



## Soil: Our Natural Capital

### The role of soil and soil management in decarbonising agriculture

Professor R Jane Rickson, FIAgrE  
Cranfield Soil and AgriFood Institute  
Cranfield University

Institution of Agricultural Engineers Annual Conference  
October 11<sup>th</sup>, 2017

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# Soil: Our Natural Capital

## The role of soil and soil management in (de)carbonising agriculture



### Outline of the presentation

1. The issue of carbon and climate change
2. The role of soil in the carbon cycle
3. How much soil carbon do we have?
4. How can we increase soil carbon?
5. Take home message



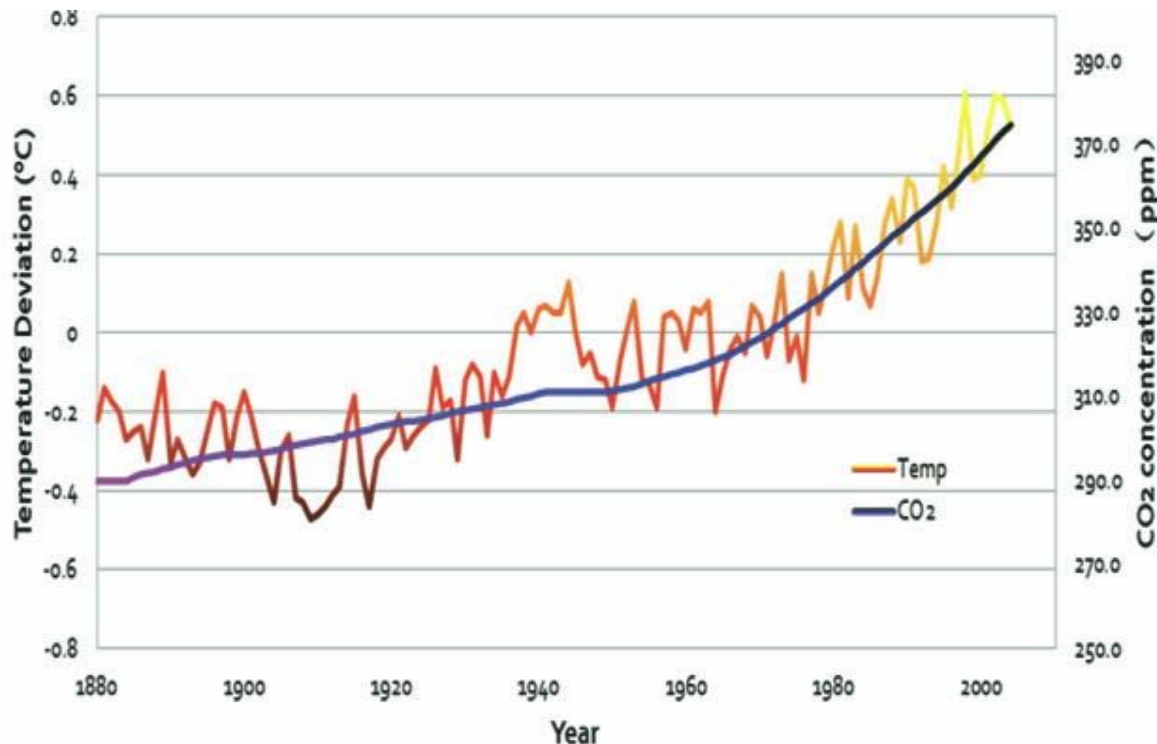
Acknowledgement: K. Ritz



# 1. The issue of CO<sub>2</sub> and climate change

Increased CO<sub>2</sub> in the atmosphere associated with:

- temperature rises (global warming)
- climate change
- extreme weather events
  - sea temperatures and hurricanes?



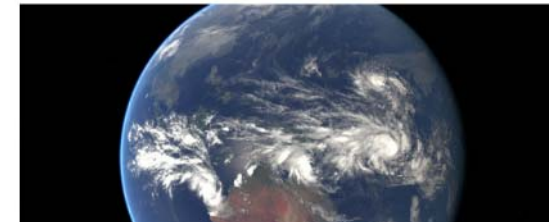
<http://www.coalnews.net/papers/November2013/HTML/files/assets/seo/page16.html>



## Extreme weather events of 2015: Is climate change to blame?

Last updated on 21/06/2015, 5:45 pm

Record temperatures, heatwaves and a brewing El Nino are making this year one of the more unusual in recent history



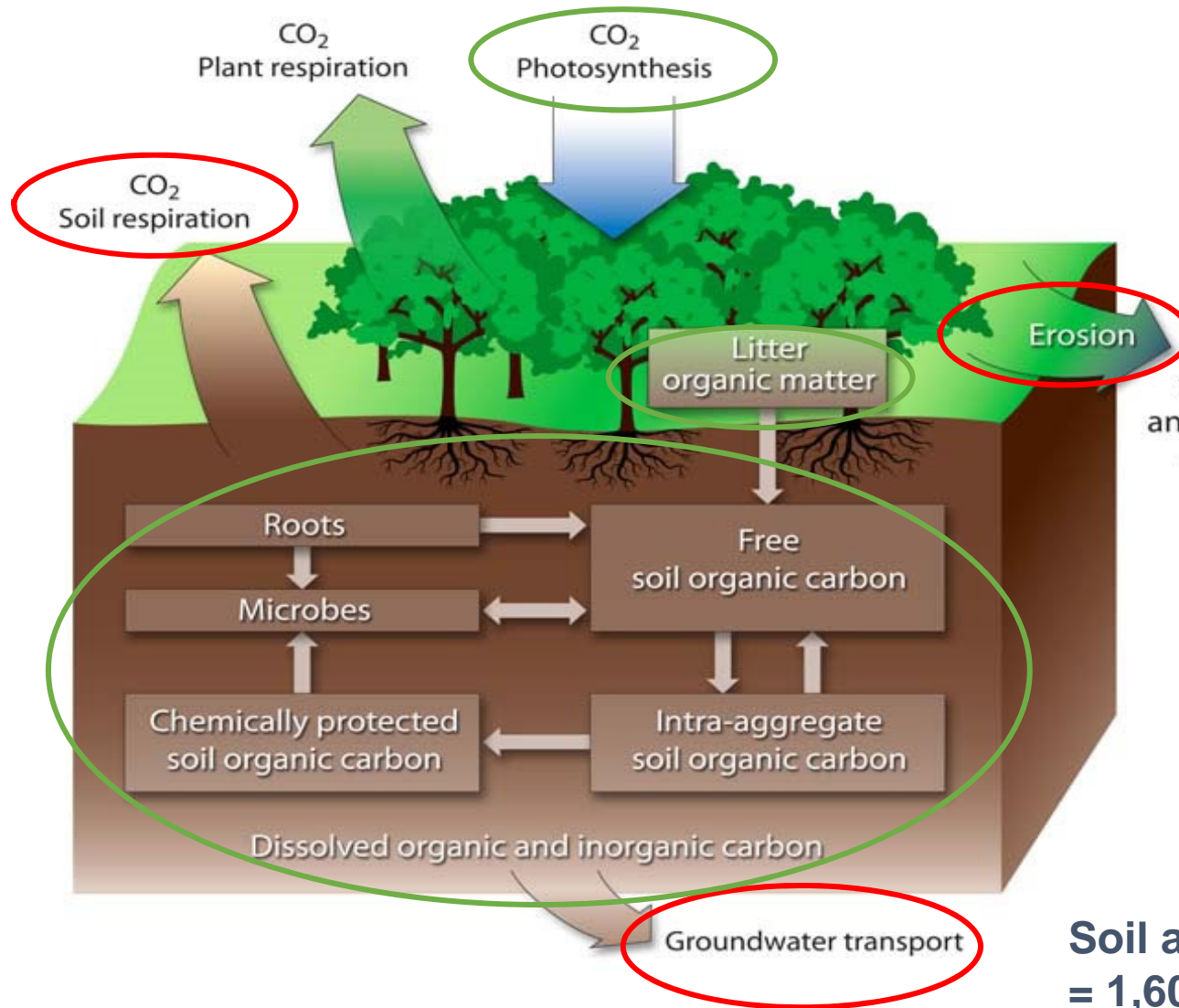
Cumbria flooding, Carlisle, NW England, December 2015



## **2. The role of soil in carbon cycle**



## 2. The role of soil in the carbon cycle



Organic matter transport and sediment trapping



**Soil as a global store of carbon**  
**= 1,600 Gigatonnes C**  
**= 1,600,000,000,000 tonnes C**  
**(N.B. Vegetation = 610 Gt C)**



2.

60p

14 NEWS

SCIENCE

# Healthy soil's ability to trap carbon dioxide 'is a no-risk climate solution'

By Katie Grant

If you want to combat global warming, you could start by looking under your feet, researchers have suggested.

