Soil carbon accounting: options to measure, monitor, and address project-level issues

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Potential trade-offs between environmental integrity and economic incentives

Issues that may arise in efforts to maintain environmental integrity

- What is accuracy of soil C measurements or estimates?
- Are changes in land use and climate considered?
- Are other environmental effects (e.g., changes in GHG emissions) considered?
- Additionality, permanence, saturation, & leakage
- Consider simplicity & flexibility

Issues that may arise if incentives for C sequestration are provided

- What level of accuracy is desired?
- What are acceptable amounts of time and costs associated with measuring and monitoring?
- What are acceptable levels of economic risk (e.g., risk of not meeting sequestration obligation)?
- Who is eligible for incentives (targeting)?
- Consider simplicity & flexibility

Focus: soil C changes in agricultural soils

Conventional Tillage (CT)

No-Till (NT)

Photos courtesy of Donald Tyler, Univ. of TN, West TN Ag. Exp. Station

Presentation outline

I. Current options for measuring and monitoring

A. Summary of measurement options

B. Issues associated with measurement options

C. Discussion of carbon management response curves

1. Project-level issues
2. Accounting for other greenhouse gases

II. Comparison of options

III. Conclusions

Option 1: Measuring soil carbon change

- **Ex situ – soil sampling (analyzed in lab)**

- **In situ – soil sampling (analyzed in field)**
  - **Laser Induced Breakdown Spectroscopy**
    (Cremers et al. 2001, Martin et al. 2002)
  - **Surface-Enhanced Raman Scattering**
    (Stokes & Vo-Dinh 2001)
  - **Inelastic Neutron Scattering**
    (Wielopolski et al. 2000)

- **Eddy Covariance – net ecosystem exchange**

Option 2: Estimating soil carbon change

- **Remote sensing capabilities**
- **Process models**
- **Database accounting**

See also:
Post et al. 2001. Monitoring and verifying changes of organic carbon in soil. **Climatic Change 51:73-99**.

Option 3: Incentive based on practice

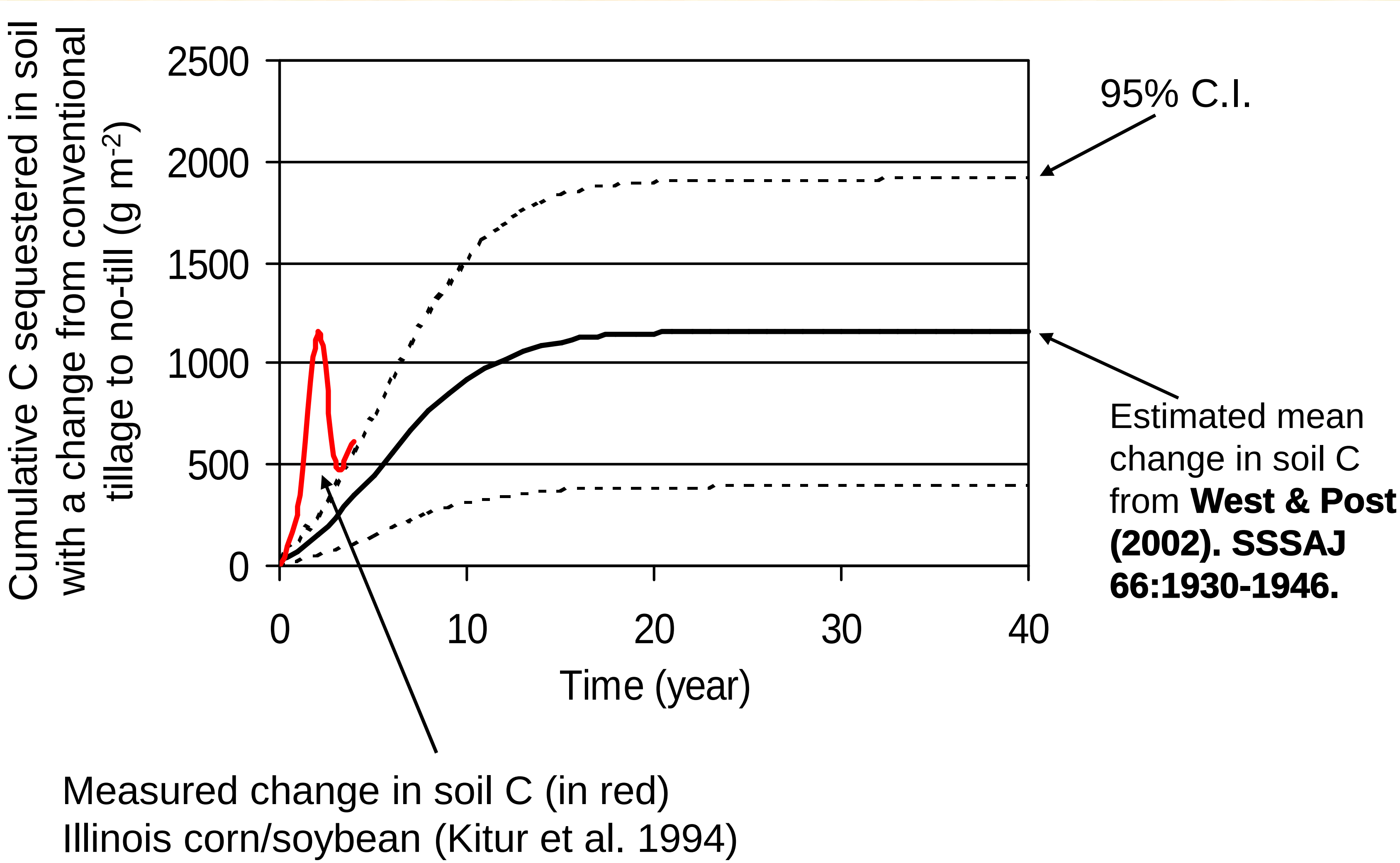
Approach similar to Conservation Reserve Program:

- Payments for cropland “set aside” for a fixed time period.
- Decreases in soil erosion are not measured.

