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Soil carbon sequestration and organic farming – a review of the evidence

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Common ground: agroecology, food sovereignty and organic farming in practice - The 10th Organic Producers' Conference

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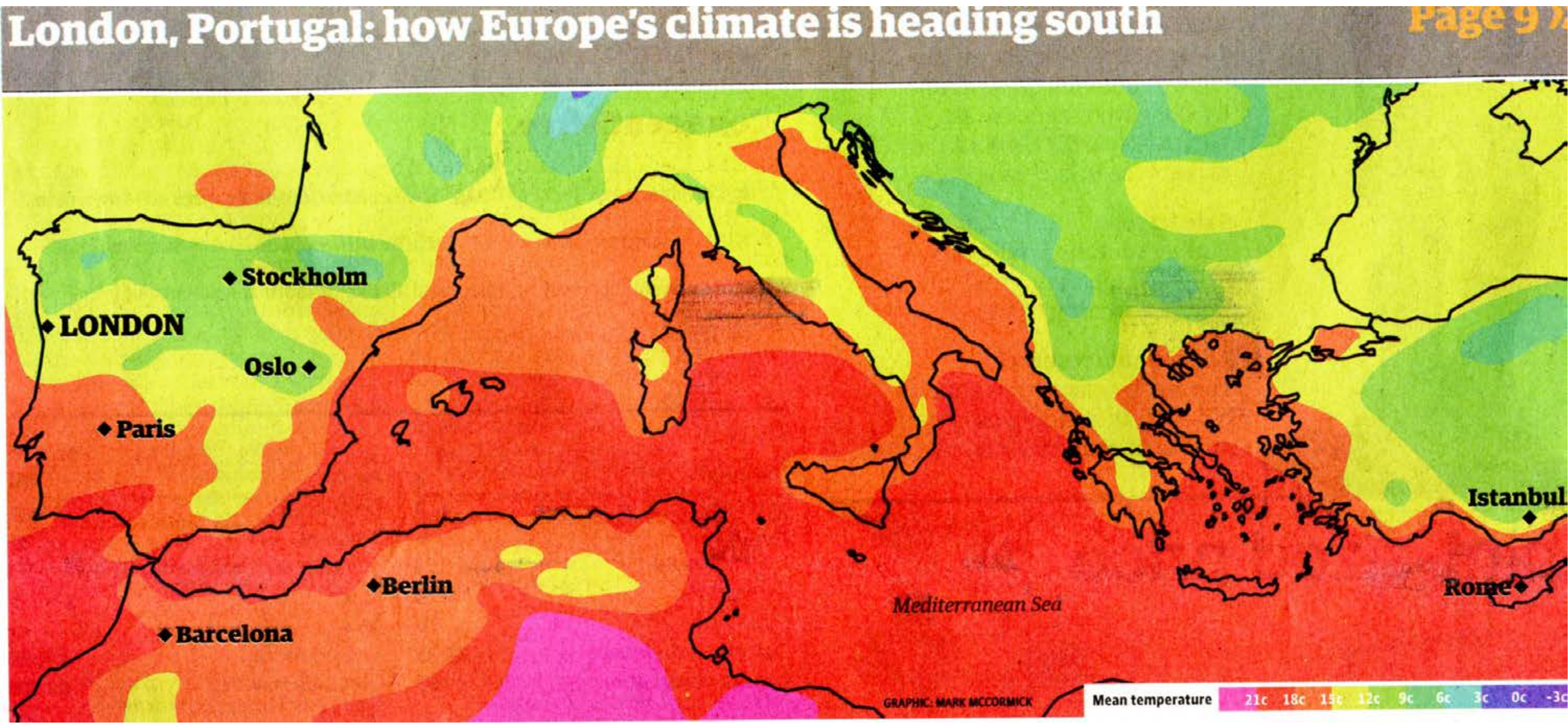
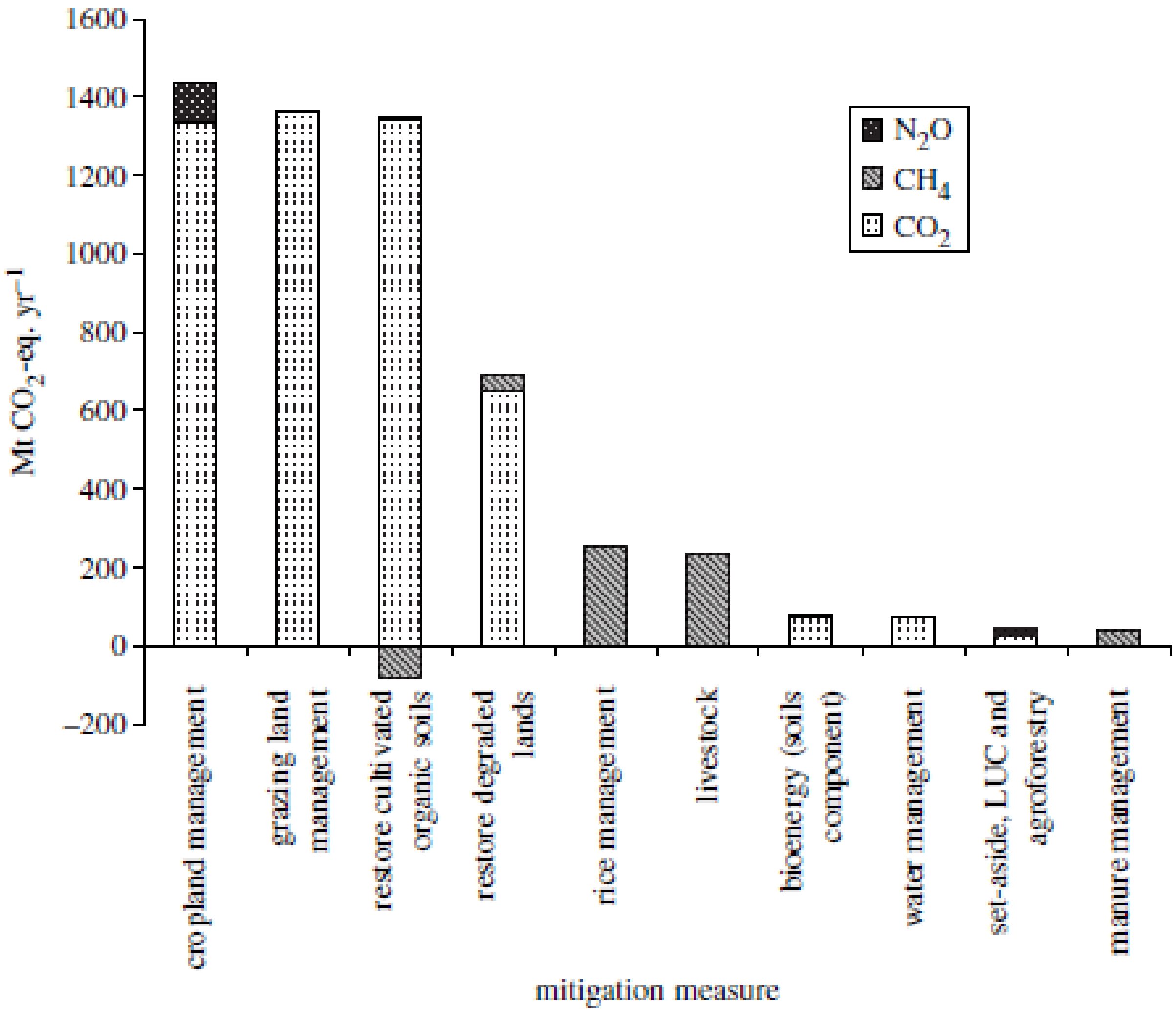


