CSITE 2004 Review

Net Impact on Greenhouse Gas Emissions

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Introduction

Task title: Net Impact on Greenhouse Gas Emissions

Task concept: Conduct research contributing to the scientific basis for net greenhouse gas accounting.

This concept entails:

- Investigating C dynamics, GHG emissions, and general biogeochemical cycling associated with terrestrial C sequestration strategies in order to increase the accuracy of net C/GHG flux estimates.

- Develop and refine methods to scale up field measurements to regional/continental scales while maintaining highest resolution possible.

Overall objectives

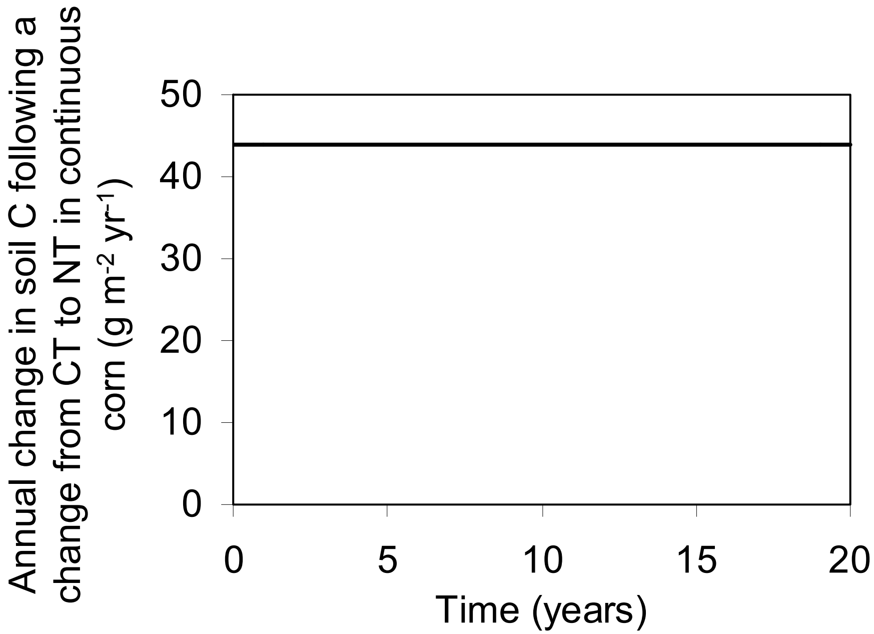
- Increase accuracy of sequestration potentials
  - Compile and aggregate estimates by climate and land management
  - Include temporal component in estimates of sequestration potential

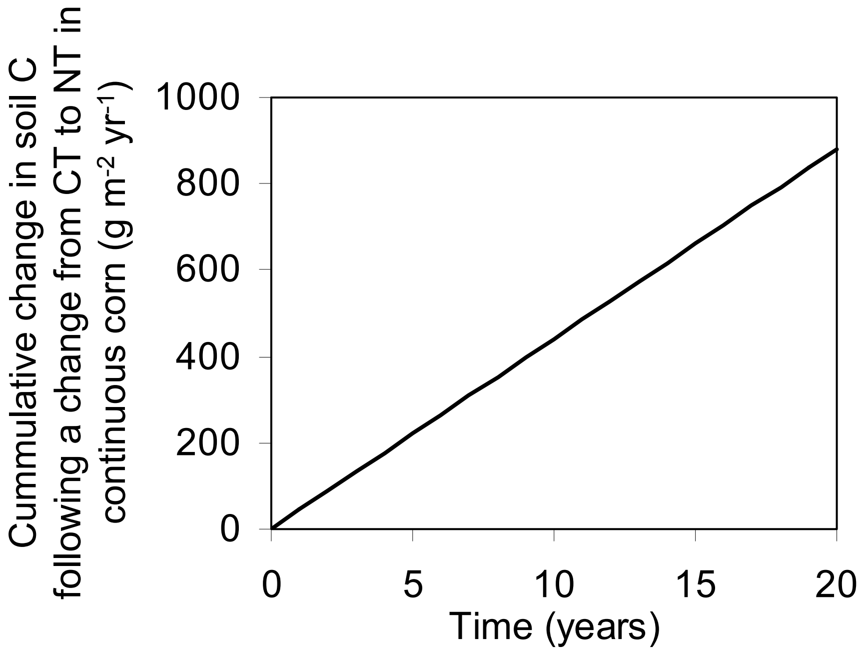
- Estimate impact of sequestration strategies on net emissions
  - CO_2 and N_2O
  - Land productivity and land-use change

