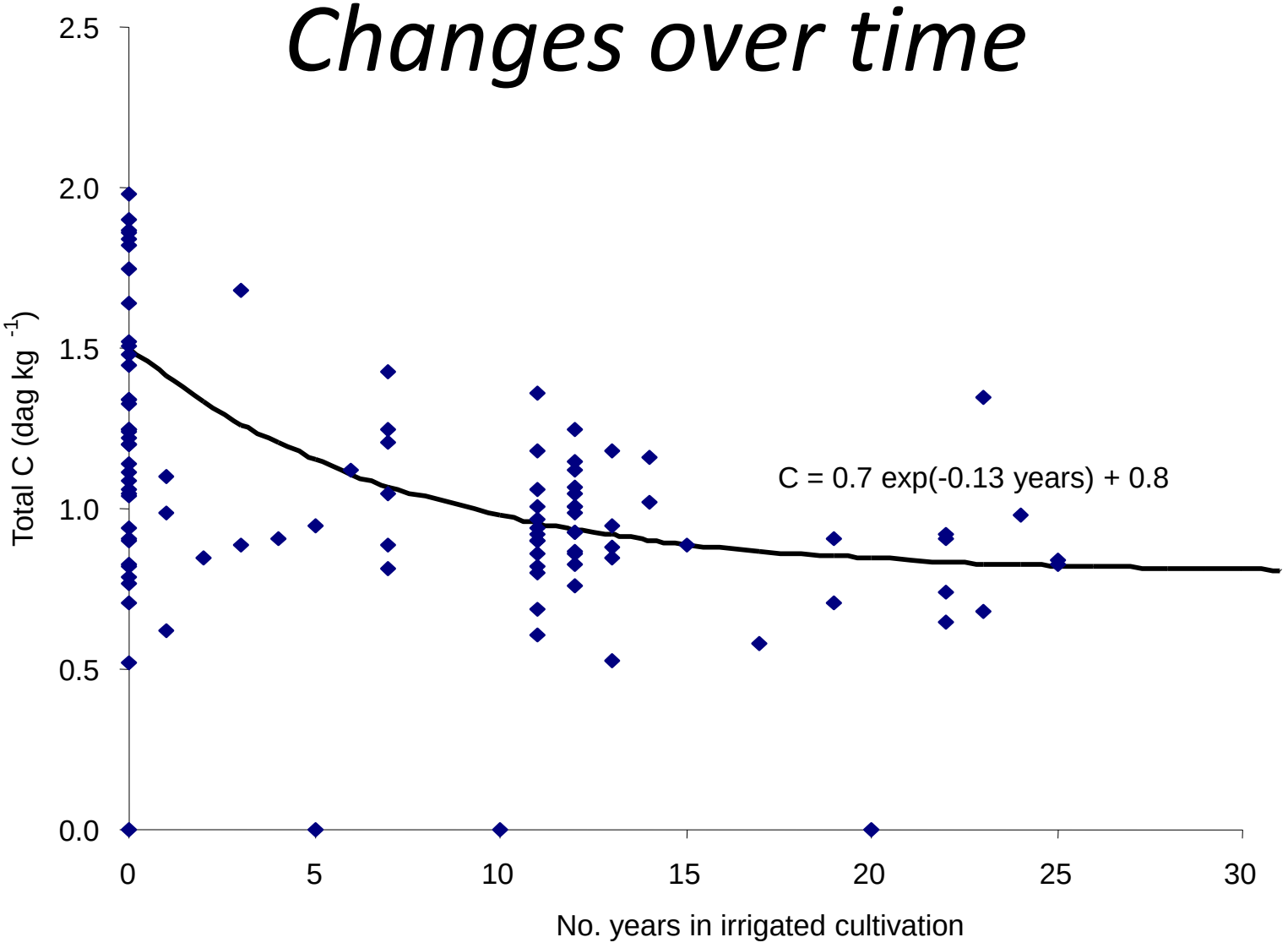
Alex McBratney, Budiman Minasny, Brendan Malone, Ichsani Wheeler & Sophie Gulliver

Faculty of Agriculture Food & Natural Resources

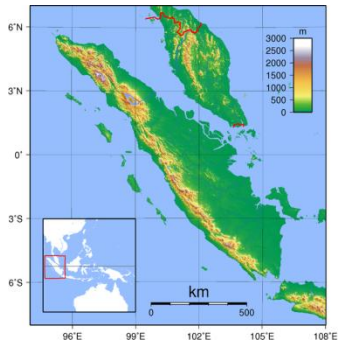
Australian Government
Australian Research Council

The sequestration/auditing issue

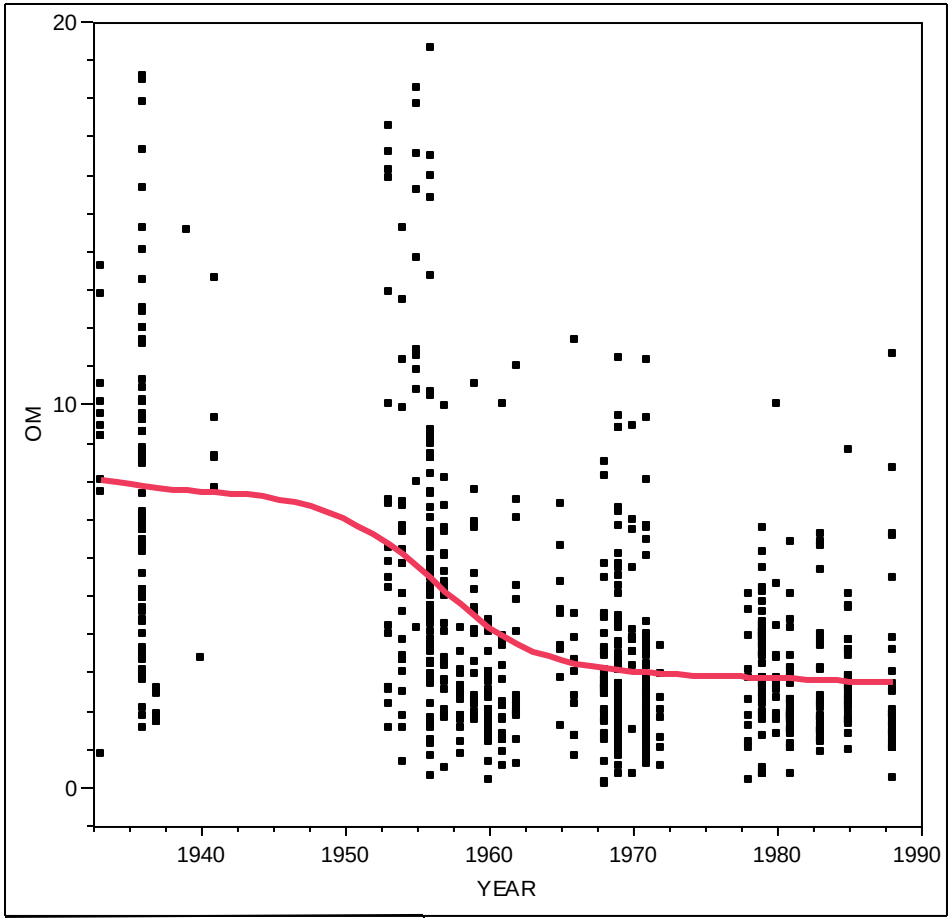
Namoi valley NSW- Total soil C Changes over time



