# When to elect cropland management, grazing-land management or revegetation under the Kyoto Protocol


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Land-use Related Choices under the Kyoto Protocol, Selecting Activities under Kyoto Protocol Article 3.4,
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# Outline

- Article 3.4 activities
- Factors to consider
- Carbon benefits and their uncertainty ranges
- Risk of potential need to report carbon liabilities
- Monitoring/data collection and reporting costs
- Trade-offs and synergies
- The range of incentives required to achieve the desired objectives

# Human-induced activities under Article 3.4 in the first commitment period

- revegetation
- forest management
- cropland management
- grazing land management.

# Factors to consider when electing an article 3.4 activity

- Carbon benefits and their uncertainty ranges resulting from the adoption of each Art. 3.4 activity;
- Risk of potential need to report carbon liabilities as a result of the adoption of each Art. 3.4 activity,
- Monitoring/data collection and reporting costs,
- Trade-offs and synergies with other objectives, such as environmental or socio-economic considerations
- The range of incentives (if any) that may be required to achieve the desired GHG and other objectives.

# Carbon benefits and their uncertainty ranges

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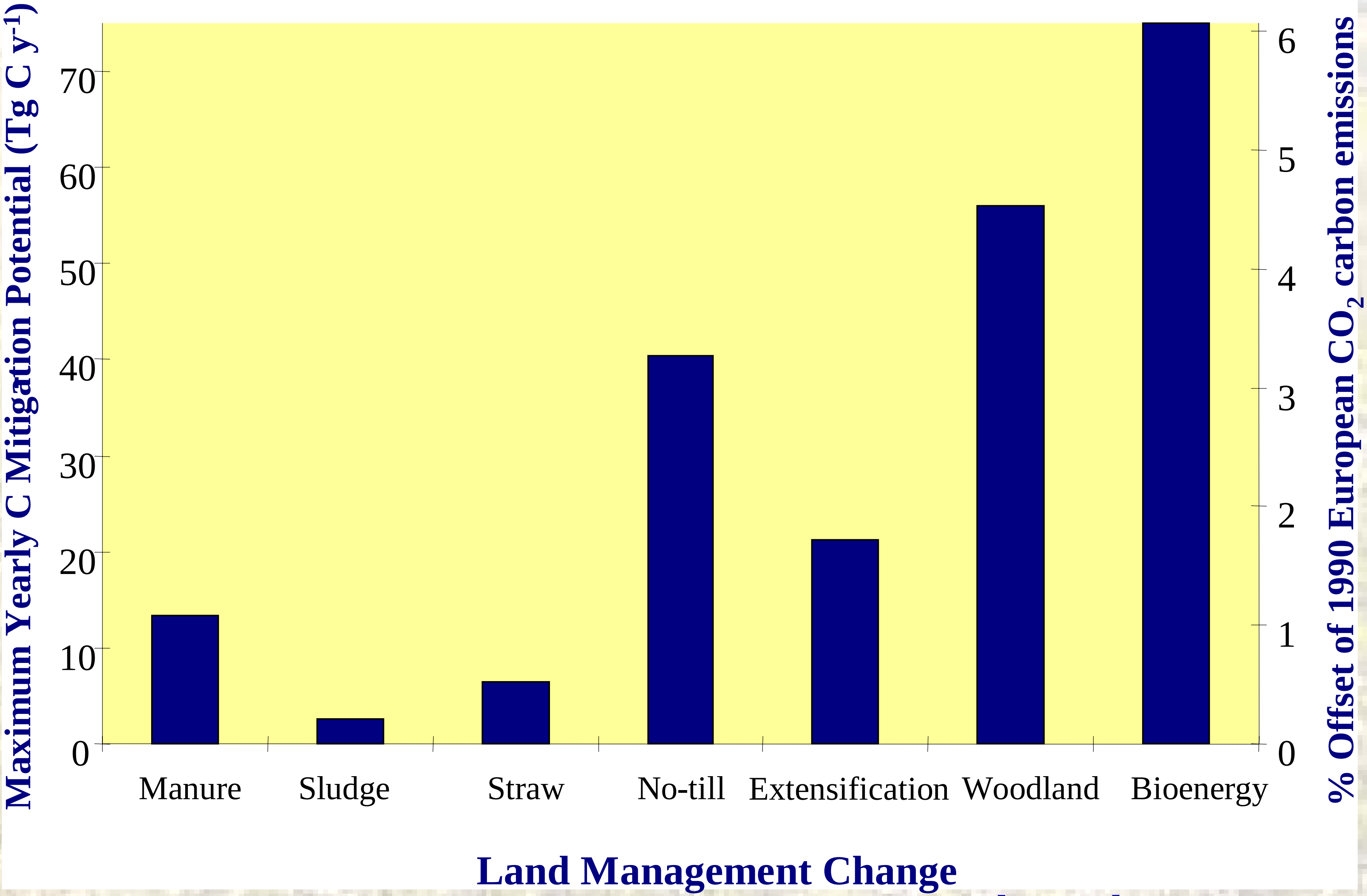
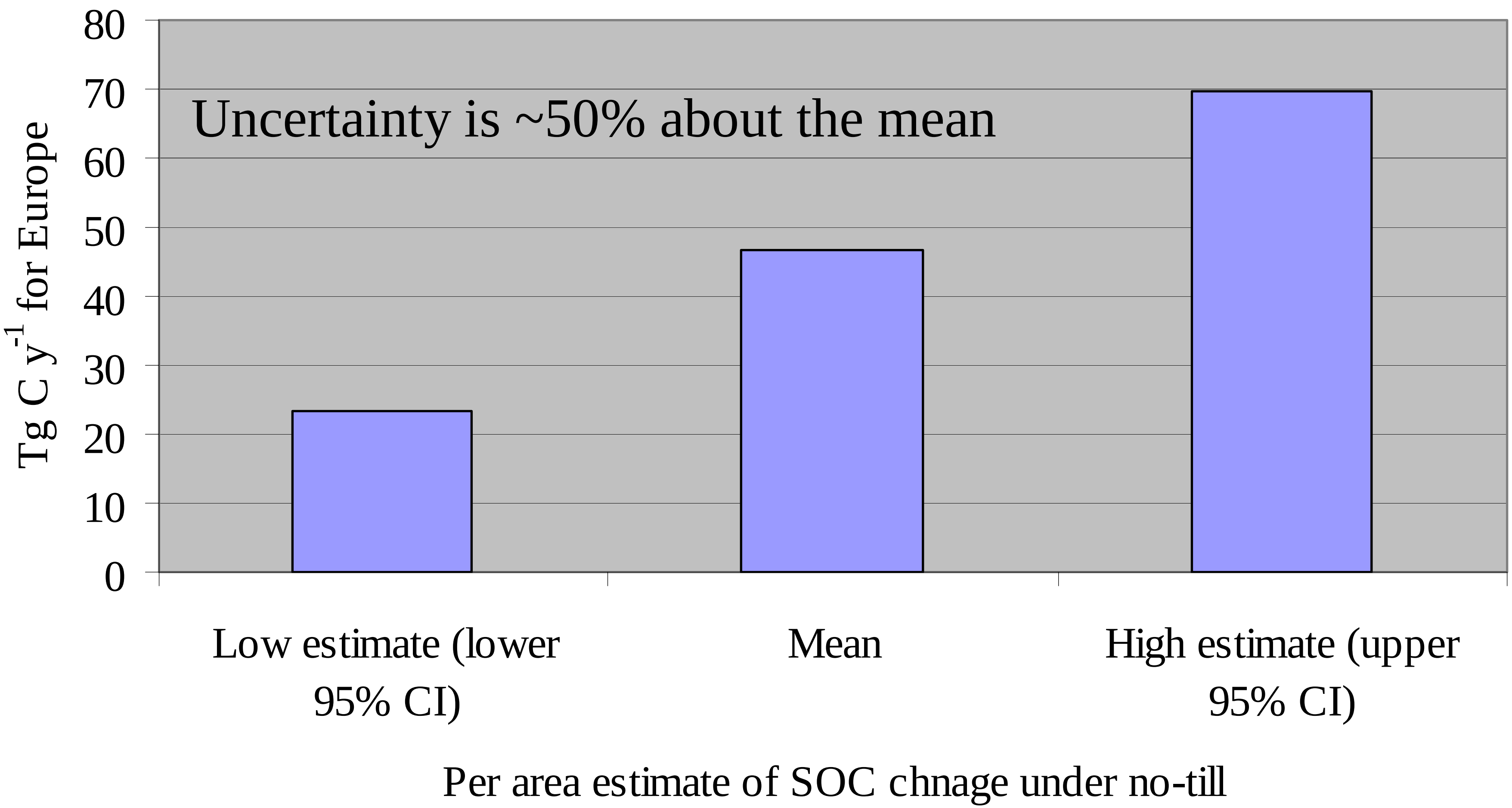


