Australian-German College of Climate & Energy Transitions

Science and Pretzels

9 April 2014

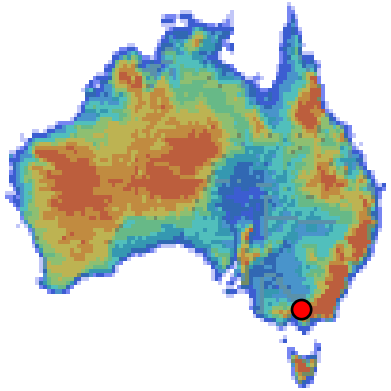
The limits to carbon sequestration in Australian agricultural soils

Shu Kee Lam, **Deli Chen**, Arvin Mosier, Rick Roush

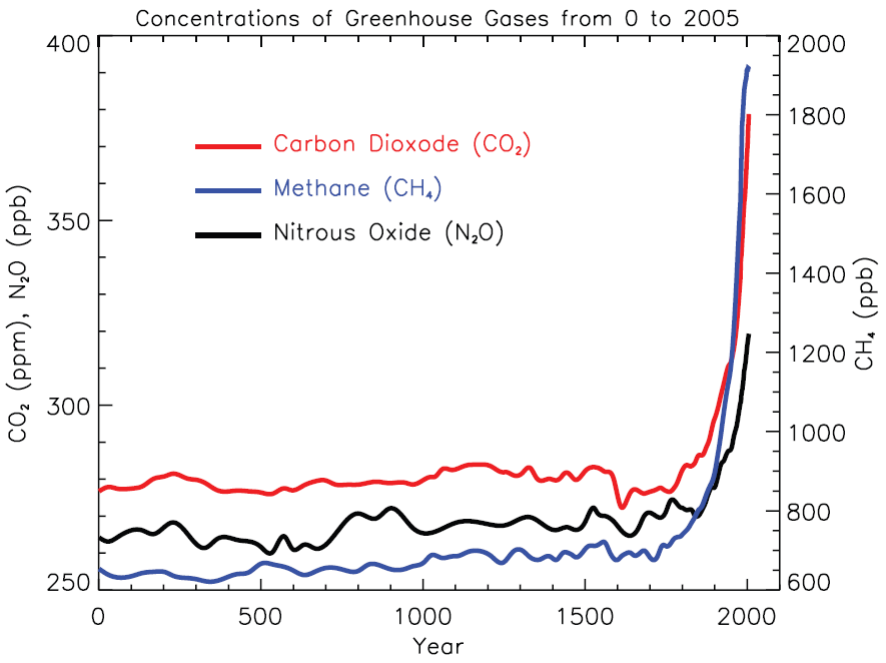
Melbourne School of Land and Environment

The University of Melbourne

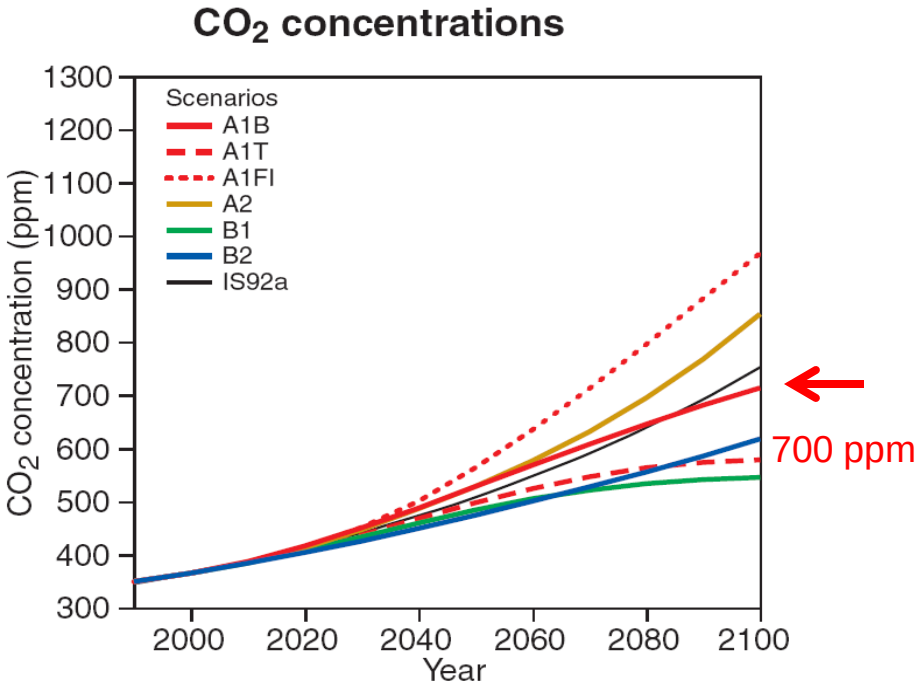
(Australia's No. 1 University)