Carbon accounting issues related to carbon measurements (Option 1)

- Is it reasonable to provide an incentive based on natural variability of soil carbon measurements?
- How do we know when soil C has reached saturation or a new equilibrium?
- Do we know that all change in soil C is due to the change in practice (is there a control plot or baseline estimate)?

Example: Comparison between measured and estimated changes in soil carbon



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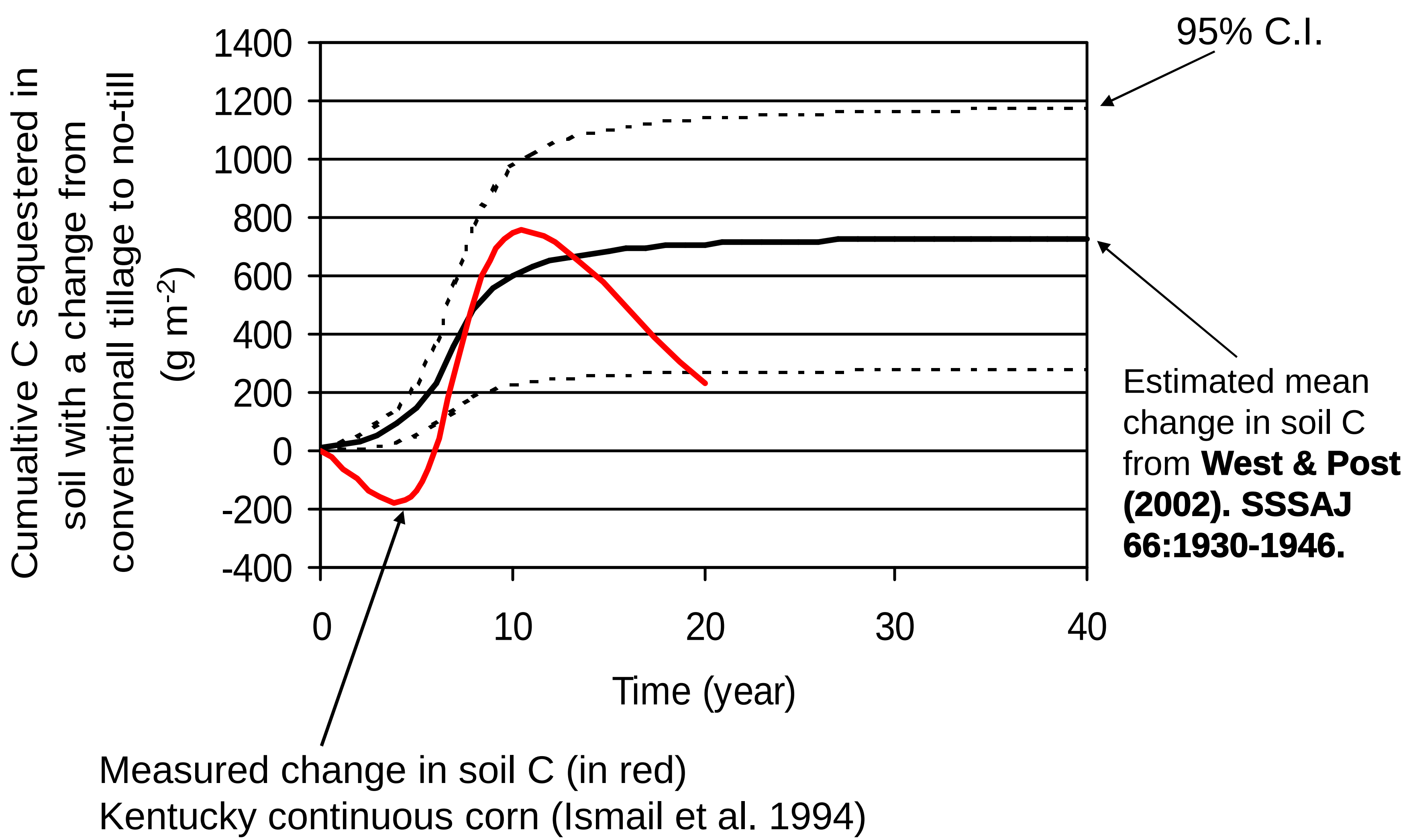