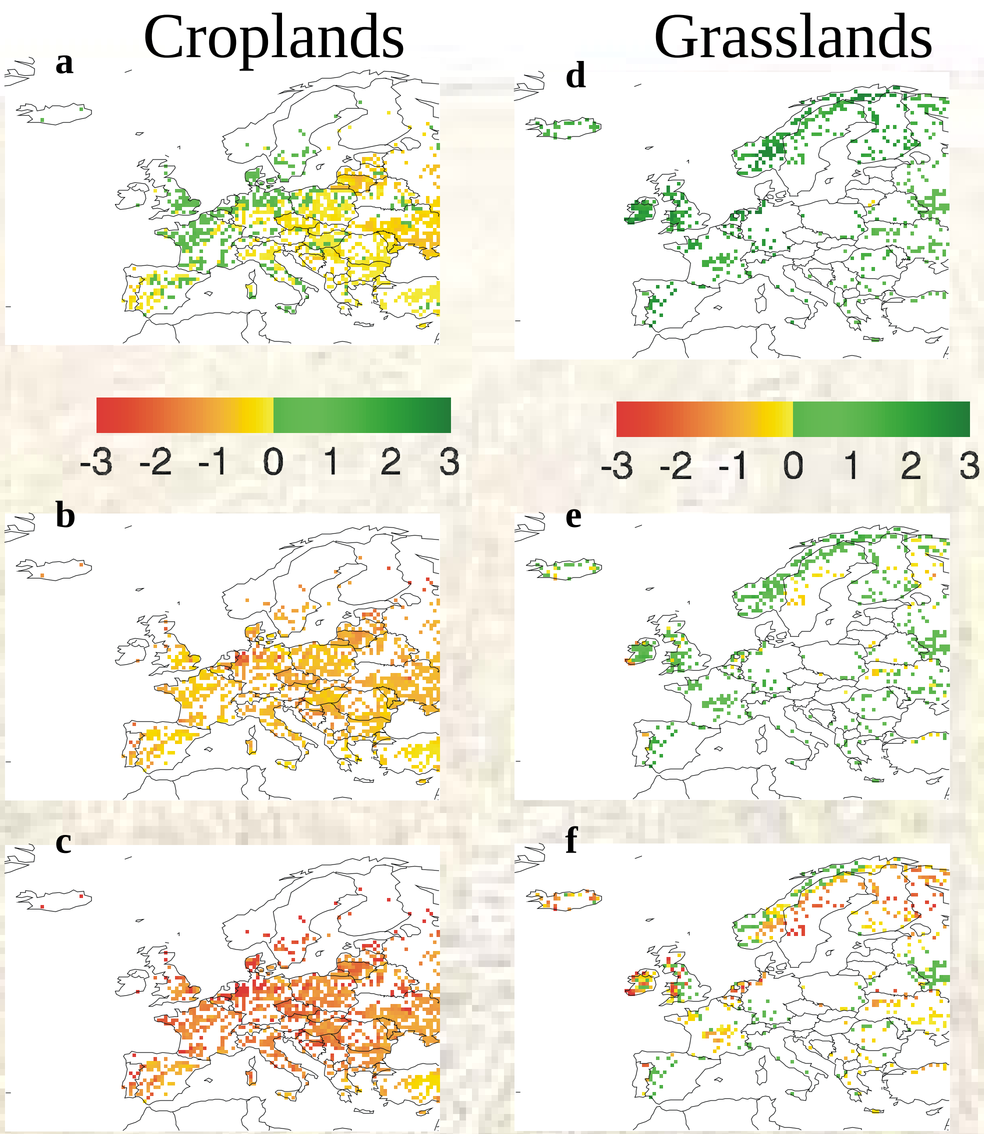

Smith *et al.*, 2000 *GCB*

# Uncertainty ranges




From data in Smith *et al*., 1998 *GCB*

## Carbon fluxes in SOC in Europe (t C ha$^{-1}$ y$^{-1}$) in the 1st commitment period (business as usual scenario)



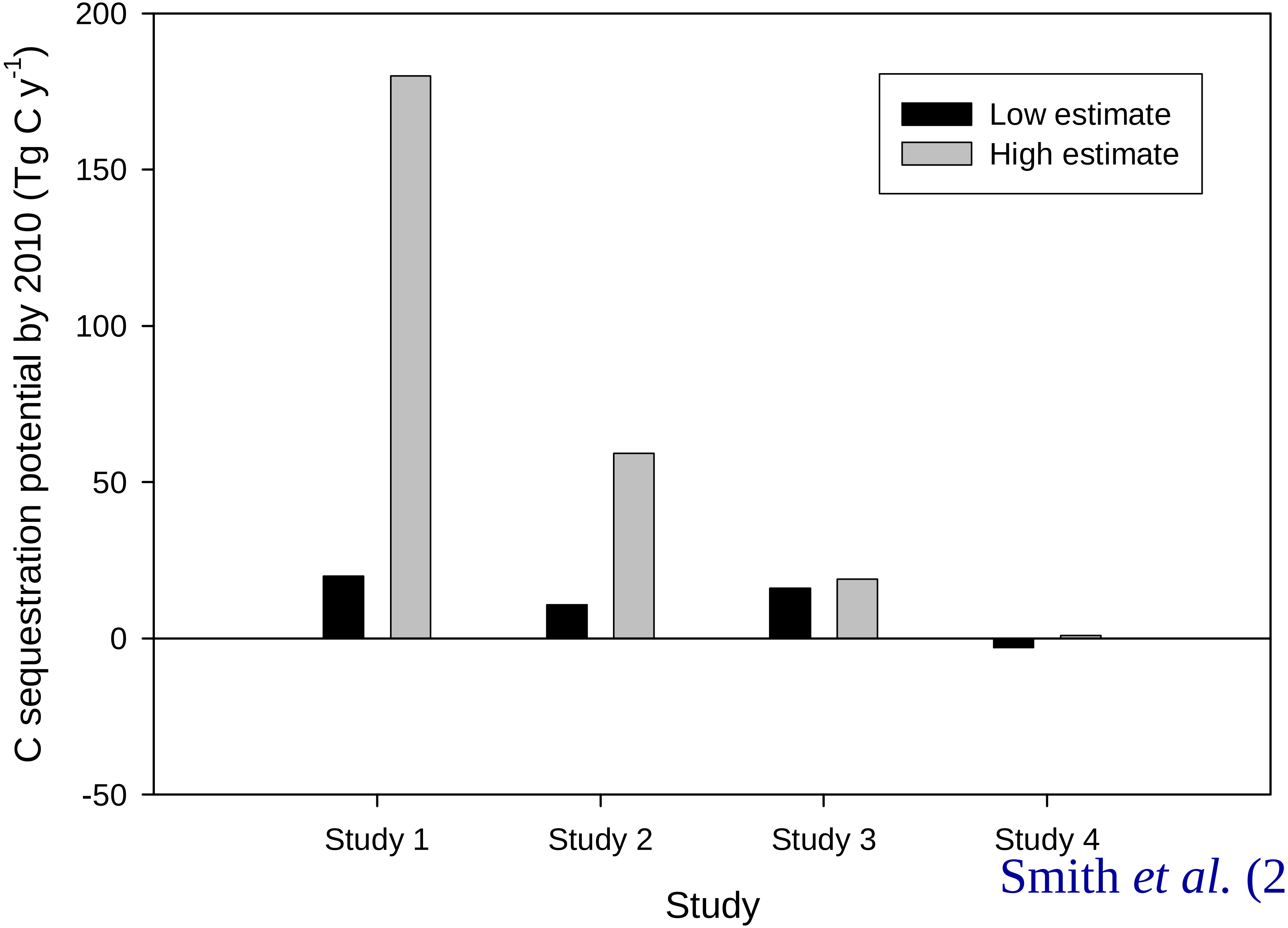

**Using mean soil organic carbon content minus S.D.**

**Using mean soil organic carbon content**

**Using mean soil organic carbon content plus S.D.**

Mean figure for the European Union (EU15) estimated to be 78 (SD: 37) Mt C y-1 (Vleeshouwers & Verhagen, 2002)

# Uncertainty ranges of C mitigation potential




Smith *et al.* (2004)

# Uncertainty ranges of C mitigation potential

Maximum value

Minimum value

GHG mitigation potential

**Biological potential**

Biologically / physically constrained potential (e.g. land suitability)

Economically constrained potential

Socially / politically constrained potential - **estimated realistically achievable potential (~10% of biological potential)**

Smith (2004)