Rising atmospheric CO_2

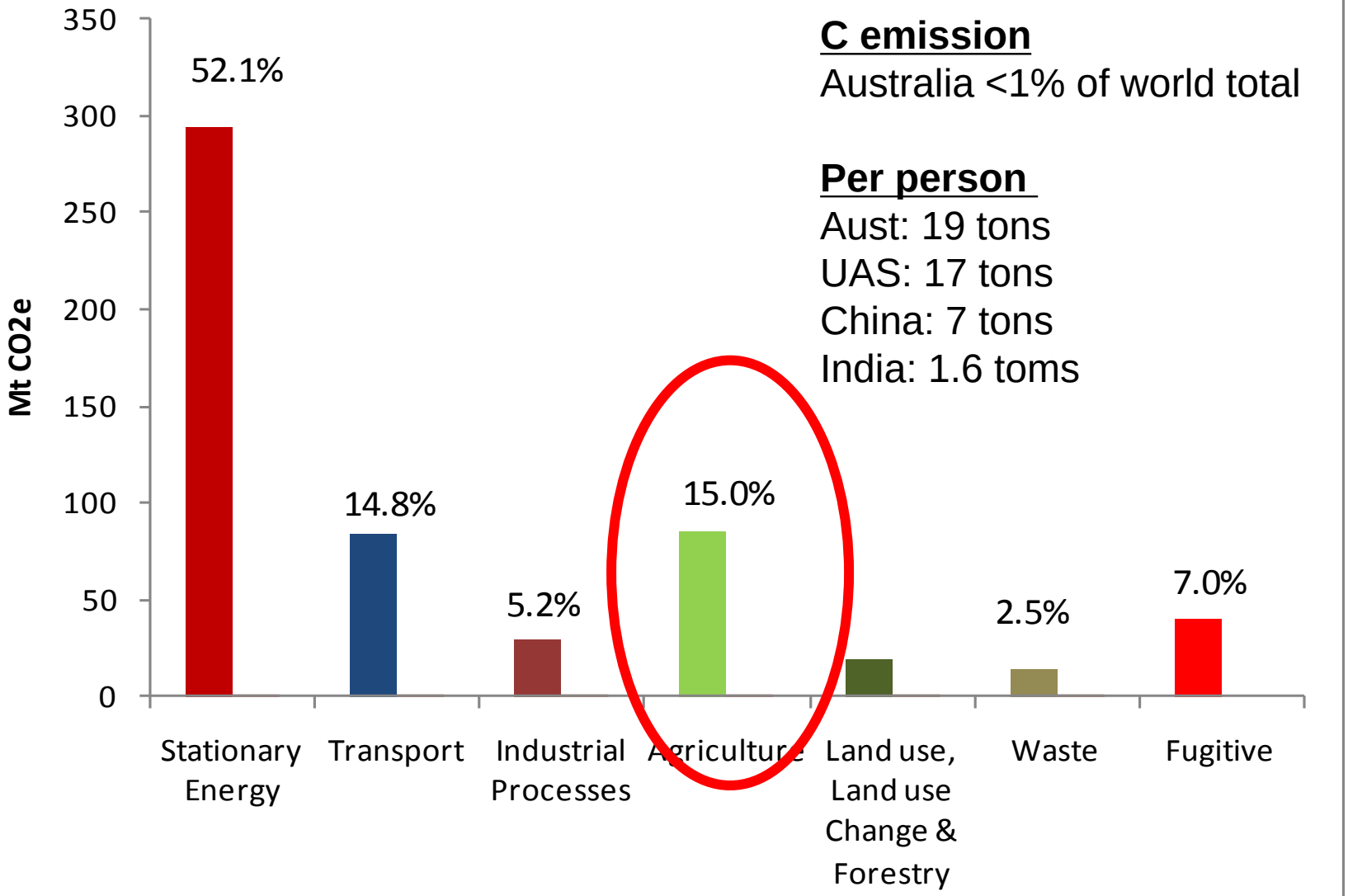


Concentration of greenhouse gases from 0 to 2005 (Forster et al. 2007)

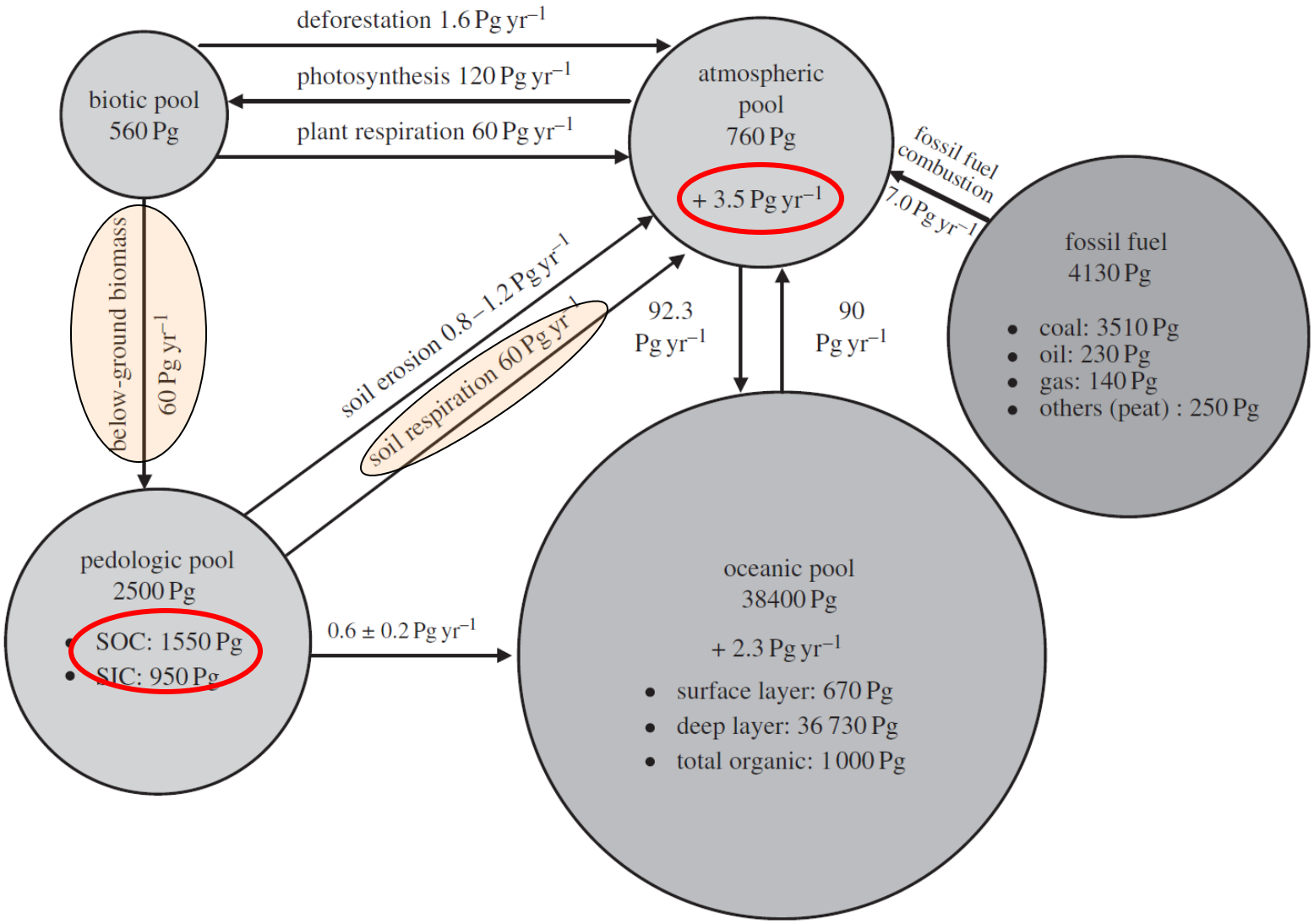


Predicted CO_2 levels (Houghton et al. 2001)