Guardian 15/5/07 – reporting French work

Global Mitigation Potential:



"agriculture could offset, at full biophysical potential, about 20% of total annual CO_2 emissions"

Smith et al. (2008) Greenhouse Gas Mitigation in Agriculture

Images: ORC and Wiki Commons

Organic farming practices and carbon sequestration:

Author and country of study	Type of trial and farming systems covered	Farming systems covered	length of trial (years)	Organic vs conv. % difference	significant **
Pulleman et al. 2003	Farm systems trial: conv.; org; perm pasture	Arable and perm. pasture	70	**+60%**	Y at 5%
Armstrong Brown et al. 2000	Soil assessment of 30 org and conv. farm pairs	Hort.	1	**+57%**	trend
		Arable	1	**+34%**	trend
		Pasture	1	**-12%**	n/s
Kirchmann et al. 2007	3 Field plots: conv.; org; control	Arable	19	**+31%**	not given
Friedel et al. 2000	Soil assessment: 2 plots: org. and conv.	Arable	21	**+11%**	n/s
Hepperly et al. 2006	3 field plots: manure based org; legume based org; conv.	Arable - manure	26	**+25%**	Y at 5%
		Arable - legume	26	**+20%**	Y at 5%
Raupp and Oltmanns, 2006	3 field plots: inorganic fertiliser; org manure; biodynamic manure	Arable	25	**+19%**	n/s
Marriot and Wander, 2006	Farming systems trial: legume and manure; legume manure; legume based; conv.	Arable	10 avg	**+14%**	Y at 5%
Fließbach et al. 2007. DOK trial	4 Field-plots: organic; biodynamic; conv. mineral fertiliser; unfertilised control	Arable - biodynamic	21	**+6%**	not given
		Arable - organic	21	**+2%**	not given

Smith et al. 2011

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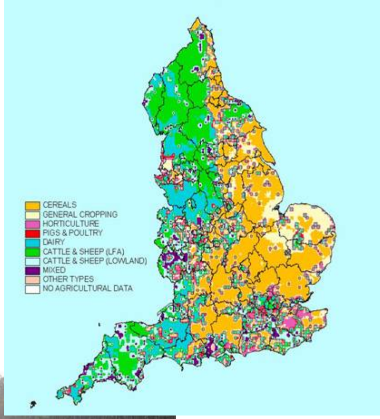
Organic farming practices and carbon sequestration:

Use of legumes and livestock manures in agroecological systems can also lead to greater amounts of soil carbon

Whilst these practices are not limited to the organic sector, the mixed nature of organic farms more readily allows for their application

Recent meta-analysis by Gattinger et al. (2012)* confirms higher soil organic carbon concentrations (0.18 ± 0.06%) and stocks (3.50 ± 1.08 t C ha−1) in top soils under organic management.