# Carbon benefits and their uncertainty ranges

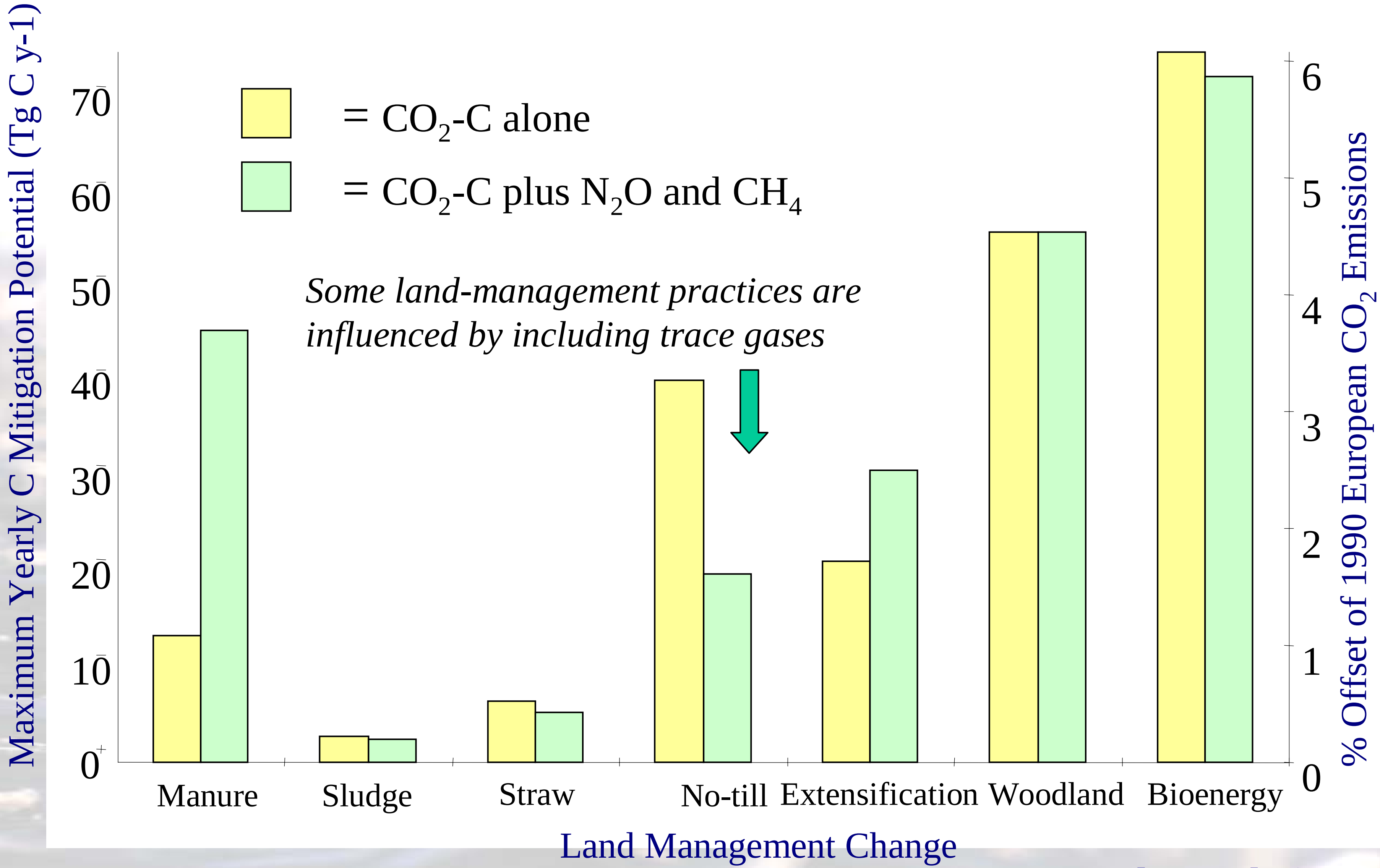
| Practice | Soil carbon sequestration potential (t C $ha^{-1}$ $y^{-1}$) | Estimated uncertainty | Total soil carbon sequestration potential for EU15 (Mt C $y^{-1}$)† | Realistic soil carbon sequestration potential for EU15 (Mt C $y^{-1}$) by 2012 |
|---|---|---|---|---|
| Zero-tillage | 0.38 (0.29)* | >50% | 24.4 | 2.4 |
| Reduced tillage | <0.38 | >>50% | <24.4 | <2.4 |
| Set-aside | <0.38 | >>50% | 2.4 (maximum) | 0 |
| Permanent crops | 0.62 | >>50% | 0? | 0? |
| Deep-rooting crops | 0.62 | >>50% | 0? | 0? |
| Animal manure | 0.38 (1.47)* | >>50% | 23.7 | ? |
| Cereal straw | 0.69 (0.21)* | >>50% | 5.5 | ? |
| Sewage sludge | 0.26 | >>50% | 2.1 | ? |
| Composting | 0.38 | >>50% | 3 | 3? |
| Improved rotations | >0 | Very high | 0? | 0? |
| Fertilization | 0 | Very high | 0 | 0 |
| Irrigation | 0 | Very high | 0 | 0 |
| Bioenergy crops | 0.62 | >>50% | 4.5 | 0.9 |
| Extensification | 0.54 | >>50% | 11 | ? |
| Organic farming | 0-0.54 | >>50% | 3.9 | 3.9 |
| Convert cropland to grassland | 1.2-1.69 (1.92)* | >>50% | 8.7-12.3 | 0 |
| Convert cropland to woodland | 0.62 | >>50% | 4.5 | 4.5 (maximum) |

† = Carbon sequestration potentials limited only by availability of land, biological resources and land-suitability. All estimates based on extrapolation from Smith et al. (2000) except those marked *, where the figure in brackets is derived from Vleeshouwers & Verhagen (2002). For full list of assumptions, limitations and sources, see Freibauer et al. (2003).

From Smith (2004) (after Freibauer *et al.*, 2004)

Risk of potential need to report carbon liabilities

# C mitigation potential with and without trace gases




Smith *et al.* (2001)

