Carbon Sequestration: Implications for grassland systems

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With thanks to:

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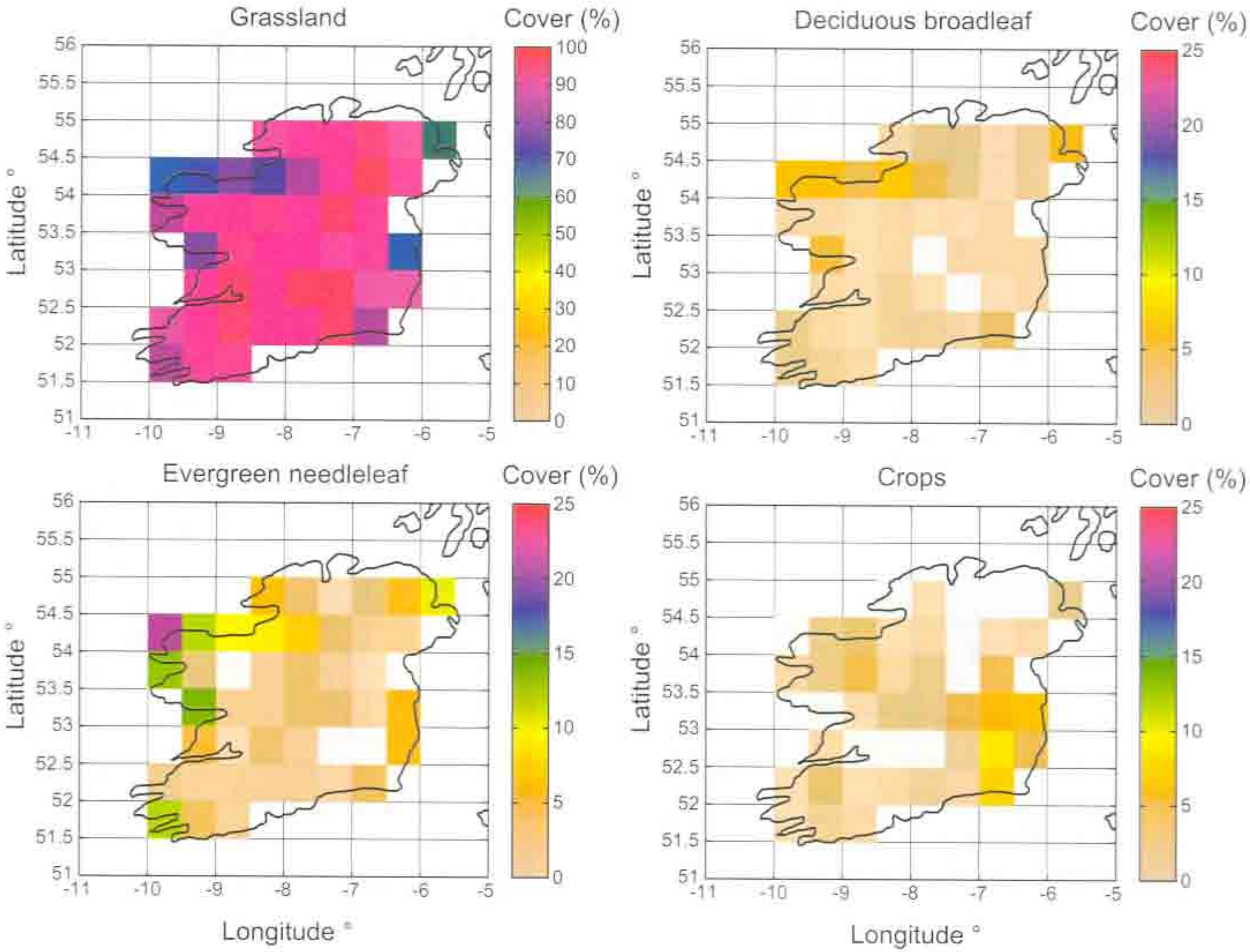
Outline

- The carbon cycle in grasslands
- Where is the carbon?
- There are more GHG’s than CO_2
- Measuring and modelling pools and fluxes
- Conclusions and key questions

Land cover of functional types in Ireland

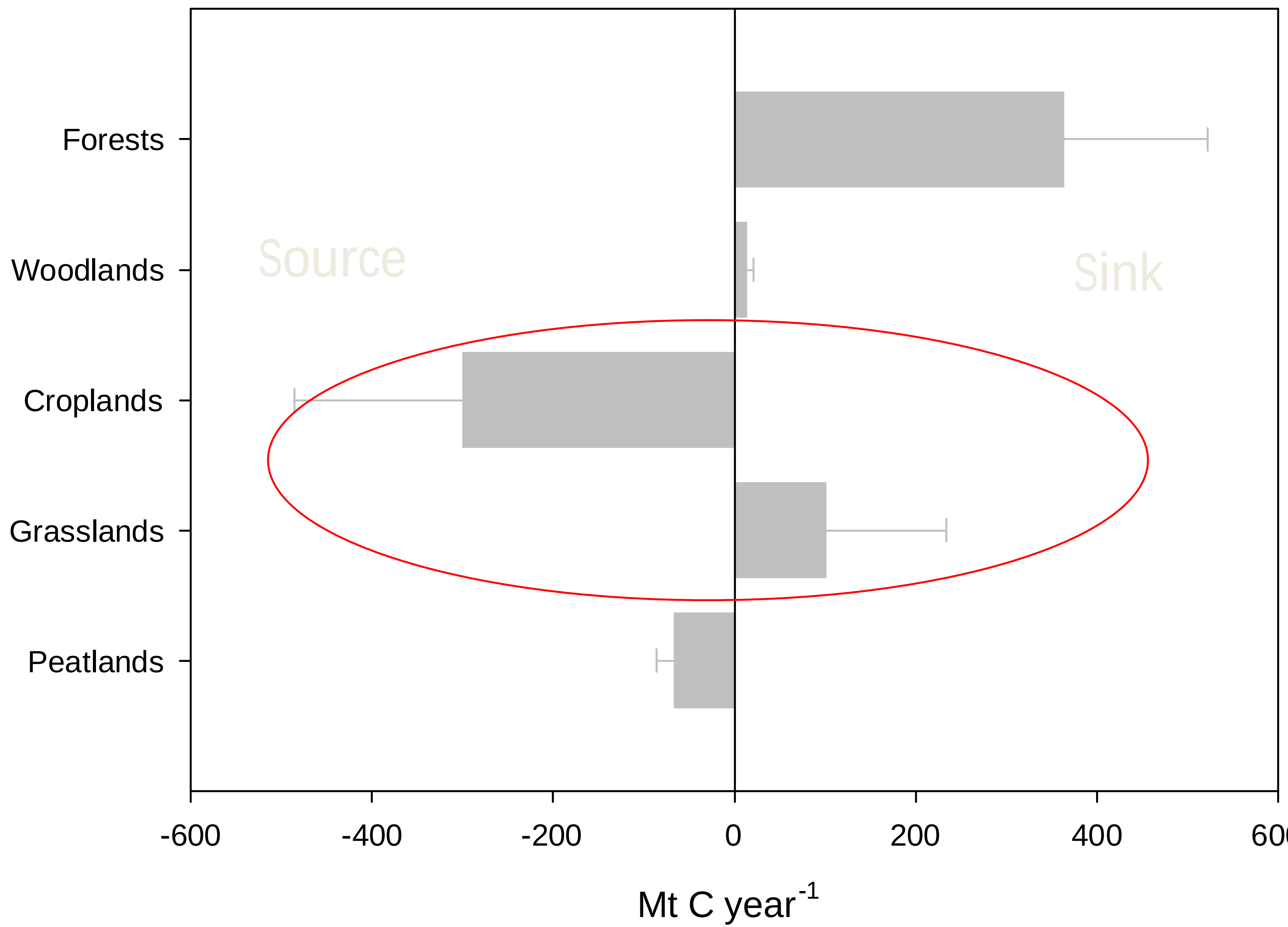


Woodward et al. (2010)

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.

Uncertainties in the carbon balance of European ecosystems before the start of CarboEurope (Janssens et al. Science, 2003).



Geographic Europe

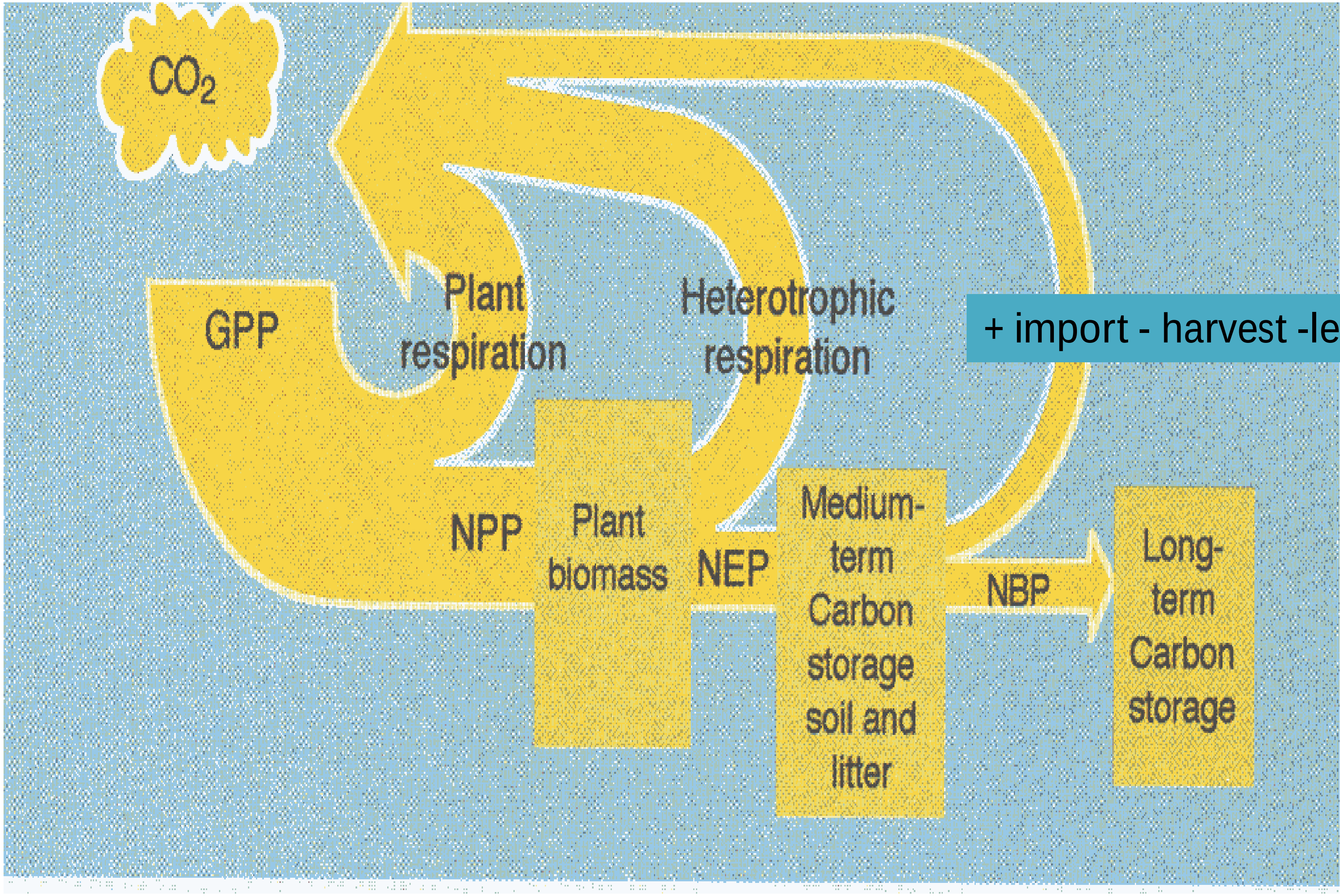
Fossil fuel emissions = 1850 Mt C per year