Lower reliance on imported feed within organic systems can help to avoid deforestation/land clearance for growing crops such as soya and maize



*Gattinger et al. 2012. Enhanced top soil carbon stocks under organic farming

Image: Defra & Wiki Commons

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Organic farming practices and carbon sequestration:

Practice	Annual gain in soil carbon (t CO_2(e) ha)	Source
Grass/clover leys	0.25 - 0.75	Adger et al. 1992
Permanent pasture establish.	2.6	Pretty and Ball. 2001
Hedgerow establishment	1.9	Falloon et al. 2004
SRC willow establishment	2.2	Falloon et al. 2004
Broadleaf woodland (established)	1.5	CALM calculator

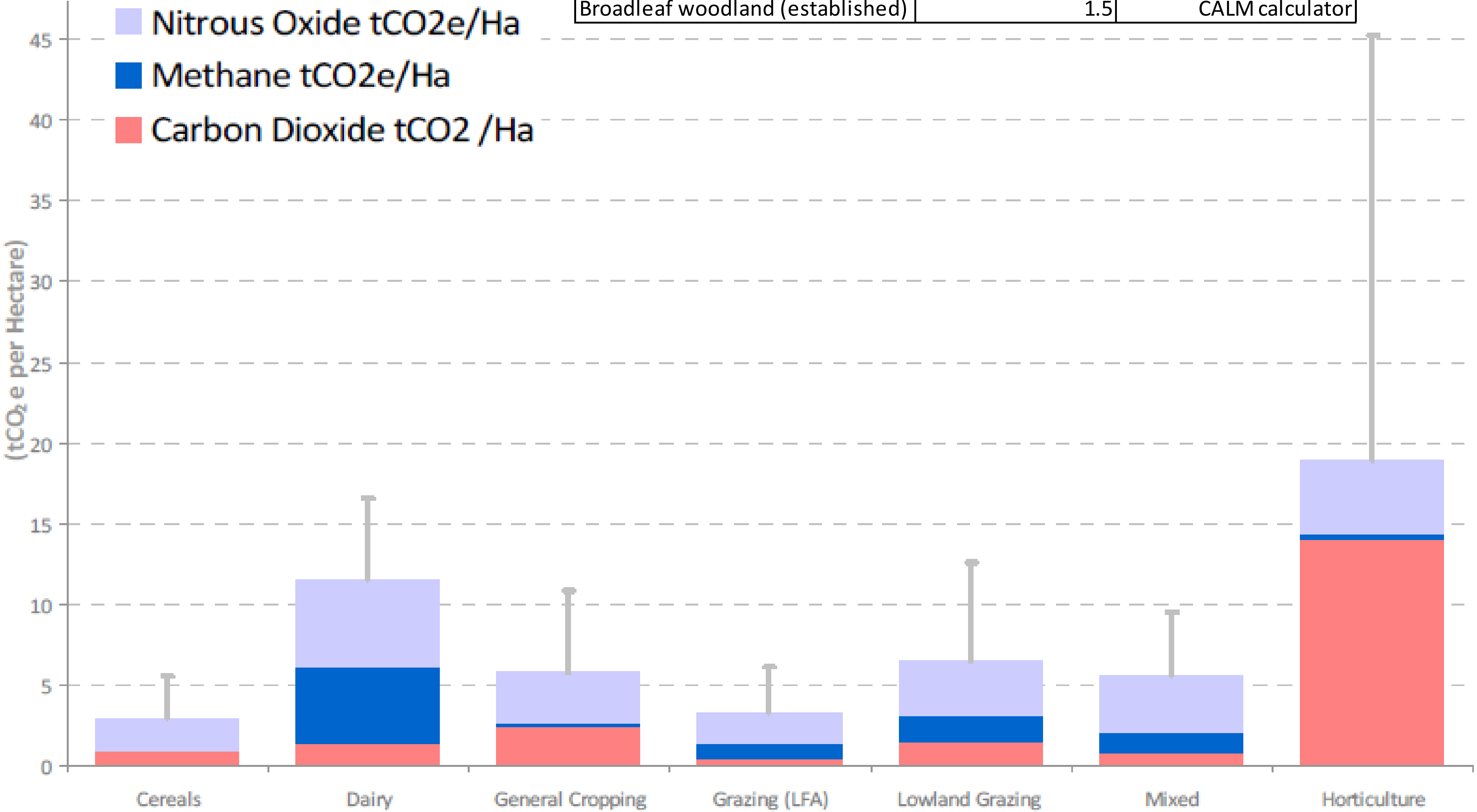

Image: Natural England Carbon Baseline Survey Project (2008)

