In this afternoons presentation I have been asked to talk about the science of soil carbon and specifically,

Where are we up to with current research,

What we know,

Where the gaps are,

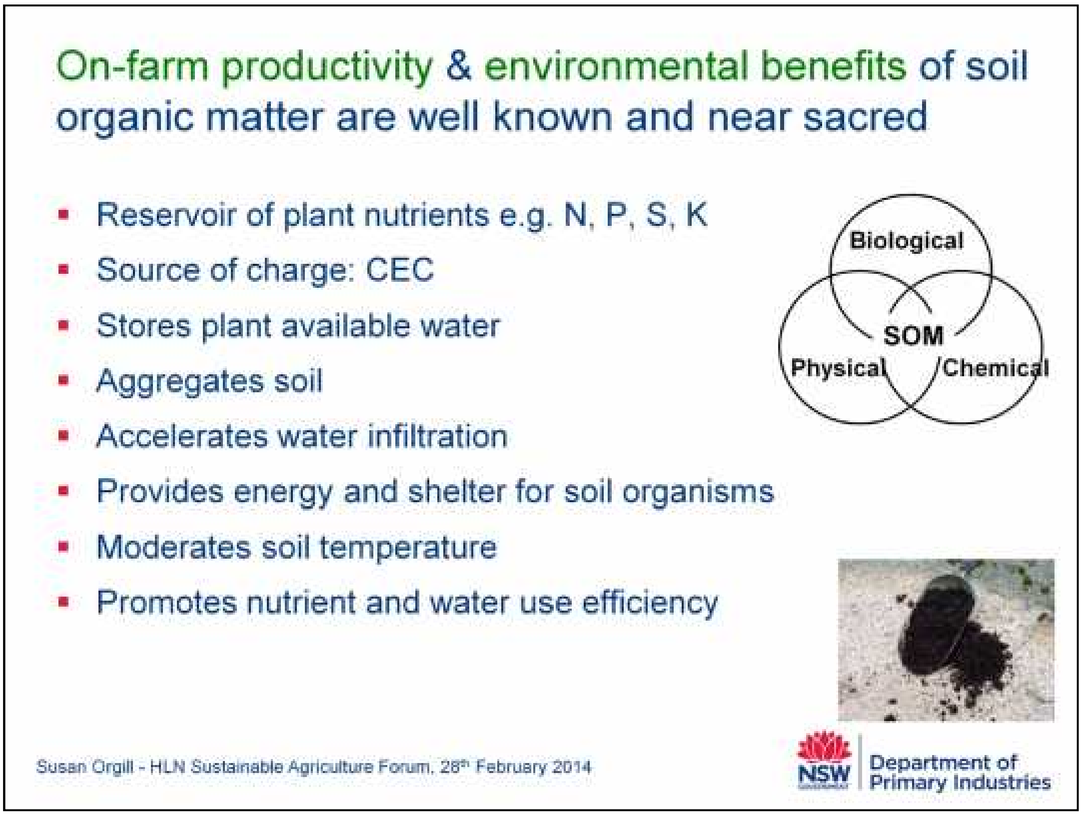
Where the opportunities are for agriculture to play role in sequestering more carbon in soil, and

The role of nutrients in soil carbon and the tradeoffs associated with this…

LINK; but to start with the take home messages..

Take home messages…

- Different types of organic matter in soil; some decompose more quickly than others
- Soils vary in their capacity to accumulate and store carbon
- Net carbon sequestration in soil is generally slow and unspectacular under agriculture
- Farm productivity is closely linked to soil functions that depend on decomposition of organic matter
- There *are* land management options to increase soil carbon but this may come at a cost
- Nutrients play an important role in accumulating soil carbon



SOM provides multiple functions and benefits for agricultural productivity and sustainability.

Firstly, through photosynthesis, C storage in soils provides a temporary sink of C that could otherwise be warming the atmosphere.

SOM positively correlates with CEC, nutrient availability, pH, soil aggregation, stability and water retention and negatively correlates with bulk density.

SOM provides nutrients, energy and shelter for soil organisms. Decomposition of SOM facilitates the production of microbial structural units, metabolites and stimulates nutrient immobilisation and mineralisation.

SOM forms and strengthens organic bonds between clay and sand particles and microaggregates. Improved soil structure increases: aeration, infiltration, storage and transmission of water and nutrients, resistance to wind and water erosion and promotes seed germination and root growth.

Increasing soil organic matter improves soil structure, increases nutrient cycling and encourages soil organisms

The same could be asked of a poorly managed site… why don't levels keep getting lower?