Sectoral Greenhouse Gas Emissions Australia

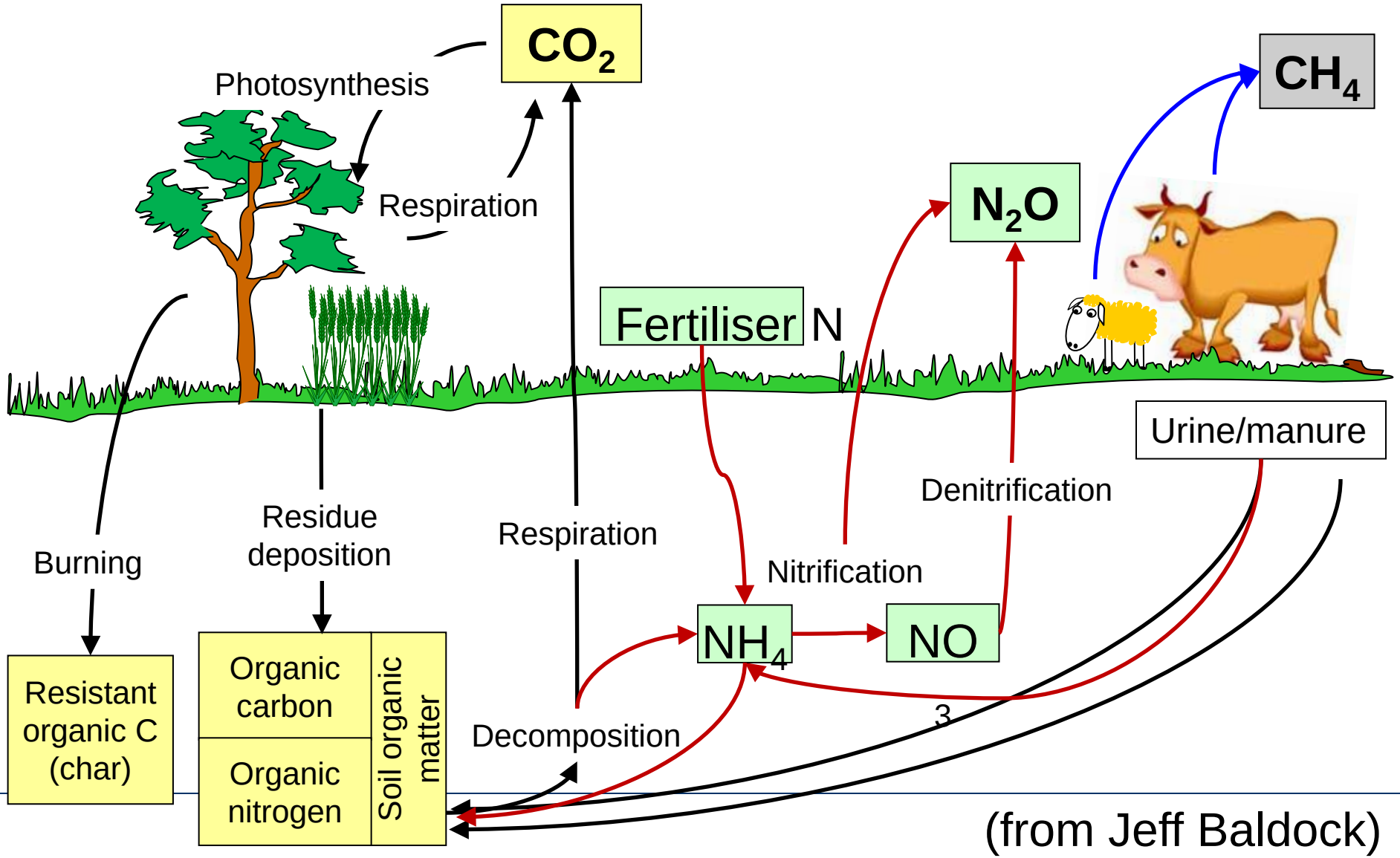


Global C pools and fluxes between them



(Lal 2008)

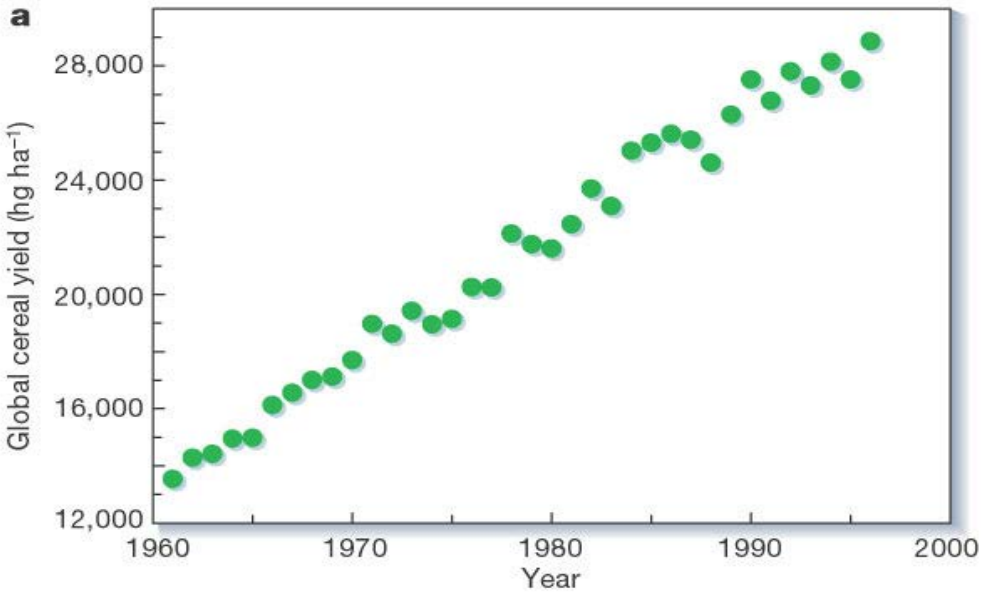
Agricultural greenhouse gases (C and N interteraction)