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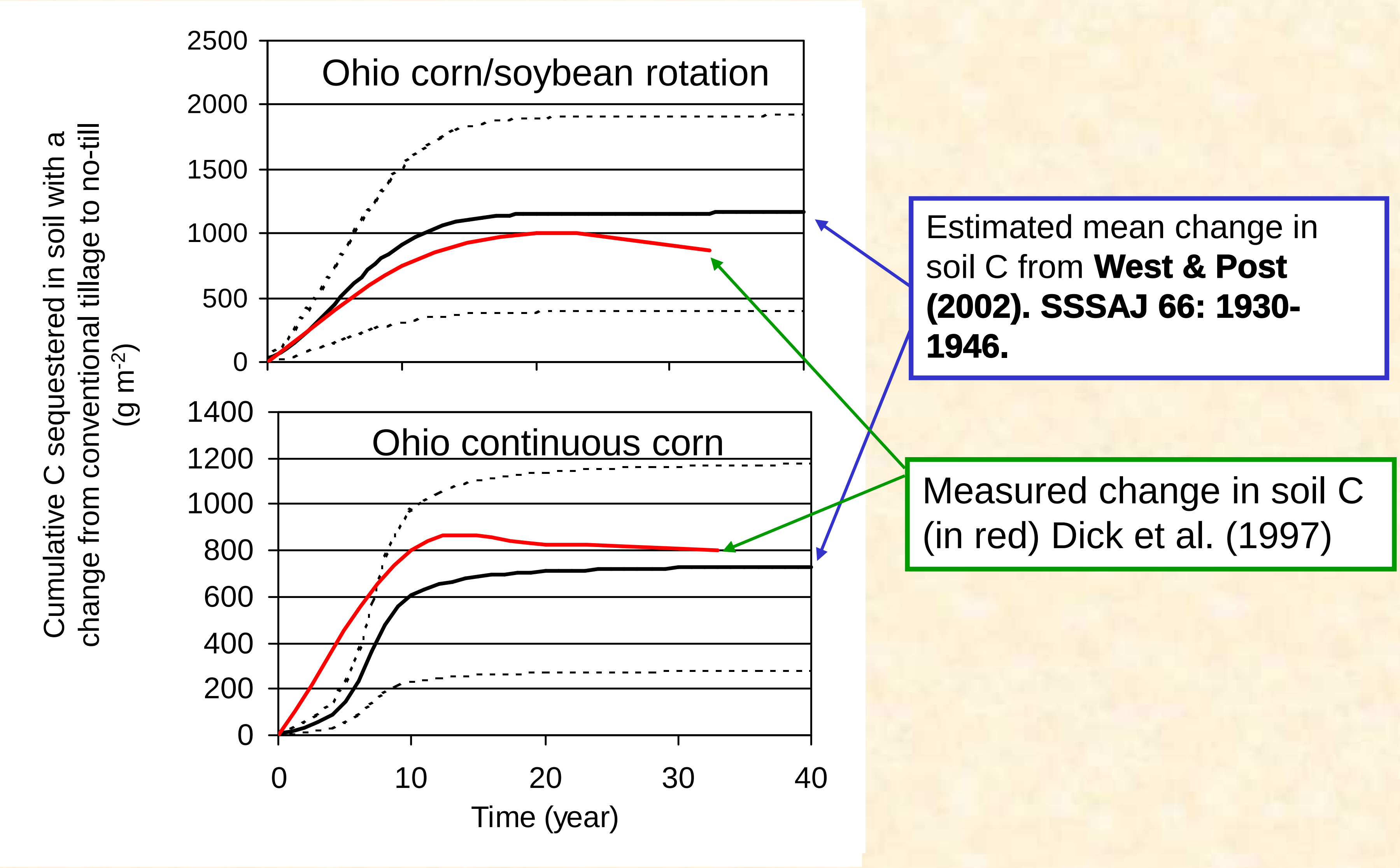
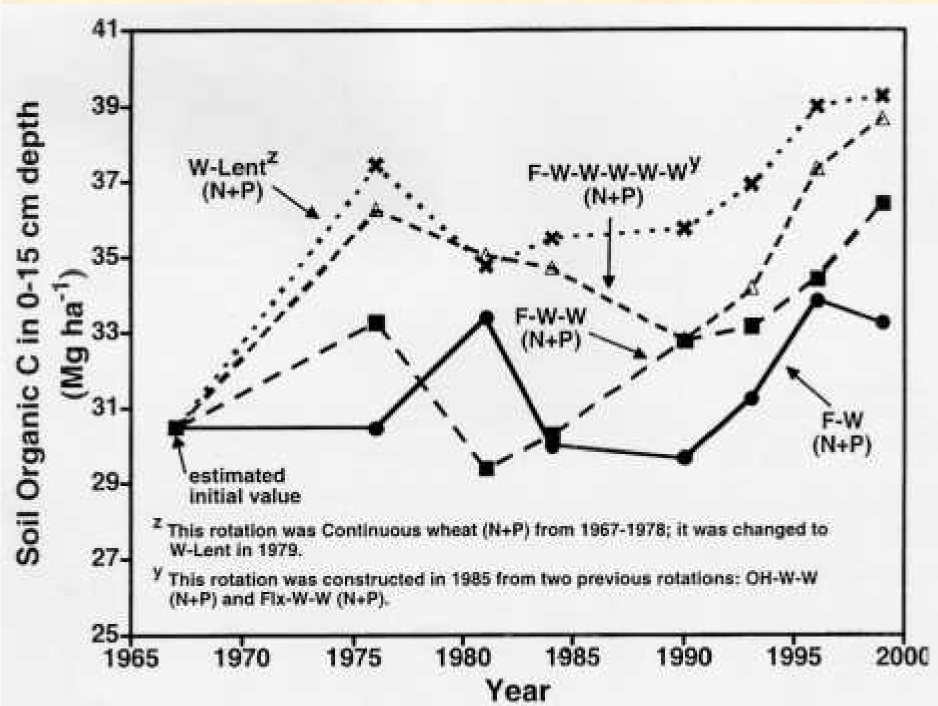
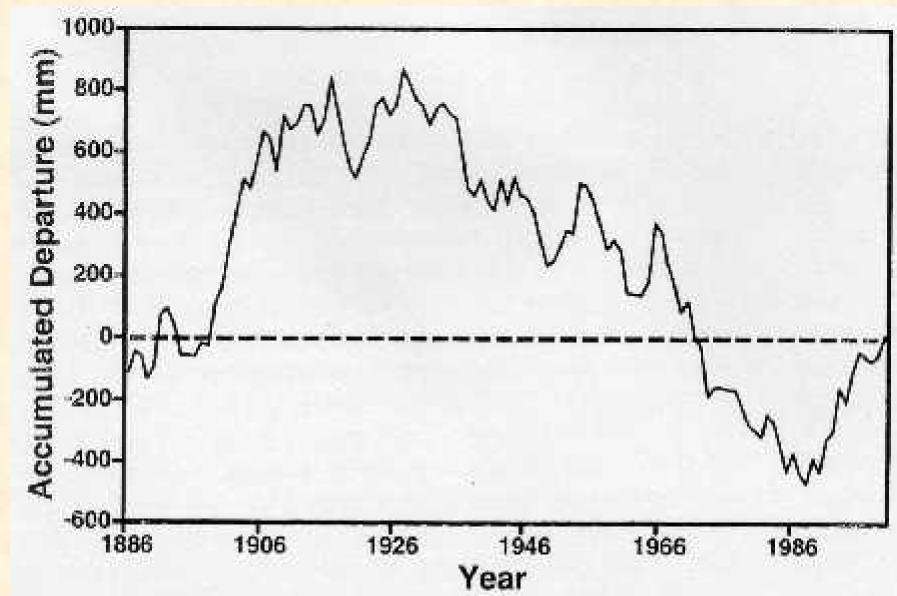