To answer this we need to think about what SOM actually is, how it increases and how our land management influences it…

Different types of organic matter in soil; some decompose more quickly than others

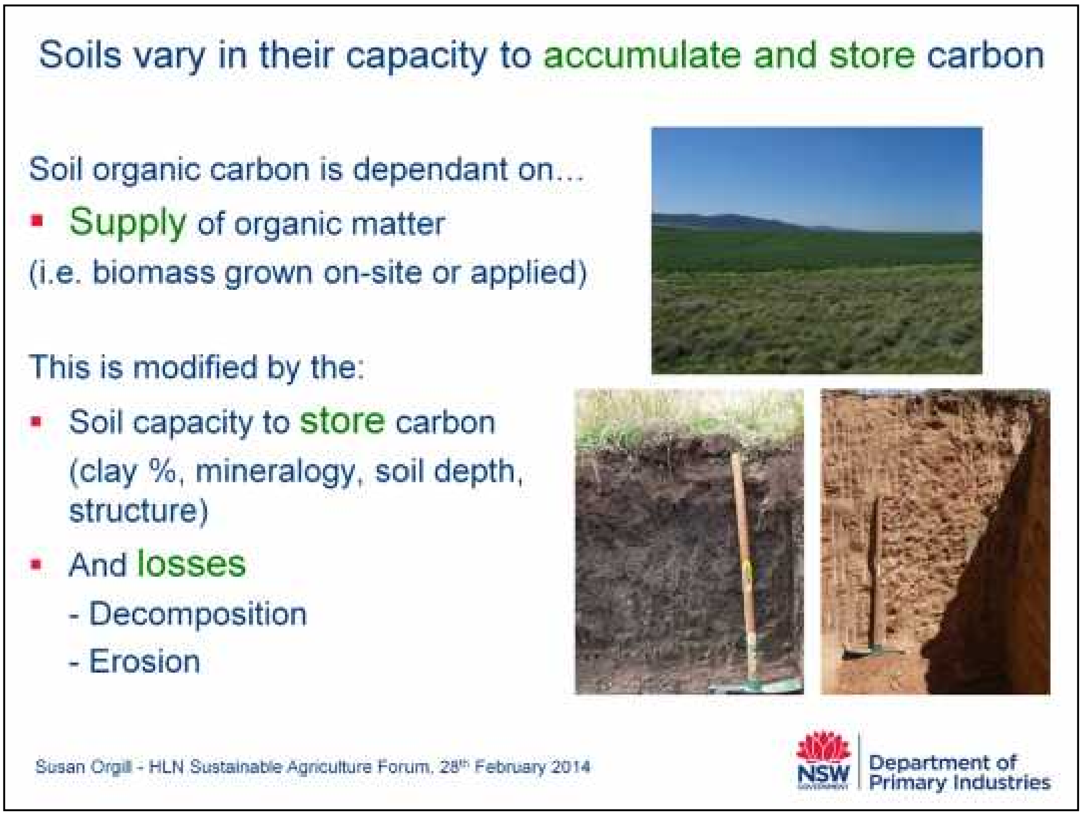
- Carbon is what we *measure;* soil organic matter is approx 58% by weight

  1826: "*SOM averages close to 58% in content of carbon*" (Sprengel)
  1945: "*…This figure is still accepted today.*" (Schollenberger)

- The rest is N, P, S, K and a range of trace elements

- Soil Organic Matter ("SOM")
  - <2mm partially decomposed organic res
  - microscopic organisms
  - humus
  - charcoal

Fast ↓ **Slow** ↓ **Very slow**



Soils vary in their capacity to sequester and ‘protect’ carbon; depends on soil type, climate, vegetation and land management

Increasing soil organic matter improves soil structure, increases nutrient cycling and encourages soil organisms

Soils vary in their capacity to sequester and ‘protect’ carbon; depends on soil type, climate, vegetation and land management

Perennial pasture example:
Introduced and native pastures in SE NSW

Region – parent material	Vegetation	Depth (70cm)	
Monaro			
Basalt	Introduced	160.4 (10.8)	n.s.
	Native	156.9 (10.1)	
	Remnant	116.3 *	
Deep granite	Introduced	78.0 (11.4)	n.s.
	Native	75.0 (11.1)	
	Remnant	44.6 *	
Shallow granite	Native	43.3 (3.2)	

Presented here is survey data from over 70 sites in SE NSW.