# Short-term vs. long-term mitigation

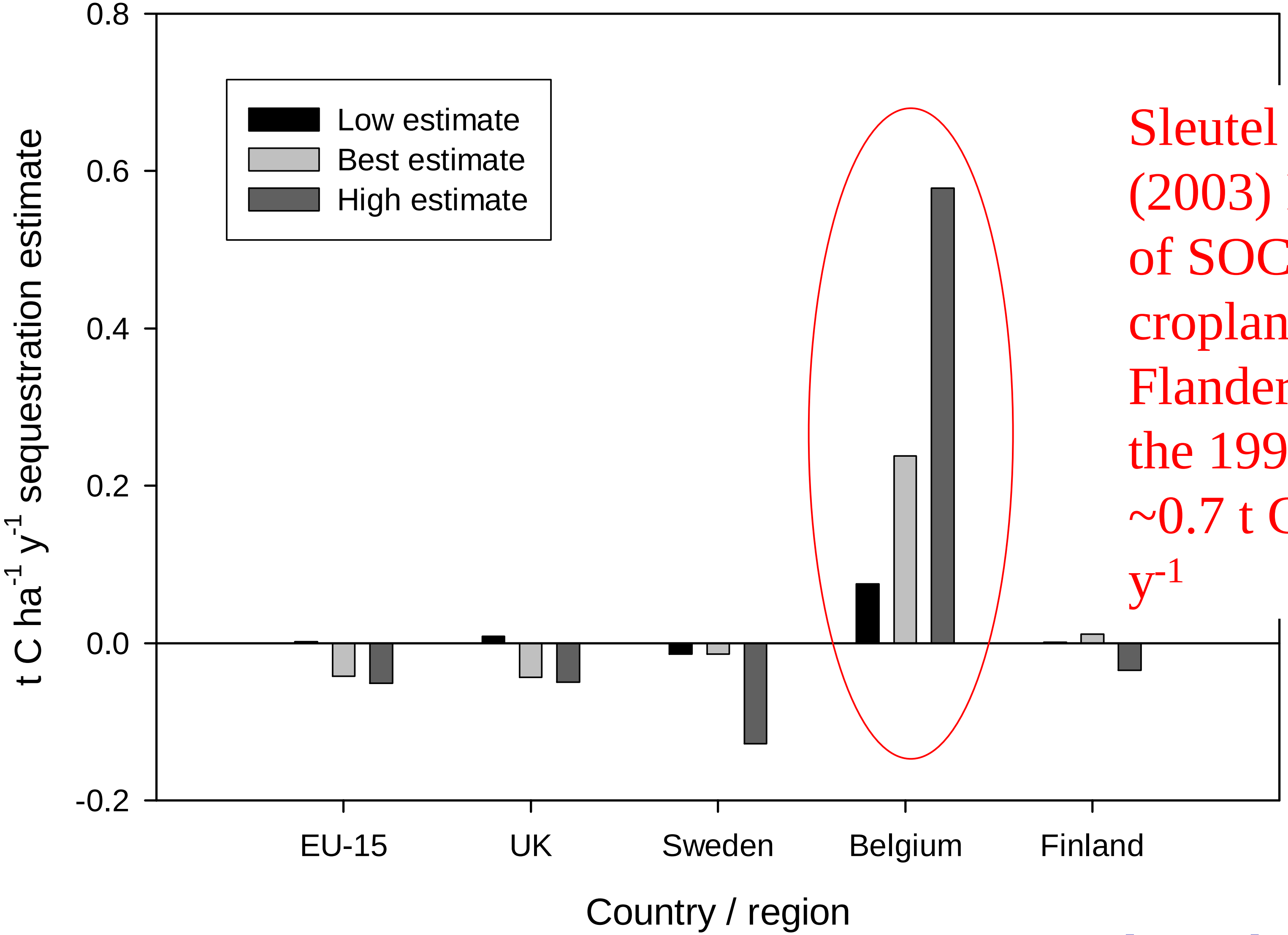
**Table 1** Annual differences in soil-derived greenhouse gas fluxes and global warming potential (GWP) between no-till and conventional till systems.

| | No-till minus Conventional till | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year 5 | | | | Year 10 | | | | Year 20 | | | |
| | $kg\ ha^{-1}\ yr^{-1}$ | | GWP[1] | | $kg\ ha^{-1}\ yr^{-1}$ | | GWP | | $kg\ ha^{-1}\ yr^{-1}$ | | GWP | |
| | Estimate | s.e.[2] | Estimate | s.e. | Estimate | s.e. | Estimate | s.e. | Estimate | s.e. | Estimate | s.e. |
| Soil Organic C | | | | | | | | | | | | |
| humid | 194 | 4 | -710 | 16 | 213 | 2 | -780 | 7 | 222 | 1 | -815 | 4 |
| dry | -306 | 6 | 1123 | 21 | -37 | 3 | 137 | 10 | 97 | 2 | -356 | 6 |
| $N_20$ | | | | | | | | | | | | |
| humid | 3.8 | 0.8 | 1114 | 237 | 1.1 | 0.8 | 330 | 222 | -4.2 | 1.9 | -1238 | 565 |
| dry | 1.3 | 1.5 | 398 | 431 | 0.9 | 1.2 | 268 | 367 | 0.0 | 1.6 | 8 | 466 |
| $CH_4$ | | | | | | | | | | | | |
| humid | -0.6 | 0.1 | -13 | 3.1 | -0.6 | 0.1 | -13 | 3.1 | -0.6 | 0.1 | -13 | 3.1 |
| dry | -0.6 | 0.1 | -13 | 3.1 | -0.6 | 0.1 | -13 | 3.1 | -0.6 | 0.1 | -13 | 3.1 |
| Soil-derived GWP | | | | | | | | | | | | |
| humid | | | 391 | 238 | | | -463 | 222 | | | -2066 | 565 |
| dry | | | 1508 | 432 | | | 392 | 367 | | | -361 | 466 |

s.e. = standard error and GWP units are $CO_2$ equivalents ($kg\ ha^{-1}\ yr^{-1}$). Values in the columns headed by year 5, 10 and 20 are estimates for 5, 10 and 20 years after conversion from conventional till to no-till. Estimates are based on output of linear mixed-effect modelling of all currently available data.