Some conclusions from CarboEurope-IP(2010)

- 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.

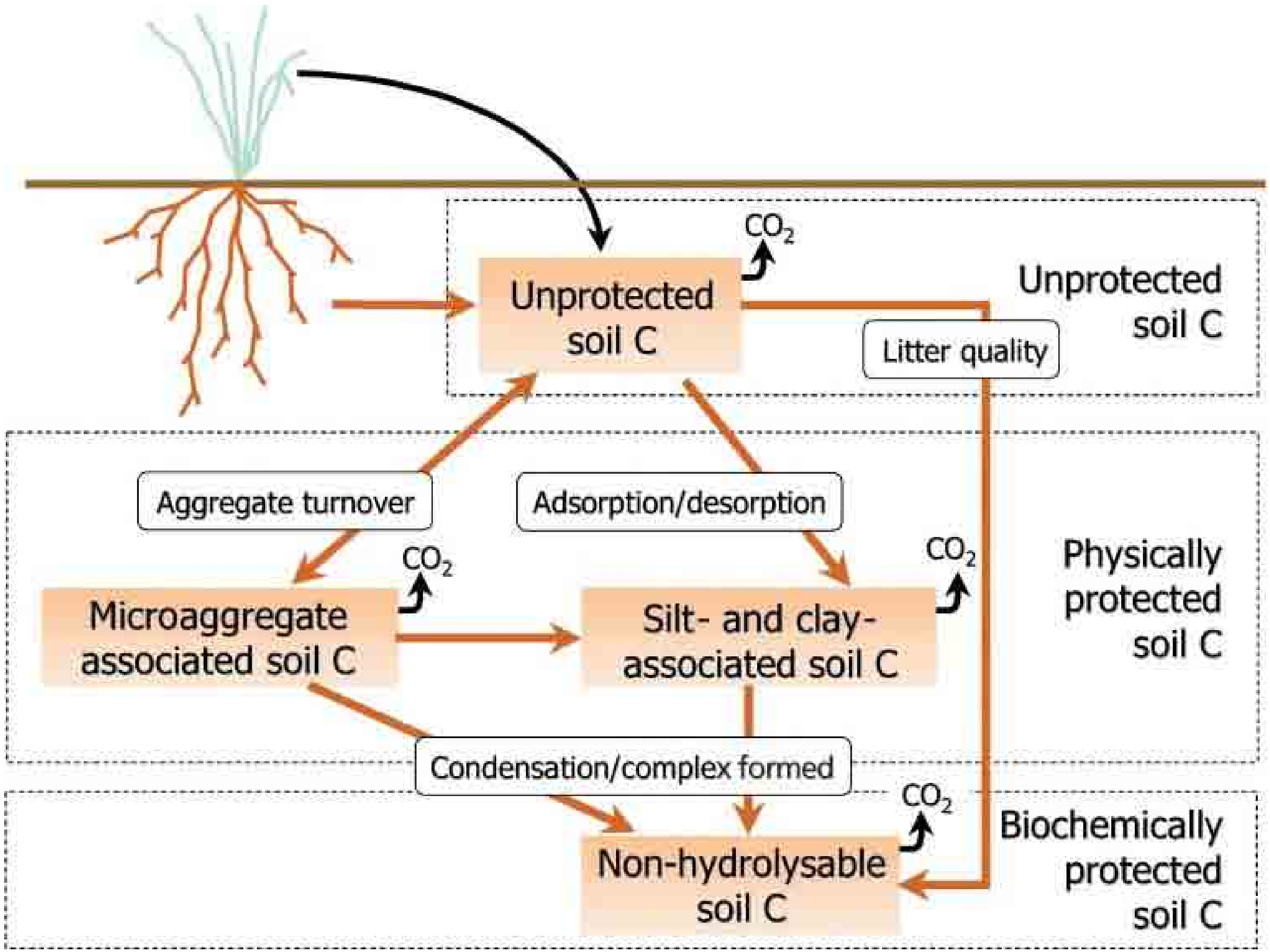
The Carbon Cycle in Grasslands

Ecosystem Carbon Uptake and Storage



+ import - harvest -leaching

Conceptual model of C dynamics after Six *et al.* (2002), showing measurable pools.



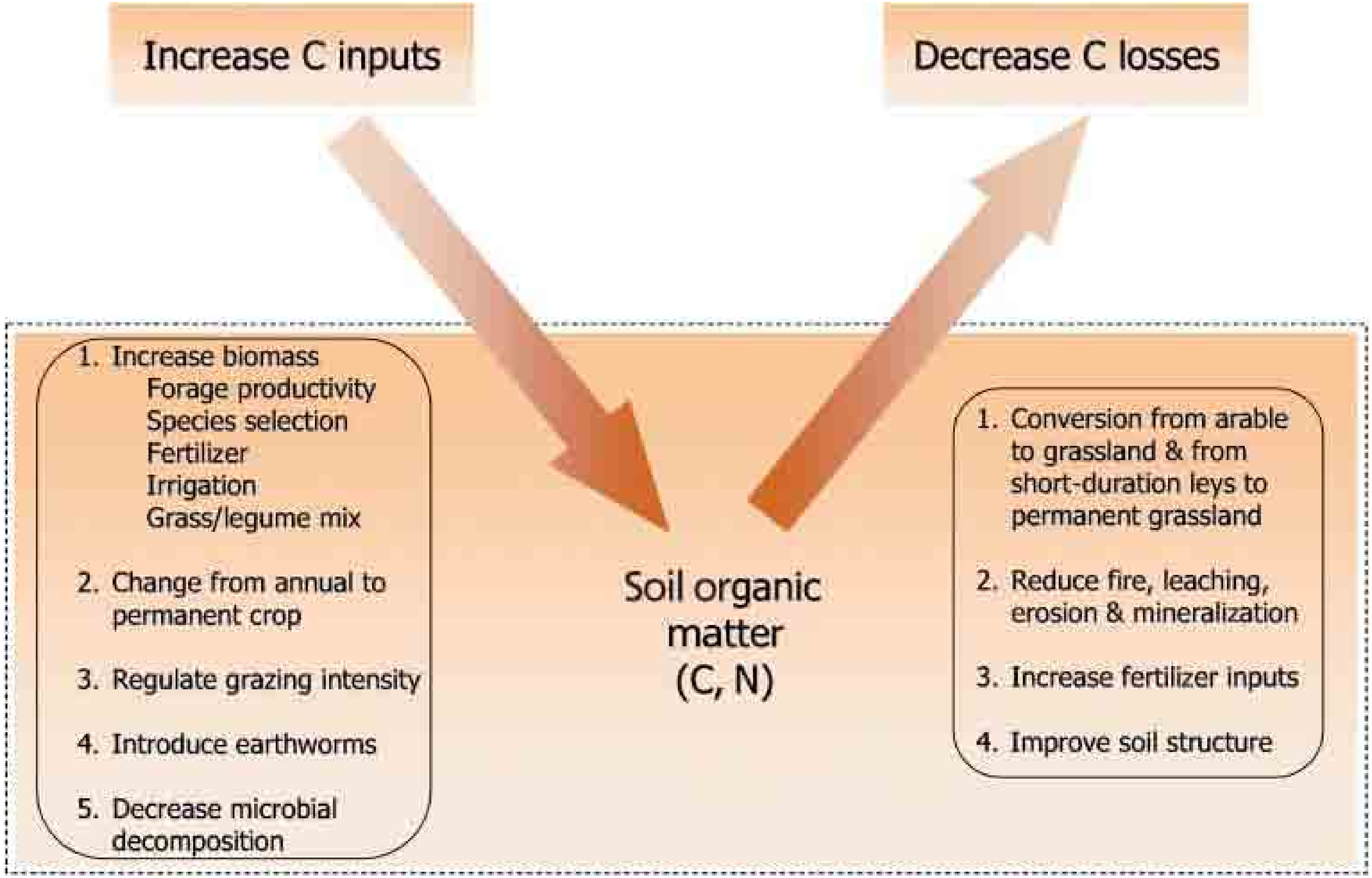
What are the limitations?

- 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?