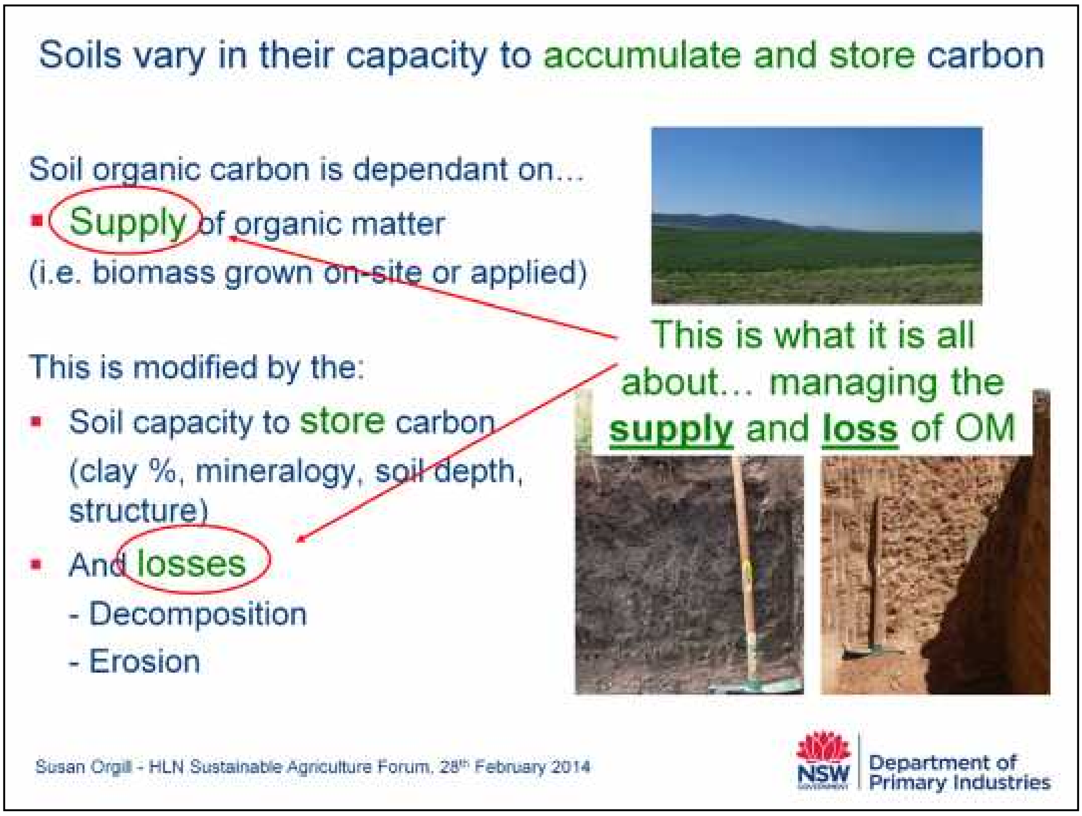
Firstly, you can see the significant influence of parent material on soil C. There are several reasons for this including the superior water and nutrient holding capacity of clay-rich basalt soils and their ability to protect OC molecules.

Secondly, there was no difference between native and introduced perennial pastures, but there was more carbon in soil under agricultural management than remnant vegetation.

This is an important point, while there has been a significant decline in C in agricultural soils, most of this happened a long time ago with aggressive management, droughts and rabbit plagues. If we had of been farming the same as we have over the past ten years there may have been very little decline in soil C.

CLICK

Thirdly, with the same parent material and vegetation class there is a difference with region, i.e. rainfall distribution and temperature.



Soils vary in their capacity to sequester and 'protect' carbon; depends on soil type, climate, vegetation and land management

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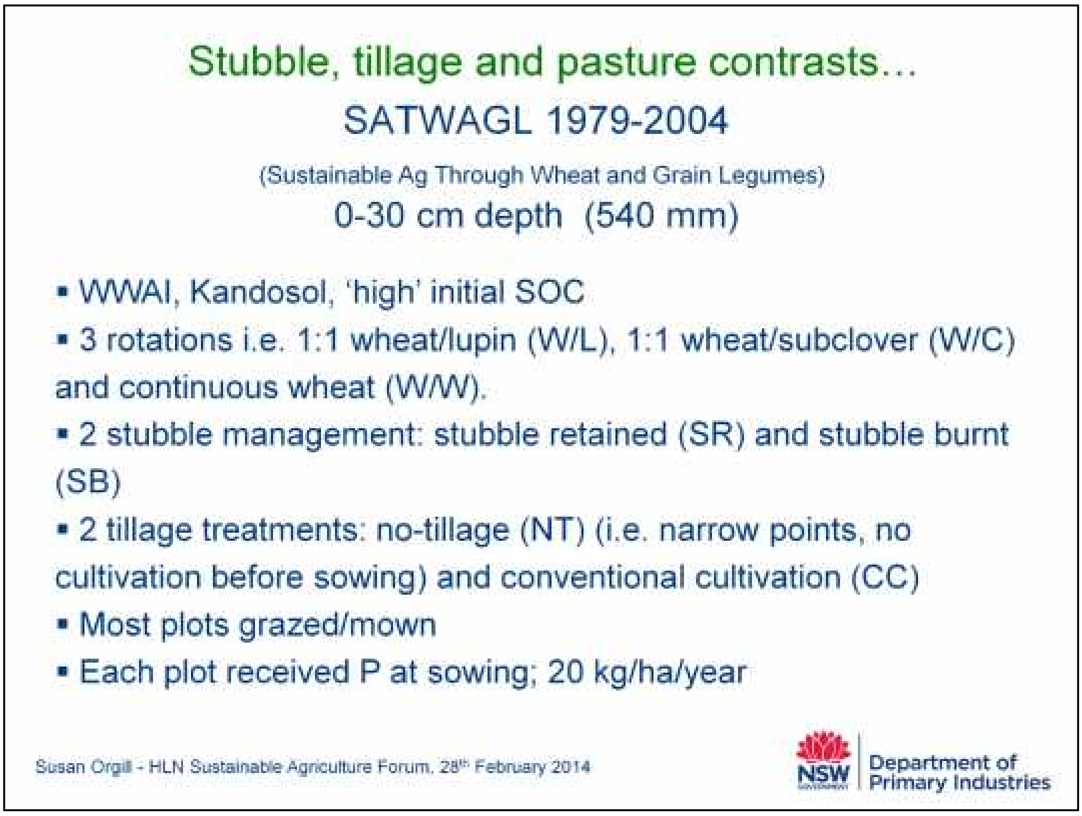
LINK;

Now that sets the scene for considering farming practices to increase the soils carrying capacity.