- Investigate means to combine all the above in a framework to estimate, monitor, and account for regional net C and GHG flux from agriculture, with the intention of including all ecosystems in the future.

Estimates of sequestration potential

Mean sequestration rate





Estimates of sequestration potential

- Comparison of soil C sequestration rates between IPCC 1997 guidelines and two other analyses

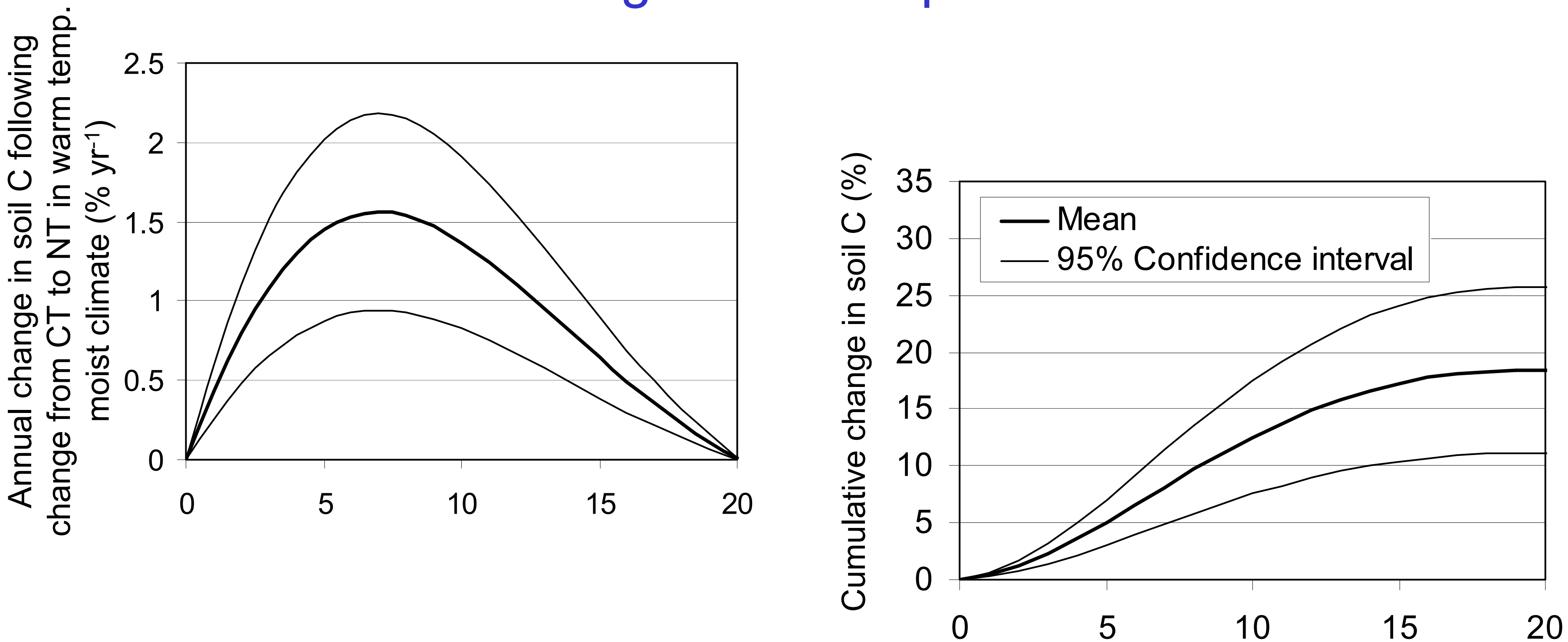
	Coverage	**CT → NT**	**Enhanced residue production**
IPCC (1997)	Global (temperate)	10%	10%
West & Post (2002)	Global	15 ± 3%	6 ± 2%
Ogle et al. (2003)	U.S.	13 ± 3%	7 ± 2%