Changes in soil carbon due to climate suggest the need to consider issues of additionality and saturation





Campbell et al. 2001. **Canadian Journal of Soil Science 81:383-394.**

Introducing Option 4

Option 1: Measuring soil carbon change

Option 2: Estimating soil carbon change

Option 3: Incentive based on practice

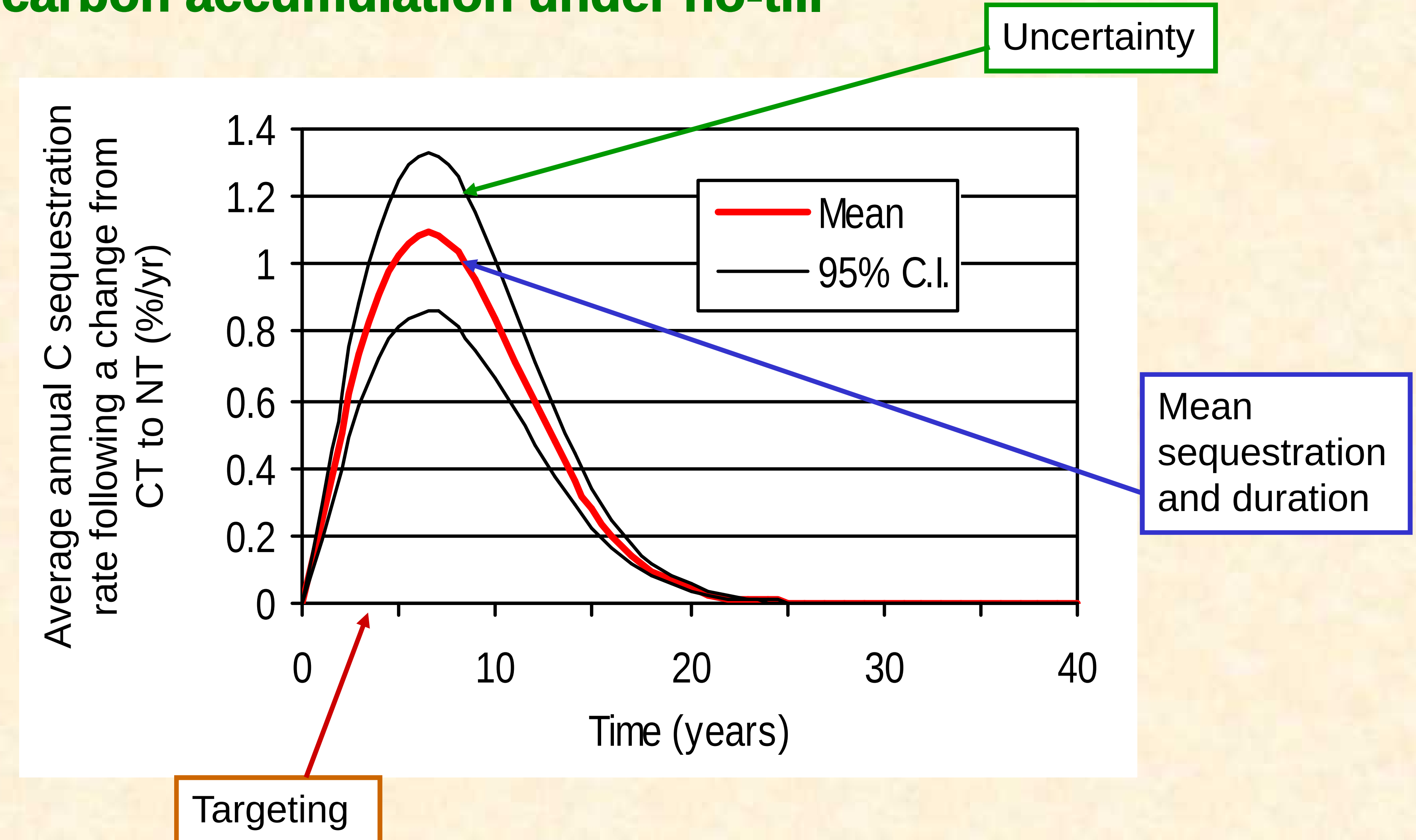
Option 4: Estimate change in C based on **practice** using average **measured** responses

Approach is a hybrid between options 1, 2 and 3:

- Development of Carbon Management Response Curves

Carbon Management Response Curves —

carbon accumulation under no-till

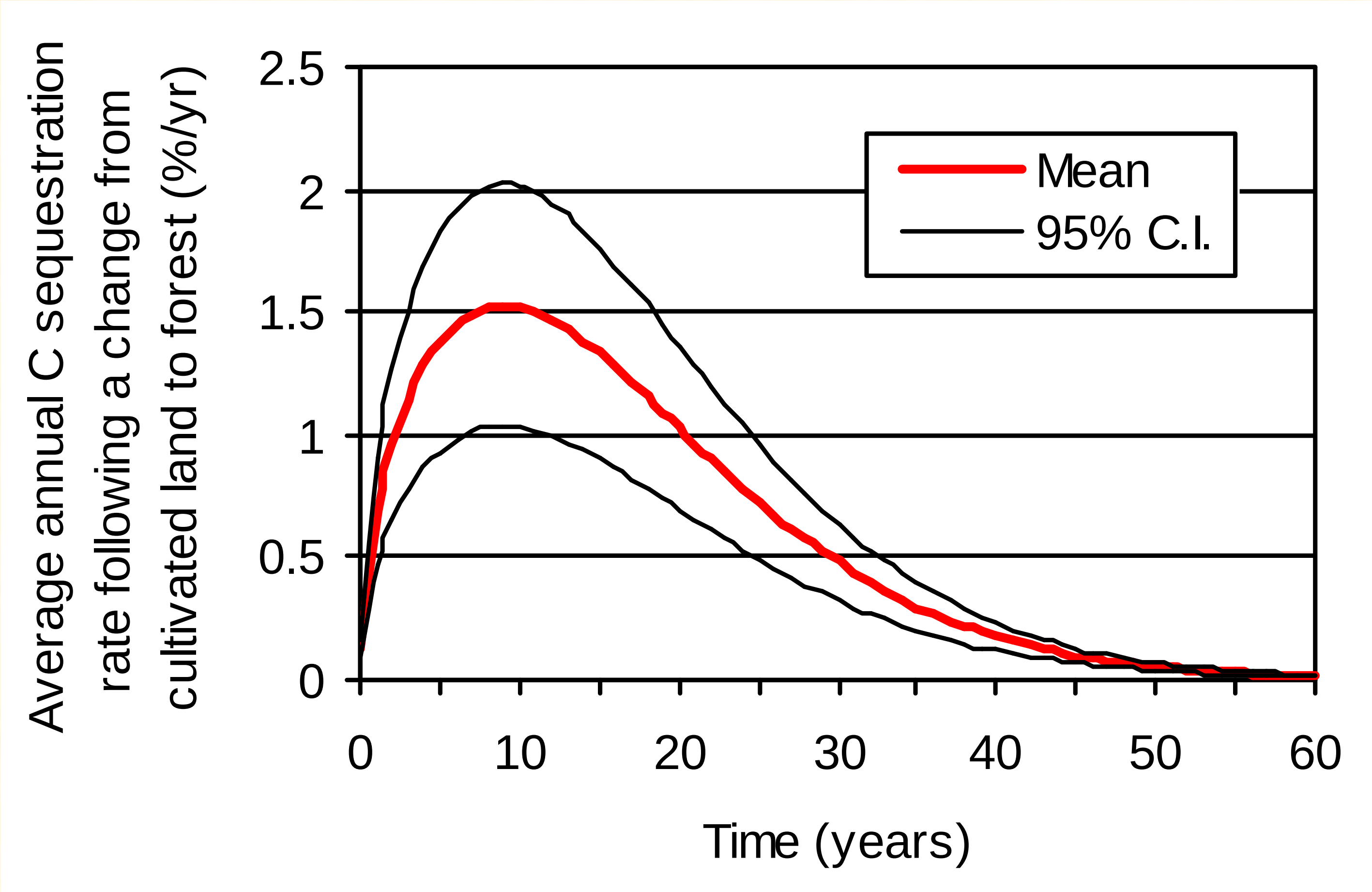


Estimate: 11 ± 2% (normalized to original land use)

Source: West & Post (2002). **Soil Sci. Society of Am. J. 66:1930-1946**

Carbon Management Response Curves —

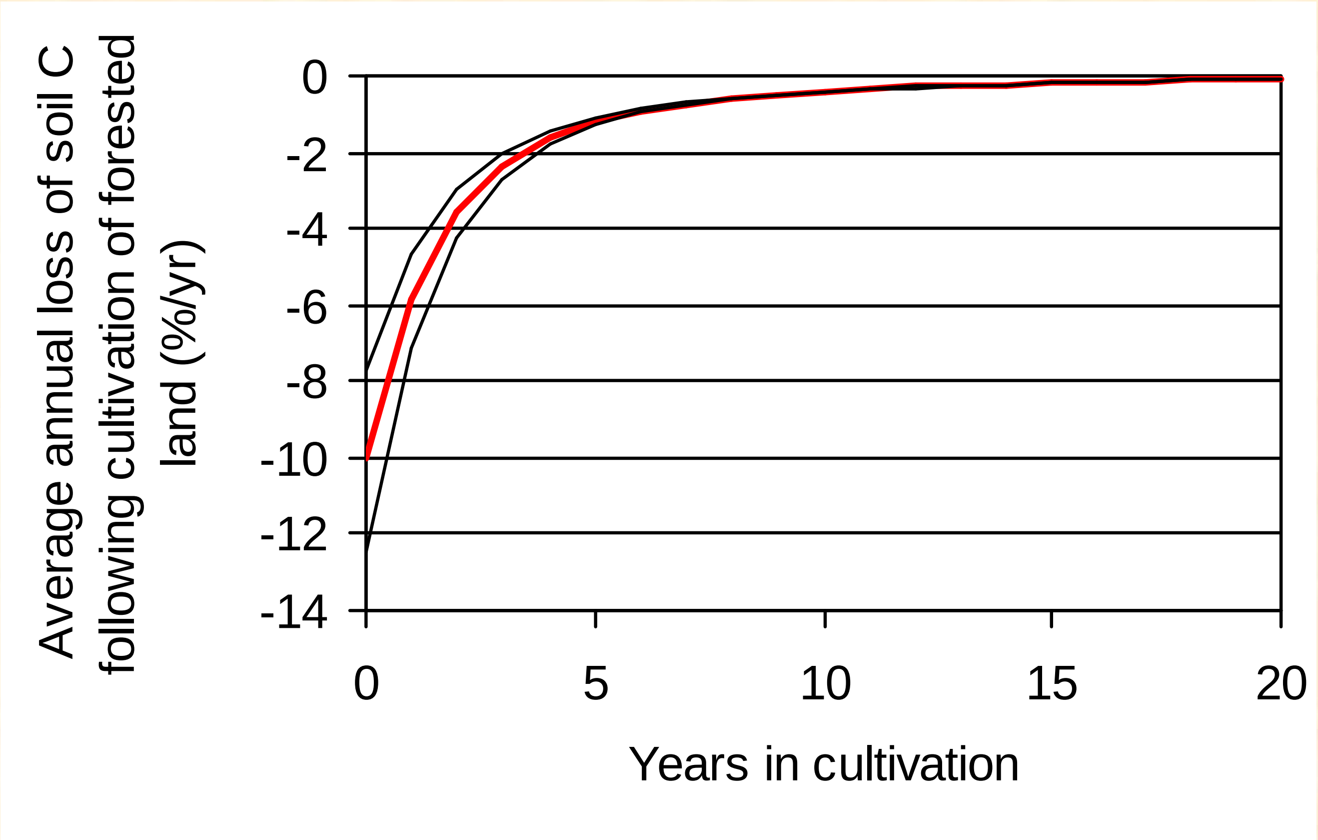
carbon accumulation following afforestation