Stubble, tillage, and grazing contrasts… These treatments were selected to show differences in stubble management and rotation.

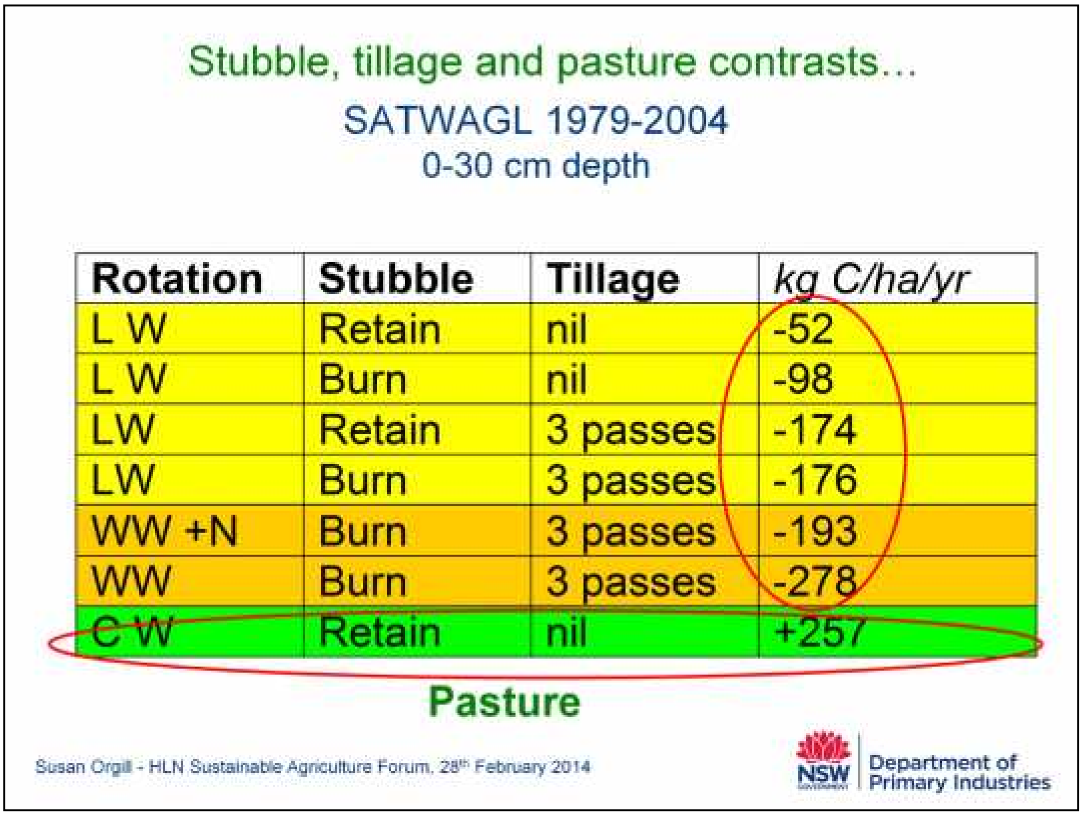
-3 rotations i.e. 1 : 1 wheat/lupin (W/L), 1 : 1 wheat/subclover (W/C), and continuous wheat (W/W).

-2 stubble management: stubble retention (SR) and stubble burnt (SB)

-2 tillage treatments were no-tillage (NT) (i.e. narrow points, no cultivation before sowing) and conventional cultivation (CC) (three cultivations using offset tandem disc harrows until 1992 and thereafter scarifiers in the SR treatments, and scarifiers in the SB treatments since 1979).

-Most plots grazed (some mown) 10 DSE/ha during the grazing season, but not grazed over summer.

-Each plot received P at a sowing at rate of 20 kg/ha/year.