IPCC. 1997. Greenhouse Gas Inventory Reference Manual, v. 3.
West and Post. 2002. Soil Science Society of America Journal 66:1930-1946.
Ogle et al. 2003. Global Change Biology 9:1521-1542.

Estimates of sequestration potential

Mean sequestration rate over time (provides estimates of sequestration duration and new steady state)

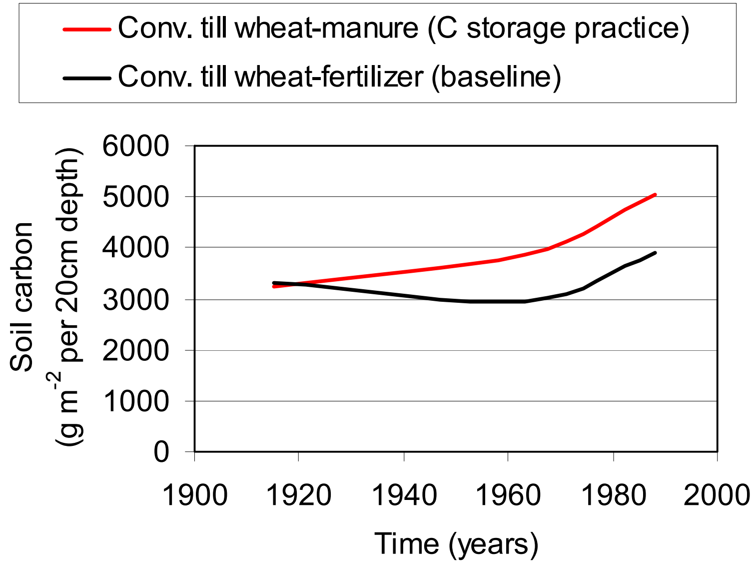
Carbon Management Response Curves

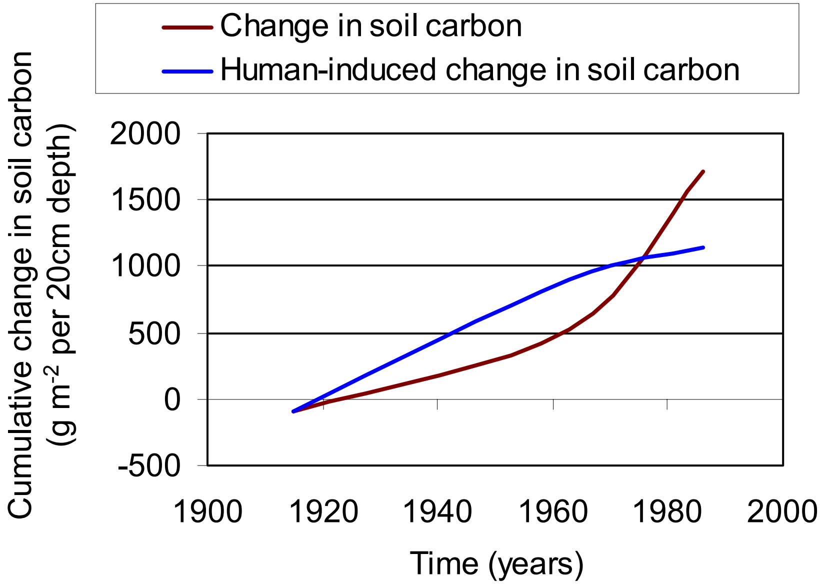


West et al. 2004. Environmental Management 33:507-518.

