Carbon Sequestration in Temperate Grasslands: potential, measurement and monitoring.

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Temperate grasslands

- About 20% of Earth’s natural vegetation is grassland (Melillo et al., 1993).
- Temperate grassland amounts to 20% of European land area (Soussana et al., 2004).
- C sequestration potential of permanent pastures worldwide is between 0.01 and 0.3 Gt C yr\(^{-1}\) (Lal, 2004).
- Soil C stocks show a high spatial variability – depends on soil composition, structure and depth and climate.
What affects C sequestration?

- Past and current land use changes.
- Agricultural management.
- Horizontal transfer of hay/silage and manure.
- Non-linear kinetics.
The Global Carbon Cycle
Terrestrial Ecosystem Carbon Uptake and Storage
Conceptual model of C dynamics after Six et al. (2002), showing measurable pools.
Decomposing roots and detritus become encrusted with mineral particles forming microaggregates.

Decomposition continues at a slow rate in stable aggregates, due to formation of organomineral associations.

Eventually, organic binding agents decompose sufficiently for aggregate to be destabilized, accelerating decomposition until new aggregate is formed.
Aggregate organisation in the soil
Management options to increase carbon in grassland ecosystems.

1. Increase biomass
   - Forage productivity
   - Species selection
   - Fertilizer
   - Irrigation
   - Grass/legume mix

2. Change from annual to permanent crop
3. Regulate grazing intensity
4. Introduce earthworms
5. Decrease microbial decomposition

Soil organic matter (C, N)

1. Conversion from arable to grassland & from short-duration leys to permanent grassland
2. Reduce fire, leaching, erosion & mineralization
3. Increase fertilizer inputs
4. Improve soil structure

Increase C inputs
Decrease C losses
What are the limitations?

• Soil C stores ‘saturate’.
• Only C that is locked into mineral particles (or wet peat) is removed from the active C cycle.
• The inactive store is vulnerable to land-use change.
• It is very difficult to prove that C stocks change over a 5-year (commitment) period.
• Intensive soil sampling is required.
• Are there other ways of doing it?
Measuring pools: Carbon losses from soils across England and Wales, 1978-2003 (Bellamy et al., 2005)

Original C g kg\(^{-1}\)

Rate of change

\(<-2 \text{ g kg}^{-1} \text{ yr}^{-1}\)

\(-2.0 \text{ to } -1.5\)

\(-1.5 \text{ to } -1.0\)

\(-1.0 \text{ to } -0.5\)

\(-0.5 \text{ to } 0.0\)

\(> 0.0\)

\(<20\)

\(>300\)
Measuring fluxes: Carbon cycling in grazed grassland

Fluxes in t C ha\(^{-1}\) yr\(^{-1}\). Continuous grazing at 2 livestock units ha\(^{-1}\)

From: Soussana et al. (2004).
$\text{CO}_2$ fluxes are monitored using **eddy correlations**, including the use of 3D sonic anemometers and fast infrared gas analysers.
Daily CO$_2$ fluxes over grassland, May and June 2002.
Comparison of Carbon flows through land use types in Europe.
CarboEurope–IP data.
Janssens et al. (unpublished)
Example of fractionation by size and density scheme

8 mm sieved soil

>250 mm fraction
- Coarse POM
- Micro’s (mM)

<53 mm fraction
- Silt + clay
- Light fraction (< 1.85 g cm\(^{-3}\))
- Intra-microaggregate POM (iPOM)

53-250 mm fraction (m)
- Light fraction (< 1.85 g cm\(^{-3}\))
- Intra-microaggregate POM (iPOM)

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Exploiting δ13C signals from C4 grasses

Data suggest a large potential for soil C storage under a Miscanthus system established on former arable land, mainly in the upper 30 cm.

After 14 years of Miscanthus plantation, differences in soil C contents can mainly be attributed to soil C storage in the microaggregate within macroaggregates fraction.

Analyze the potential for soil C storage under Miscanthus system when established on previous grassland.

Compare the size and density fractionation method with other fractionation techniques in their ability to extract SOM pools that match theoretical pools in soil C models.
Some conclusions from CarboEurope-IP

- The full mitigation potential of the terrestrial vegetation in Europe is not realised because of GHG emissions from intensive agriculture including grasslands.
- Including non-CO$_2$ GHGs reduces the continental sink by about 70%.
- The new estimates of CarboEurope-IP suggest that grasslands are a stronger sink than estimated in 2003.
- Uncertainty for grasslands are approximately twice those for forests.
In conclusion: Some key questions

• What are the chemical and biological processes that move carbon into long-term storage in grasslands?
• Can these processes be managed?
• Can the slow accumulation of C in grassland soils be detected within periods of less than a decade?
• Can this be done on a global scale?