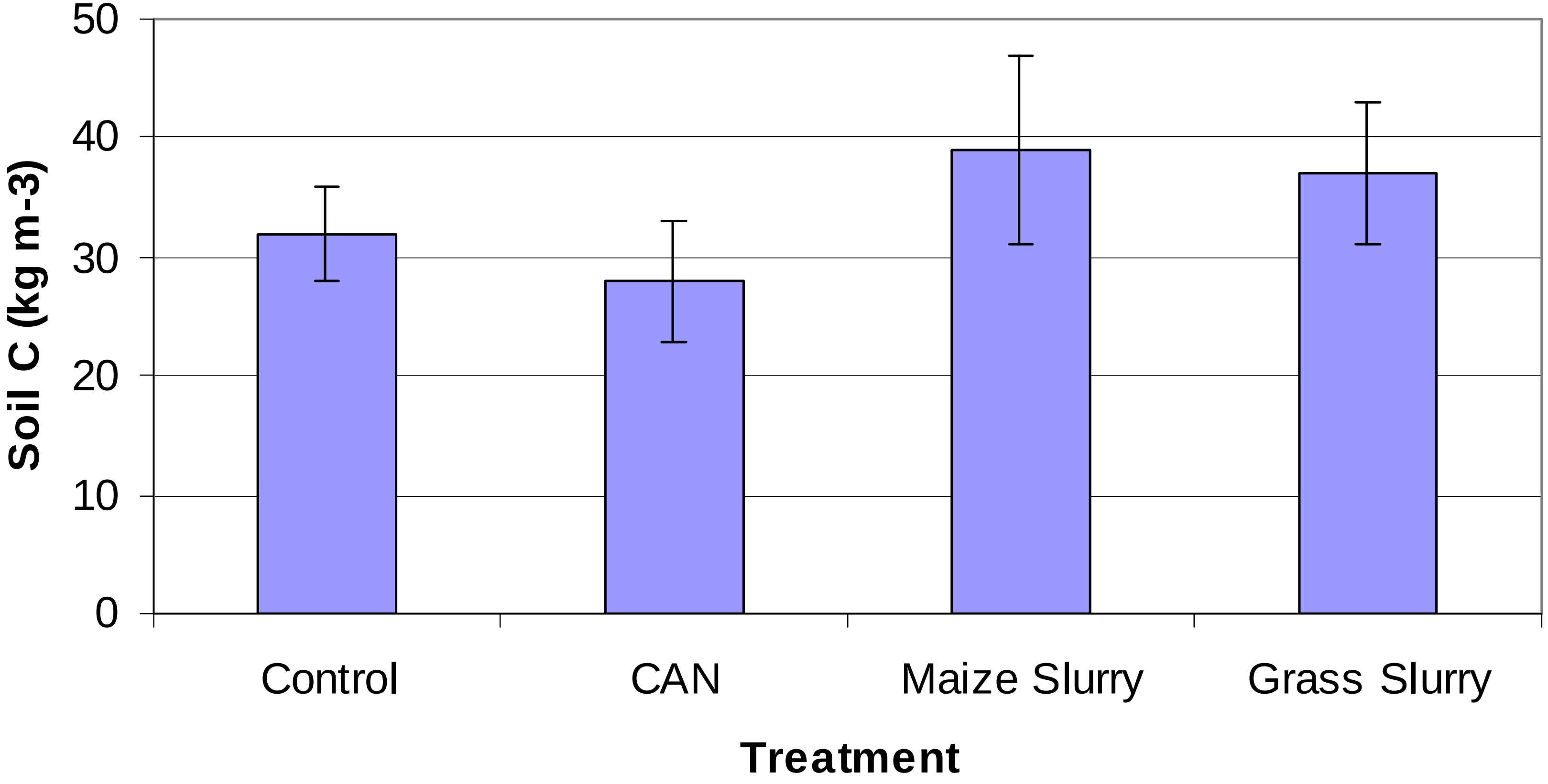
What affects C sequestration?

- Past and current land use changes.
- Agricultural management.
- Horizontal transfer of hay/silage and manure.
- Non-linear kinetics.

Management options to increase carbon in grassland ecosystems.



Effect of organic inputs on soil C



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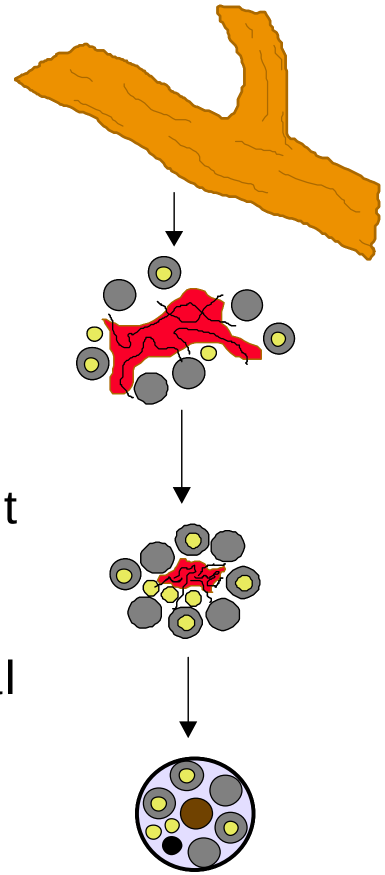
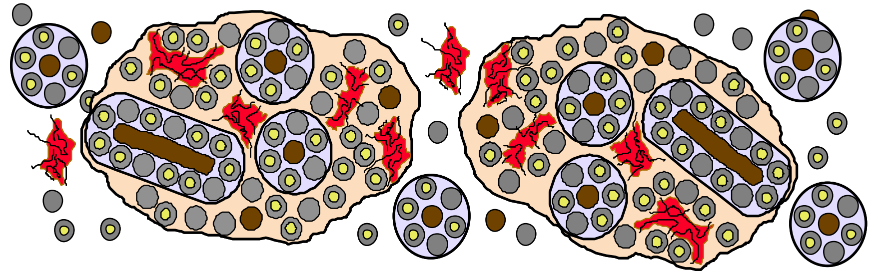
The SOM aggregation concept

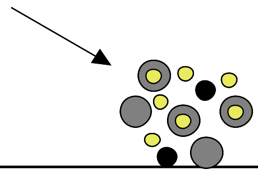
Decomposing roots and detritus become encrusted with mineral particles forming microaggregates