Odeh McBratney et al. (2002)



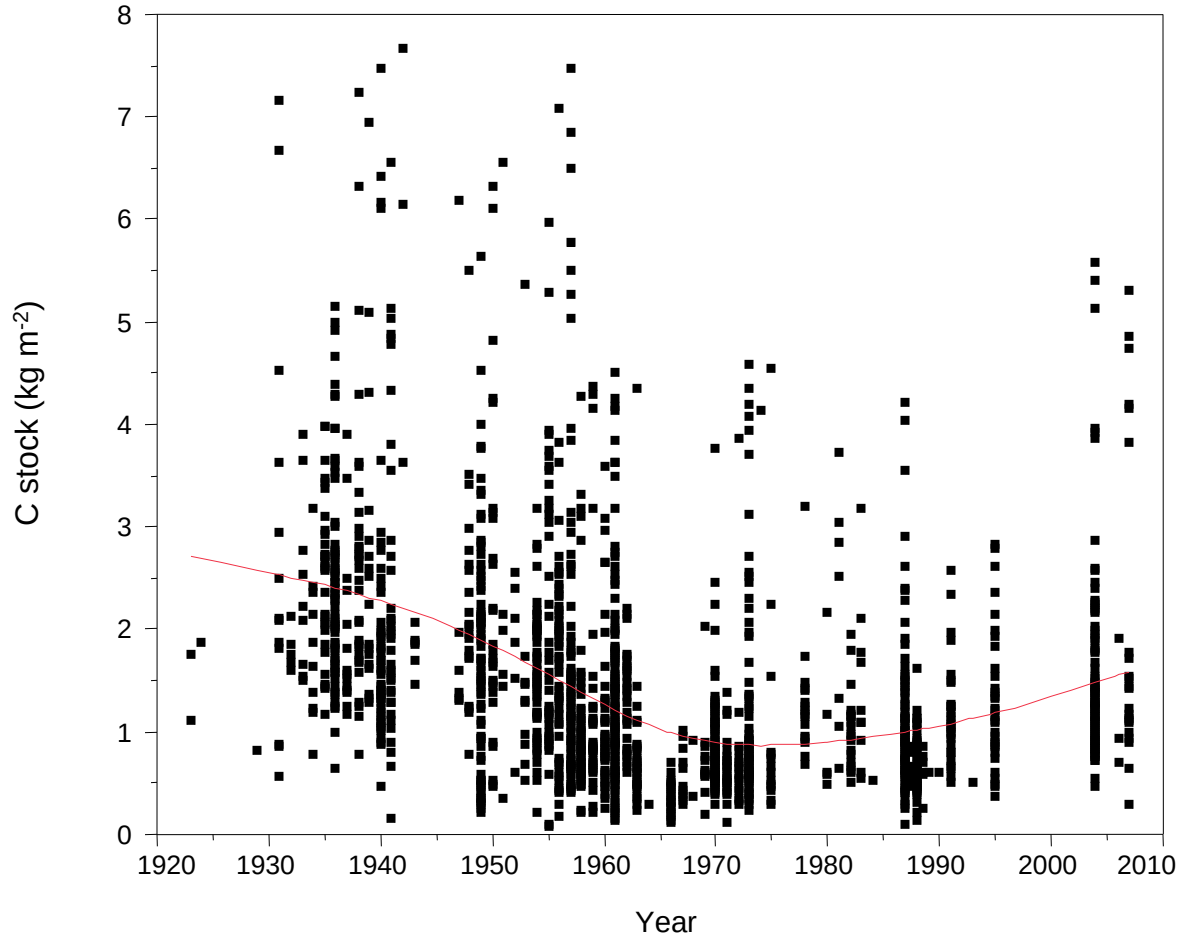
The change in Organic matter content of soils in Sumatra , Indonesia



For the top 15 cm
A reduction from 57 t/ha (4.5% C in 1940)
to 25 t/ha (1.5% C in 1970)

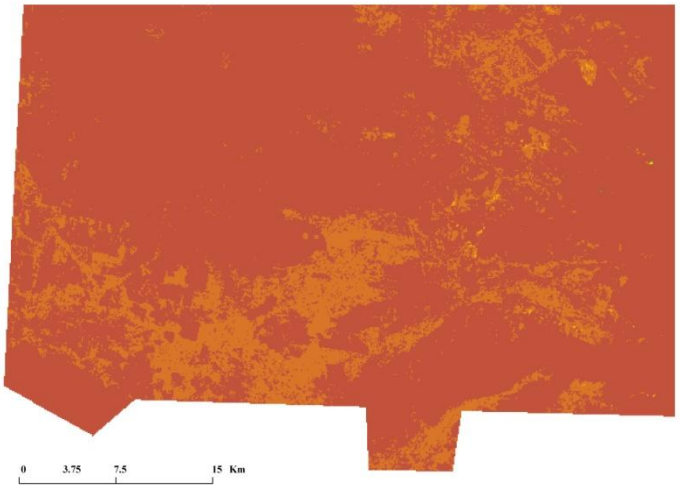
Carbon escaping from soil

Java

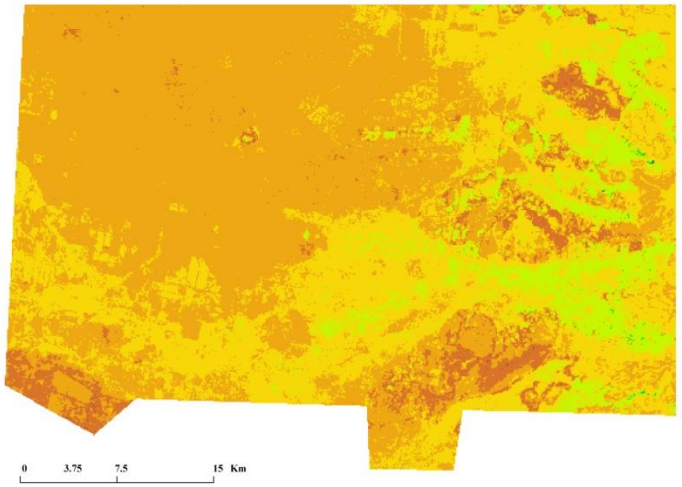

C stock (kg m-2)
Year
0
1
2
3
4
5
6
7
8
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Total soil carbon density to 1m
Edgeroi NSW