(from Jeff Baldock)

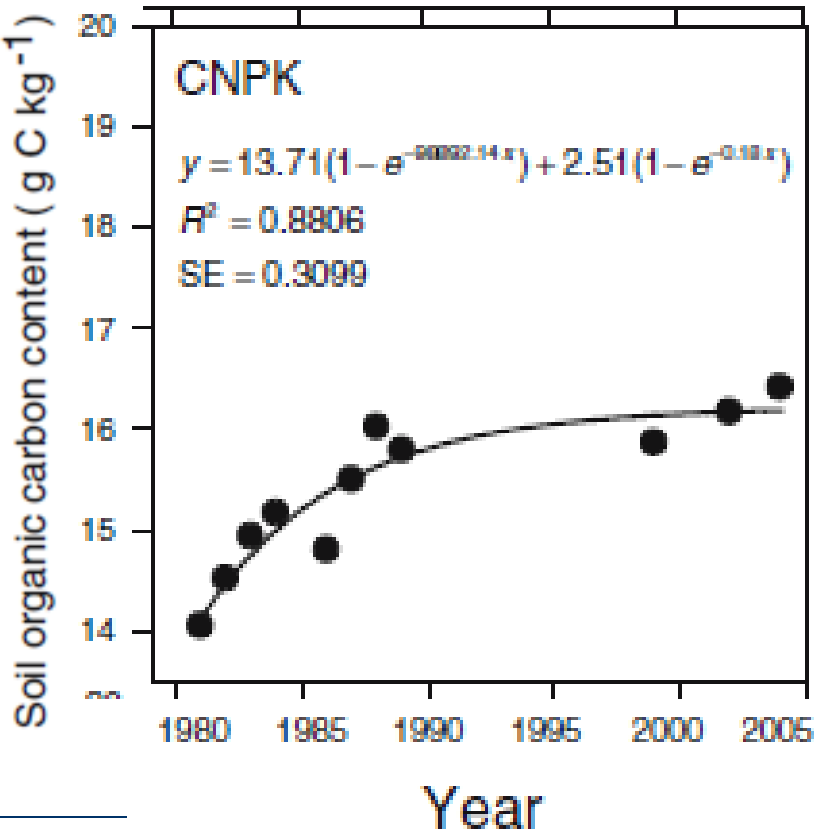
Is Soil C really declining?