Soil has the potential to "significantly" offset global emissions, scientists from Stanford University in the US have claimed. Many studies suggest its ability to trap carbon dioxide is "much greater" than previously estimated, they believe.

The research, published in the journal *Annual Review of Earth and Systemic Sciences*, states that soil could be instrumental in mitigating the effects of a rapidly changing climate.

Carbon dioxide is a heat-trapping greenhouse gas, which is released through human activities such as deforestation and burning fossil fuels, as well as natural processes such as respiration and volcanic eruptions.

Increased levels of greenhouse gases cause the Earth to warm, a process known as global warming. The planet's average temperature has risen about 1.5°C since the late 19th century, a rise driven largely by increased carbon dioxide and other human-made greenhouse gases.

Cher...  
soil organic carbon

Dissolved organ...

FRIDAY  
6 OCTOBER 2017  
Number 23143

Food and Agriculture Organization of the United Nations



A woman crossing one of several streams which feed an irrigation canal used for climate-smart agriculture in Tanzania. ©FAO/Daniel Hayduk



Soils help to combat and adapt to climate change by playing a key role in the carbon cycle

store of carbon

= 1,000 Gigatonnes C  
 = 1,600,000,000,000 tonnes C  
 (N.B. Vegetation = 610 Gt C)

[https://public.ornl.gov/site/gallery/originals/Carbon\\_Transformation\\_.jpg](https://public.ornl.gov/site/gallery/originals/Carbon_Transformation_.jpg)



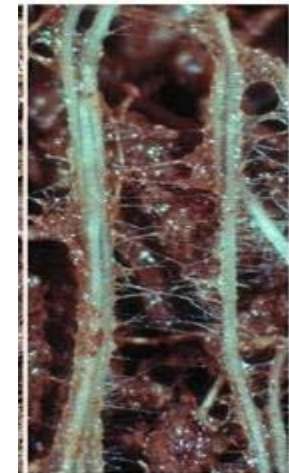
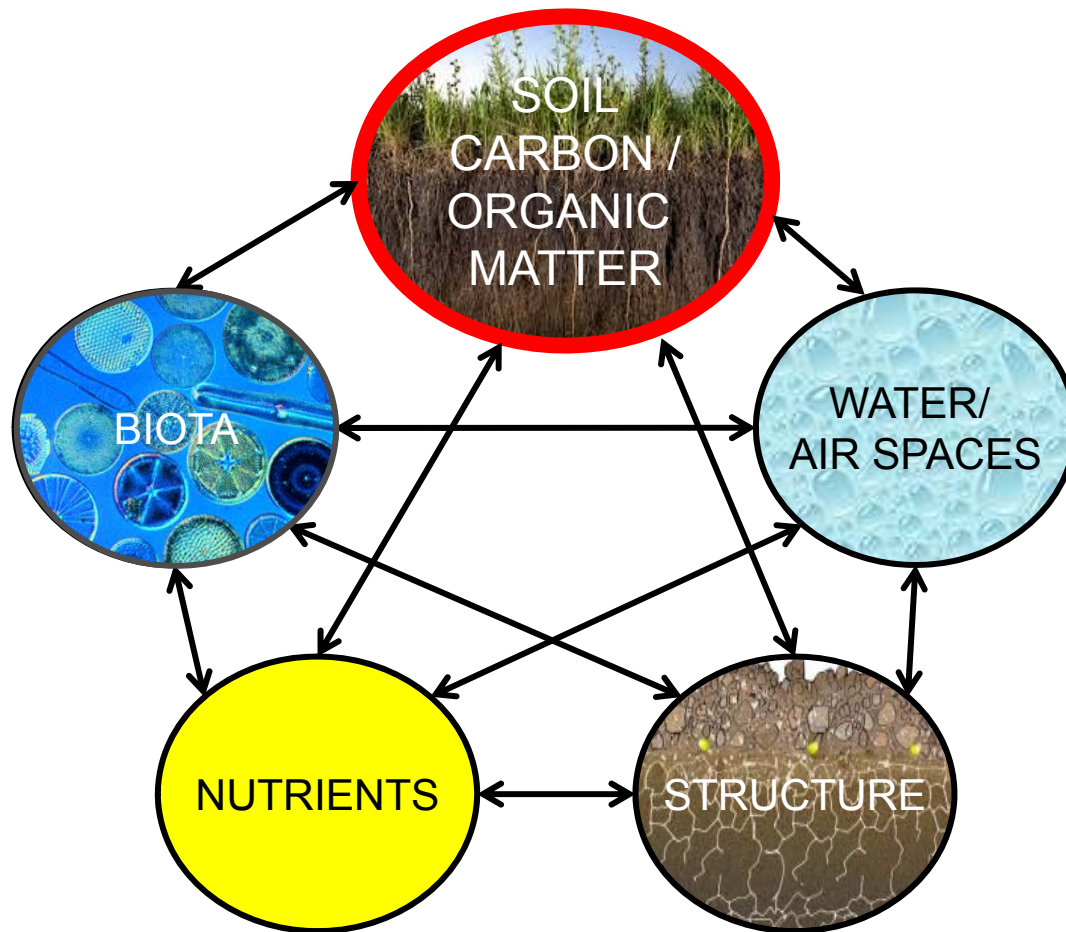


## 2. The role of soil in the carbon cycle



Soil carbon plays many other roles too....

Soil health and delivery of essential ecosystem goods and services



Soil health: the “pivotal 5” and their interrelationships  
(after K Ritz, pers. comm)



### 3. How much soil carbon do we have?







### 3. How much soil carbon do we have?



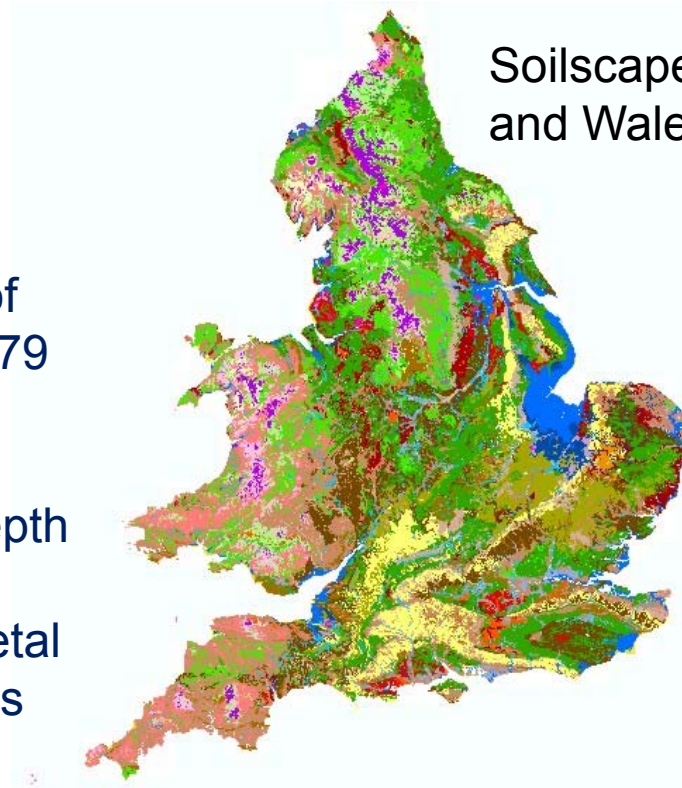
The National Soil Inventory, Soil Survey of England and Wales, 1979 – 1983

5 km grid, 0 – 15 cm depth

Organic carbon, pH, metal concentrations, nutrients

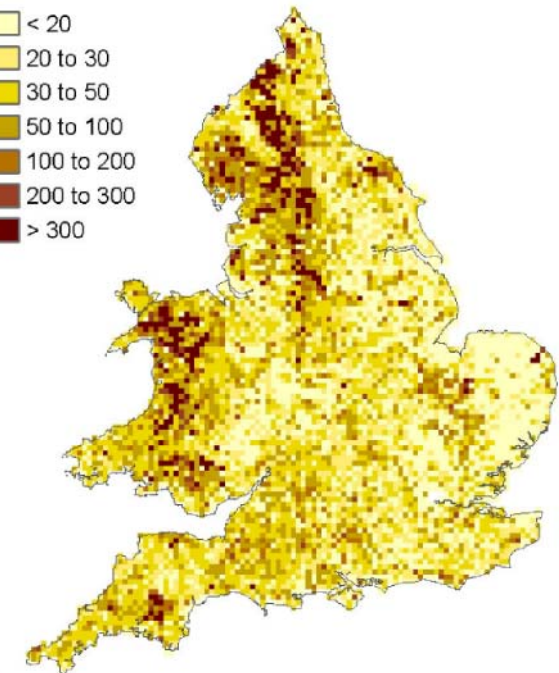
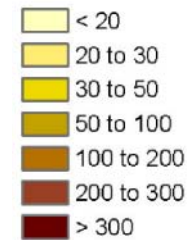
747 Soil Series