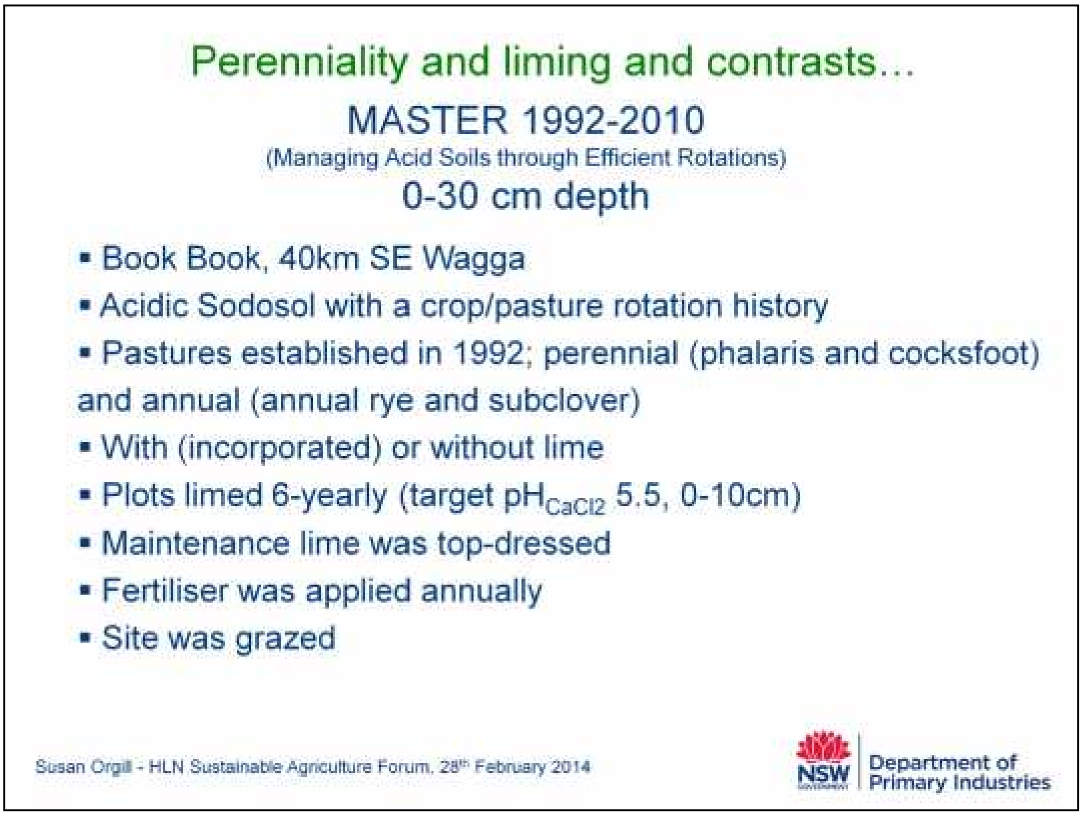


Rotation	Stubble	Tillage	*kg C/ha/yr*
L W	Retain	nil	-52
L W	Burn	nil	-98
LW	Retain	3 passes	-174
LW	Burn	3 passes	-176
WW +N	Burn	3 passes	-193
WW	Burn	3 passes	-278
C W	Retain	nil	+257

Presented here are 7 of the 13 SATWAGL treatments.

Including a pasture, such as clover in the rotation increased C accumulation by the greatest amount, i.e. 0.3t/C/ha

LINK; Continuing on looking at the role of pastures in increasing soil carbon…



MASTER (Managing Acid Soils through Efficient Rotations)

-Experiment established on a highly acidic soil with a crop/pasture rotation history

-Book Book, 40km SE Wagga

-Sodosol

-Prior to 1985, annual pastures of subterranean clover and volunteer annual grass weeds and other broadleaf weed species. In May 1985, site was limed (540 kg/ha) and sown to phalaris, cocksfoot, and subterranean clover. Poor establishment and persistence.

-Two types of pastures, perennial (phalaris and cocksfoot) and annual (annual rye and subclover), each with or without lime application, were established in 1992 as part of the MASTER experiment.

-Lime was applied to a given plot at 6-year intervals. The target pHCa of 5.5 in top 10cm. The initial lime was incorporated but the maintenance lime was top dressed.

-Fertiliser was applied annually and the site was grazed.

Perenniality and liming and contrasts…

MASTER 1992-2010
0-30 cm depth

Rotation	*kg C/ha/yr*	
Perennial pasture	+499	
Annual pasture	+496	~0.5t/C/ha/yr
Perennials limed	+552	
Annuals limed	+462	

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Remembering this soil was quite degraded, pasture, regardless of perennial or annual, lime or not lime increased soil carbon at approximately 0.5t/C/ha/yr.

LINK; Now lets take a brief look at the role or tillage in the soil C story…

Stubble management contrasts…

Rutherglen
0-20 cm depth
… At 28 years, t_o=1.9%SOC (590 mm)

%SOC	Burnt stubble		Retained stubble	
Depth (cm)	Cult-scar	DD	Cult-	DD
0 - 5	1.09	1.24*	-	1.12
5 - 10	0.77	0.76	-	0.74
10 - 20	0.41	0.46	-	0.46

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Struggling to see any increases or decreases. May change slightly with BD information, yet to be included, but generally after 28 years very little difference.