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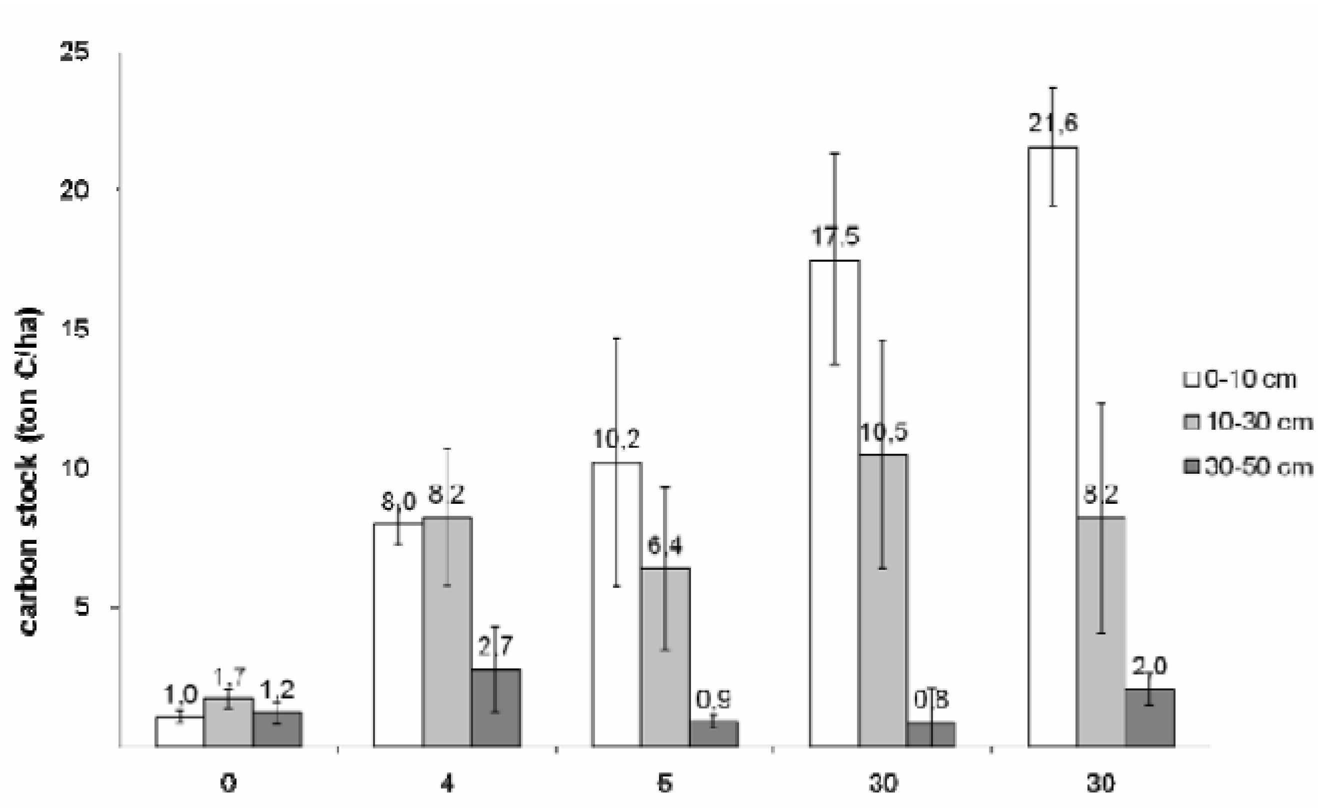
Soil & More International

Compost application for reclaiming desert soils in Egypt:



Mitigation potential of 3.1-3.4 t CO2e/ha/yr

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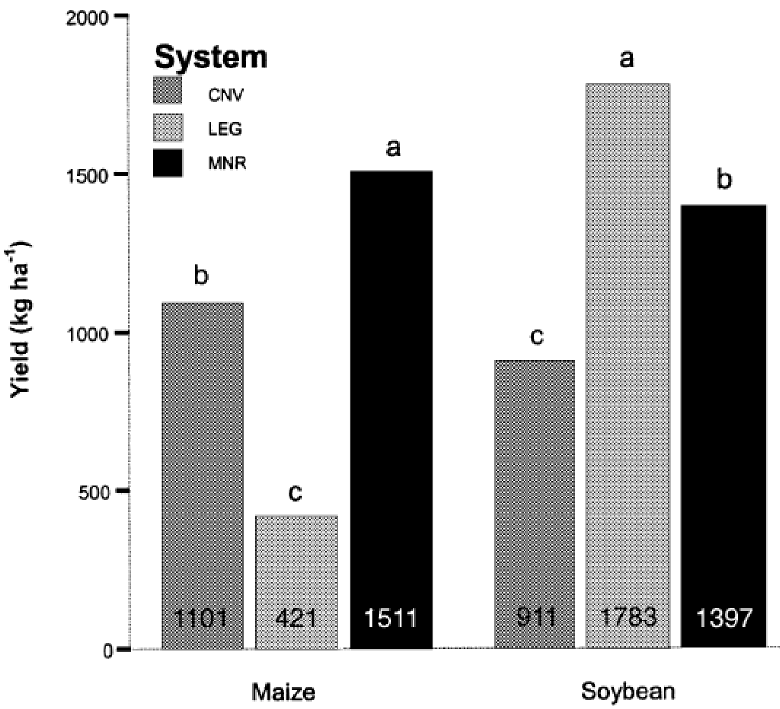
SEKEM