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



Microaggregates ~ 50-250 µm

Particulate organic matter colonized by saprophytic fungi

Silt-sized aggregates with microbially derived organomineral associations

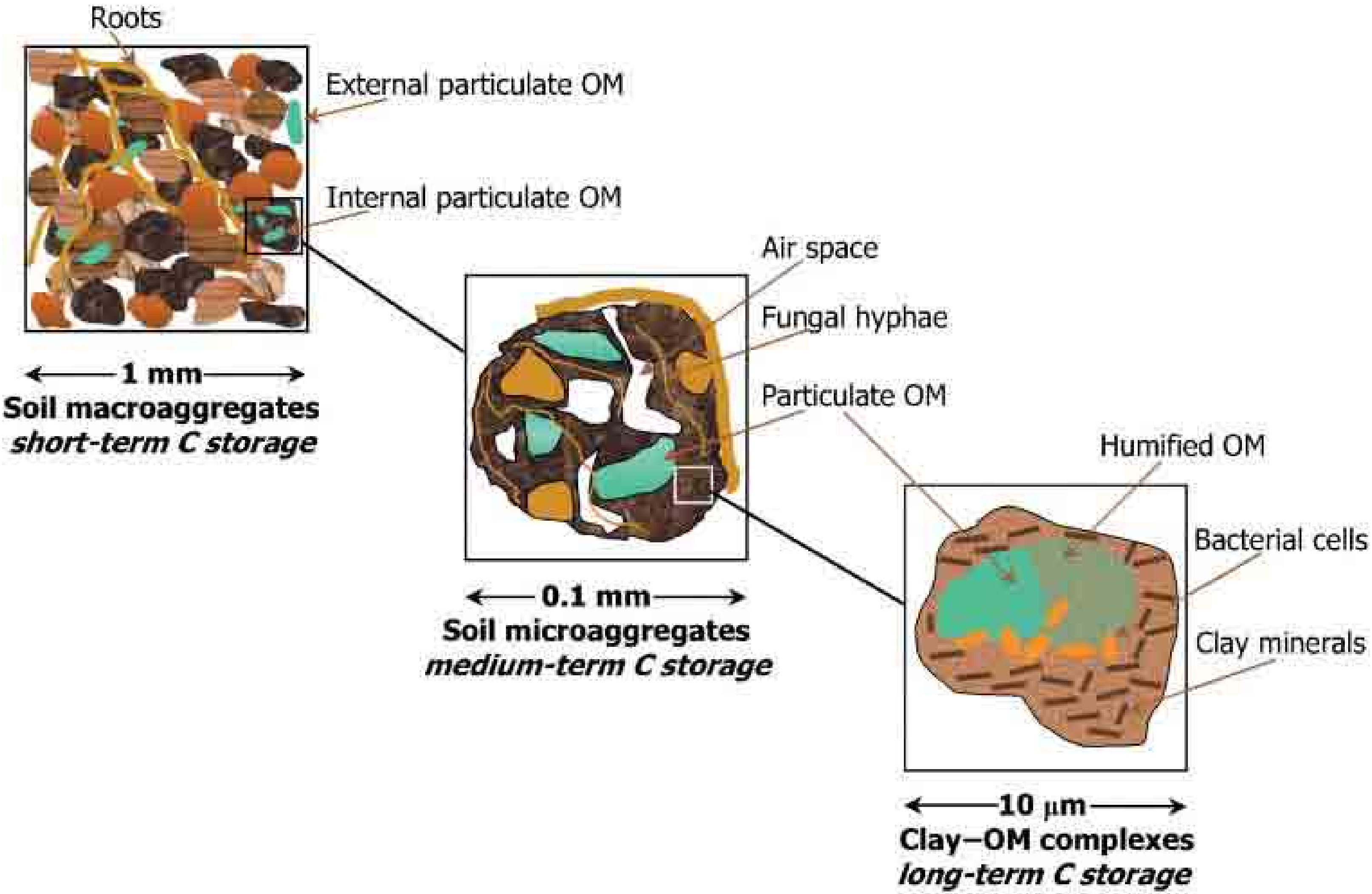
Plant and fungal debris

Fungal or microbial metabolites

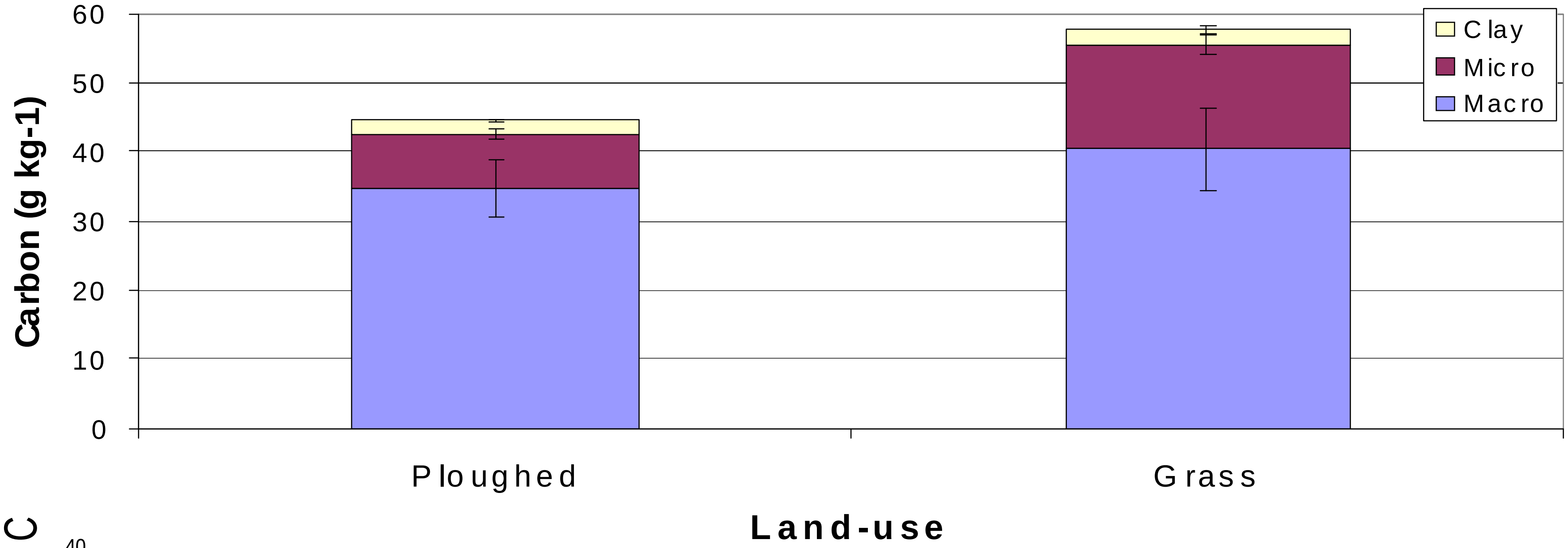
Biochemically recalcitrant organic matte