Estimate: 37±12% (normalized to original land use)

Sources: Gao & Gifford (2002), Paul et al. (2002), Post & Kwon (2000)

Carbon Management Response Curves —
soil carbon loss following cultivation



Estimate: -30 ± 5% (normalized to original land use)

Sources: Mann 1986, Post & Mann 1990, Davidson & Ackerman 1993, Murty et al. 2002

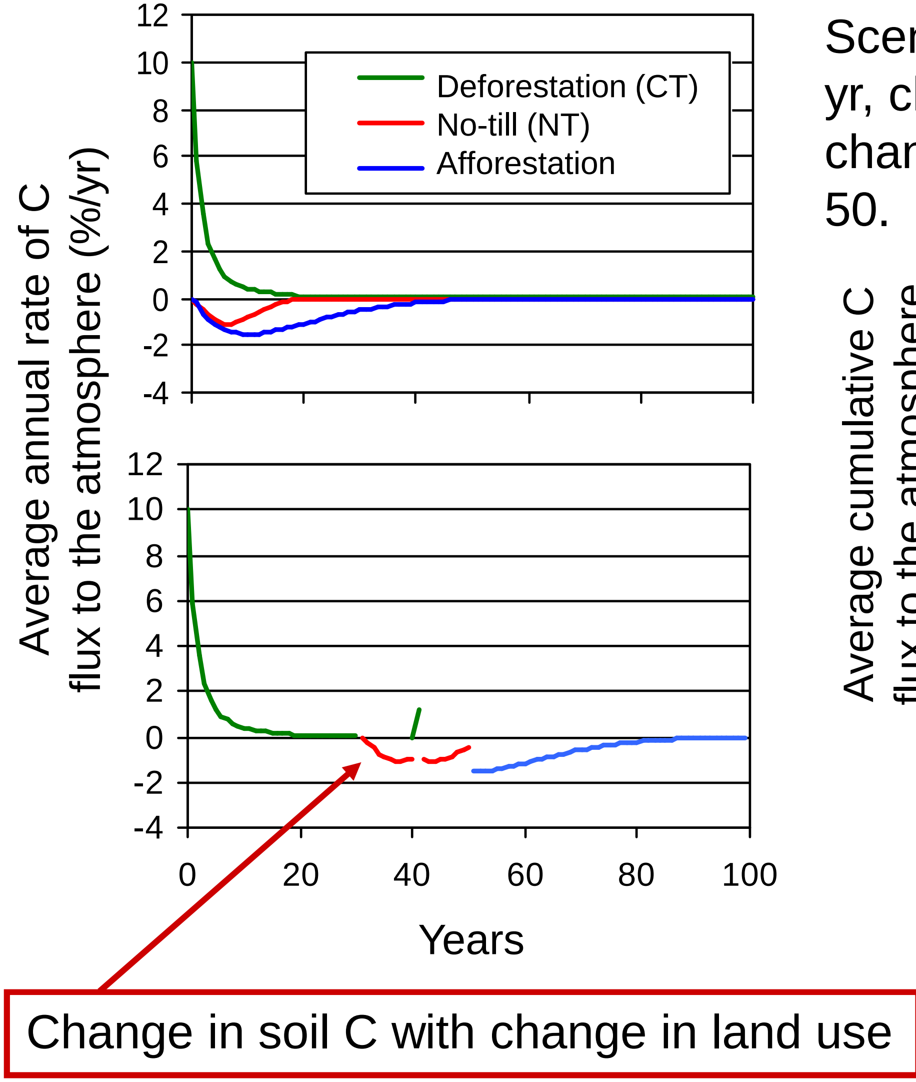
Carbon Management Response Curves —
Integrating changes in land use