Long term globe cereal yield



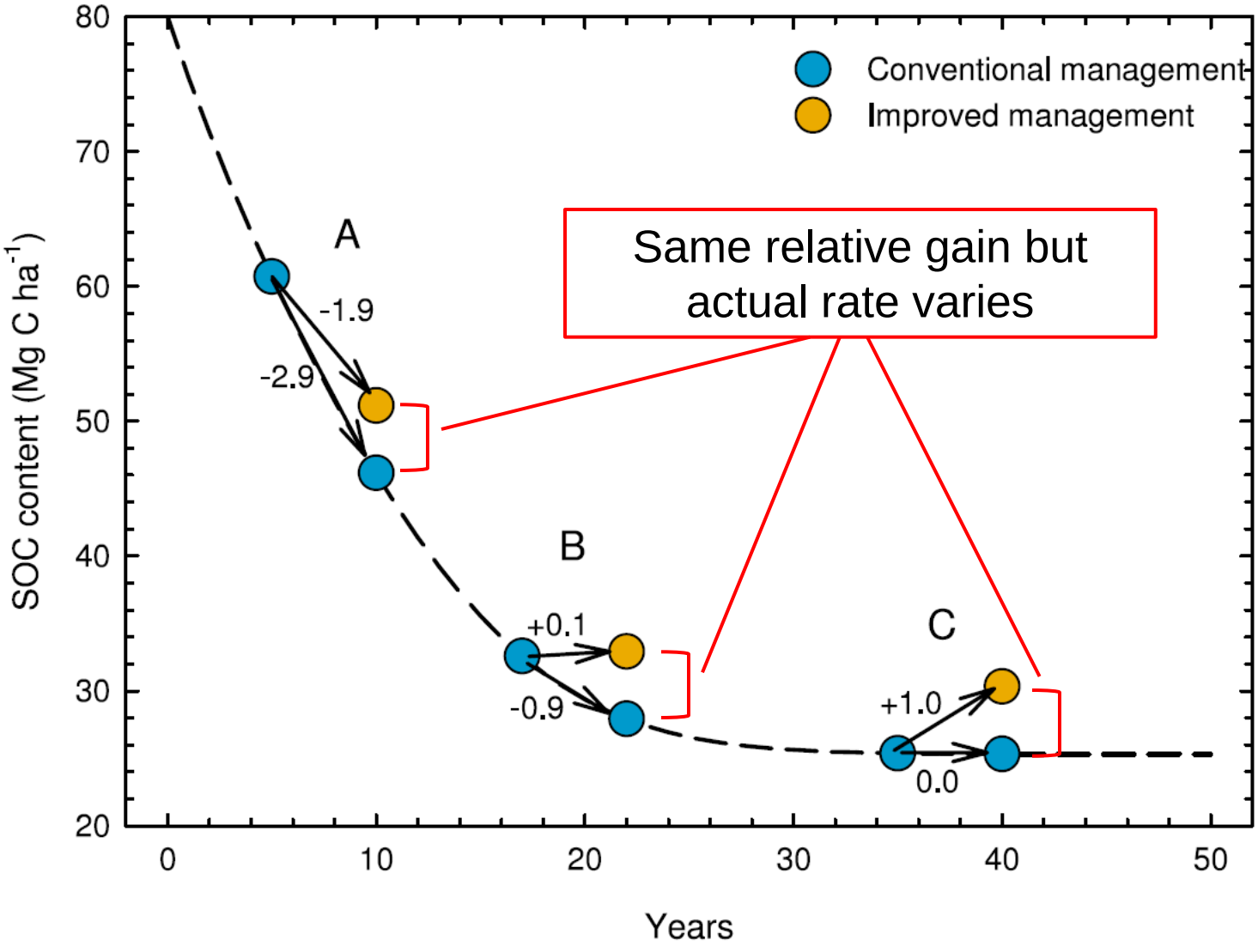
Tilman et al, 2002. Nature

Long term China studies



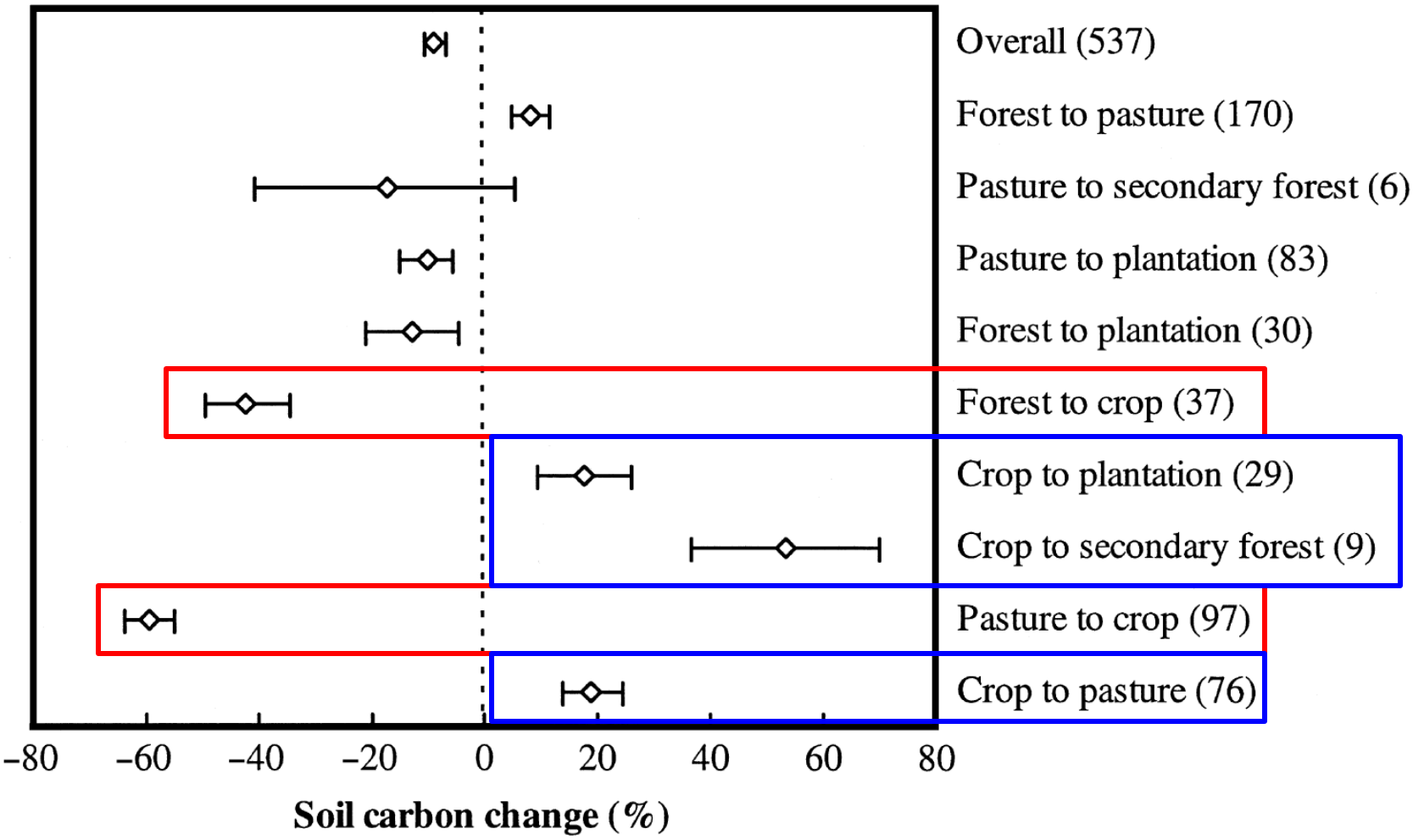
Shen et al, 2007. Bio Ferti Soils

Can agricultural soil sequester C?



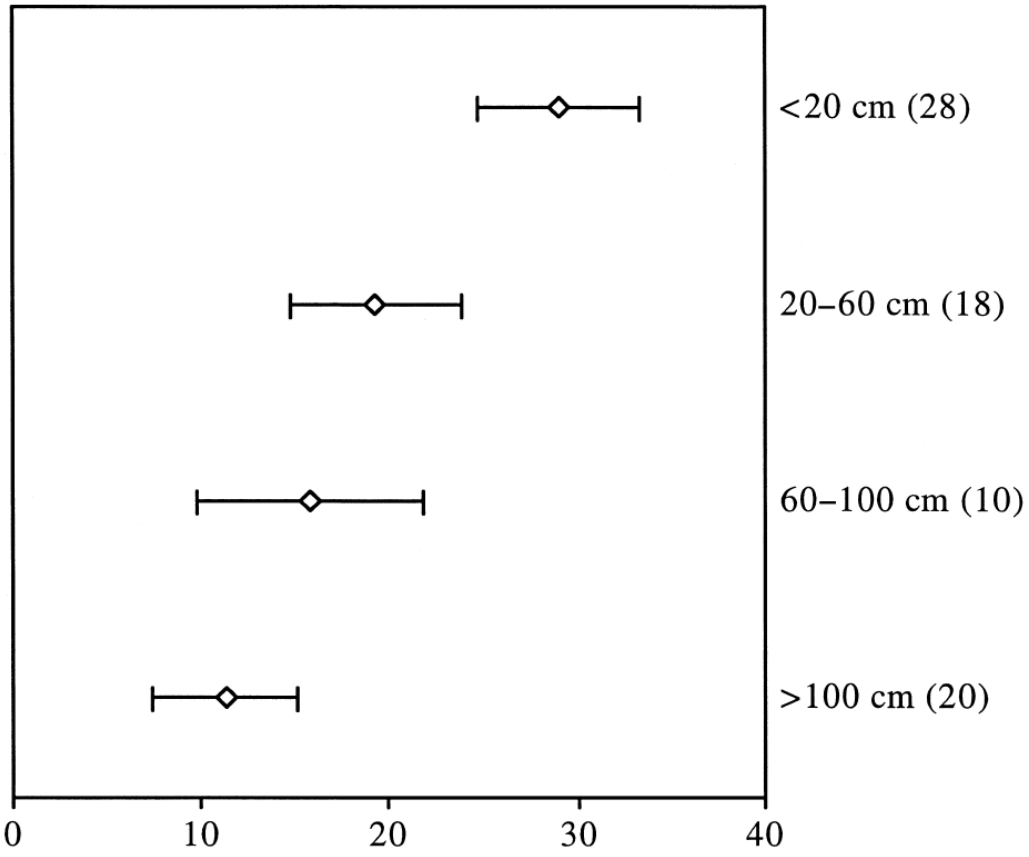
(Sanderman and Baldock 2010)