306 Soil Associations



Soilscapes of England and Wales

Carbon g kg<sup>-1</sup> (c. 1980)



Hiraethog (B.Adams)



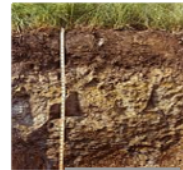
Denbigh (B.Adams)



Wilcockis



Cegin (B.Adams)





### 3. How much soil carbon do we have?



- Some sites resurveyed 1994 – 2003
- Mean annual rate of loss = 0.6 g of organic carbon per kg of soil
- For soils with >100 g carbon per kg, annual rate of loss = > 2 g per kg

#### Estimated annual soil C loss:

England & Wales alone

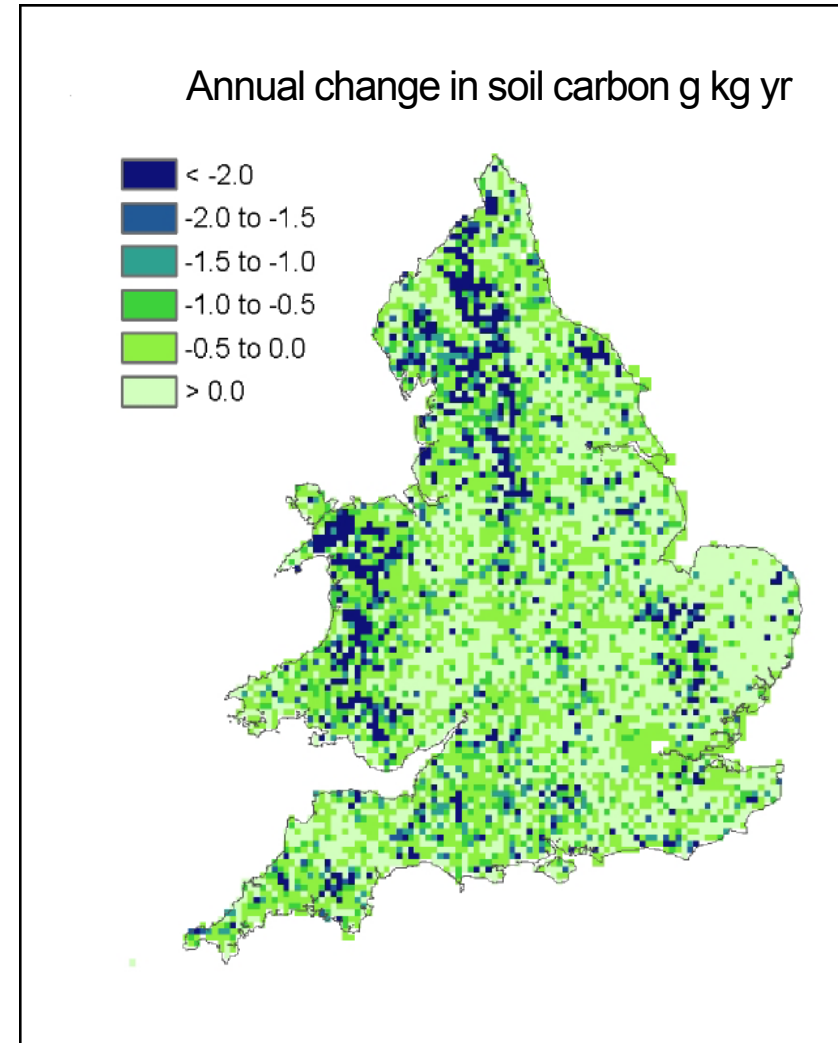
**≈ 4.4 million tonnes**

(costs c. £558 million/ yr  
(Graves et al., 2015))

For UK ≈ 4.4 x UK / E&W C stock

**≈ 13 million tonnes**

???How can this be replaced?



Carbon losses from all soils across England and Wales 1978-2003 (2005) Pat H. Bellamy, Peter J. Loveland, R. Ian Bradley, R. Murray Lark & Guy J.D. Kirk, *Nature* 437 pp 245 – 248.





## 4. How can we increase soil carbon?

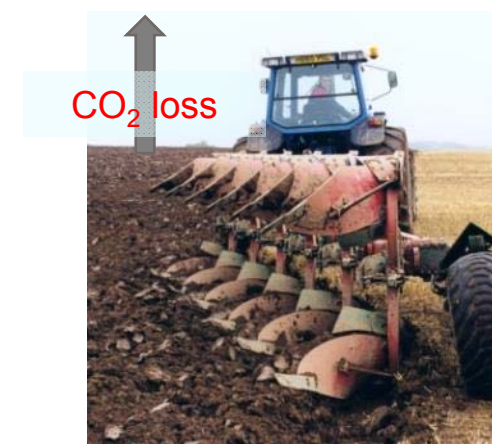
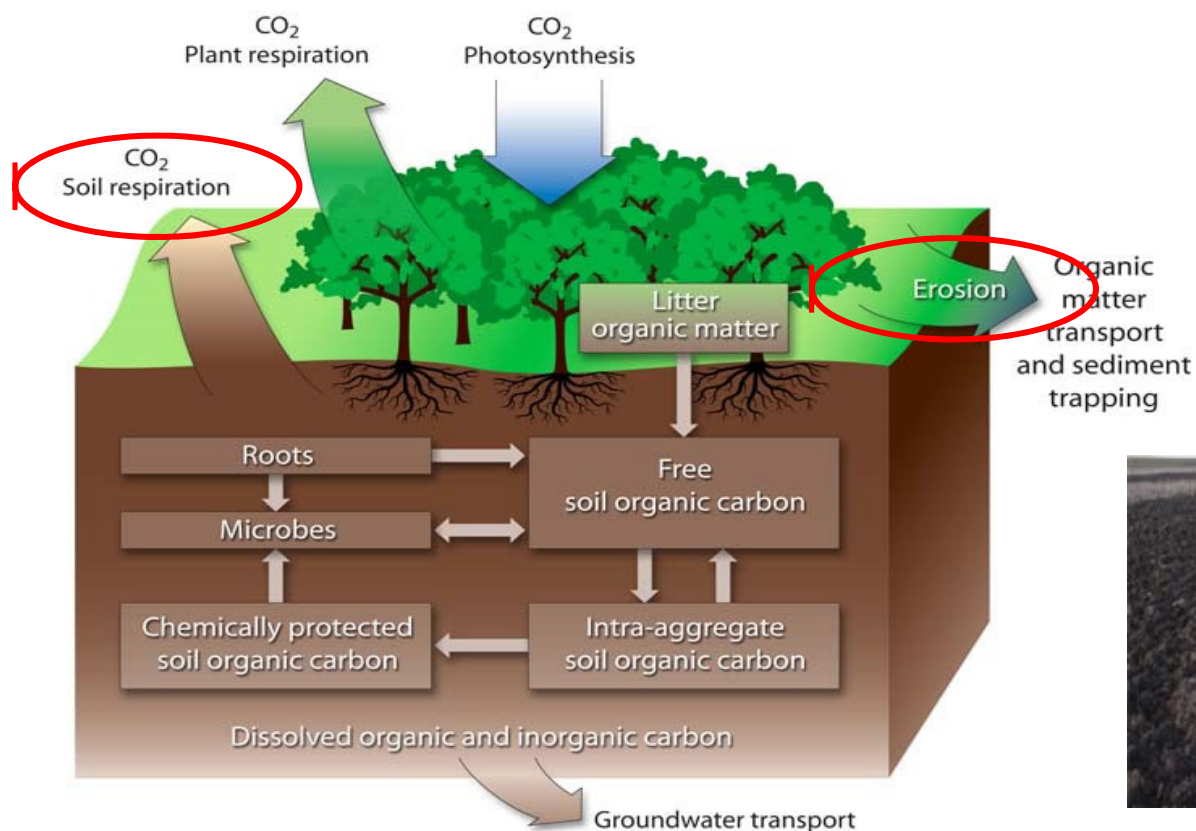


## 4. How can we increase soil carbon?

### A. Reduce CO<sub>2</sub> losses from soils

Avoid exposing soil carbon (C) to the atmosphere (oxygen; O<sub>2</sub>) = CO<sub>2</sub>