Six *et al.* (2004) *GCB*

# Estimates might not always be realised

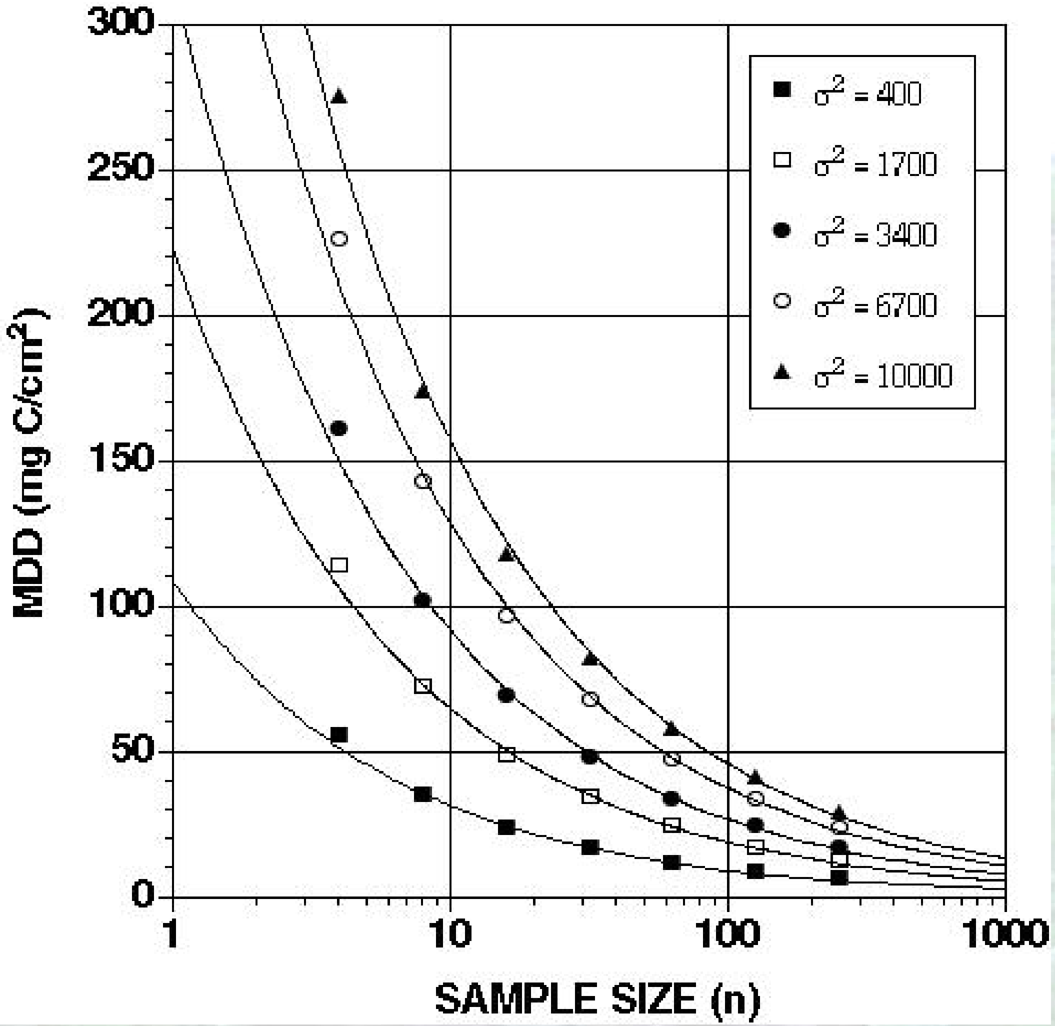



Sleutel *et al.* (2003) Loss of SOC from cropland in Flanders over the 1990s of ~0.7 t C $ha^{-1}$ $y^{-1}$

Smith *et al.* (2004)


# Monitoring/data collection and reporting costs


# Minimum detectable difference and sample size




Garten & Wullschleger (1999)

# Minimum detectable difference

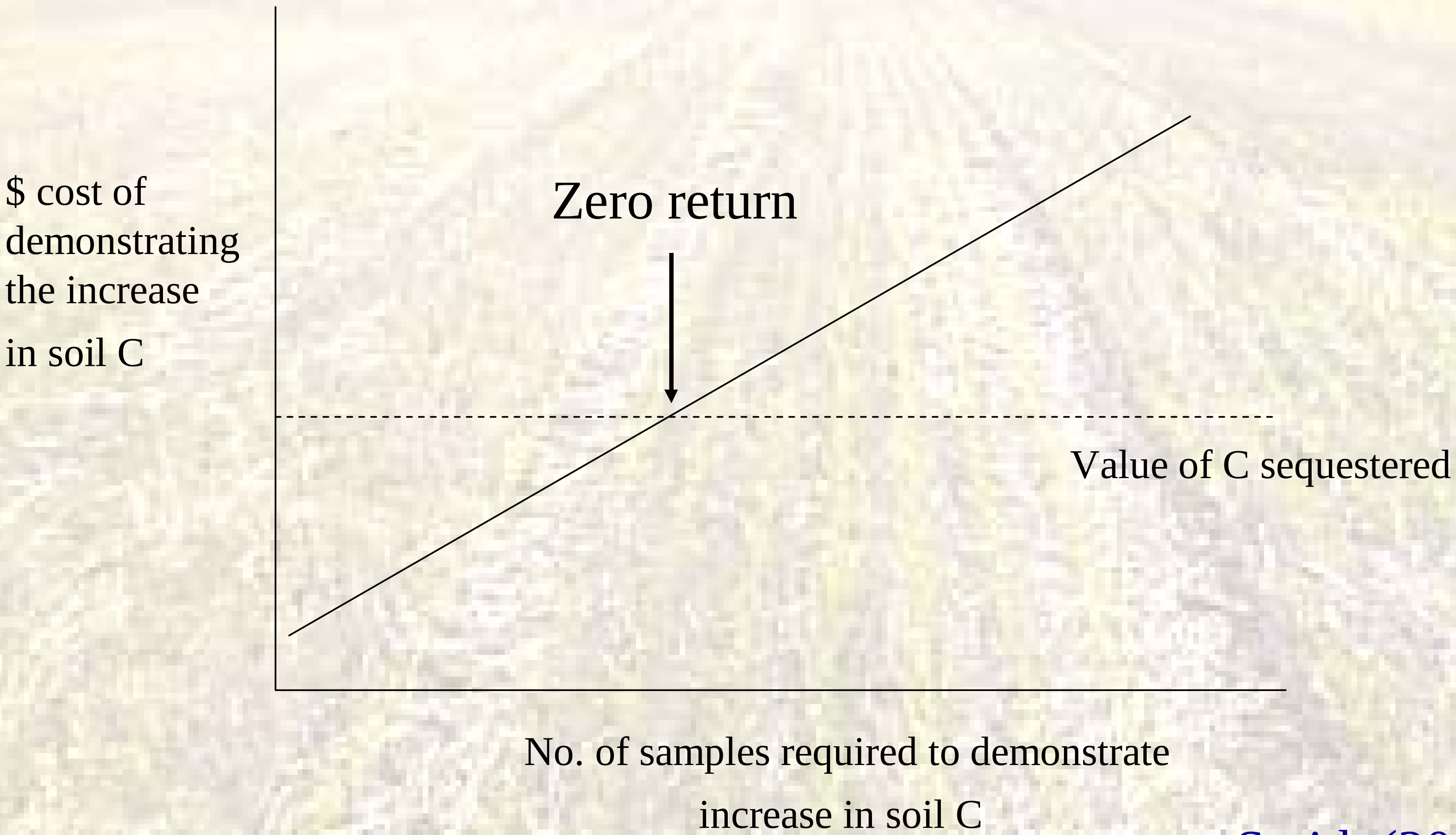
- For change of 5 t C/ha over 5 years (or 10-15% of background C), 16 samples are needed to obtain 90% confidence
- The smallest changes that can be detected with the same level of confidence (90%) are 1 t C/ha over 5 years (or 2-3% of background C), but only with very large (>100) samples