Land use change on soil C



(Guo and Gifford 2002)

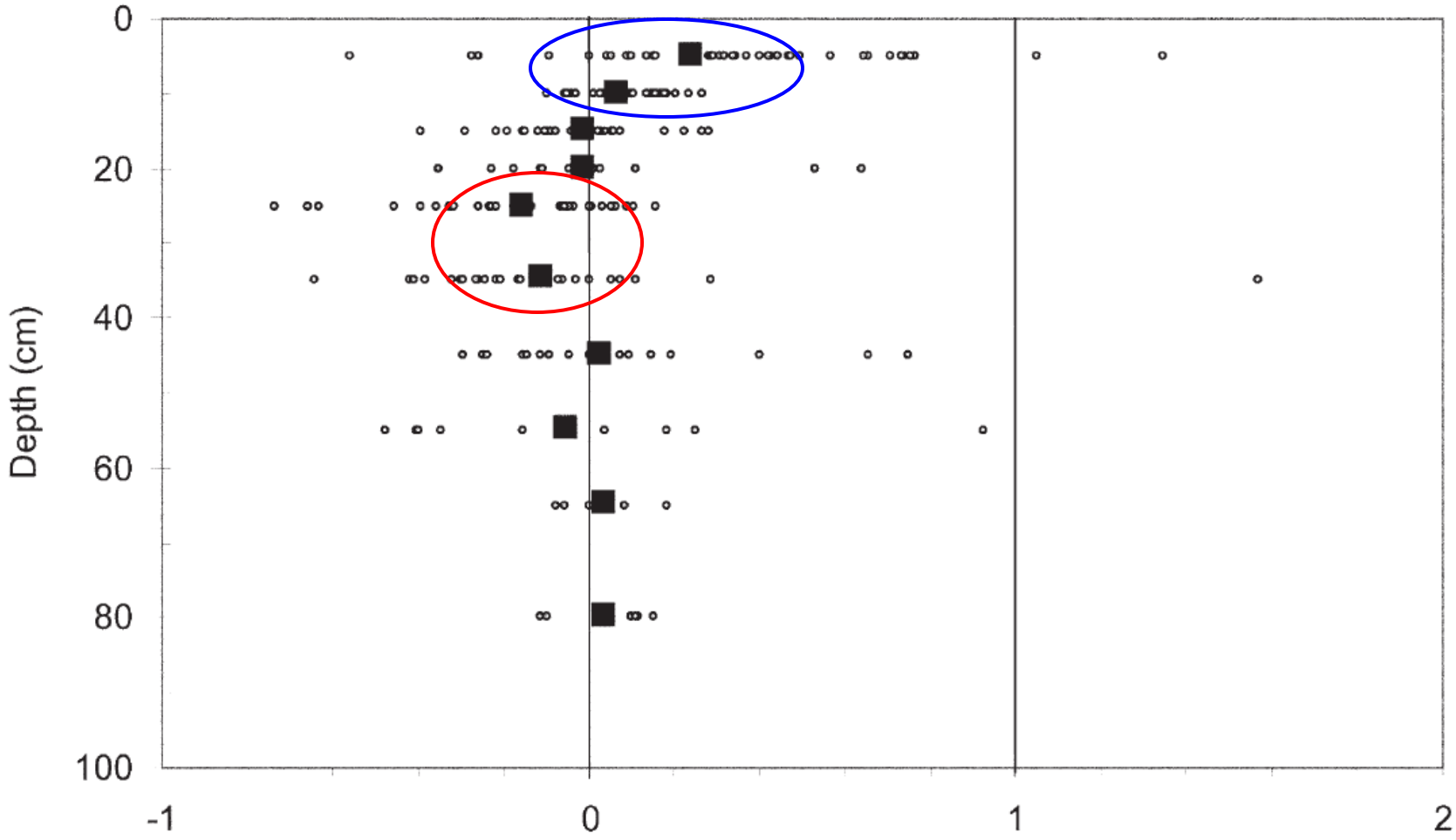
Effects (conversion to pasture) vary with soil depth



Effect of pasture (from crop) conversion on soil organic C (%)

(Guo and Gifford 2002)

Effects (no-till) vary with soil depth



(Angers and Eriksen-Hamel 2008)