Stubble management contrasts…

Harden (still to be published…) At 21 years…
0 - 20 cm depth

%SOC	Burnt stubble	Retained stubble
Depth (cm)	DD	DD
0 - 5	1.27	1.33
5 - 10	0.72	0.71
10 - 15	0.46	0.45
15 - 20	0.33	0.32

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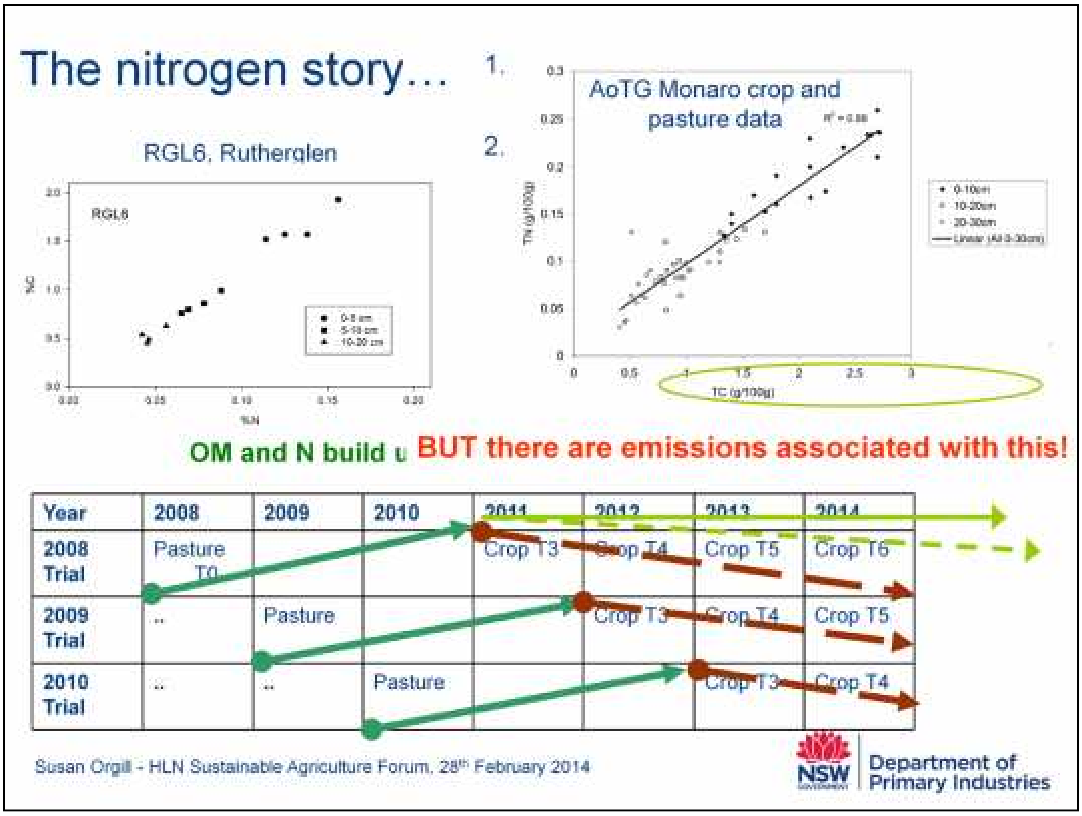
Harden trial, John Kirkegard
After 21years not much happening.

So what does this tell us?

1. Change in OC associated with management is not rapid: -300 to +550 kg/C/ha.30cm /yr

2. Increases in OC are more associated with the pasture phase compared with stubble management or tillage

Now lets consider why pastures and nutrients are important...



Five treatments, 3 sowing years (autumn 2008, 2009, 2010):

Lucerne (and subclover), Cocksfoot (and subclover), Chicory (and subclover), Phalaris (and subclover) and Crop only

Rutherglen Grain Legume Trial 6

Relationship between TC and TN. We know two things; 1. pasture phases are important to increase N for the cropping phase and 2. carbon and nitrogen are linked, i.e. you need N to increase C. If you crop after the pasture-N buildup phase (which is agronomically desirable) it has to decrease C. So you either build up N for crop, or build up N for C and apply bagged N for the crop.

Nutrients required to sequester organic carbon…

Nutrients	C	N	P	S
Wheat straw	10 000	152	23	37
Perennial ryegrass	10 000	759	49	63

(Kirkby *et al.* 2014 and unpublished Orgill data)

1. Crops and pastures need nutrients to grow and supply OM
2. Soil organisms can sequester 'new' organic carbon
3. Soil organisms need nutrients to grow and stabilise OM