Garten & Wullschleger (1999)

# Costs

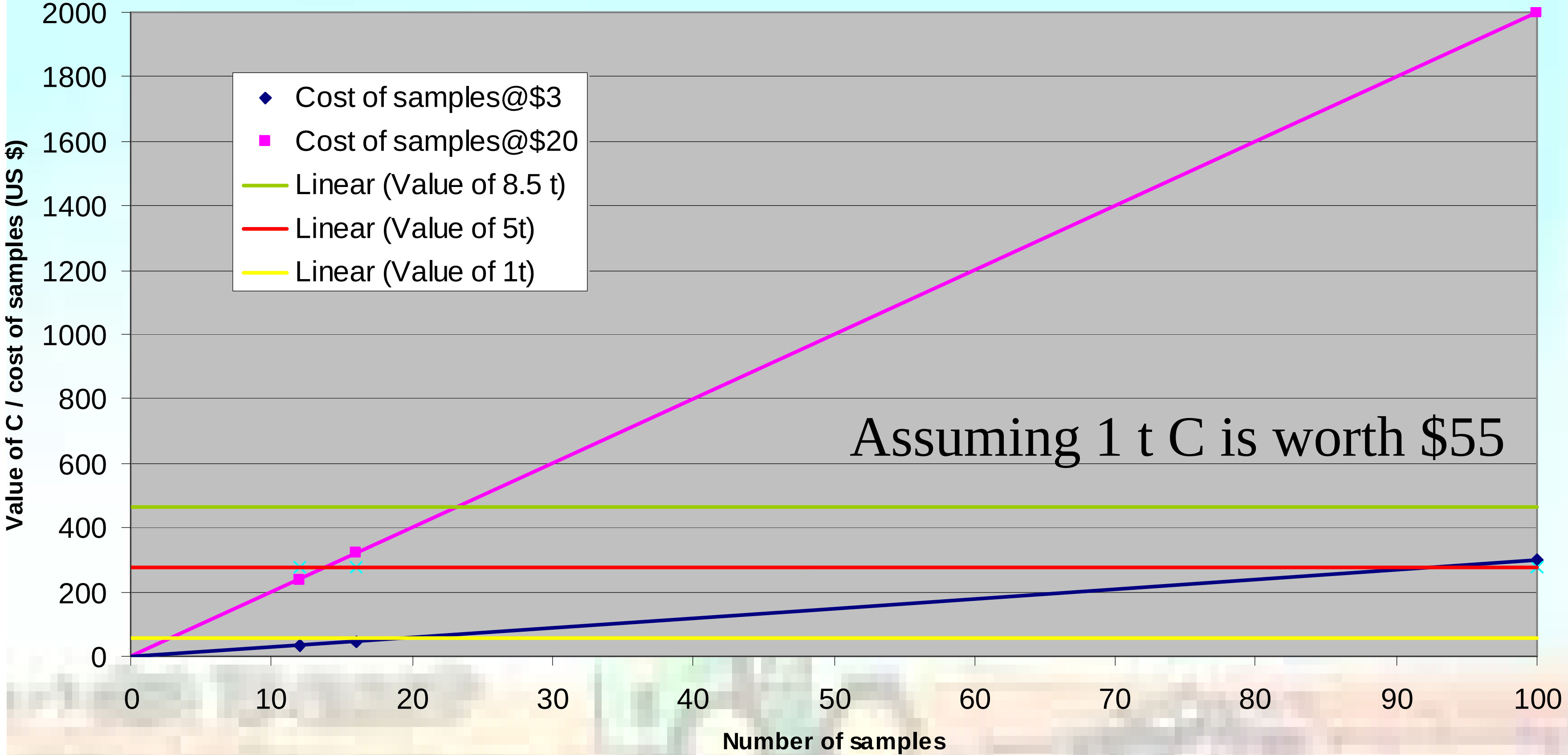
- Range from US$ 3 where labour costs are very low to about US$ 20
- Consistent with estimates of Izaurralde *et al*. (1999).

# Demonstrating an increase in soil C




Smith (2004)

# Costs of demonstrating an increase in soil C




- 1 t C over 5 years needs 100 samples costing $300-2000; C value = $55: never feasible
- >5 t C over 5 years needs 16 samples, costs $48-320, C value = >$275: if sample costs are low, could be feasible
- >8.5 t C over 5 years needs 12 samples costing $36-240, C value = $462.5: always feasible

Falloon & Smith (in prep.)