LOWER 99%

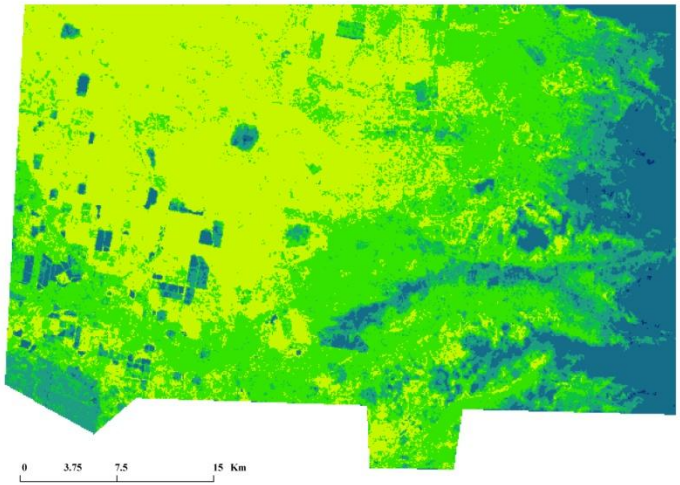


MEAN



carbon density
(kg m^{-2} to 1 m)

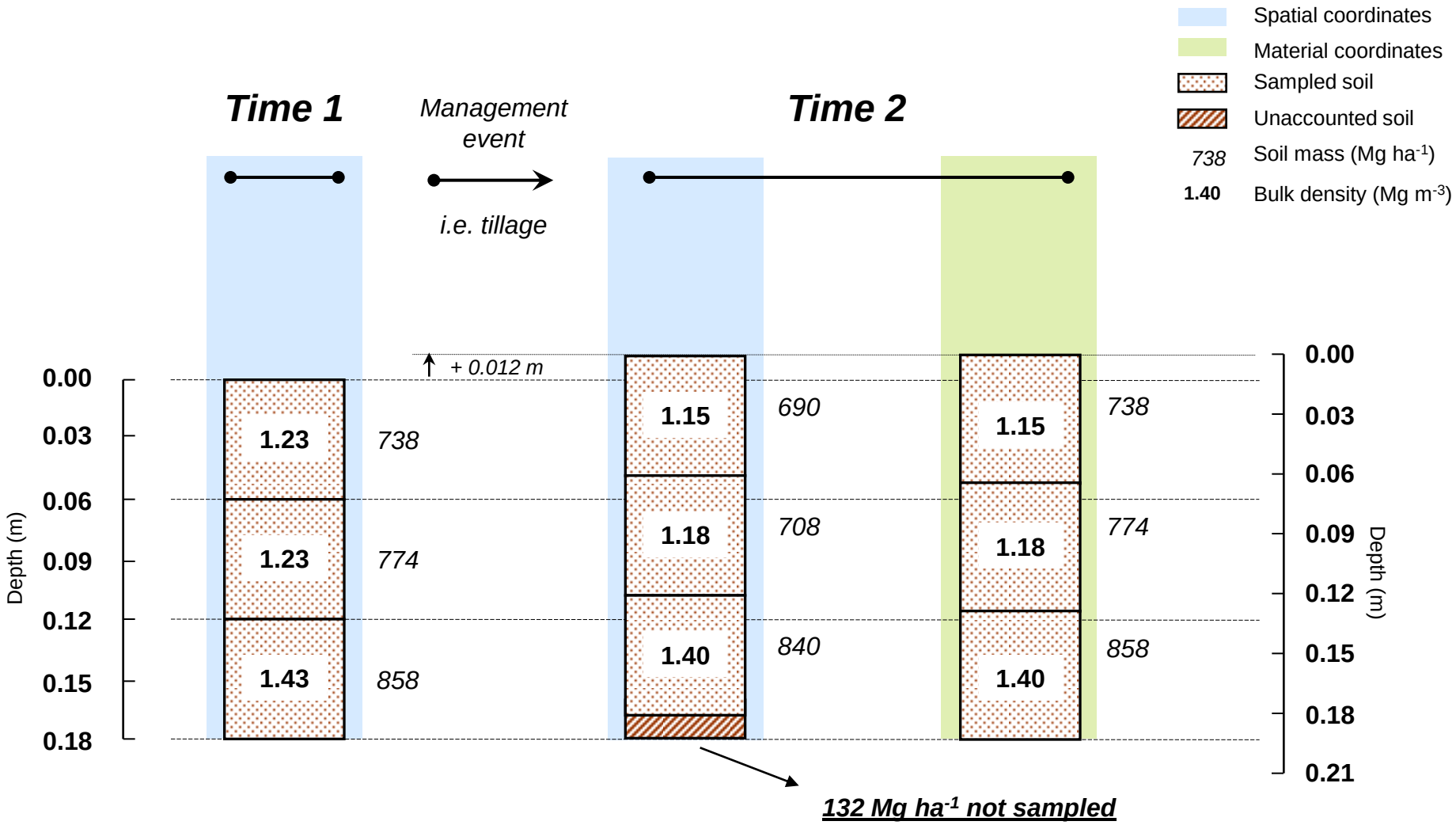
- 0 - 2
- 2 - 6
- 6 - 9
- 9 - 12
- 12 - 17
- 17 - 23
- 23 - 28
- 28 - 35
- 35 - 45
- 45 - 90