- **less inversion tillage; more non-inversion, reduced tillage system**



Acknowledgement: Iain Dummett

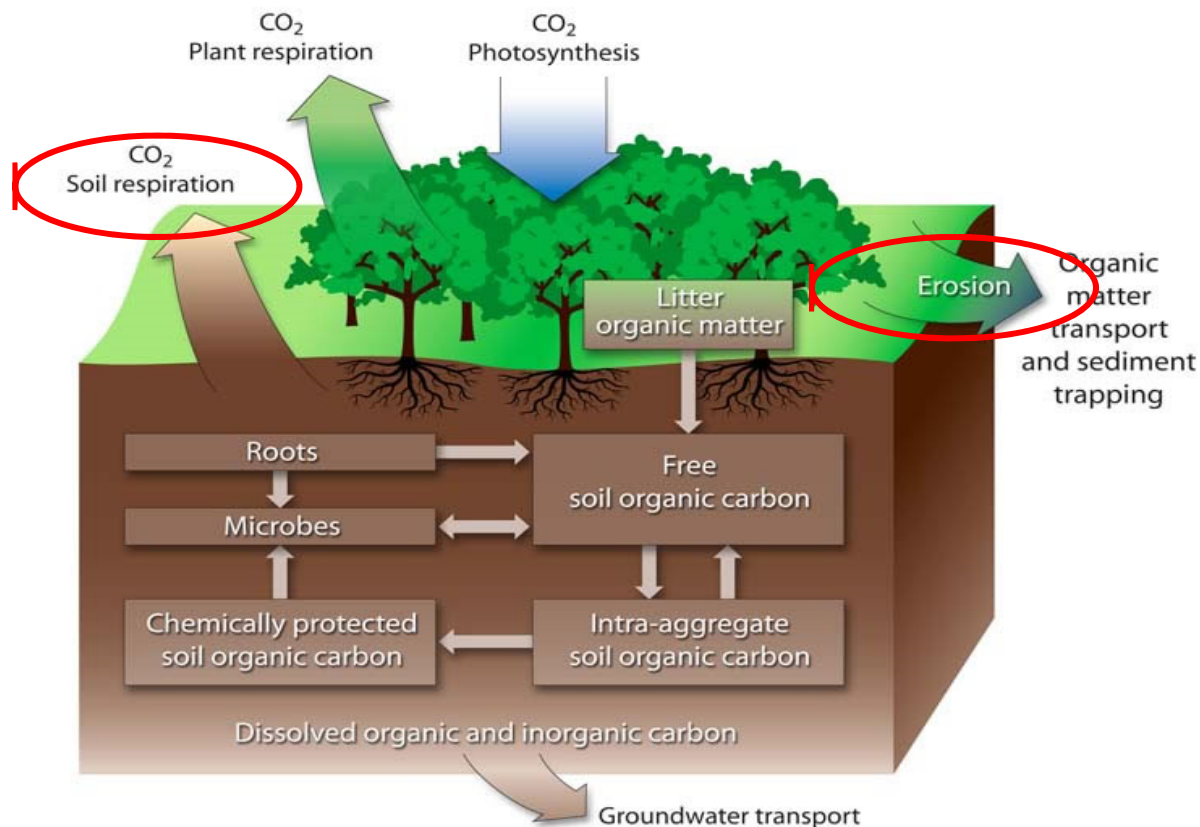


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- less inversion tillage; more non-inversion, reduced tillage system
- **less soil erosion**

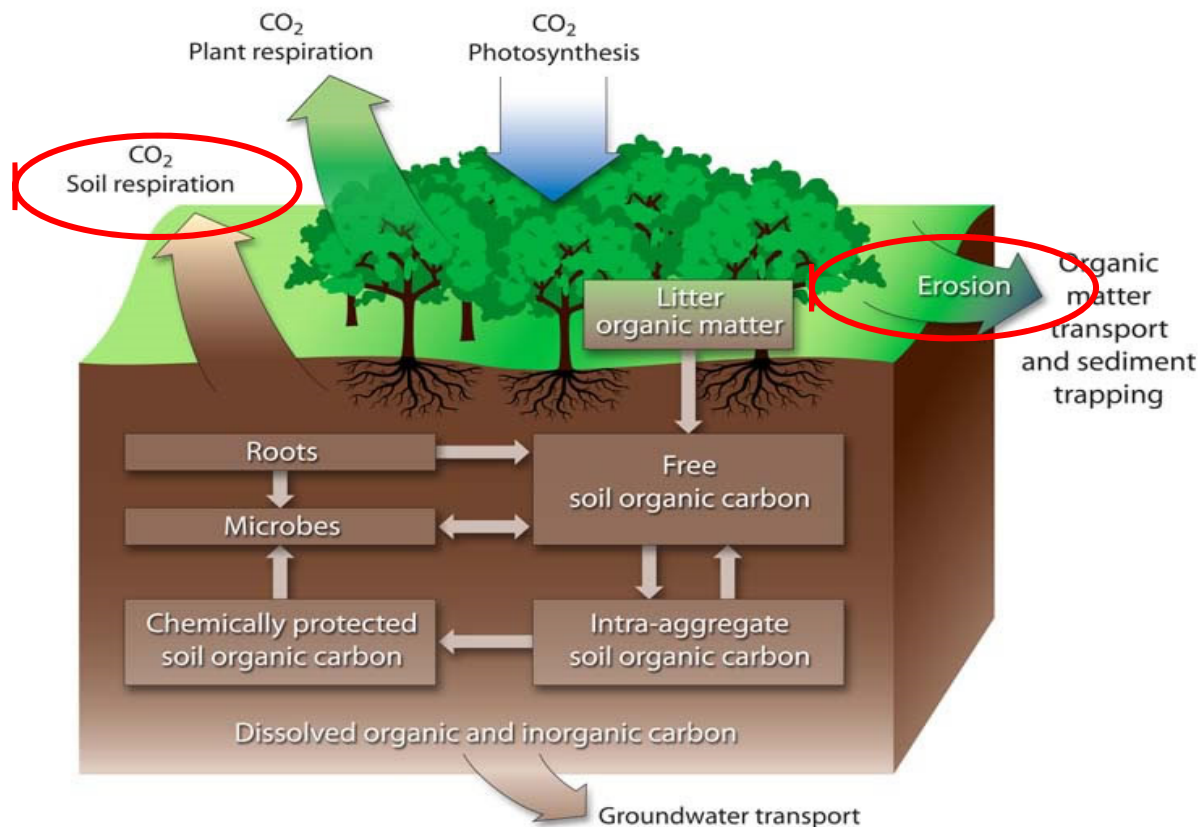


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- less soil erosion
- **avoid draining wetlands**