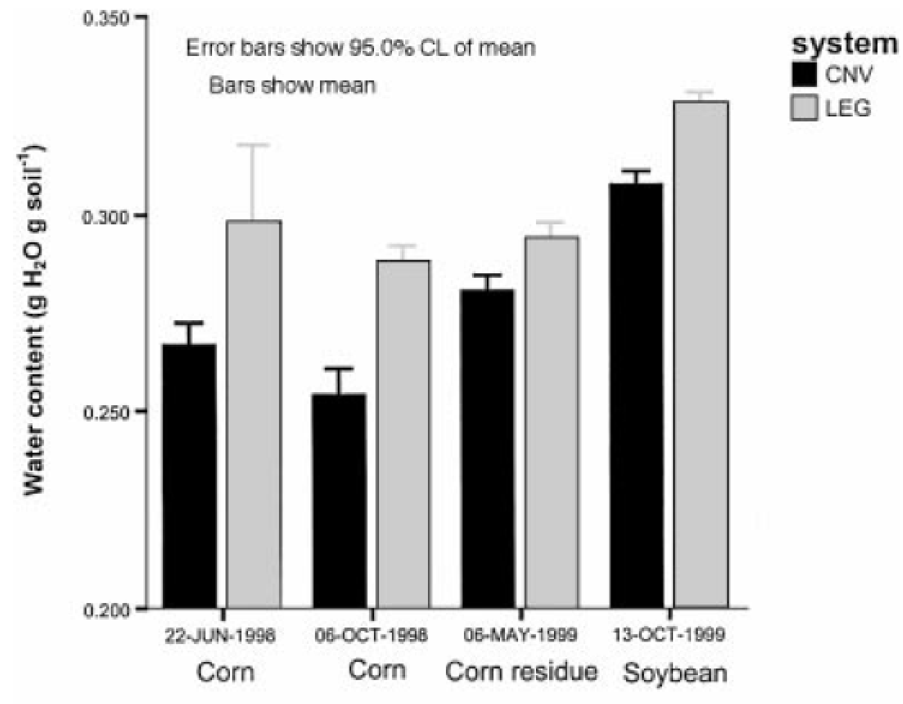
www.sekem.com

1987……

2009

Healthier soils =
improved yields and water retention in drought conditions:





Letter, D. W., Rita Seidel, and William Liebhardt. "The performance of organic and conventional cropping systems in an extreme climate year."*American Journal of Alternative Agriculture* 18.03 (2003): 146-154.


Better infiltration, retention, and delivery to plants helps avoid drought damage
Organic
Conventional

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Organic matter increases infiltration:

Organic **Conventional**

Picture: FiBL DOK Trials

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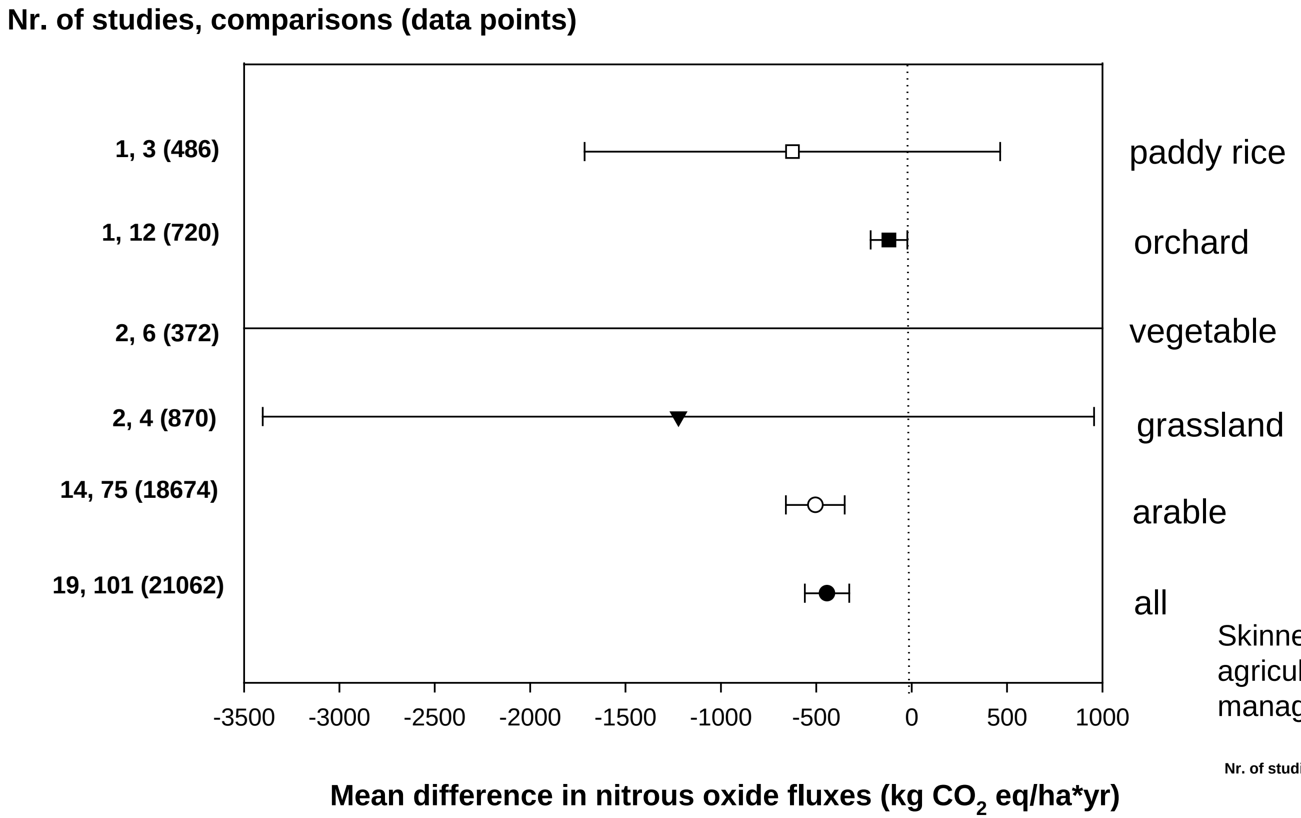
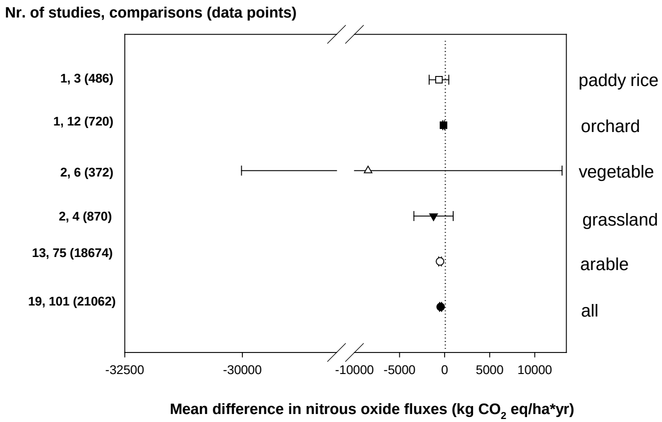
Less N_2O emissions from organically managed soils:



less nitrous oxide (approx 450 kg CO_2 eq./ha yr) from organically managed soils
- average duration of system comparison: 9.2 years