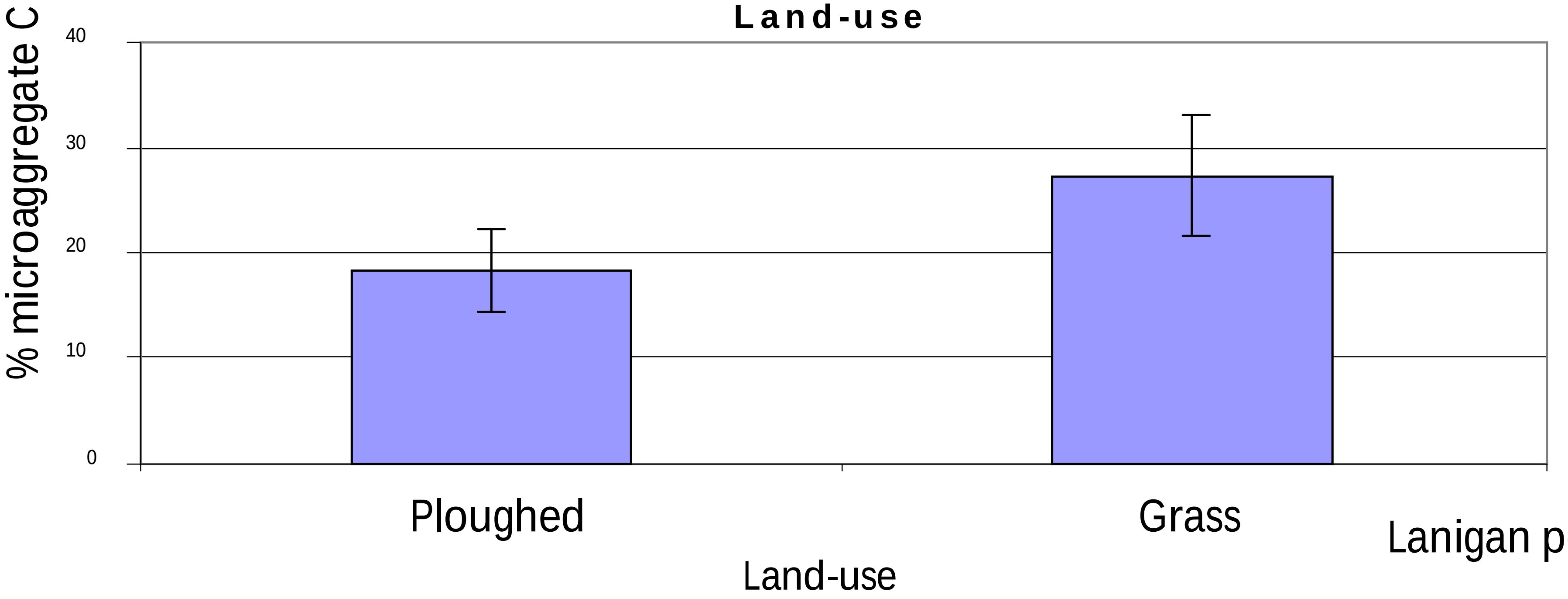
Clay microstructures

Aggregate organisation in the soil



Comparison of soil aggregate structure under tillage and pasture





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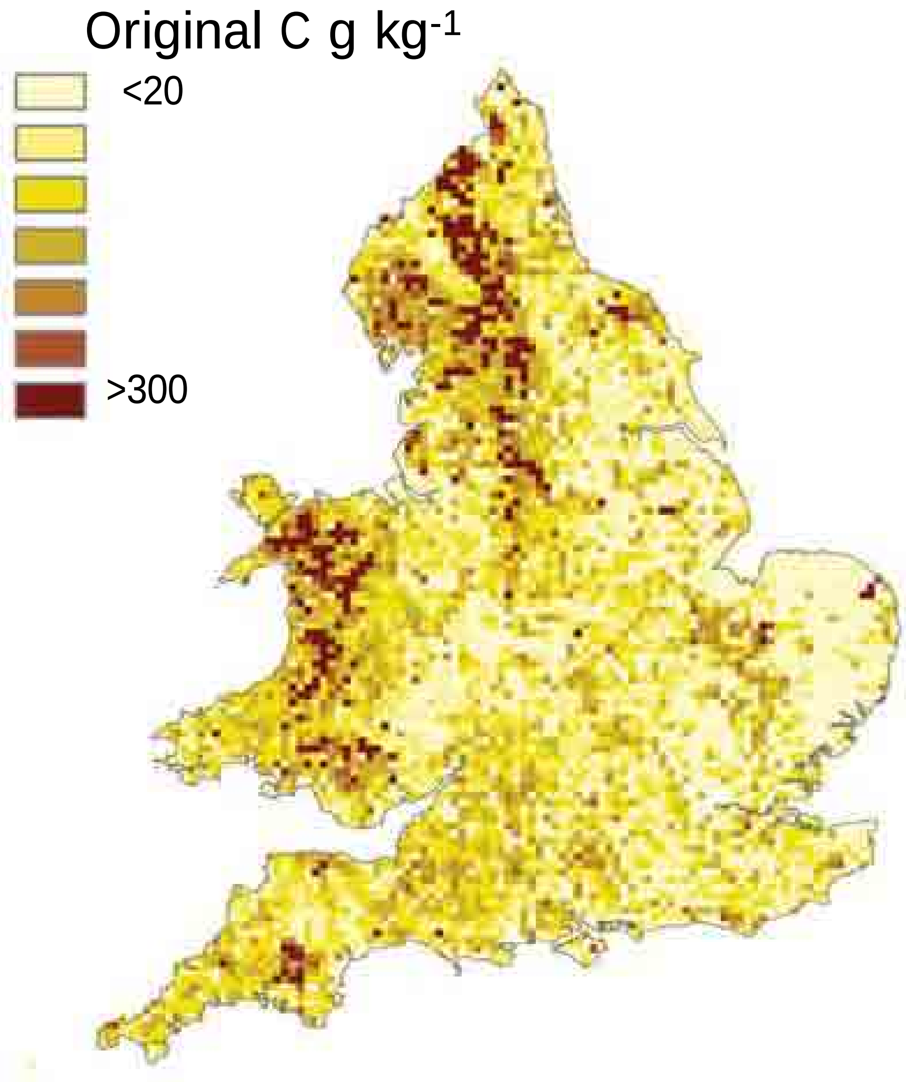
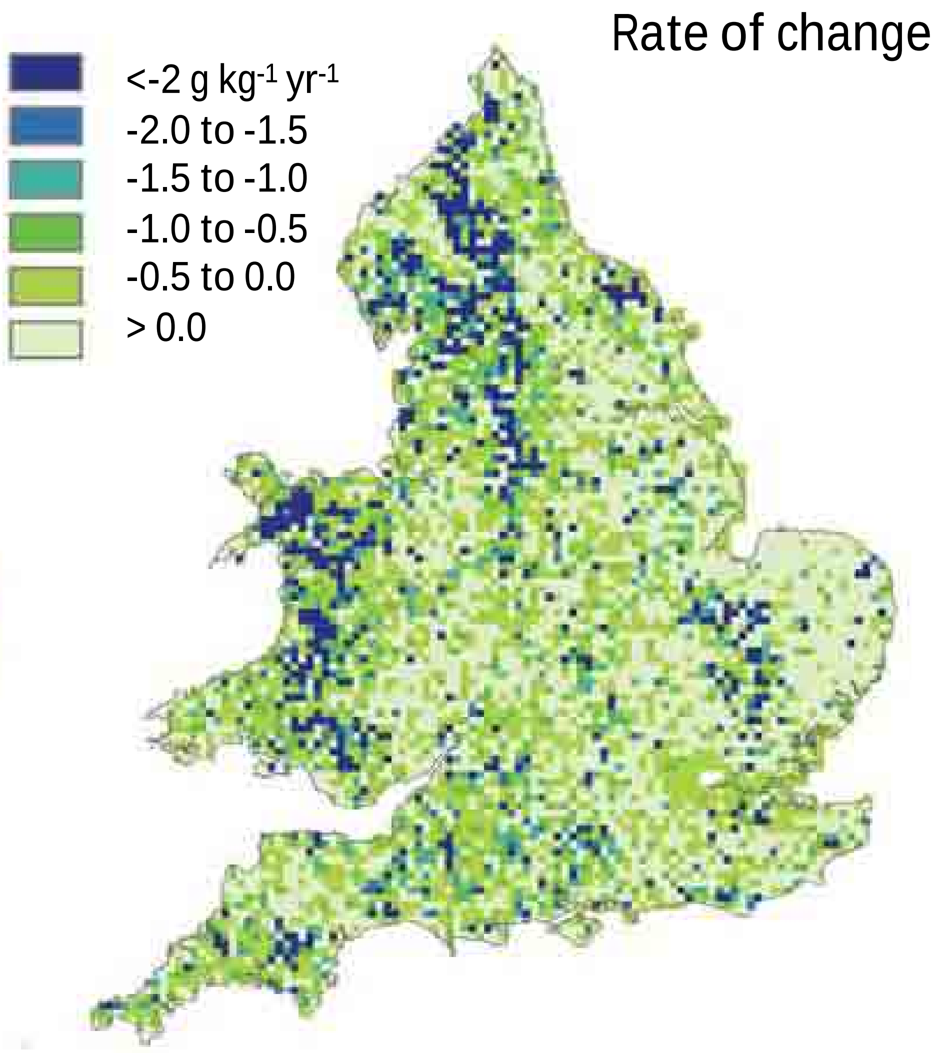
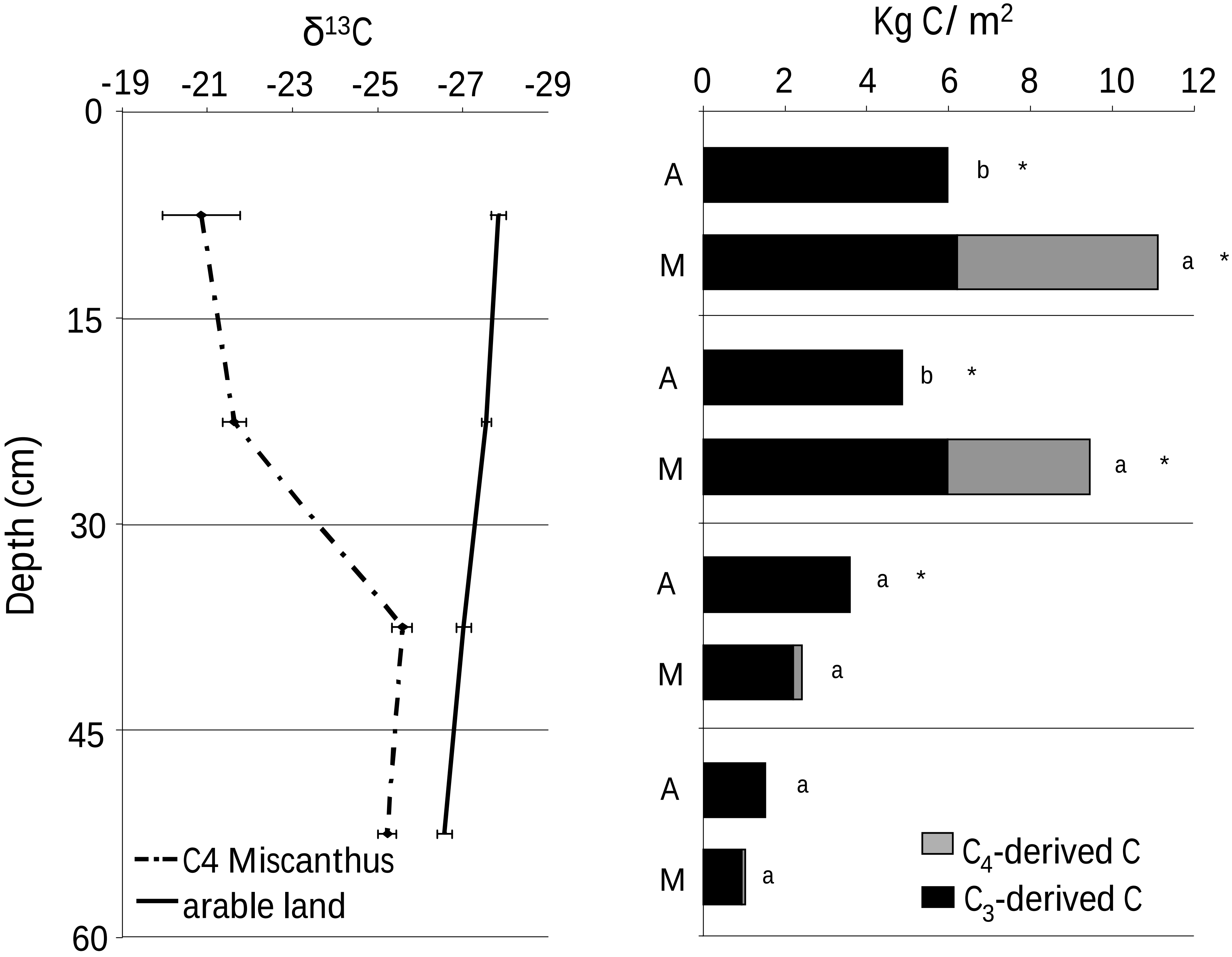
Measuring pools: Carbon losses from soils across England and Wales, 1978-2003 (Bellamy et al., 2005)