In Australia……

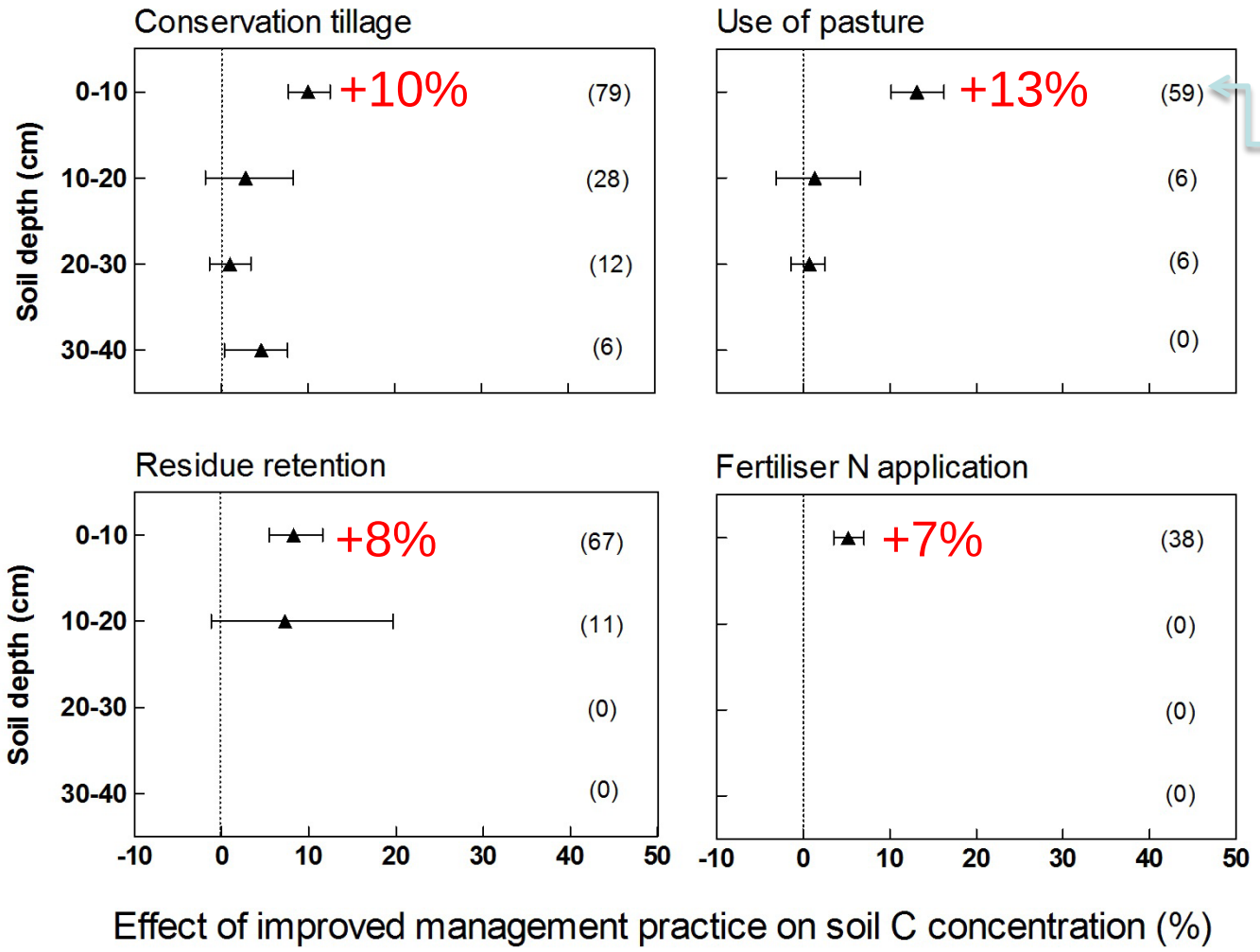
- Carbon farming initiative (CFI)
  - farmers and land managers earn carbon credits by storing carbon or reducing GHG emissions
  - AUD 23 per tonne of CO_2-equivalent (maybe abolished by the new government)

- Can improved management practices increase soil carbon in Australian cropping systems?
- What is potential?
- Is it economically feasible?

Methods of meta-analysis

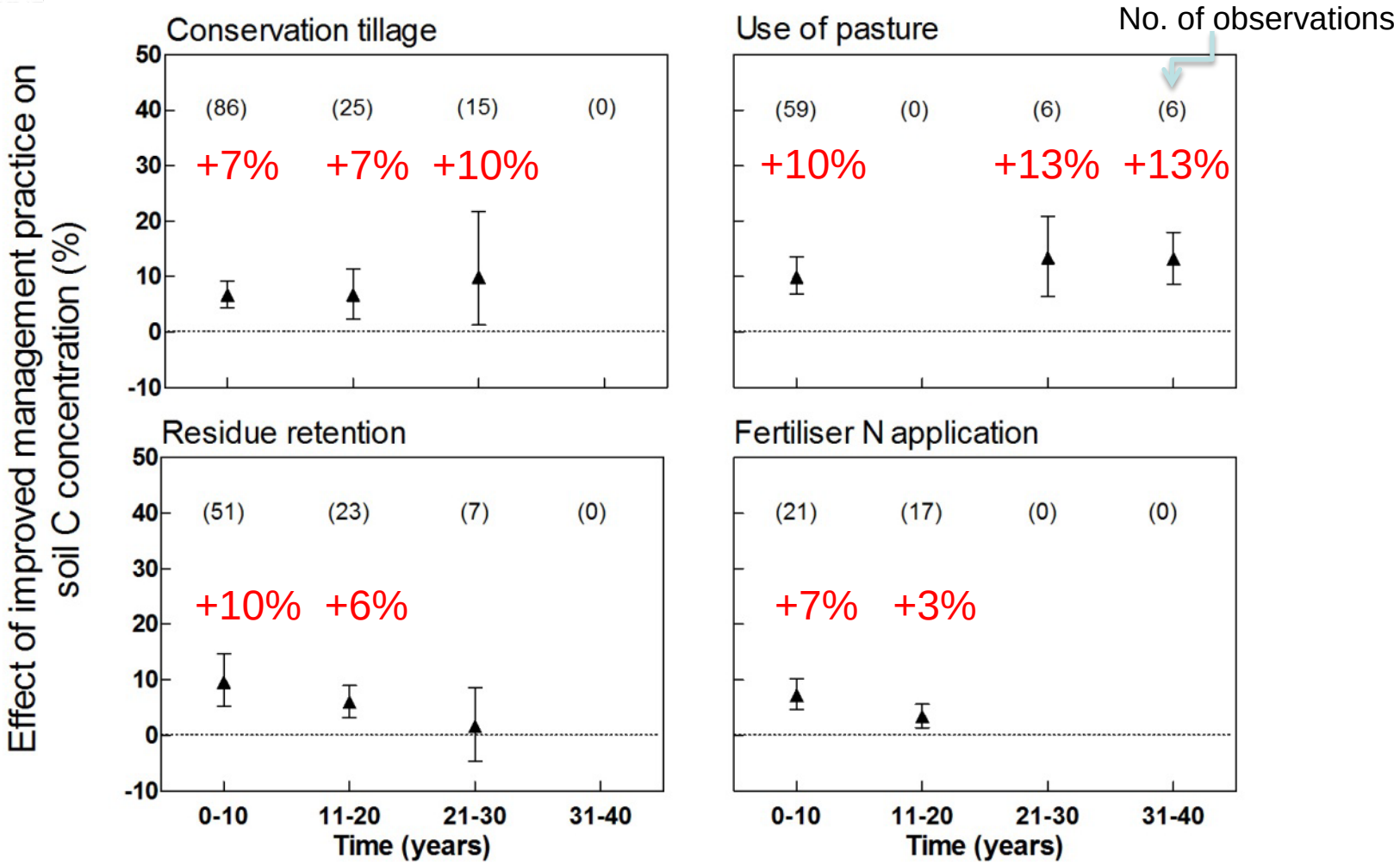
- Improved management practices, viz. conservation tillage, residue retention, the use of pasture, and fertiliser N application, all peer reviewed publications of Australia studies (from 1984 to present)
- Response metric: natural log of the response ratio (r = response to treatment/response to control)
- Percentage change due to treatment: $(r - 1) \times 100$
- Weighting function (by replication)
- Significant effects if the confidence intervals did not overlap with zero
- MetaWin 2.1