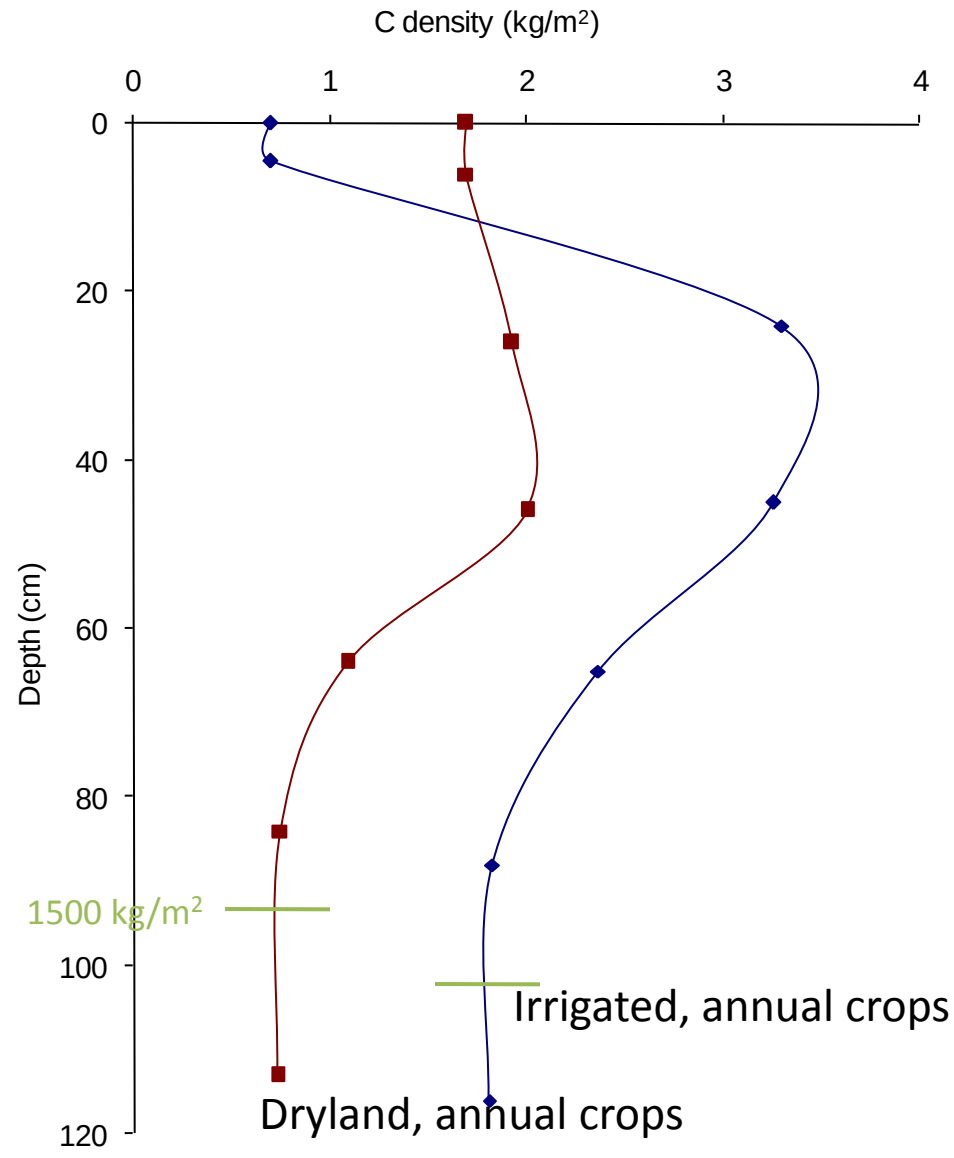
UPPER 99%

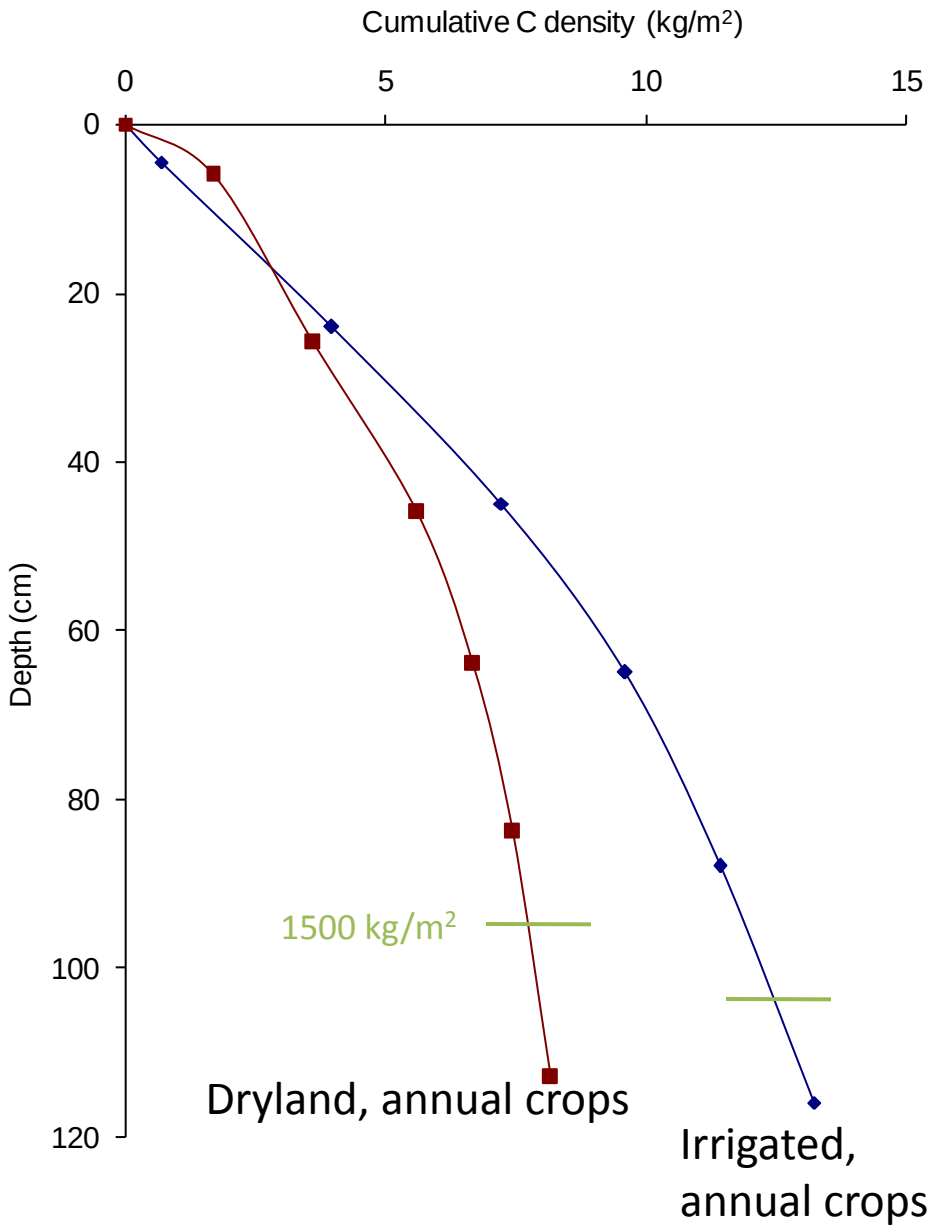
Spatial(length or depth) or material (mass) coordinate system?