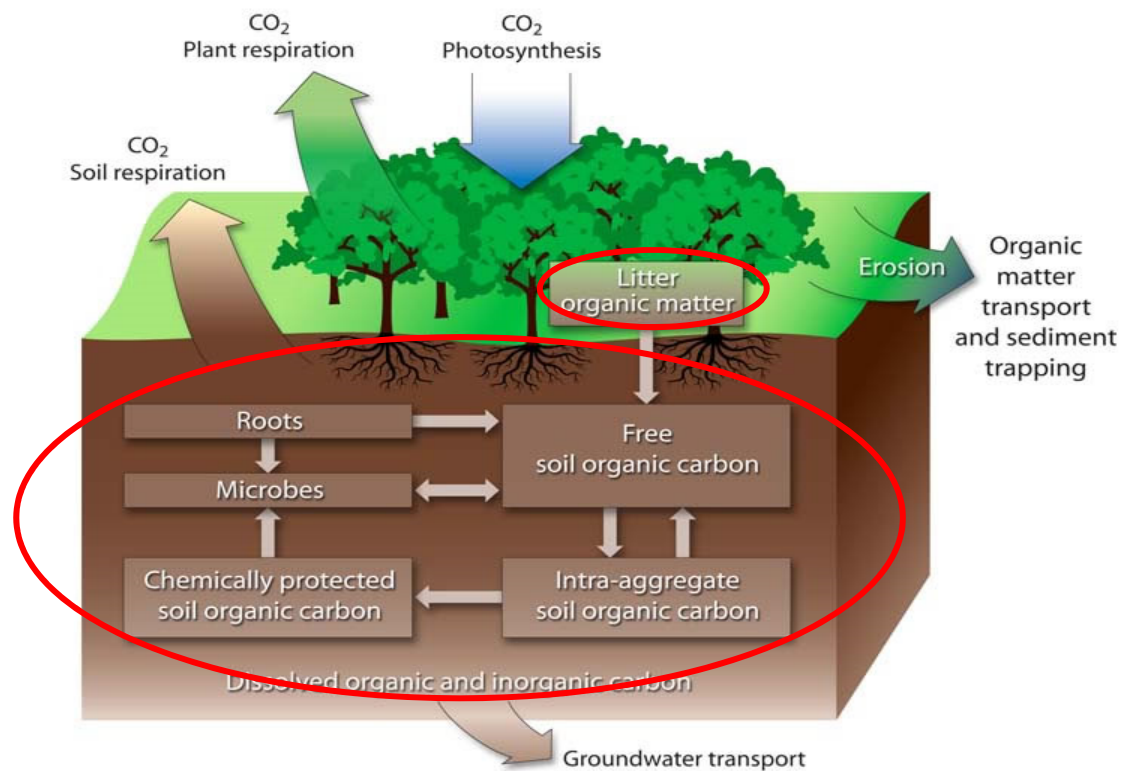




## 4. How can we increase soil carbon?



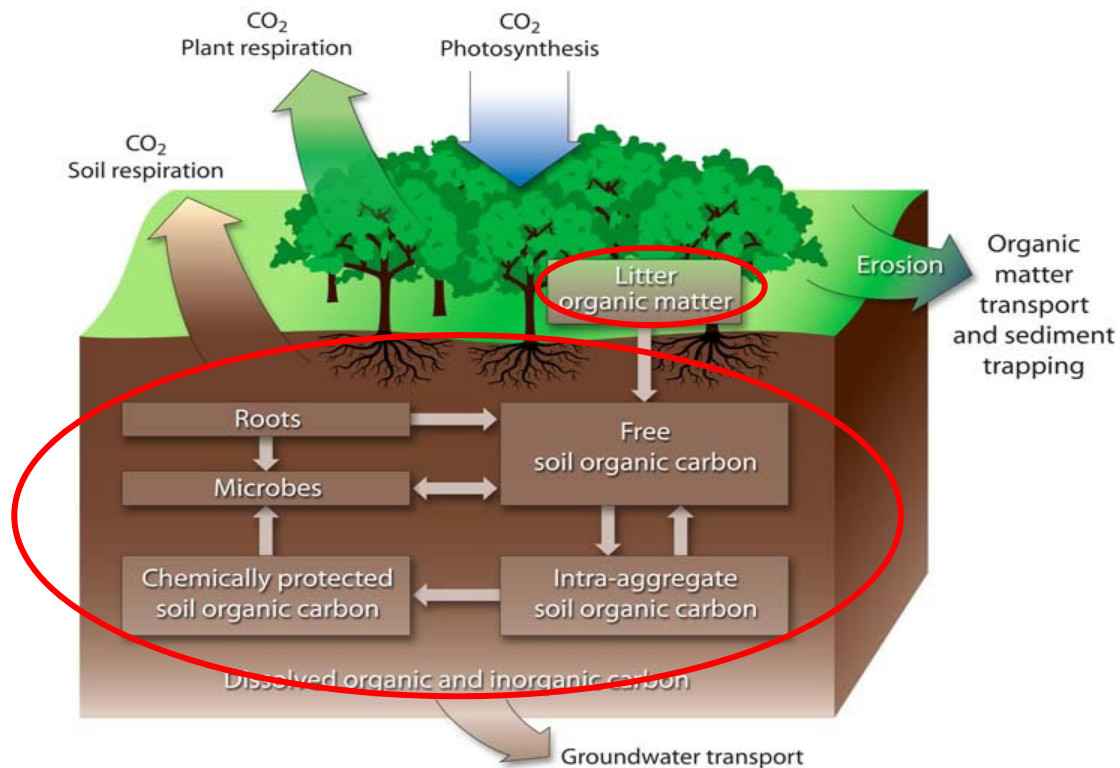
### B. Increase soil carbon storage (sequestration)



## 4. How can we increase soil carbon?

### B. Increase soil carbon storage (sequestration)

- Change land use (e.g. arable to forestry or agroforestry)
  - e.g. Scottish Government: 16,000 ha per year of new forest planting (March 2016)

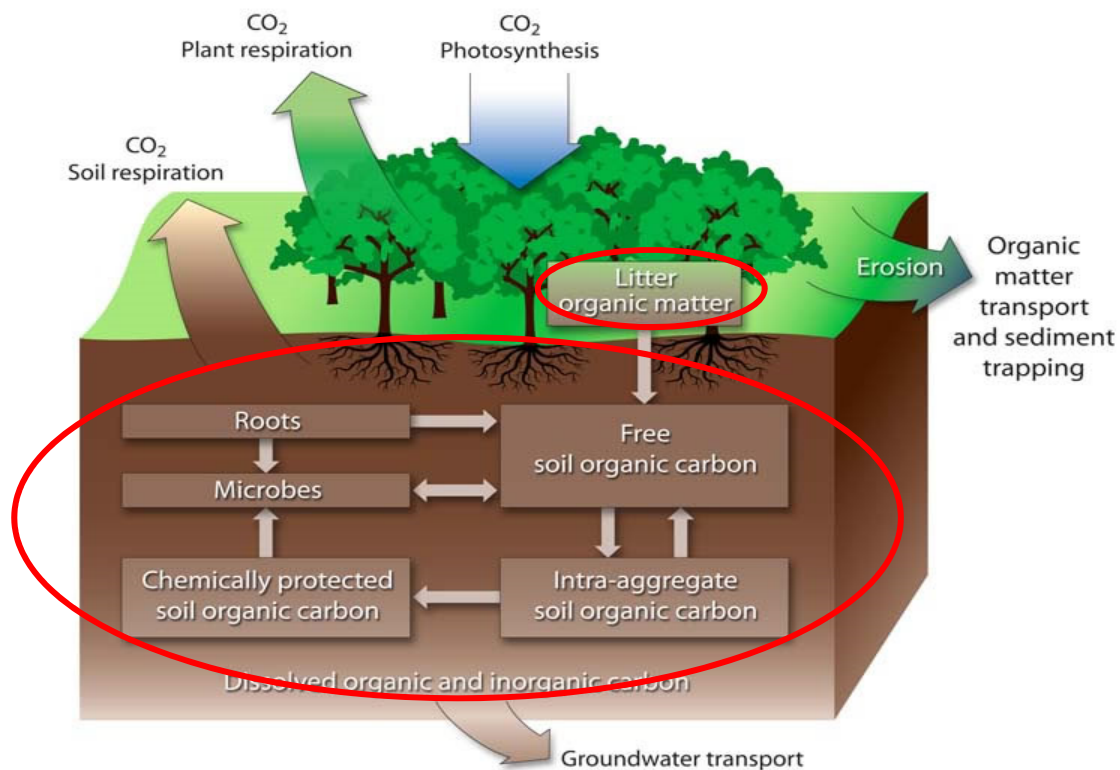




## 4. How can we increase soil carbon?

### B. Increase soil carbon storage (sequestration)

- Change land use (e.g. arable to forestry or agroforestry)
- **Reduced tillage systems (retain residues [and reduce CO<sub>2</sub> emissions])**





# Reduced tillage systems and carbon storage (Dr Mikhail Giannitsopoulos)



**Control Treatment: Two Pass**



**Claydon Hybrid**



**Sumo DTS**



**Mzuri Pro-Til 3**



**Vaderstad Seed Hawk**



**Vaderstad Rapid A**



Results: How tillage affects soil quality e.g. soil carbon  
Different letters show statistically significant differences