Changes in soil C (%) with soil depth



- Improved practices increased soil C concentration by around 10%
- Highest at surface soil; decreased with depth

Changes in soil C (%) with management duration



- Improved practices sustained soil C concentration for at least 20 years
- Longer effect under conservation tillage and pasture use

Changes in soil C stock with soil depth

Soil depth (cm)	Relative change in C stock (kg C ha^{-1} $year^{-1}$)	
	mean	95% CI
Conservation tillage		
0–10	139.4	100.8 to 184.1
10–20	23.6	–26.7 to 75.1
20–30	21.2	4.7 to 34.9
30–40	36.2	0.0 to 79.9
Residue retention		
0–10	62.1	31.4 to 91.0
10–20	29.9	–4.8 to 71.0
20–30	1.8	–8.6 to 11.2
30–40	NA	NA
Use of pasture		
0–10	140.3	69.2 to 250.1
10–20	–17.5	–153.1 to 127.6
20–30	13.6	–59.9 to 65.4
30–40	NA	NA
Fertiliser N application		
0–10	47.3	27.6 to 65.8
10–20	11.0	1.3 to 20.0
20–30	1.5	–8.3 to 11.2
30–40	NA	NA

Changes in C stock with management duration

Duration (year)	Relative change in C stock (kg C ha^{-1} year^{-1})		CO_2-equivalent	C credit [a] (I)	N input to stabilise C storage [b]	N cost to stabilise C storage [c] (II)	Financial returns (I–II)
	mean	95% CI	(kg CO_2 ha^{-1} year^{-1})	($ ha^{-1} year^{-1})	(kg N ha^{-1} year^{-1})	($ ha^{-1} year^{-1})	($ ha^{-1} year^{-1})
Conservation tillage							
0–10	150.4	96.8 to 210.2	551.47	12.7	15.0	19.6	–6.9
11–20	99.5	58.2 to 141.5	364.83	8.4	10.0	13.0	–4.6
21–30	40.3	0.6 to 85.6	147.77	3.4	4.0	5.3	–1.9
31–40	5.8	–5.7 to 19.6	0	0	NA	NA	NA
Residue retention							
0–10	146.6	40.0 to 275.9	537.53	12.4	14.7	19.1	–6.8
11–20	71.0	46.1 to 97.8	260.33	6.0	7.1	9.3	–3.3
21–30	20.9	–14.9 to 65.3	0	0	NA	NA	NA
31–40	4.4	–3.8 to 13.3	0	0	NA	NA	NA
Use of pasture							
0–10	131.5	41.6 to 258.5	482.17	11.1	13.2	17.2	–6.1
11–20	NA	NA	NA	NA	NA	NA	NA
21–30	75.1	57.4 to 95.2	275.37	6.3	7.5	9.8	–3.5
31–40	59.7	39.5 to 78.7	218.90	5.0	6.0	7.8	–2.8
Fertiliser N application							
0–10	67.4	20.0 to 112.0	247.13	5.7	6.7	8.8	–3.1
11–20	39.6	18.4 to 60.4	145.20	3.3	4.0	5.2	–1.8
21–30	NA	NA	NA	NA	NA	NA	NA
31–40	14.1	6.8 to 21.9	51.70	1.2	1.4	1.8	–0.7

[a] carbon price of AUD 23 Mg^{-1} CO_2-equivalent (Australian Government 2012)
[b] soil C:N ratio of 10:1 (Carlyle *et al*. 2010)
[c] N cost of AUD 600 Mg^{-1} urea (46%N) (McCormick 2010; Mulvany 2011)

Conclusions

- In Australia, common agricultural management practices increased soil C by around **10%,** but mostly in the surface **10 cm** of the croplands, mostly in the first **10 years**.
- The effects of these practices on soil C diminished with time.
- Australia's Carbon Farming Initiative may not provide financial incentives for adopting any of the targeted practices for decades.
- Carbon sequestration in Australian agricultural soils is limited both technically (biophysically and methodologically) and economically.

Lam, et al, 2013. The potential for carbon sequestration in Australian agricultural soils is technically and economically limited. ***Scientific Reports,*** *3, 2179,* doi:10.1038/srep02179

Implication for the government's policy

- 100m ha of managed cropland and modified pasture in Australia
- Assuming 100% take-up of the improved practices, and without their potential for increased emissions of CH_4 from grazing animals and N_2O from additional nitrogen fertilizer.
- Only 53.3m tones of CO_2 equivalent sequestered in soil, comparing to the government's Direct Action Plan target of 85m tones