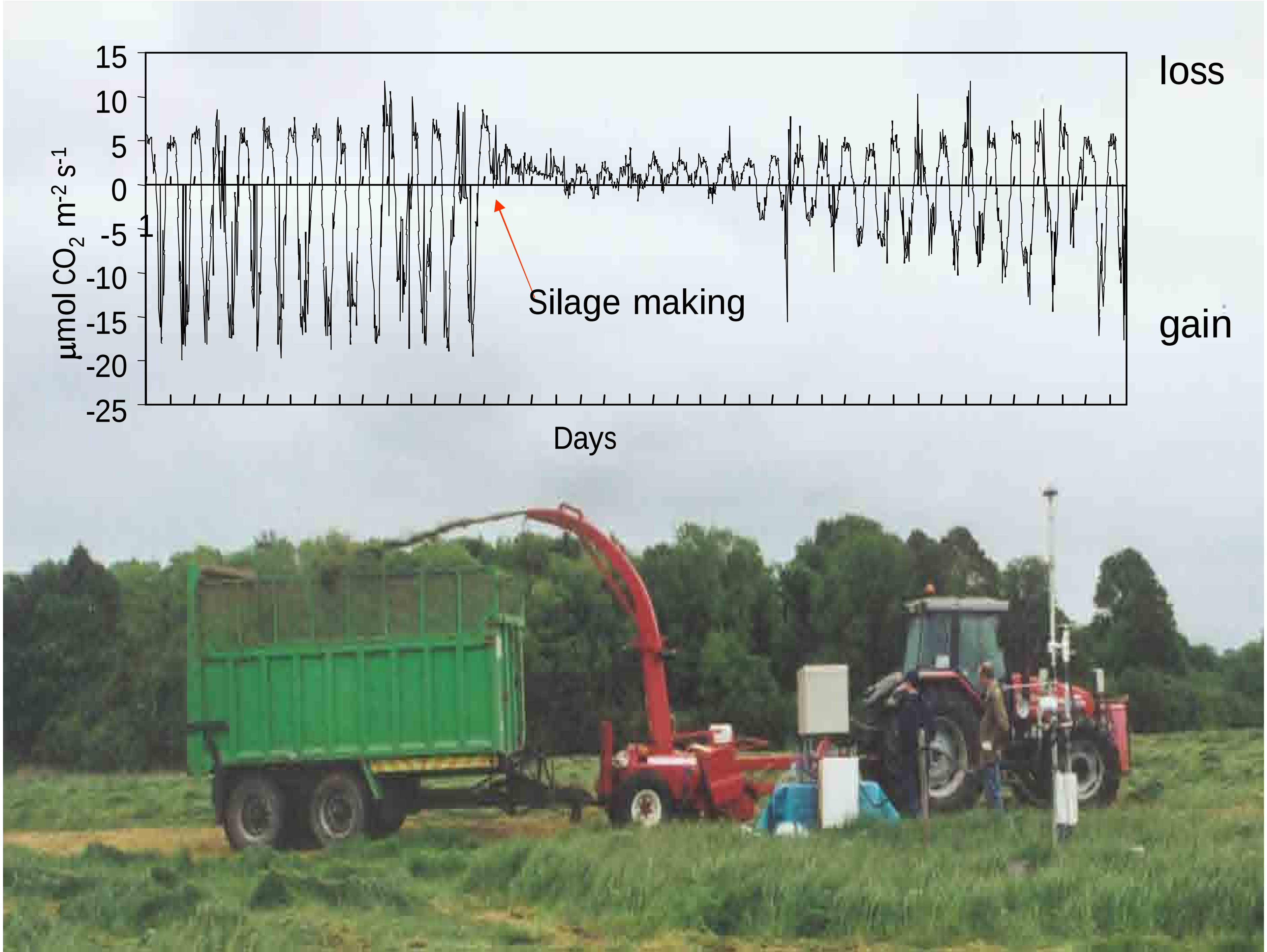




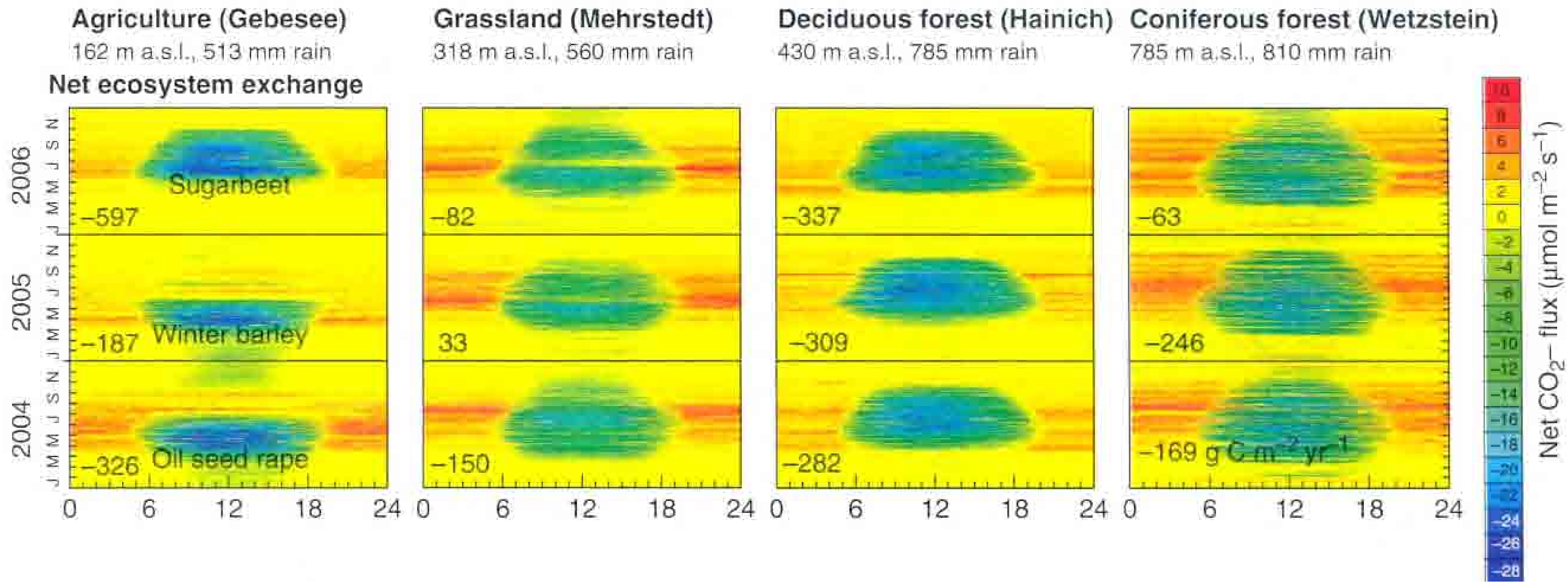

δ13C
-19
-21
-23
-25
-27
-29
Depth (cm)
0
15
30
45
60
C4 Miscanthus
arable land
Kg C/ m2
0
2
4
6
8
10
12
A
b *
M
a *
A
b *
M
a *
A
a *
M
a
A
a
M
a
C4-derived C
C3-derived C

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.



Flux fingerprints for different land uses



Annual sums for NEE (g C m^{-2} yr^{-1})

from: Schulze et al. (2010)

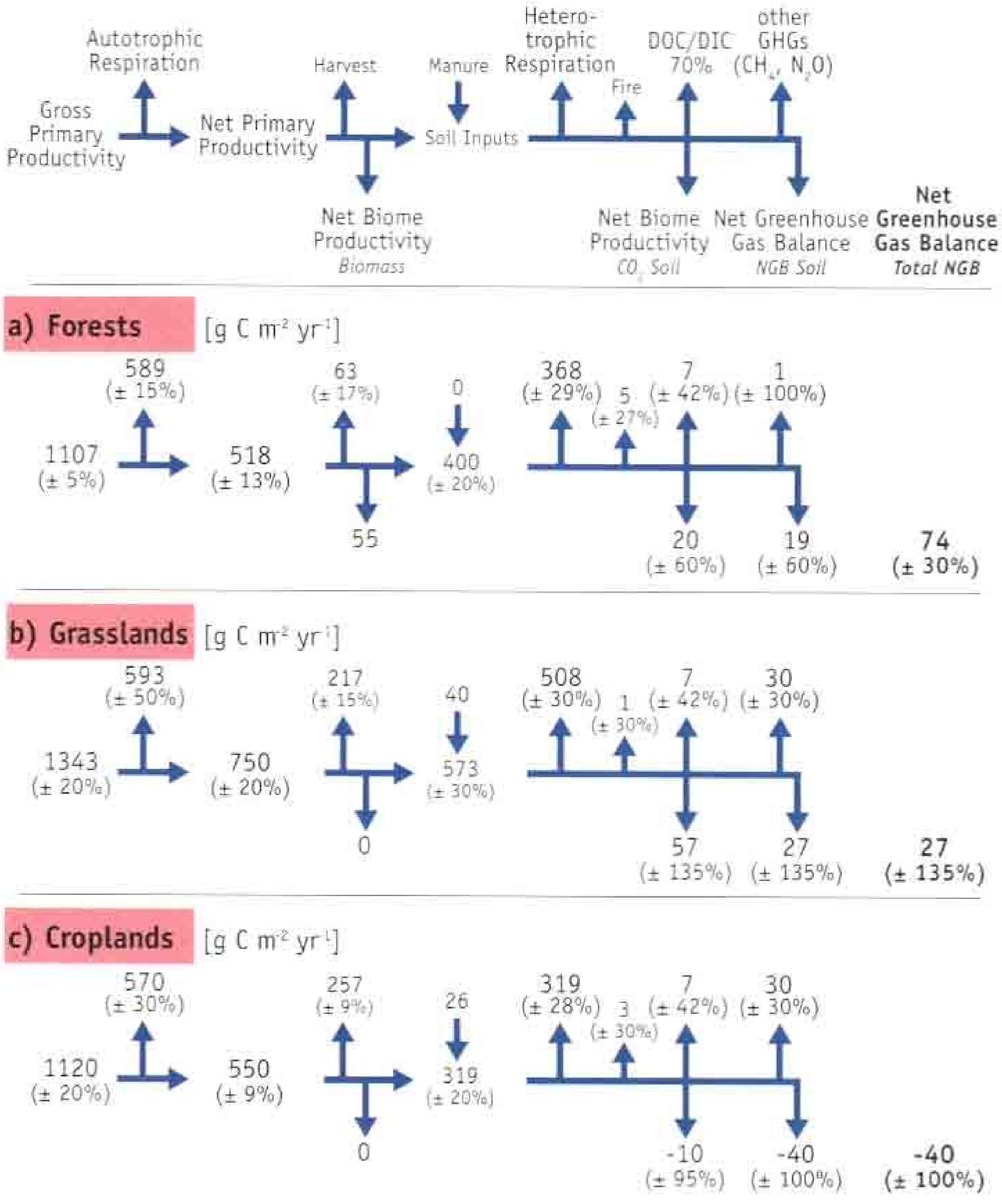
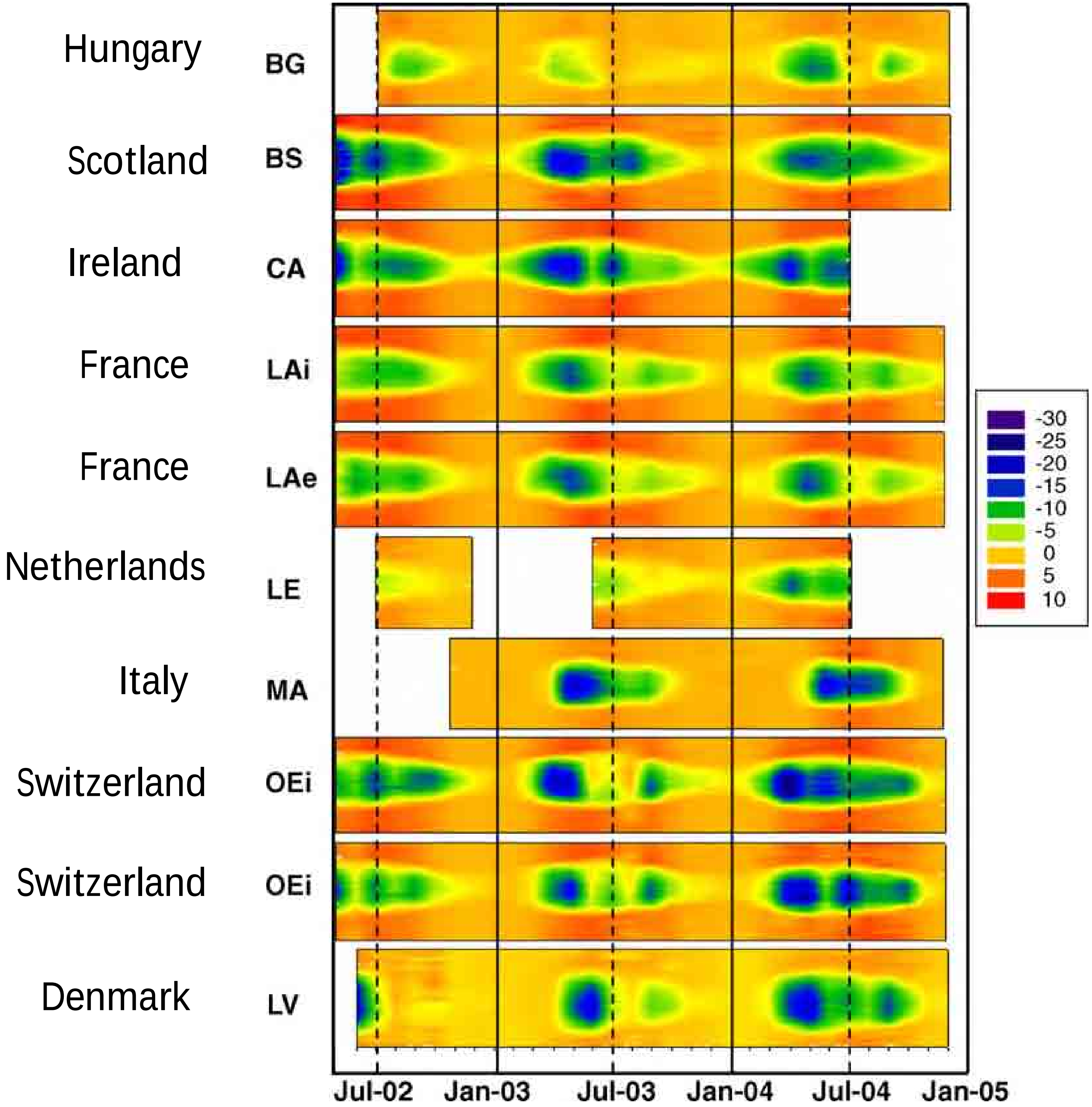


Fig. 63: Carbon flow through major land use types from CO_2 fixation (Gross

Comparison of Carbon flows through land use types in Europe.