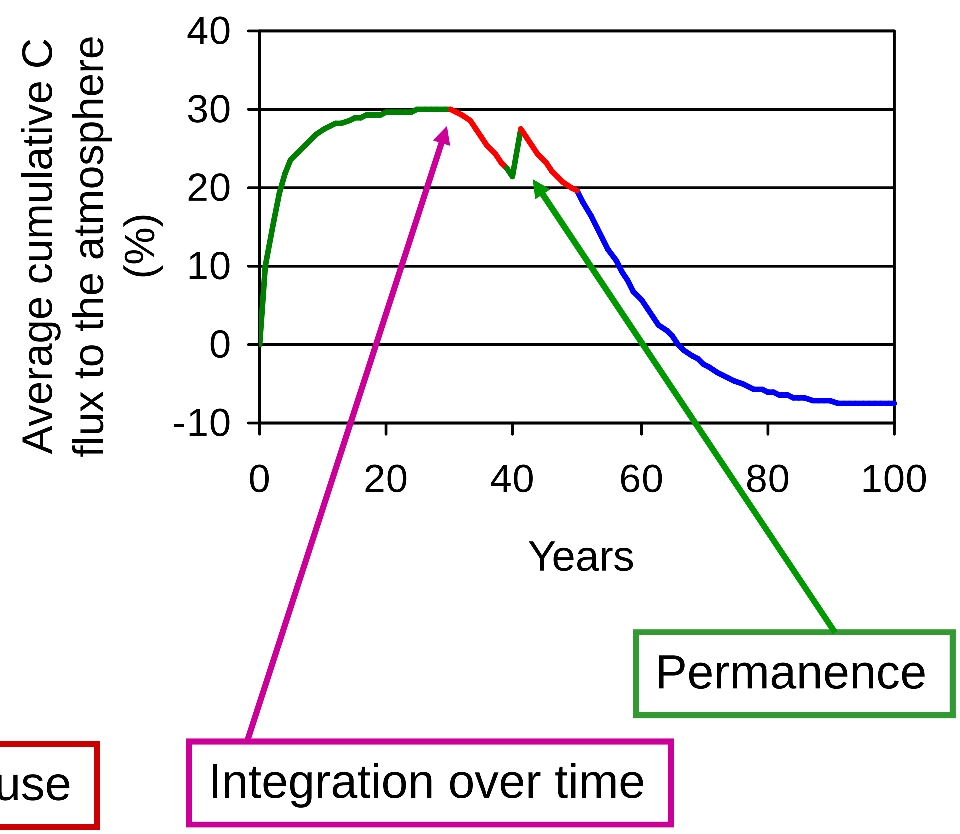
"…there are not enough data available to perform a meta analysis of the land use change from pasture or forest to no-tillage crop."

- Guo & Gifford (2002)

Estimating carbon stocks following changes in land management using CMR curves

Scenario: Deforest, cultivate with CT for 20 yr, change to NT for 10 yr, use CT for 1 year, change back to NT for 10 yr, reforest at year 50.



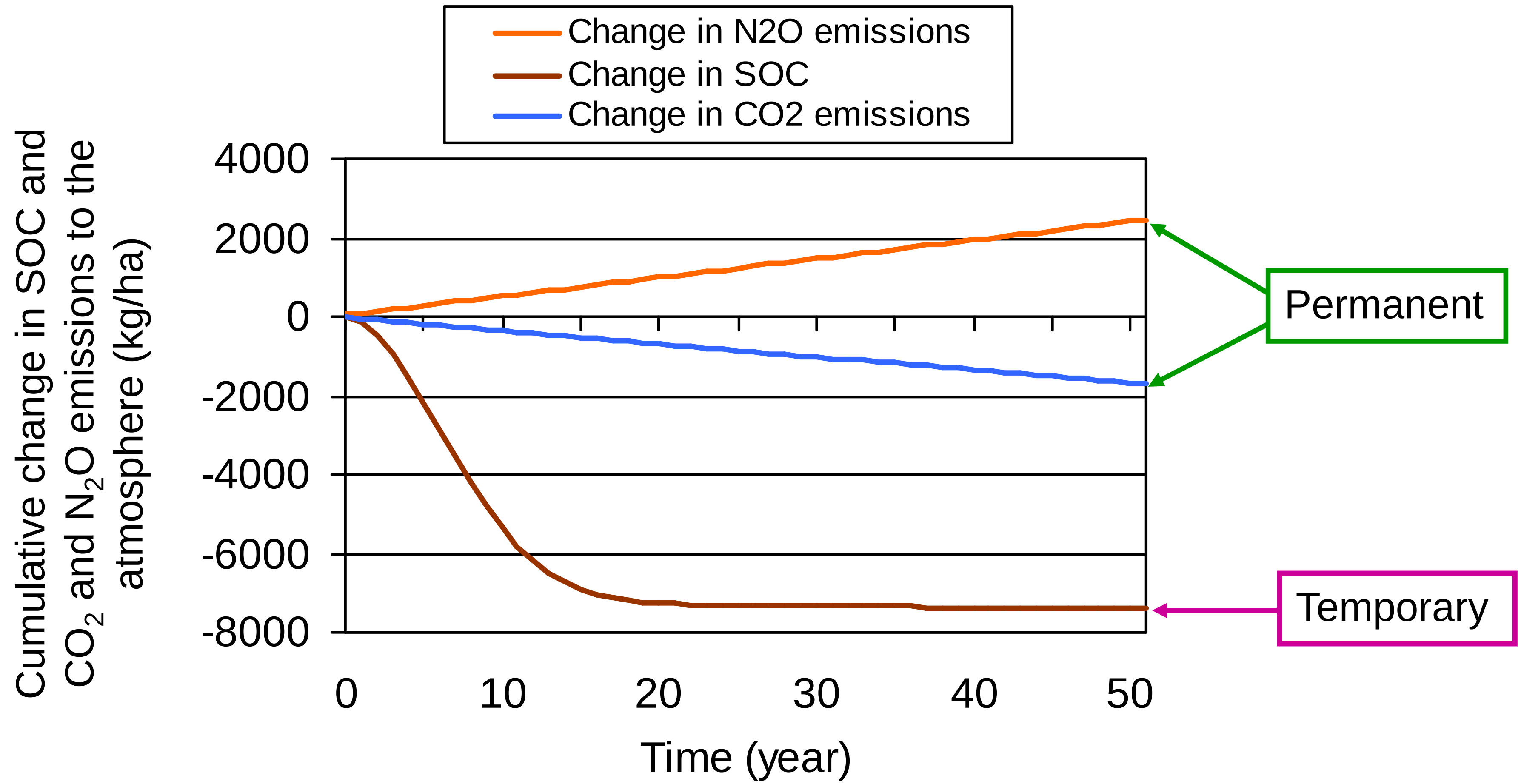


Estimating changes in GHG emissions associated with soil C sequestration using CMR curves