Skinner et al. (2014) Greenhouse gas fluxes from agricultural soils under organic and non-organic management



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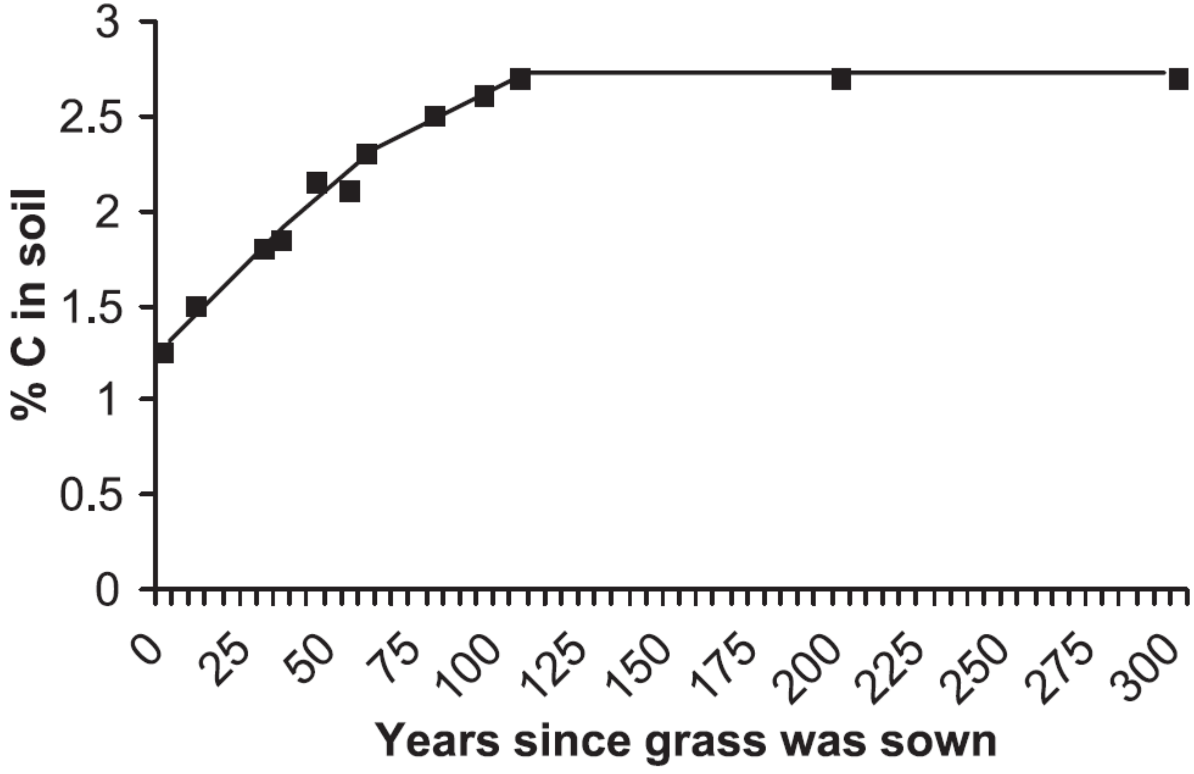
Limited potential to increase soil carbon stocks through land use change– difficult to capture within models and a lack of long term trials:

The accumulation of total soil carbon in silty clay loam soils at Rothamsted, UK, when old arable land is sown to permanent grass. Adapted from nitrogen content in Figure 18.10 of Jenkinson (1988).