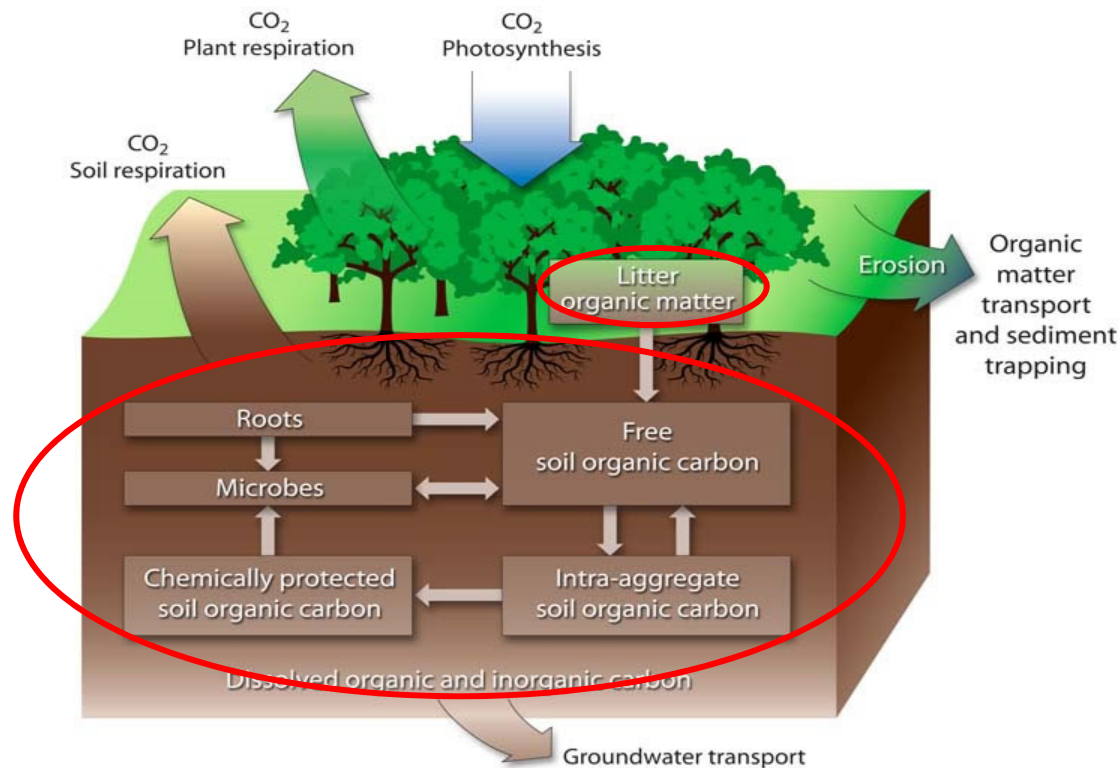
	Penetration resistance MPa	Organic carbon (%)	Microbial biomass carbon ( $\mu\text{g C g soil}^{-1}$ )	Earthworms / $\text{m}^2$
1	0.50 <sup>c</sup>	2.710 <sup>b</sup>	339.1 <sup>b</sup>	75.0 <sup>c</sup>
2	0.60 <sup>bc</sup>	2.789 <sup>ab</sup>	321.8 <sup>b</sup>	118.8 <sup>b</sup>
3	0.70 <sup>ab</sup>	2.829 <sup>ab</sup>	380.2 <sup>ab</sup>	137.5 <sup>b</sup>
4	0.61 <sup>abc</sup>	2.714 <sup>b</sup>	379.8 <sup>ab</sup>	103.1 <sup>bc</sup>
5	0.76 <sup>a</sup>	2.985 <sup>a</sup>	443.8 <sup>a</sup>	187.5 <sup>a</sup>



## 4. How can we increase soil carbon?

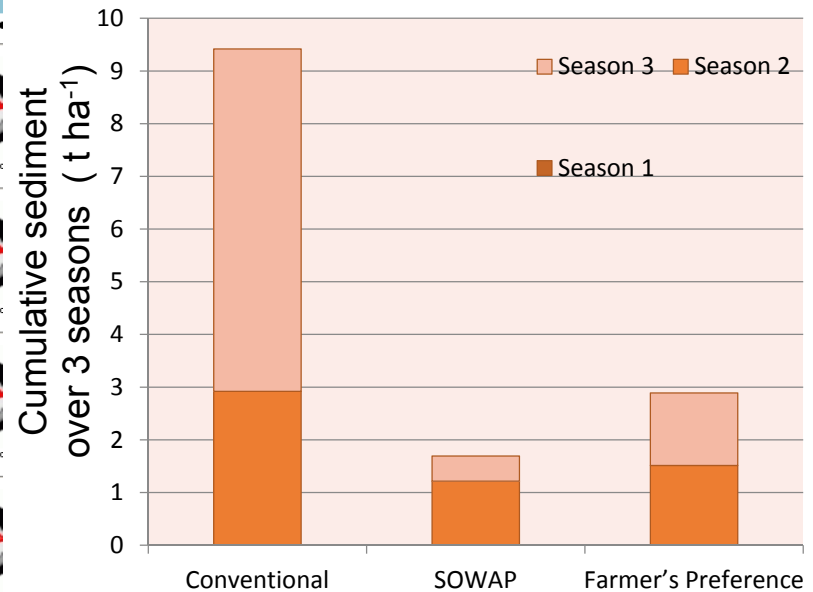
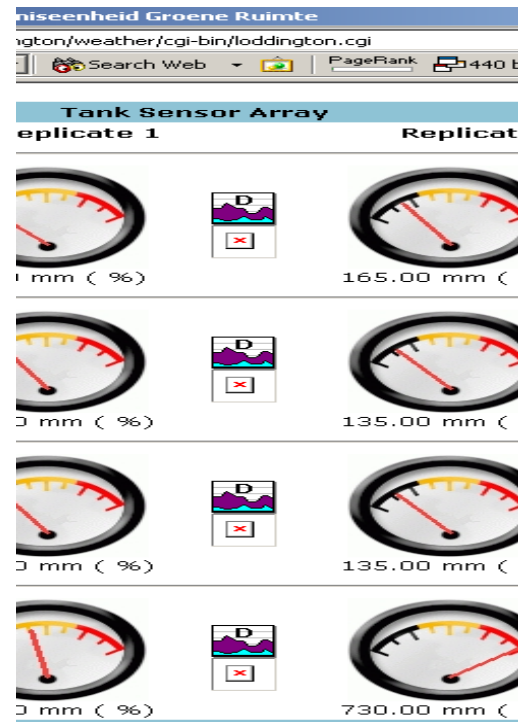
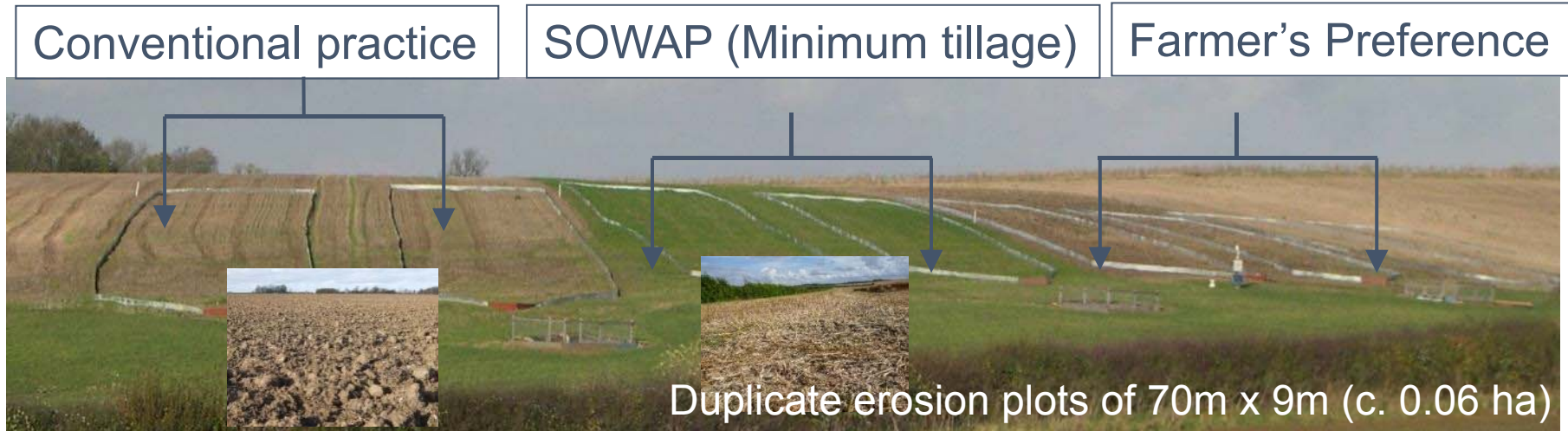
### B. Increase soil carbon storage (sequestration)

- Change land use (e.g. arable to forestry or agroforestry)
- Reduced tillage systems (retain residues [and reduce CO<sub>2</sub> emissions])
- **Control erosion (C losses in sediment and runoff)**



# B. Increase soil carbon storage: Reduce soil erosion

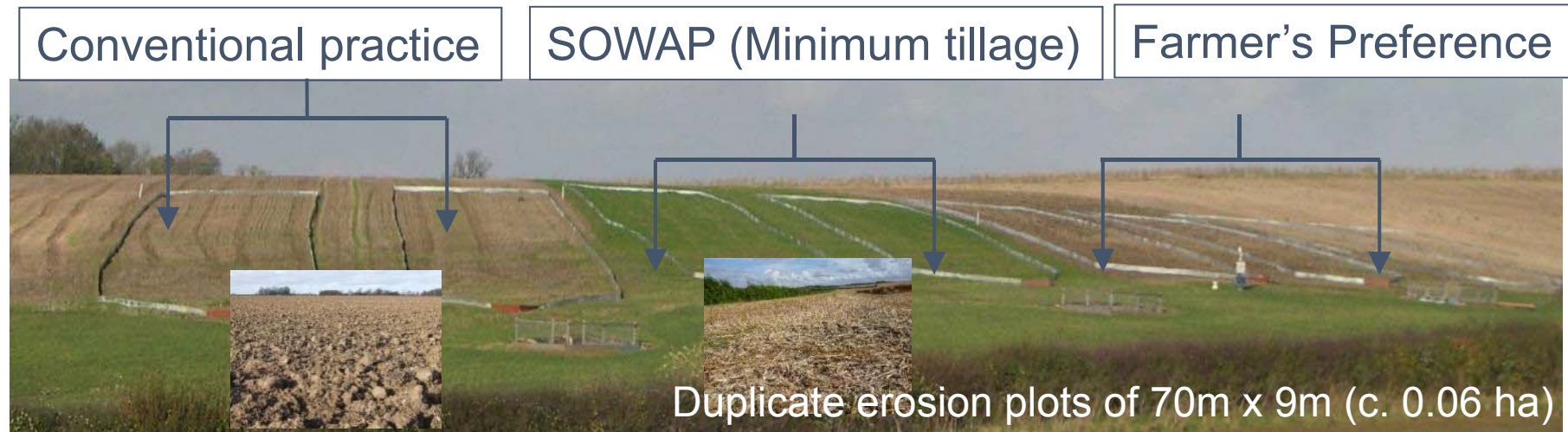
## Soil and Water Protection in Northern Europe (SOWAP)