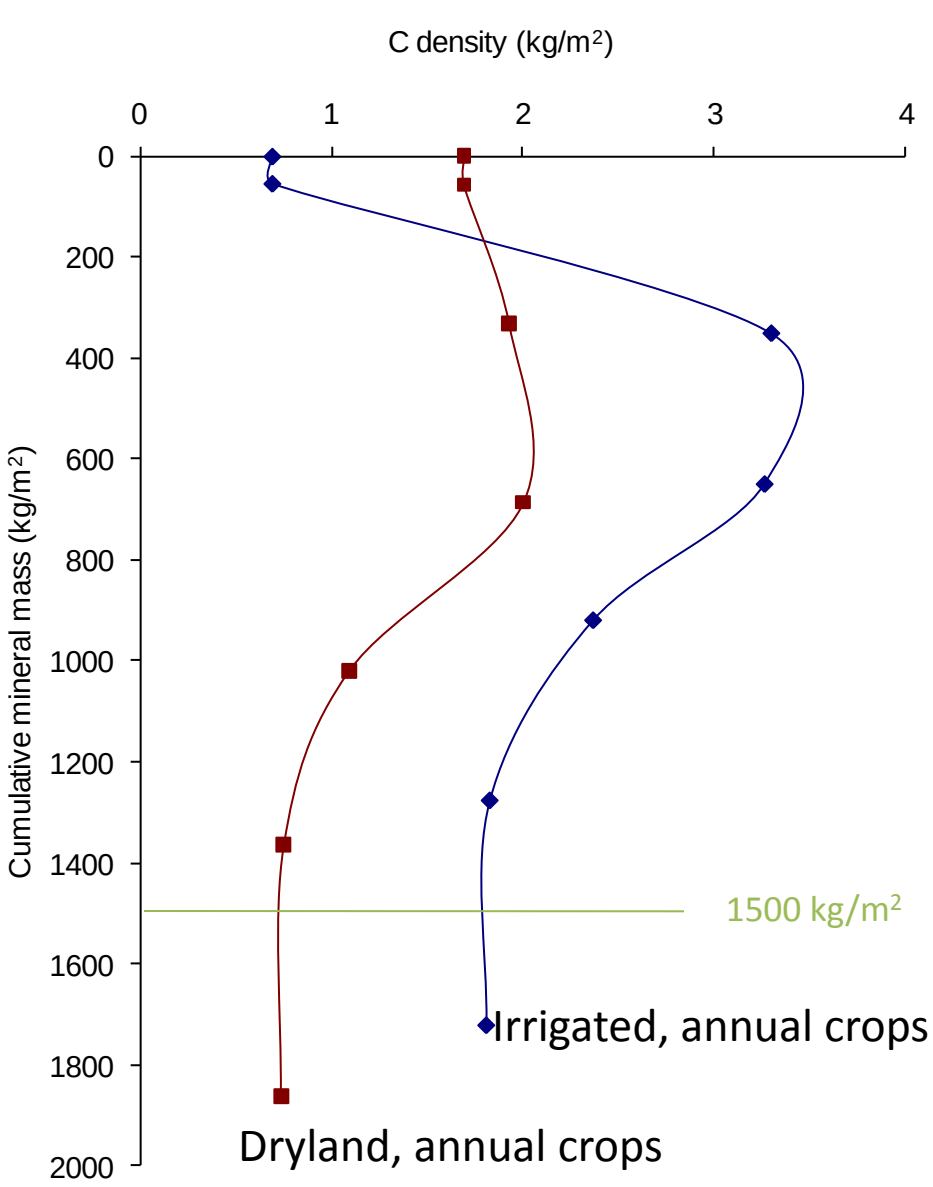
Depth may be a troublesome unit of measure…