Source: Freibauer *et al.* 2004

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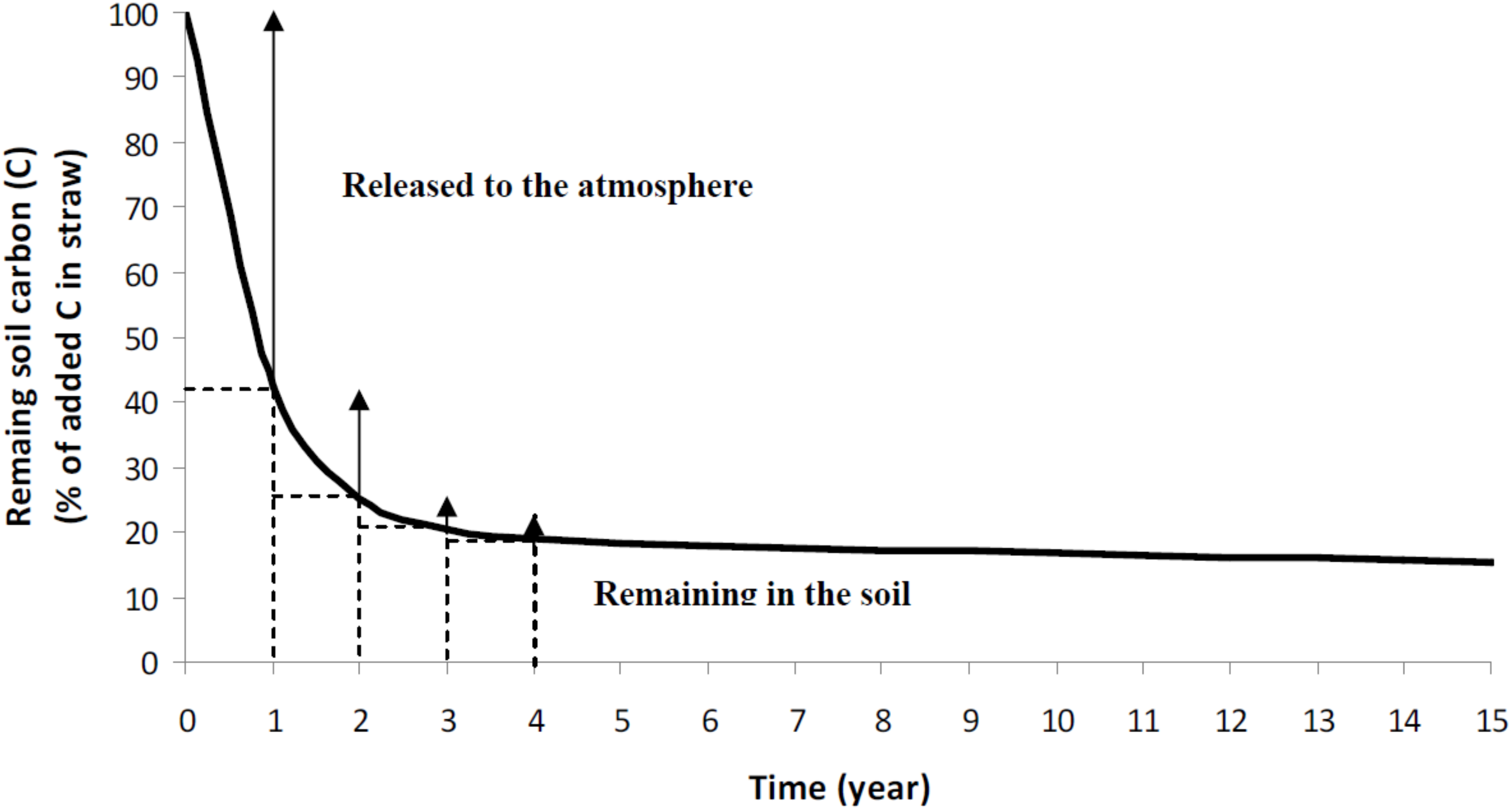

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Inconsistent results between carbon footprinting tools:

Farm number	Milk yield category	CALM - kg CO_2e for whole farm	Cool Farm Tool Kg CO_2e per litre of milk
Dairy Farm 1	HIGH	1499	1.2
Dairy Farm 2	HIGH	727	1.3
Dairy Farm 3	MEDIUM	740	1.2
Dairy Farm 4	LOW	-407	1.5

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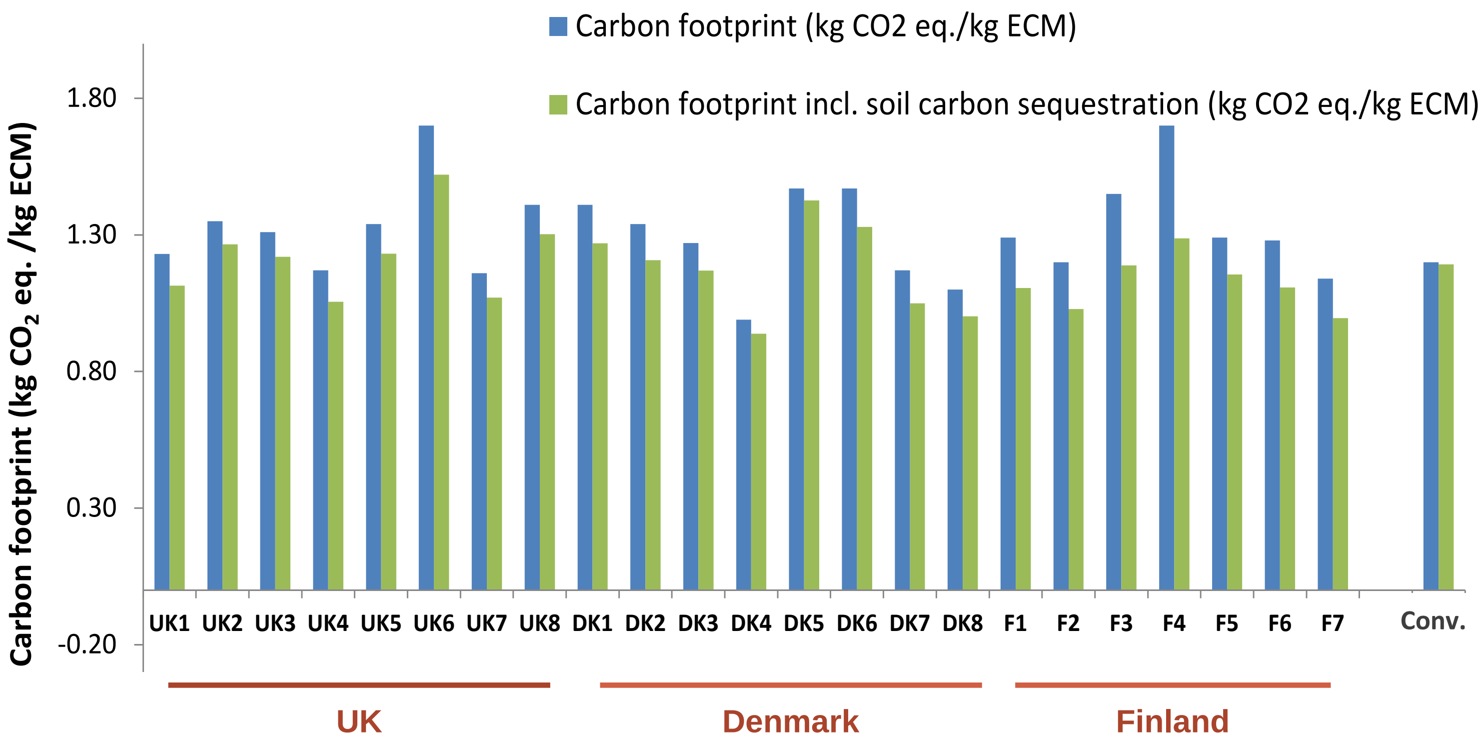
Carbon footprint of milk from 23 farms - including soil carbon sequestration