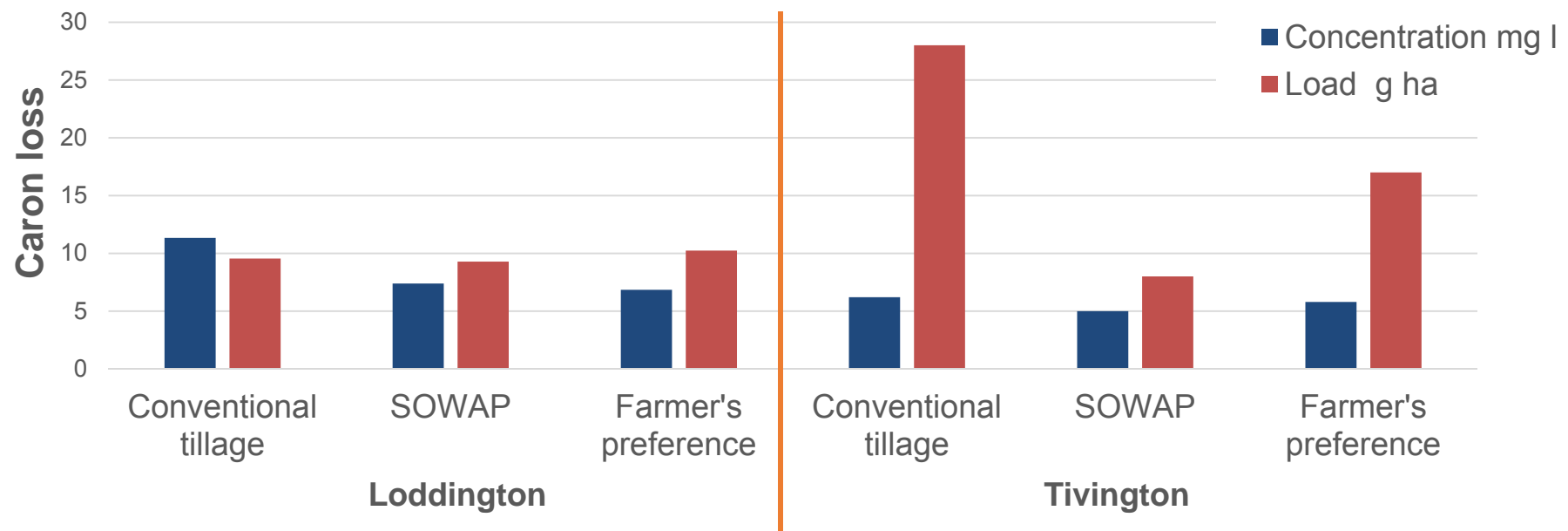


## B. Increase soil carbon storage: Reduce soil erosion

### Soil and Water Protection in Northern Europe (SOWAP)



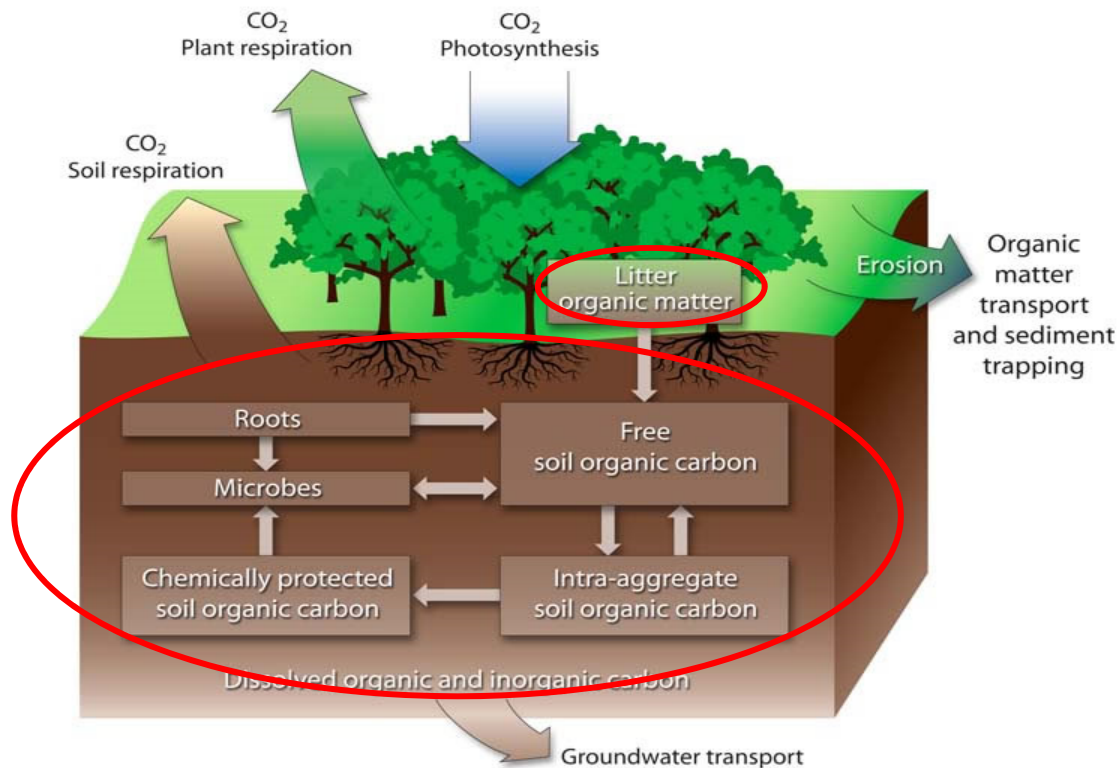
Mean carbon losses in runoff (concentrations (mg l) and loads (g ha))