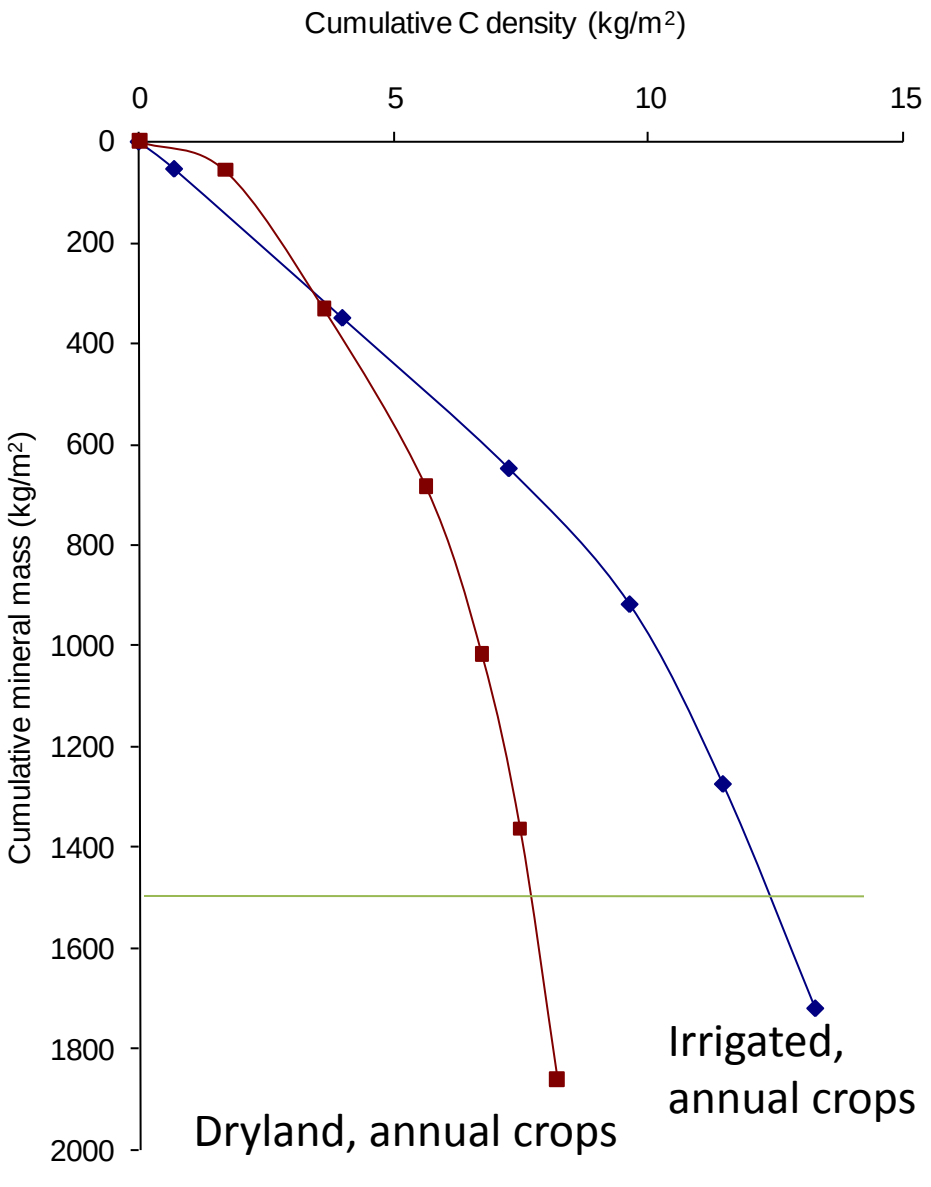


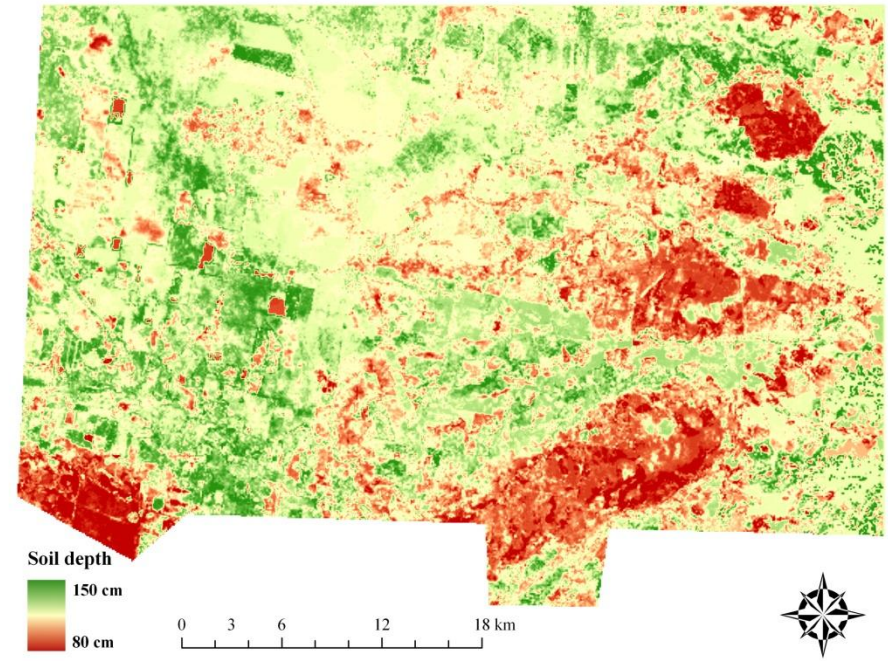
see Lee *et al.* (2009) Determining soil carbon stocks: Simple bulk density correction fail. *Agriculture, Ecosystems, Environment* **134** 251-256


C density (kg/m²)
0
1
2
3
4
0
20
40
60
80
100
120
Depth (cm)
1500 kg/m²
Irrigated, annual crops
Dryland, annual crops

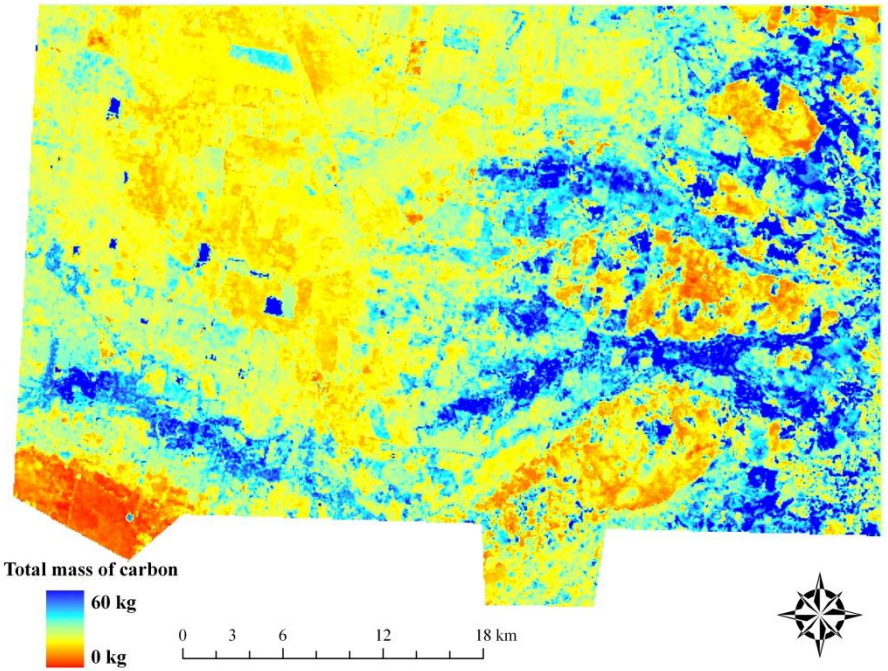

Cumulative C density (kg/m²)
0
5
10
15
0
20
40
60
80
100
120
Depth (cm)
1500 kg/m²
Dryland, annual crops
Irrigated, annual crops


C density (kg/m²)
0
1
2
3
4
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Cumulative mineral mass (kg/m²)
1500 kg/m²
Irrigated, annual crops
Dryland, annual crops


Cumulative C density (kg/m²)
0
5
10
15
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Cumulative mineral mass (kg/m²)
Irrigated, annual crops
Dryland, annual crops



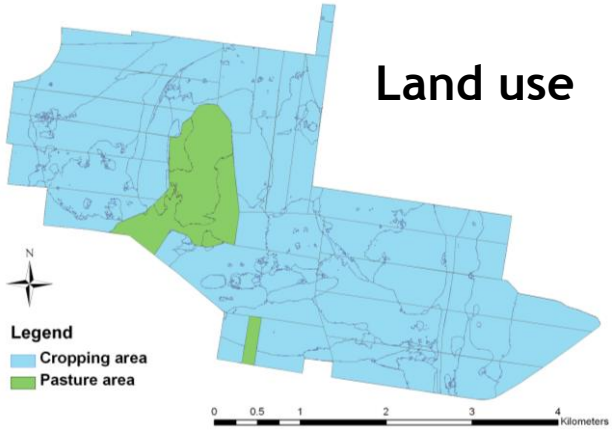
Soil depth to 1500kg/m^2 mineral material



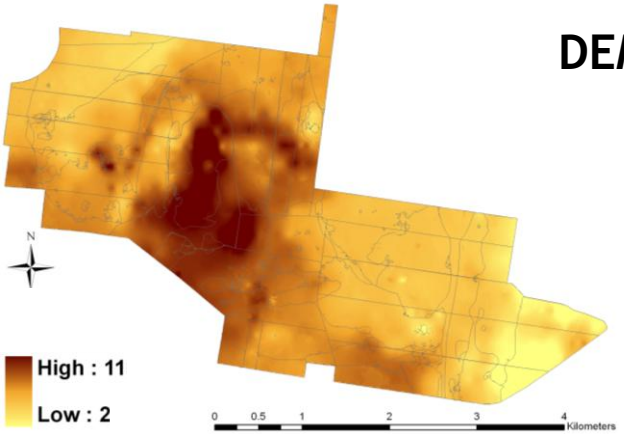
Total mass of carbon in 1500kg/m^2 soil material