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Source: Knudsen et al. (2016)

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The approach is published in J of Clean Prod (2013):

Journal of Cleaner Production 52 (2013) 217–224

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An approach to include soil carbon changes in life cycle assessments

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ABSTRACT

Globally, soil carbon sequestration is expected to hold a major potential to mitigate agricultural greenhouse gas emissions. However, the majority of life cycle assessments (LCA) of agricultural products have not included possible changes in soil carbon sequestration. In the present study, a method to estimate carbon sequestration to be included in LCA is suggested and applied to two examples where the inclusion of carbon sequestration is especially relevant: 1) Bioenergy: removal of straw from a Danish soil for energy purposes and 2) Organic versus conventional farming: comparative study of soybean production in China. The suggested approach considers the time of the soil CO_2 emissions for the LCA by including the Bern Carbon Cycle Model. Time perspectives of 20, 100 and 200 years are used and a soil depth of 0–100 cm is considered. The application of the suggested method showed that the results were comparable to the IPCC 2006 tier 1 approach in a time perspective of 20 year, where after the suggested methodology showed a continued soil carbon change toward a new steady state. The suggested method estimated a carbon sequestration for the first example when storing straw in the soil instead of using it for bioenergy of 54, 97 and 213 kg C t^{-1} straw C in a 200, 100 and 20 years perspective, respectively. For the conversion from conventional to organic soybean production, a difference of 32, 60 or 143 kg soil C ha^{-1} yr^{-1} in a 200, 100 or 20 years perspective, respectively was found. The study indicated that soil carbon changes included in an LCA can constitute a major contribution to the total greenhouse gas emissions per crop unit for plant products. The suggested approach takes into account the temporal aspects of soil carbon changes by combining the degradation and emissions of CO_2 from the soil and the following decline in the atmosphere. Furthermore, the results from the present study highlights that the choice of the time perspective has a huge impact on the results used for the LCA. For comparability with the calculation of the global warming potential in LCA, it is suggested to use a time perspective of 100 years when using the suggested approach for soil carbon changes in LCA.

1. Introduction

Climate change is increasingly regarded as a major problem and mitigation options are discussed (e.g. IPCC, 2007). Carbon sequestration, which is removal or temporary storage of carbon from the atmosphere for example in vegetation or soil, is seen as a way of mitigating climate change by temporarily avoiding some radiative forcing (Brandão et al., 2013). Soil carbon sequestration is the temporary storage (or release) of carbon in the soil and is in agricultural soils expected to hold a major potential for agriculture's global warming mitigation potential to reduce agricultural emissions and increase C sequestration. Thus, Smith et al. (2007) estimated soil C sequestration to contribute about 89% to the global mitigation potential from agriculture. However, the importance of soil C sequestration is poorly reflected in current LCA's (Koerber et al., 2009), since the majority of studies have not included soil C sequestration in the overall greenhouse gas estimations, mainly due to methodological limitations (Brandão et al., 2011). Though, recently a few LCA studies have attempted to include soil C changes – using mainly modeling and using time horizons of a few to 30 years (Hörtenhuber et al., 2010; Röös et al., 2010; Halberg et al., 2010; Hillier et al., 2009; Mila i Canals et al., 2008; Gabrielle and Gagnaire, 2008), although the time horizon used is not explicitly stated in all of the studies. Soil carbon changes are normally estimated by modeling since the full extent of the soil carbon changes caused by changes in agricultural practices will

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Reduced Tillage:

- **Limited potential of no-till agriculture for climate change mitigation according to recent paper (Powlson et al. 2014)**
- **Only small additional total organic C stock in whole soil profile—limited benefit for climate change mitigation**
- **Nitrous oxide emissions may increase**
- **Can still contribute to soil protection and climate change adaptation**

TILMAN-ORG
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Conclusion:

- Large potential for climate change mitigation through soil carbon sequestration
- Prediction of gains / losses difficult, partly due to lack of long term data
- Organic systems provide opportunities for carbon sequestration through mixed farming, woodland management and use of grass/clover leys
- Benefits may have been overestimated in some cases (e.g. long term grassland or reduced tillage)