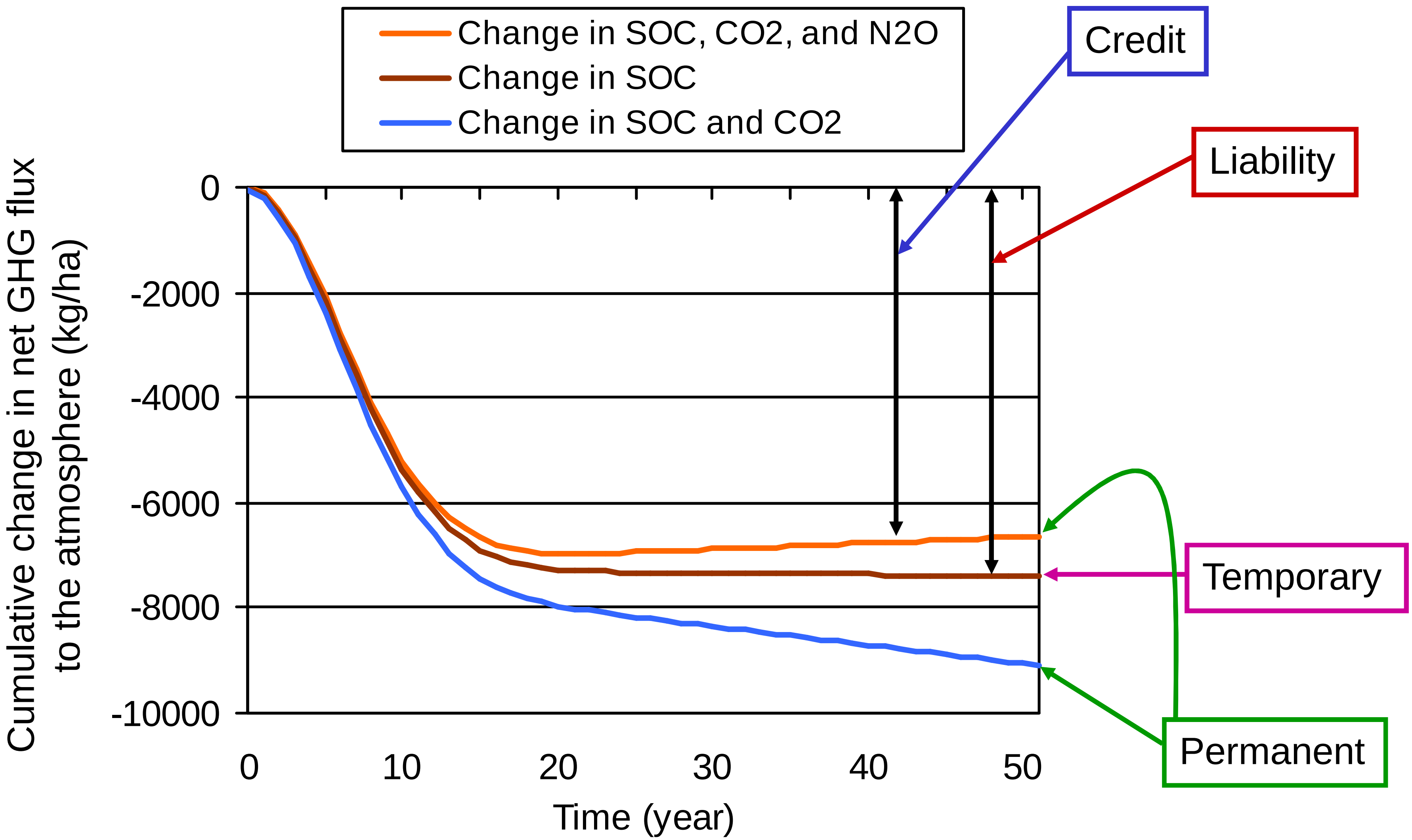
Accounting of changes in GHG emissions assumes:

- Soil C sequestration of 570 ± 140 kg C/ha/yr [normal distribution]
- Average US production inputs and associated emissions
- Estimated relationship between N fertilizer and N_2O emissions of 2.66 kg C_{eq} / kg N applied (2% of N applied)
- Potential change in N_2O emissions of 7 ± 15% with change from CT to NT [uniform distribution]
- Potential change in yield of ± 6% [uniform distribution]
- Change in cropped area that ranges from full compensation for the change in crop yield to no response to the change in yield [uniform distribution]

Savings in CO_2 and N_2O emissions are permanent while C sequestered in soil may be temporary



Emissions that are released as a result of an implemented carbon sequestration strategy may represent a future liability



Carbon management response curves — Summary

Upon further development, CMR curves may effectively address:

- Integration of practices over time
- Duration of C sequestration rates (saturation)
- Uncertainty in C sequestration rates
- Additionality (cancels out climate effect)
- Possible inclusion of net carbon/GHG accounting
- Targeting
- Permanence
- Temporal and spatial variability

A general and qualitative comparison of some options to measure/estimate changes in soil C stocks

	Cost of Measuring & monitoring	Accuracy of change in C stock	Account for saturation or seq. duration	Risk of not meeting seq. obligation	Simplicity and flexibility of accounting
Direct (in situ)	Medium	High ✓	Low-Medium	Medium-High	Low-Medium
Direct (ex situ)	High	High ✓	Low-Medium	Medium-High	Low-Medium
Practice	Low ✓	Low	Low	Low ✓	High ✓
Hybrid (avg. estimate)	Low ✓	Medium	High ✓	Low ✓	High ✓

Concluding remarks

- Options to measure & monitor partly depend on ability to address project-level issues
- Costs, simplicity, predictability, flexibility, as well as saturation, additionality, and permanence all appear to be more effectively addressed by the use of average sequestration or loss rates (CMR curves) rather than direct C measurements
- In addition, CMR curves allow for integration of several practices over time and possible inclusion of net GHG accounting
- Similar comparison could be done with economic/ incentive options and combined with measuring & monitoring options to develop a comprehensive carbon accounting framework

Acknowledgments

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