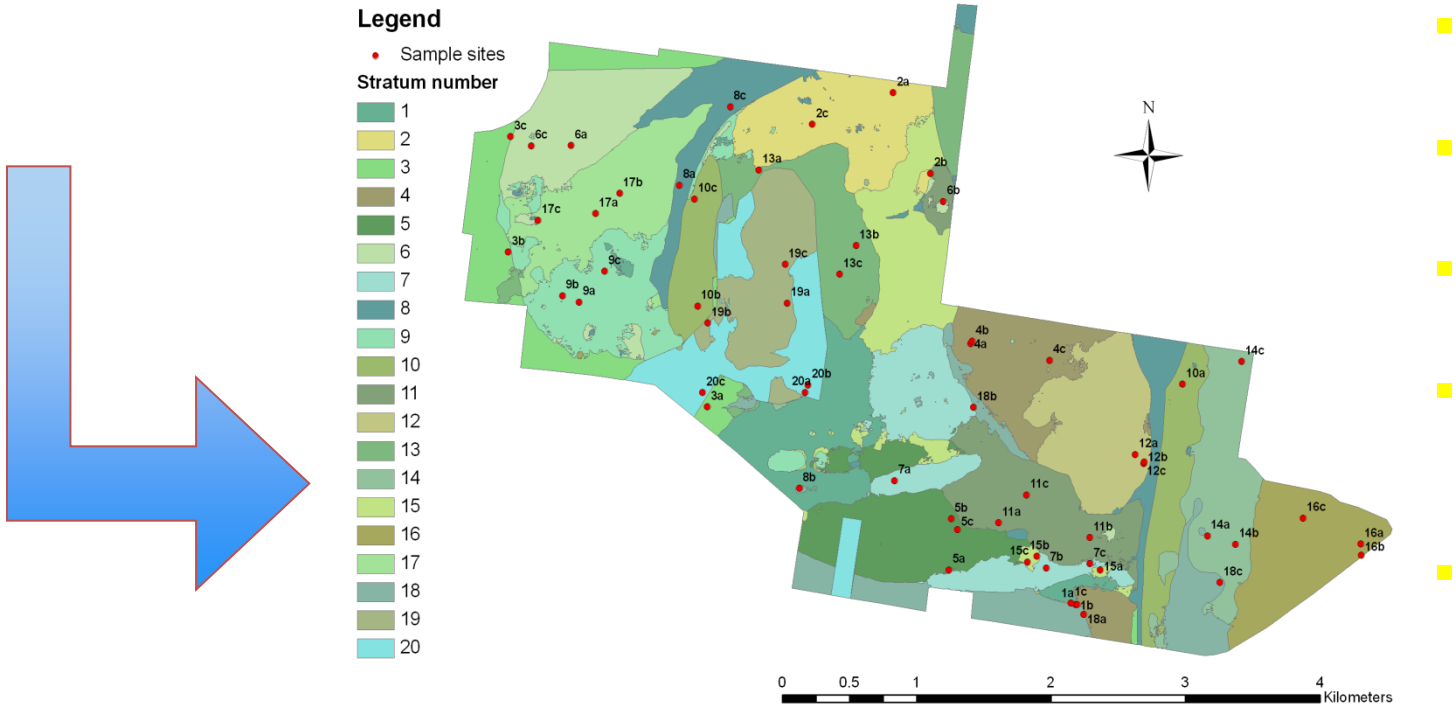
Some sums:
Area ≈ 1700km^2
Total mass of soil material (1500kg/m^2) ≈ 2.6 Pg
Total mass of carbon ≈ 200 Kt
Carbon percentage ≈ 0.8%

Land use

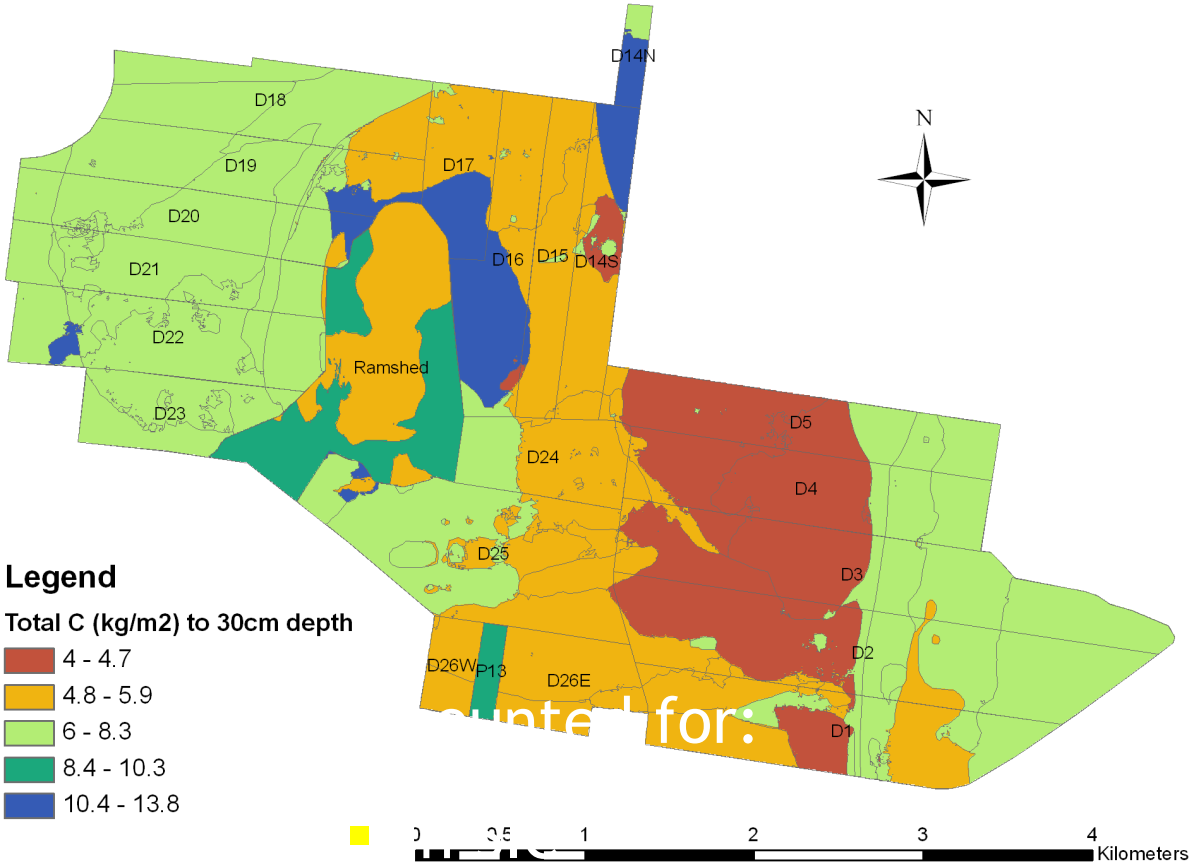

N
Legend
Cropping area
Pasture area
0 0.5 1 2 3 4
Kilometers

DEM


N
High : 11
Low : 2
0 0.5 1 2 3 4
Kilometers


Legend
Sample sites
Stratum number
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
N
0 0.5 1 2 3 4
Kilometers