CarboEurope–IP data.

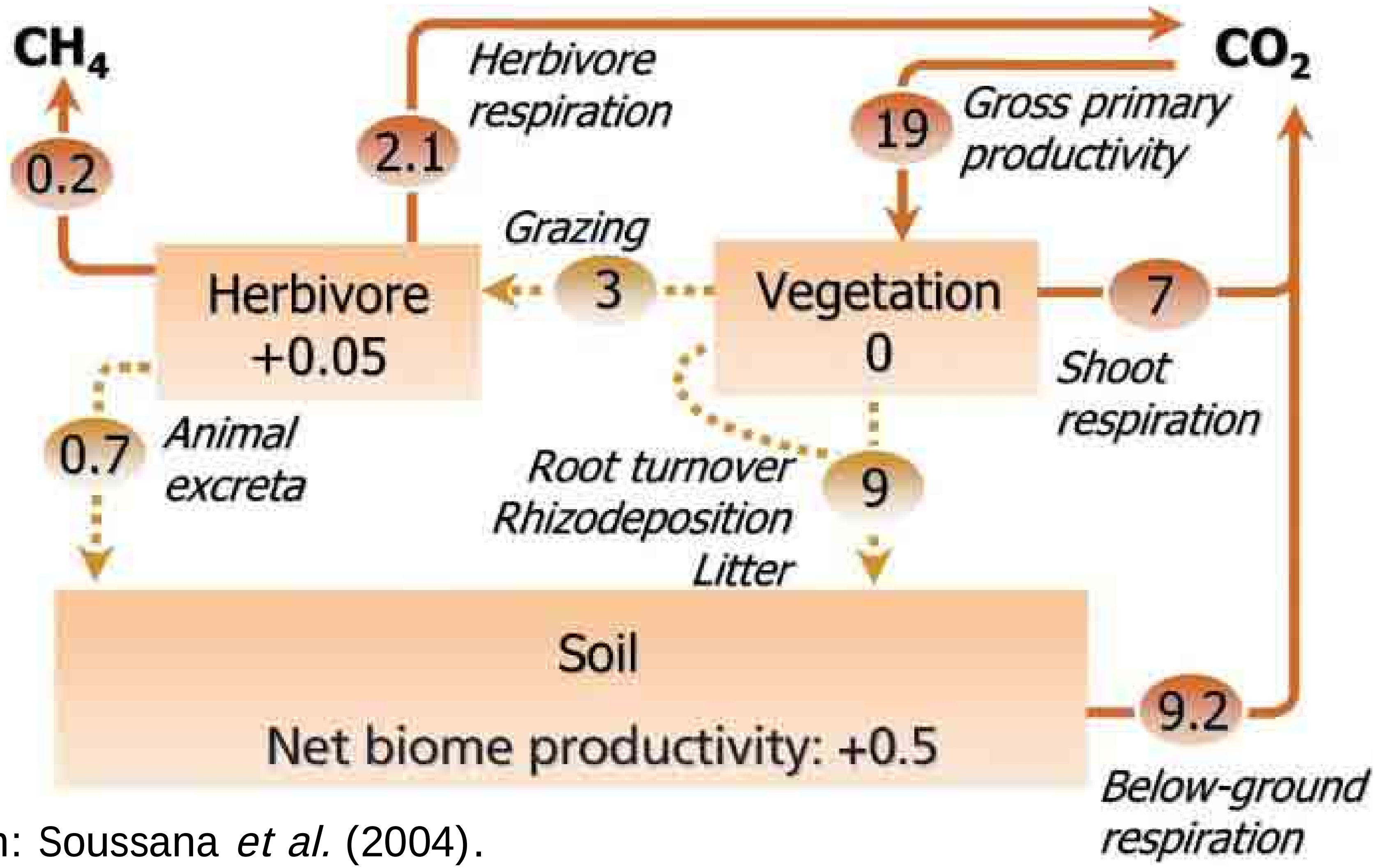
Janssens et al. (unpublished)



GreenGrass sites
Mean Diurnal NEE variation

(μmol CO_2 m^{-2} s^{-1})

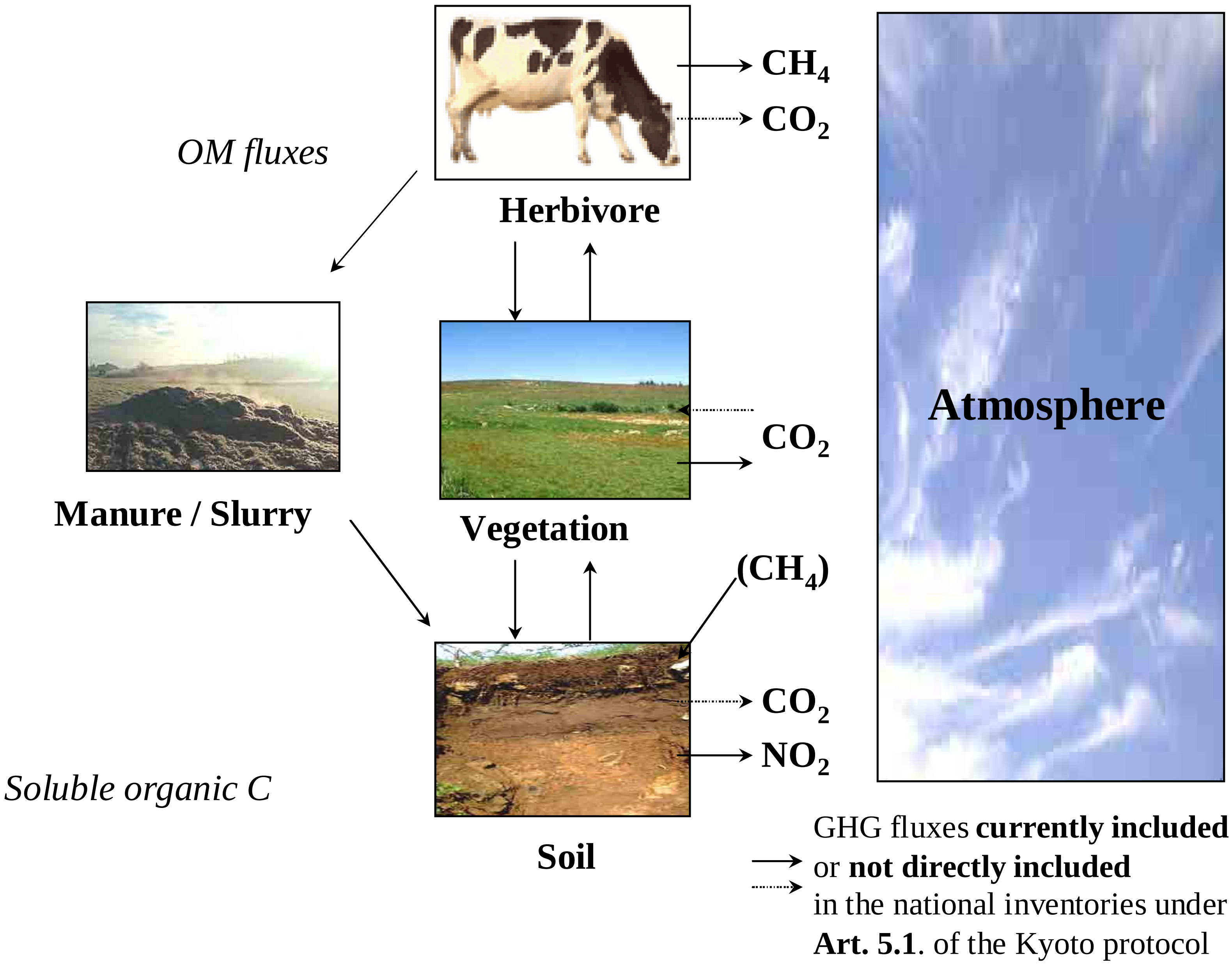
Measuring fluxes: Carbon cycling in grazed grassland