# Trade-offs and synergies


# Trade-offs and synergies

*Table 4.* Summary of potential side effects of carbon mitigation options in terms of other aspects of agroecosystem ecology.

| Land-management practice | Other potential negative impacts on agroecosystem ecology | Other potential positive impacts on agroecosystem ecology |
|---|---|---|
| No-till farming | Possibly poorer rates of seed germination | Greater soil biodiversity |
| Animal manure | Acidification | Better soil structure and fertility |
| Sewage sludge | Possible hazard from heavy metals and organic pollutants | – |
| Cereal straw | Crop pathogen accumulation, toxin production, immobilisation of nutrients, unpredictable N release | – |
| Agricultural de-intensification | Surplus arable land not available for woodland or bioenergy production | Improved soils structure and fertility. Improved livestock welfare. Greater biodiversity? |
| Natural woodland regeneraion | – | Greater biodiversity. Increased aesthetic and amenity value |
| Bioenergy crop production | – | Greater biodiversity. |

Expanded upon in ECCP WG6 and IPCC

Smith *et al.* (2001)

# Trade offs

- Greenhouse gases (possibly negative GWP) as already discussed
- Potential cost implications of some management practices
- Other environmental impacts (GMOs, pollutants, water quality, acidification, poorer productivity etc.)

Smith *et al*. (2001), ECCP (2003)

# Synergies

- Improved soil fertility
- Improved productivity / food security (Lal, 2004)
- Sustainable development opportunities
- Better soil structure and WHC
- Biodiversity improvements
- Improved livestock welfare

Smith *et al*. (2001), ECCP (2003)


Range of incentives required to achieve the desired objectives


# C mitigation potential

Maximum value | Minimum value

GHG mitigation potential

**Biological potential**

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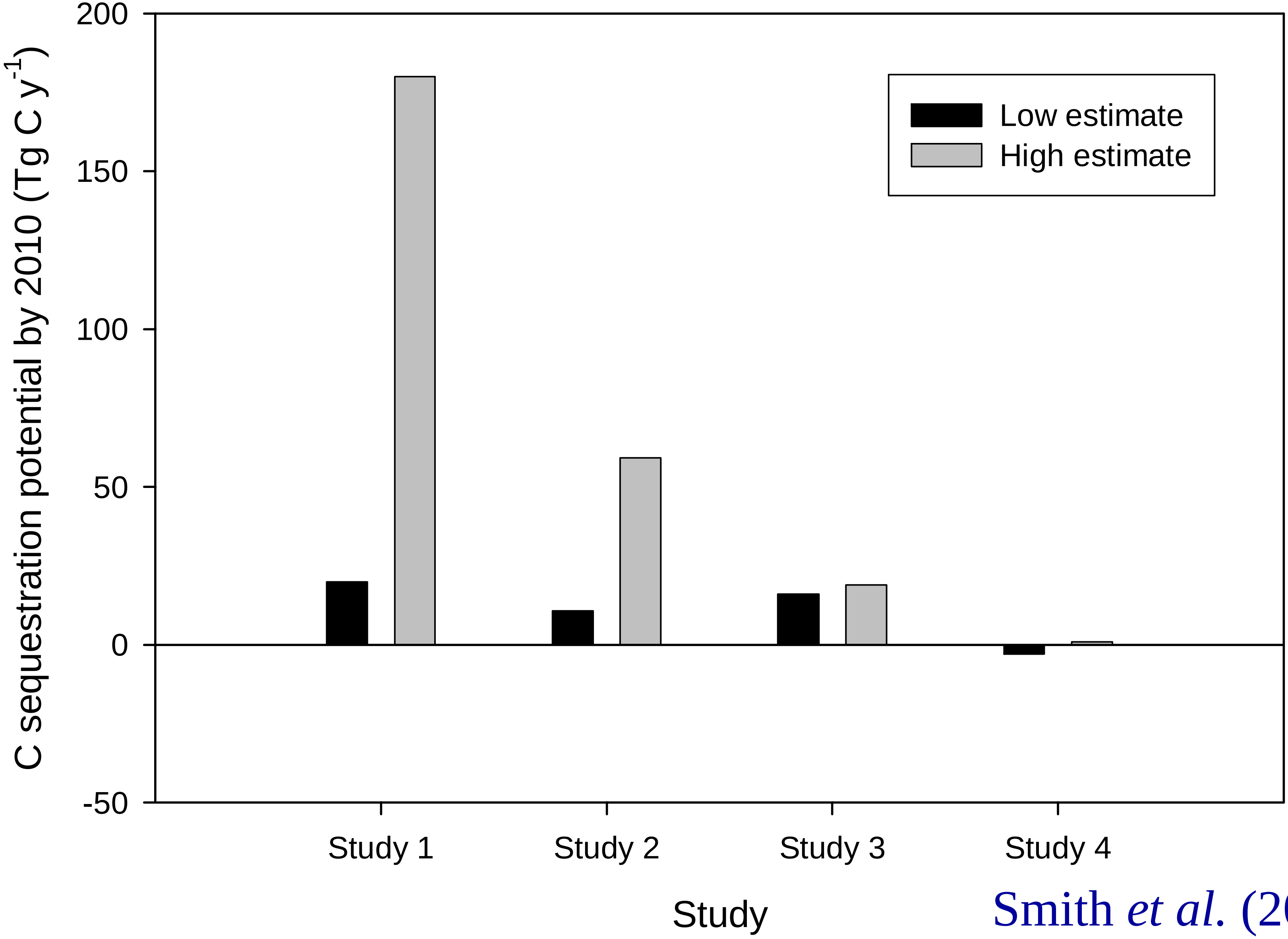
Smith (2004)

# Will C mitigation potential be realised?




Smith *et al.* (2004)

# Opportunities for policy to encourage C sequestration under CM, GM & RV

- CAP reform – move from production-based subsidies to the single farm payment
- National initiatives, e.g. policies to encourage green manuring and composting in Belgium (Sleutel *et al.*, 2005)
- Much more radical policy incentives necessary for even a fraction of the biological C sequestration potential to be realised

# Conclusions

- Large biological potential for GHG mitigation by CM, GM & RV
- Large uncertainties associated with the estimates
- Potential problems with other GHGs – risk associated with negative GWP balance
- Potential additional benefits of some practices
- Costs of monitoring high – only viable for extremely high C gains
- Incentives for CM, GM & RV weak – need to be greatly strengthened if potential is to be realised
- Electing CM, GM or RV would require very careful consideration, given that losses as well as gains would need to be reported