C density


D14N
D18
D19
D17
D20
D16
D15
D14S
D21
D22
Ramshed
D23
D5
D24
D4
D25
D3
D26W
P13
D26E
D2
D1
N
Legend
Total C (kg/m2) to 30cm depth
4 - 4.7
4.8 - 5.9
6 - 8.3
8.4 - 10.3
10.4 - 13.8
0
1
2
3
4
Kilometers

C stocks on a contiguous management unit (farm)

	Total C to 30 cm (Mg C)
Total C on whole farm	103 456
Standard error	2001
95% Confidence Interval	± 4 002
Lower 95% Confidence Limit	99 454
Upper 95% Confidence Limit	107 458

Delta C estimation

	Total C to 30 cm depth (Mg C)		
	Carbon at time 1 (C_{t1})	Carbon at time 2 (C_{t2})	$\Delta C = C_{t2} - C_{t1}$
Total C on whole farm	103 456		
Standard error	2001	$\approx$ 2001	2829
95% Confidence Interval	$\pm$ 4002		$\pm$ 5660
Lower 95% Confidence Limit	99 454		
Upper 95% Confidence Limit	107 458		

- Cost of auditing

- $10 per ha (~0.5 tonne C per ha)
- Minimum detectable 4.4 tonne per ha (+1.4mm) 95% CI
- To be sure of payment need 5 tonnes/ha over 70 tonnes/ha – 7% - raise average C from 1.6% to 1.7%

Resource costs/benefits of soil carbon sequestration e.g. water, N, P

- Increase of carbon by 1%C increases available water capacity by ~25 mm/m, say increase topsoil by 1%C (35 tonnes/ha to 25cm) = 6 mm extra AWC = 100 kg wheat per annum ~ $ 20 pa [underestimate?]

- Each tonne of carbon requires ~100kg N, and 10kg P and ~ 10kg S (1000:83:20:14) cost $140 + $ 30 + $30 = $200, price of sequestered C?

Other soil management impacts on greenhouse gases – Nitrous Oxide

Increased if additional N is intended for increased sequestration

Evidence is increased N fertiliser leads to reduced equilibrium C contents

In Australia we need water-use efficient legumes in production system for soil carbon sequestration

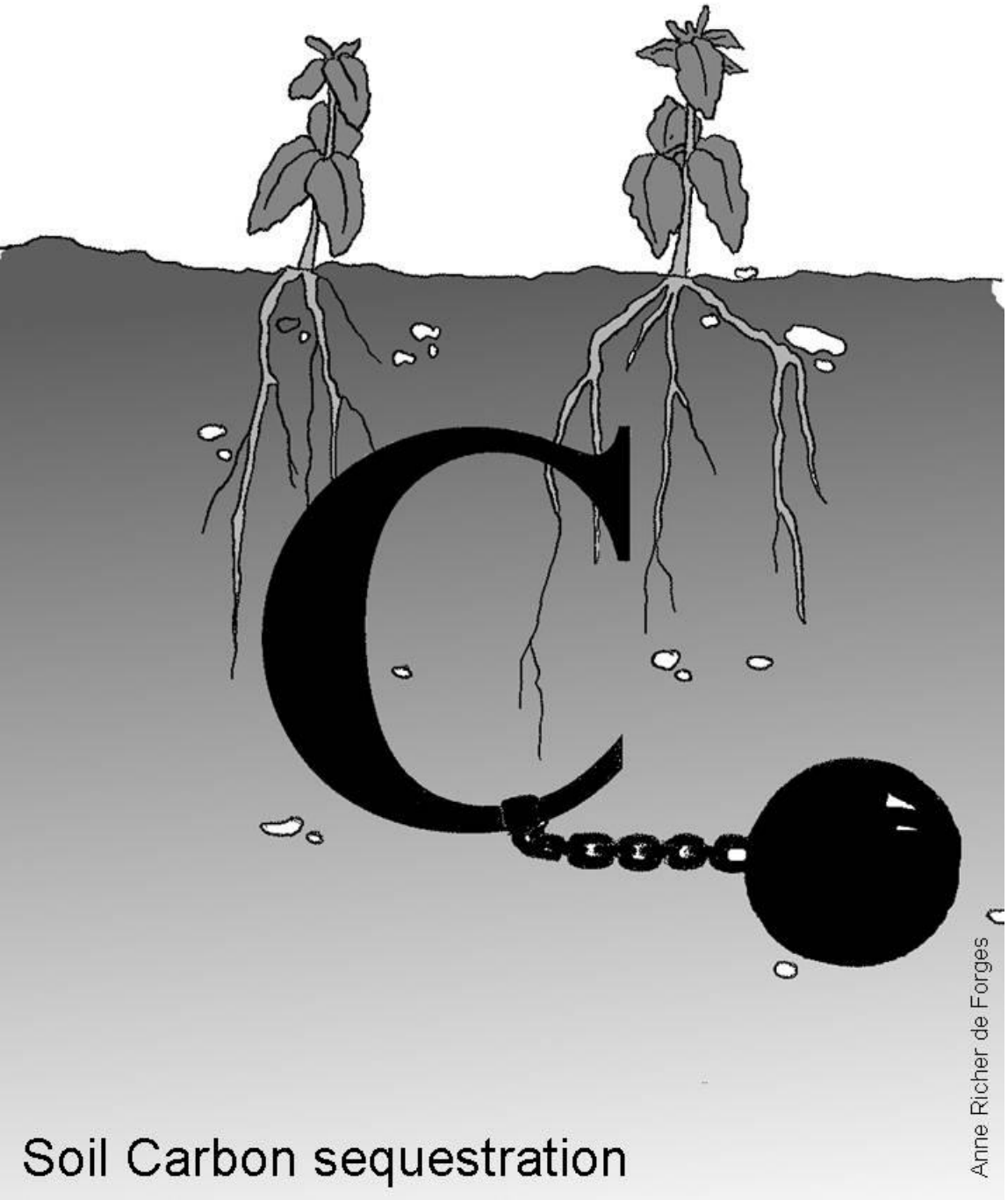
Example of Typical Commentary

Questions about the net greenhouse gas benefit of no-till agriculture together with verification difficulties are likely to prevent soil carbon sequestration from becoming a tradable commodity.

I do not agree

Nevertheless, increasing SOC has direct benefits for soil health and agricultural sustainability.

I wholeheartedly agree



Soil C

Let's include it

Let's map it

And monitor it

Let's put it back

(+20% by 2020)

And keep it there