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Carbon sequestration under grassland: The case of Europe

Sophie Bertrand
Katja Klumpp
Tiphaine Tallec (Soussana)
JB Dolle

Grassland Ecosystem Research
Clermont Ferrand, France

IDF WDS Auckland 2010
Global technical mitigation potential by 2030 of each agricultural management practice

Carbon sequestration in agricultural soils: 89%
Mitigation of CH₄ emissions: 9%
Mitigation of N₂O emissions: 2% 

(IPCC, 2007)
The GHG balance of the agriculture sector in Europe

Grassland C sequestration would play a significant role for the European agriculture sector

(Schulze et al., Nature Geosciences)
Definition of C sequestration in grassland

Variation Net C sequestration (NCS) = C inputs - C outputs
Evolution of soil carbon stock: grassland versus cropland

In grassland C stock is exclusively **belowground** and C sequestration is **slow**.

Arable, temporary grassland = strong / light C **source** depending on initial status of soil. Tillage/ploughing leads to an important **loss** of soil organic C.
How stable is organic carbon? Comparing deep and top soil

Reservoir of carbon (GtC)  Residence time (years)
0-0,2 m  600  10-300 yrs
0,2-3 m  1700  1000-15000 yrs

Highly stable deep carbon

Without supply of fresh C (energy) for microbes, deep carbon is stable

Our results do not confirm the concept of C sink saturation : no limit!

(Fontaine et al., Nature 2007)
How to measure potential carbon sequestration and greenhouse gas emissions?

On field scale

Automated chambers for N₂O

Flux tower CO₂, H₂O, N₂O and CH₄ (eddy covariance, turbulent flux technique)

Tracer SF₆
The eddy covariance method for measuring CO$_2$, H$_2$O, N$_2$O and CH$_4$ fluxes

$[\text{CO}_2] = C'$

Vertical wind = $w'$

$\{\text{CO}_2 \text{ flux} = w' \cdot c'\}$

Flux towers: Spatial scale $\approx 1 \text{ km}^2$
Net C sequestration of grazed sites (Kg C/ha/year)

\[ \text{Net Carbon Sequestration} = 1290 \]

\[ F_{\text{CO2}} \]
\[ F_{\text{CH4}} \]
\[ F_{\text{animal production}} \]
\[ F_{\text{leaching}} \]

\[ 1450 \quad 40 \quad 20 \]

Soussana, Tallec & Blanfort 2009
Carbon sequestration (NCS) according to management

(2003 - 2005)
9 sites
(g C/m²/year)

- The less carbon is used, the more is returned to the soil, which increases C sequestration
- Nitrogen supply also favours carbon sequestration

Carbon sequestration (NCS) of Grasslands

Most grasslands are a net sink of Carbon! Average: 1 T C/ha/year

Soussana, Klumpp, Tallec et al. 2010 in preparation
Net C Sequestration across Europe including all ecosystems (2005-2008)

GHG balance = Net C Sequestration - N₂O (eq CO₂) - CH₄ (eq CO₂)

Schulze et al 2009, Nature Geoscience
GHG balance across Europe

CH₄

N₂O

GHG balance

Schulze et al, 2009, Nature Geoscience
How could we use these results in a C footprint methodology?

Average data found : 1000 kg C / ha /year

In the C footprint calculation :

P. Grassland C storage F
P. Grassland < 30 years : 500 kg C / ha /year
P. Grassland > 30 years : 200 kg C / ha /year

Grassland ploughing C loss F : 1000 kg C / ha /year
lost under crop after grassland ploughing
Calculation of net emission at dairy farm level

Gross Émission (kg Eq CO₂)

Net emission

1 ha of grassland:
500 kg of C /ha/an, so 1 830 Eq CO₂

Carbon sequestration can compensate 5 to 35 % of the total emission

(Dollé et al. 2009)
Examples of results on dairy farms

Calculations have been realised on 400 French dairy farms representing different production systems.
Gross GHG emission at dairy farm level

FAO results 2010: 1.5 kg CO\textsubscript{2}/litre (production, transformation, transport)

National average: 1.15 kg eq. CO\textsubscript{2}/L milk
Net GHG emission at dairy farm level

National average: 0.97 kg eq.CO2 net/L milk
How to increase soil carbon sequestration to mitigate GHG balance

**Increase C inputs**

1. Increase biomass
   - Forage productivity
   - Species selection
   - Legumes, fertilizers
     (Irrigation)
   - Grass/legume mix

2. Change from short-term to permanent grassland

3. Reduced cutting, avoid overgrazing

4. Bring Organic Matter

**Decrease C losses**

1. Avoid ploughing up permanent grasslands

2. Conversion from arable to grassland & from short duration leys to permanent grassland

3. Reduce cutting and grazing

4. Reduce fire, leaching, erosion & mineralisation

5. Improve soil structure

**Soil Organic Matter (C,N)**
Impacts of climate variability and extremes on the C cycle in grasslands

- Interannual variability
- Agricultural management
- Greenhouse gas emissions

Lorraine, France, August 2003
Biodiversity loss may impact C sequestration

Chemical characteristics of litter

Energy

CO₂

Plant species diversity

Plant functional traits

Defoliation by cutting and grazing

Micro-environmental

Soil organic matter
Concluding remarks

• There is a clear potential for C sequestration in European grasslands: protect the stock → dairy sector can help

• An internationally agreed methodology is still missing to develop mitigation options in the livestock sector based on C sequestration.

• Reducing CH$_4$ and N$_2$O emissions from the livestock sector is strongly needed, given that soil carbon sequestration is reversible and vulnerable to climate change and biodiversity loss.

• Mitigation strategies could be based on the net GHG balance of livestock farms.
Thank you