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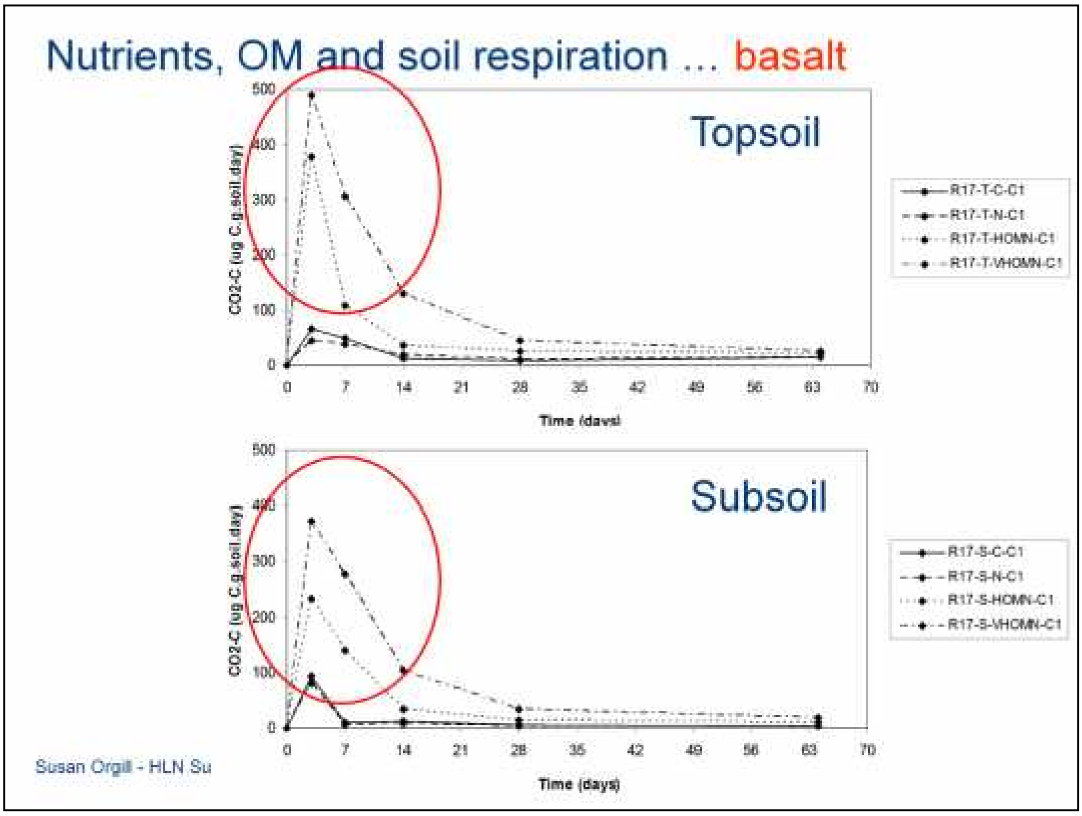
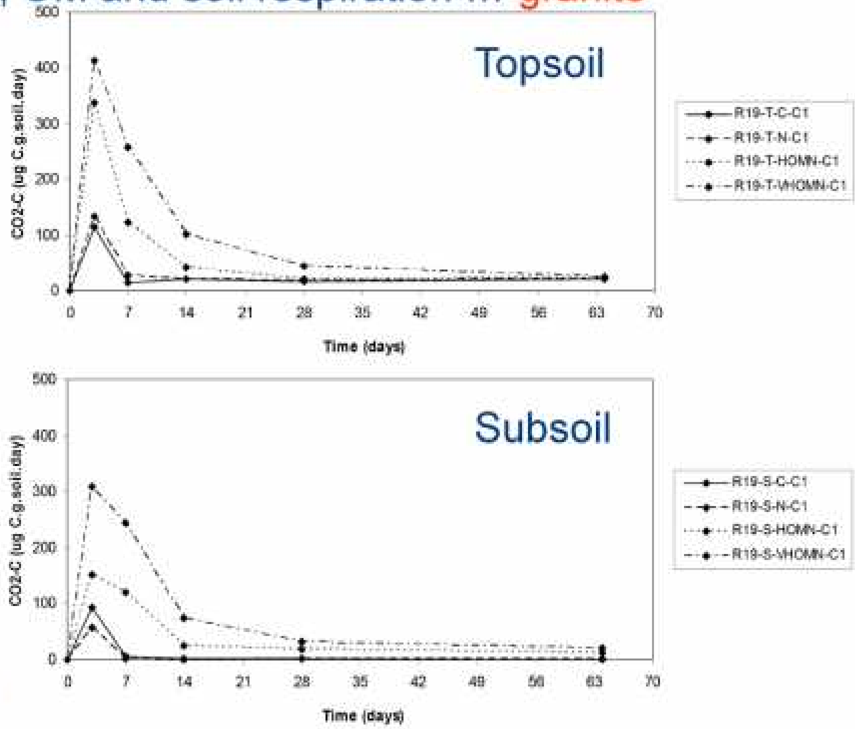


Here if we just add nutrients…. Nothing happens…

But if the microbes have nutrients and OM…. There is a lot of activity.