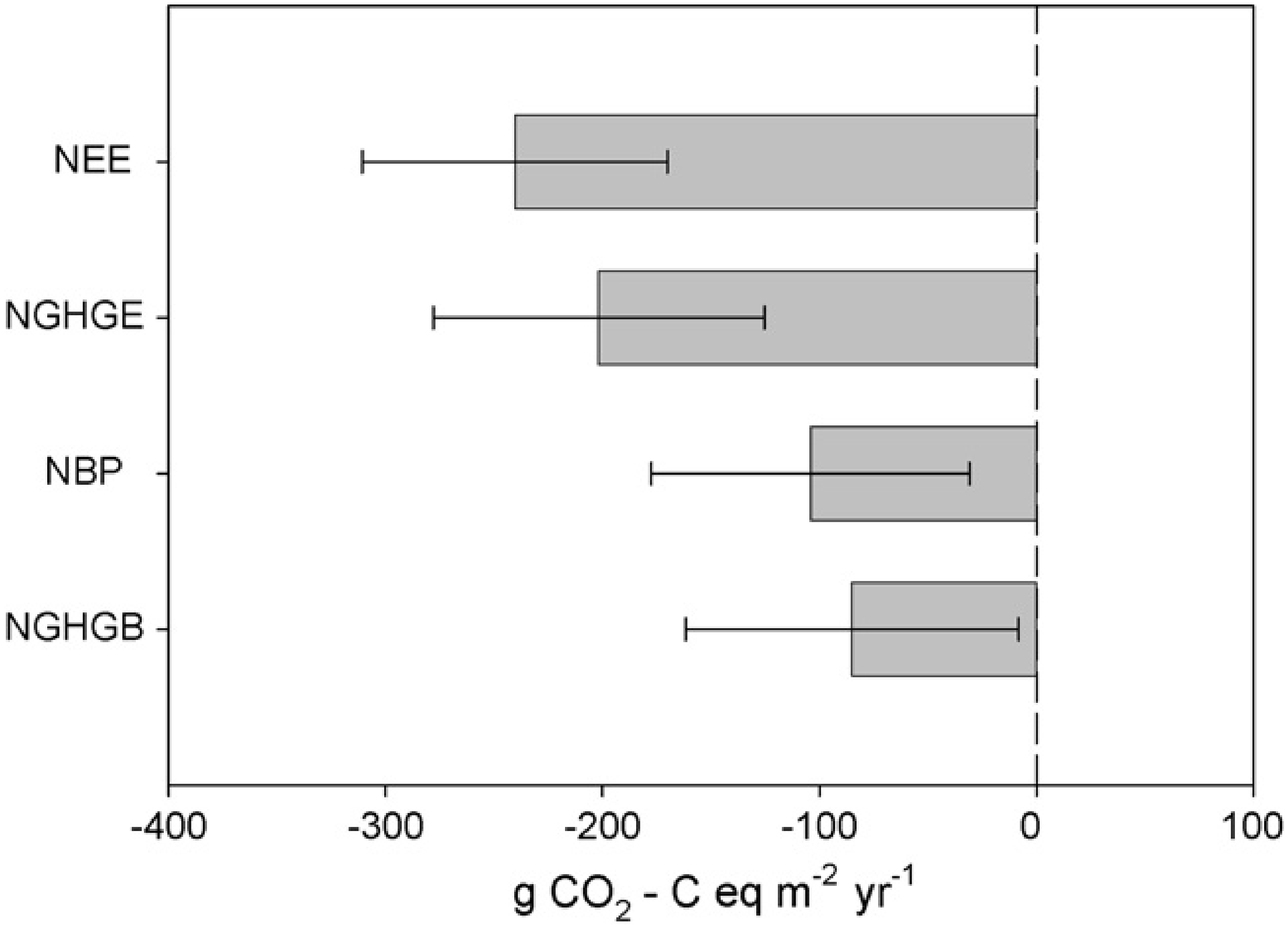
From: Soussana *et al.* (2004).

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

GHG sources and sinks in grasslands

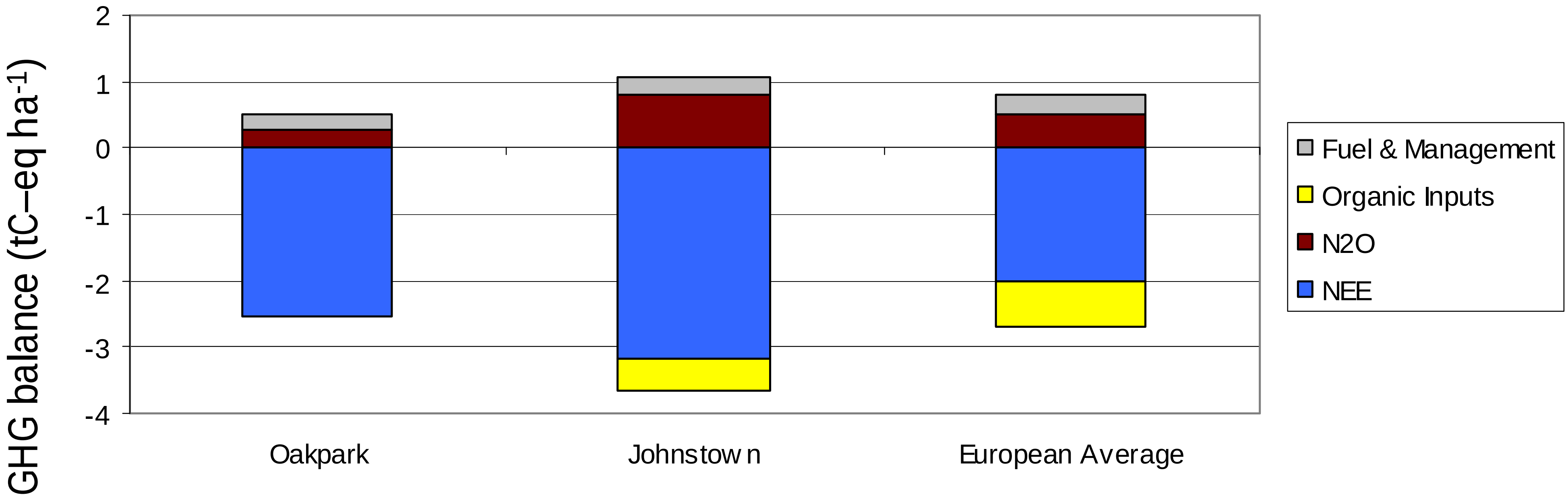


Average NEE, NBP, NGHGE and NGHGB over GreenGrass sites.



Results are means ±confidence interval of nine sites and over 2 years per site.
From: Soussana et al. (2007)

Carlow & Wexford pasture C balance



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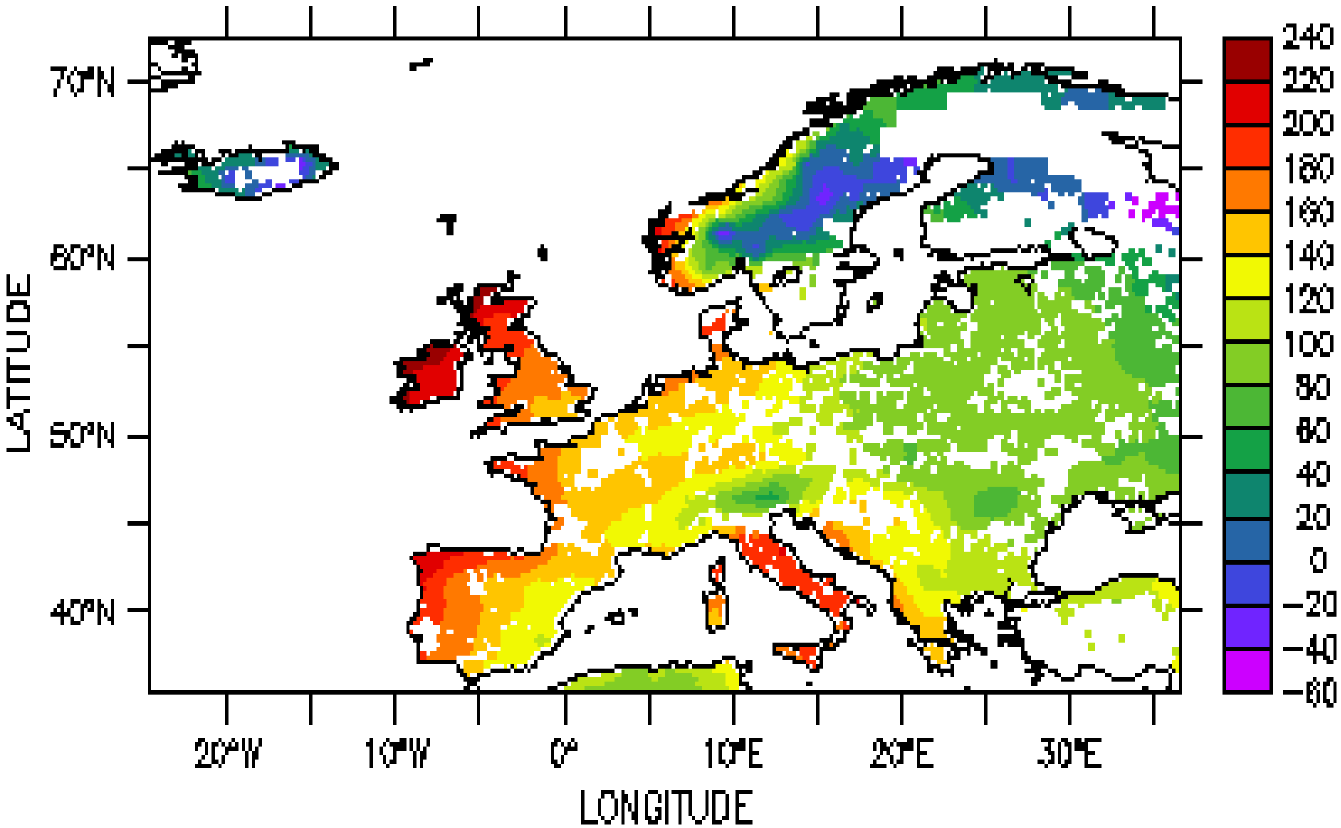
Spatial distribution of NBP of grasslands in Europe (data upscaling)



NBP (gC m−2)

Assuming a management similar to mean site management

Vuichard et al. (2007)

A word of caution!

- The existence of the above and other real-life complexities will render market-based C-trading schemes involving pastures, exposed to the risks of complicated, ill-conceived, ill-understood, poorly regulated financial instruments and arrangements that are replete with opportunity for fraudulent scams and inappropriate diversion of community wealth to the personal fortunes of scheme managers and traders, while not delivering the scheme objectives, reminiscent of those involved in the recent Global Financial Crisis (Roger M Gifford).

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 we reduce uncertainty?
- Can this be done on a global scale?

Thank You

Teagasc
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