## 4. How can we increase soil carbon?

### B. Increase soil carbon storage (sequestration)

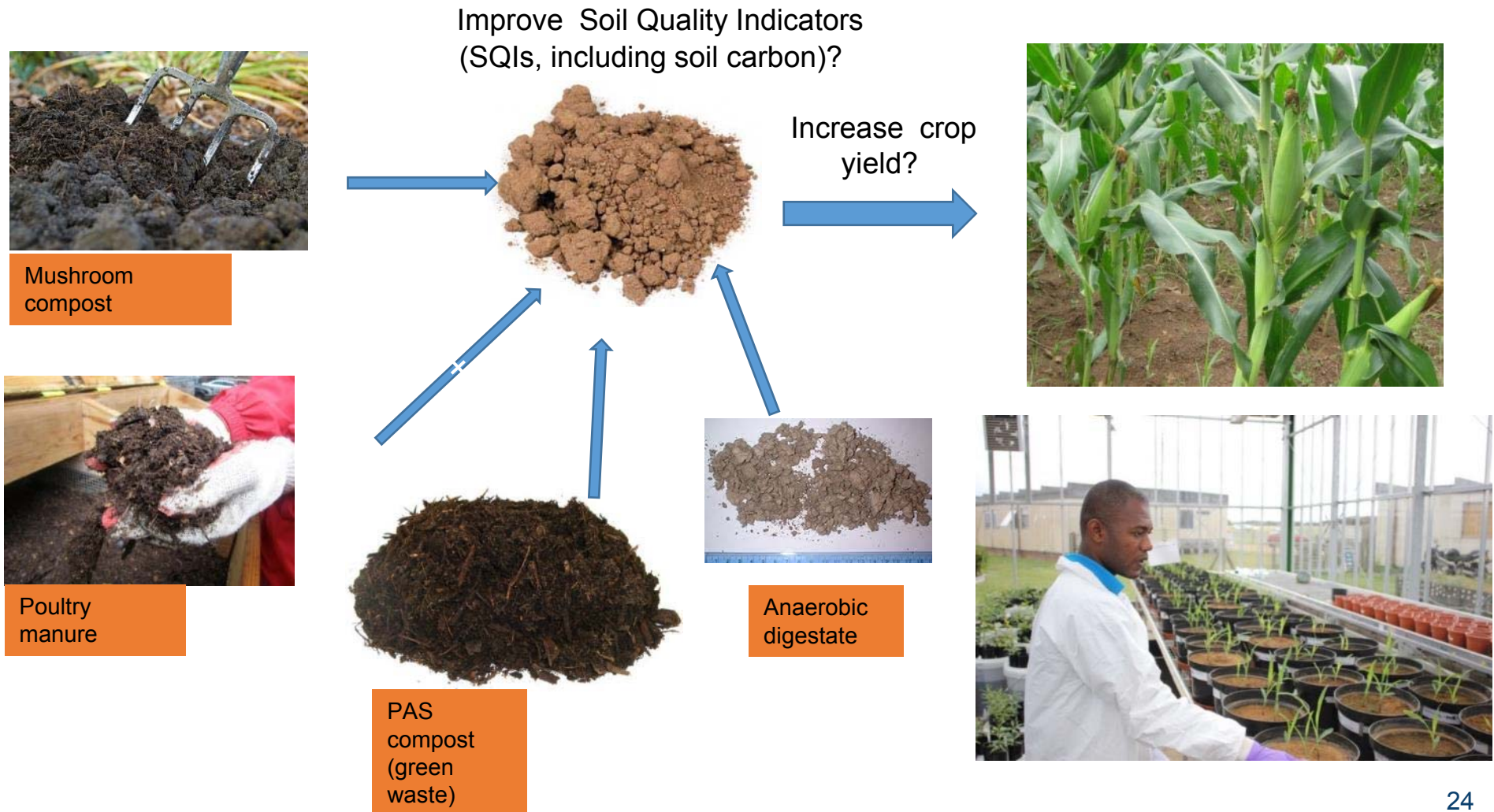
- Change land use (e.g. arable to forestry or agroforestry)
- Reduced tillage systems (retain residues [and reduce CO<sub>2</sub> emissions])
- Control erosion (C losses in sediment and runoff)
- **Add soil organic amendments**





## B. Increase soil carbon storage

Application of organic waste to restore soil health and productivity of a degraded soil (Benedict Unagwu, PhD student)

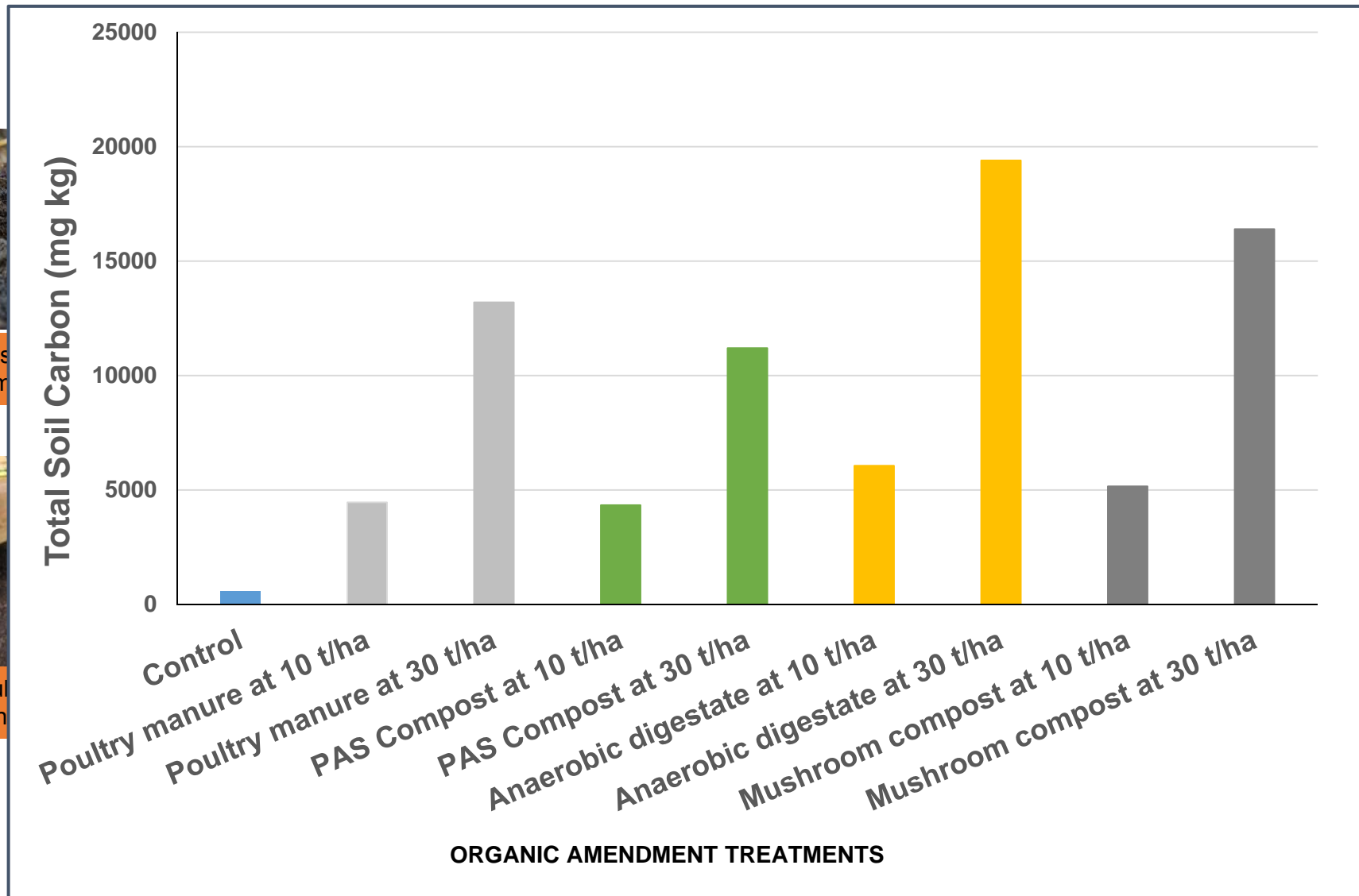






## B. Increase soil carbon storage

Application of organic waste to restore soil health and productivity of a degraded soil (Benedict Unagwu, PhD student)





## 5. Take home messages





# 5. Take home messages



**4 PER 1000**  
CARBON SEQUESTRATION IN SOILS  
FOR FOOD SECURITY AND THE CLIMATE

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt

<http://4p1000.org/understand>

**If we increase by 4‰ (0.4%) a year the quantity of carbon contained in soils, we can halt the annual increase in CO<sub>2</sub> in the atmosphere,** which is a major contributor to the greenhouse effect and climate change

increased absorption of CO<sub>2</sub> by plants :



farmlands, meadows, forests...



**+4‰ carbon storage in the world's soils**

= more fertile soils  
= soils better able to cope with the effects of climate change



## Soil carbon 4 per mille

Budiman Minasny <sup>a,\*</sup>, Brendan P. Malone <sup>a</sup>, Alex B. McBratney <sup>a</sup>, Denis A. Angers <sup>b</sup>, Dominique Arrouays <sup>c</sup>, Adam Chambers <sup>d</sup>, Vincent Chaplot <sup>e</sup>, Zueng-Sang Chen <sup>f</sup>, Kun Cheng <sup>g</sup>, Bhabani S. Das <sup>h</sup>, Damien J. Field <sup>a</sup>, Alessandro Gimona <sup>i</sup>, Carolyn B. Hedley <sup>j</sup>, Suk Young Hong <sup>k</sup>, Biswapati Mandal <sup>l</sup>, Ben P. Marchant <sup>m</sup>, Manuel Martin <sup>n</sup>, Brian G. McConkey <sup>o</sup>, Vera Leatitia Mulder <sup>n</sup>, Sharon O'Rourke <sup>o</sup>, Anne C. Richer-de-Forges <sup>c</sup>, Inakwu Odeh <sup>a</sup>, José Padarian <sup>a</sup>, Keith Paustian <sup>p</sup>, Genxing Pan <sup>q</sup>, Laura Poggio <sup>r</sup>, Igor Savin <sup>q</sup>, Vladimir Stolbovoy <sup>s</sup>, Uta Stockmann <sup>a</sup>, Yiyi Sulaeman <sup>q</sup>, Chun-Chih Tsui <sup>t</sup>, Tor-Gunnar Vågen <sup>u</sup>, Bas van Wesemael <sup>v</sup>, Leigh Winowicki <sup>t</sup>

Geoderma Journal, 292 (2017), 59-86





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