Nutrients, OM and soil respiration … granite



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There *are* land management options to increase soil carbon but this may come at a cost

Soil C sequestration may have costs in terms of:

- Nitrogen: bagged N *vs* organic N?
- Soil acidity: limestone to maintain production application of (0.059t/C or 0.217t/CO_2e per t/limestone)
- Nutrients: mineral P and S to grow more biomass (and stabilise C)

Net soil C sequestration may be slow under agriculture

There are on-farm productivity & environmental benefits to increasing soil C

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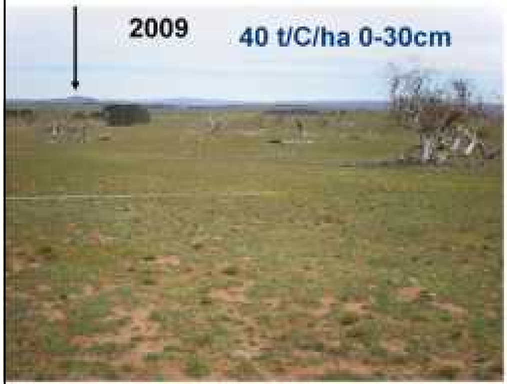
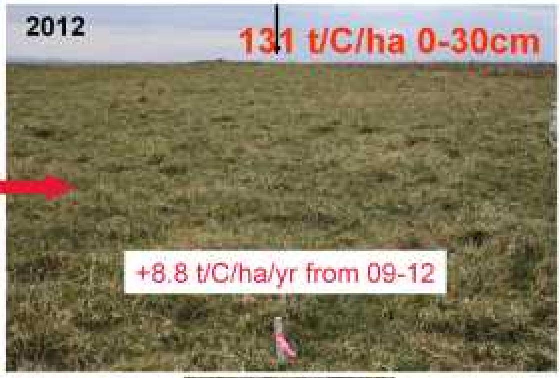
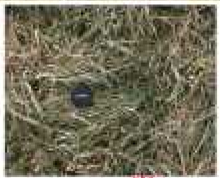
And in some cases … just add water…

Granite derived soil



Basalt derived soil





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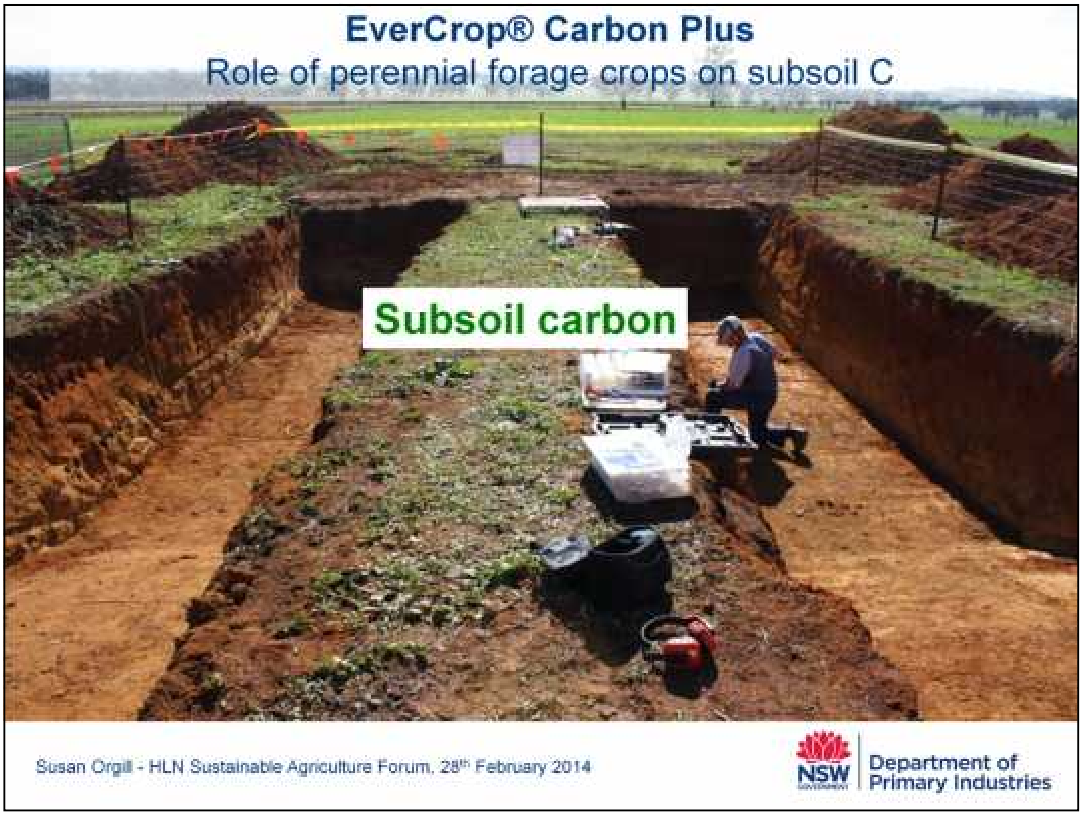
Where to now….


EverCrop® Carbon Plus
Role of perennial forage crops on subsoil C
Subsoil carbon
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NSW Rangelands Grazing Pressure and Soil Carbon Project
Understanding the influence of grazing pressure changes on C

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Monaro Farm Management Strategies and Soil Carbon Project
Management of pastures within changing landscapes
Low P vs High P
Unlimed vs Limed
Native vs Intro pasture
Pasture vs Crop
Aspect: North vs South
New vs Old pasture
Pasture vs Pines
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Where to now….
Making soil sampling and analysis cheaper…



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