Estimates of sequestration potential

- Example 1: steady state and human-induced vs. natural changes

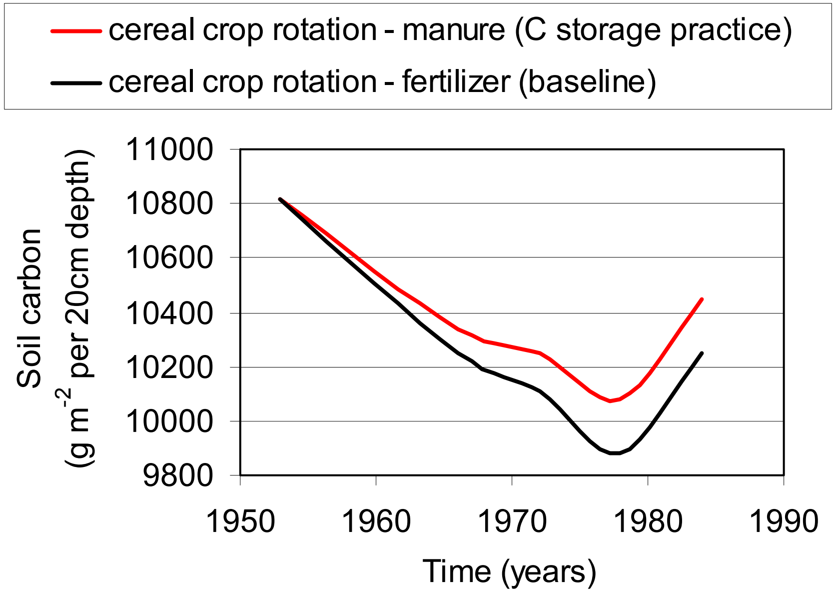


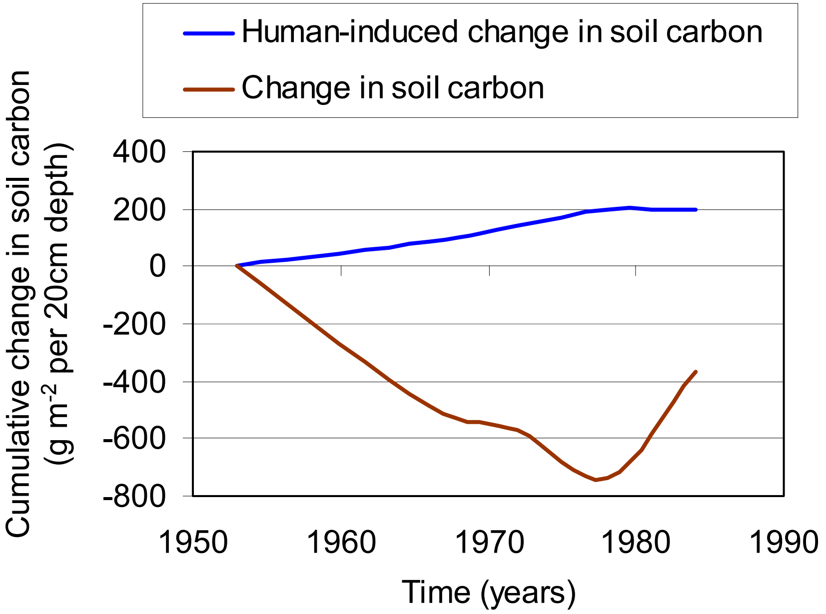


Comparison of synthetic vs. organic fertilizer in a conventional tillage wheat crop in Sanborn Field, Missouri (Buyanovsky and Wagner. 1998. Global Change Biol. 4:131-141).

Estimates of sequestration potential

- Example 2: steady state and human-induced vs. natural changes





Comparison of synthetic vs. organic fertilizer in a cereal rotation crop in Norway (Uhlen. 1991. Acta Agric. Scand. 41:119-127).

Estimates of sequestration potential

Data compilation, processing, and analysis

Carbon Sequestration Data Sets and Analyses

- **Terrestrial Carbon Sequestration Data Sets**

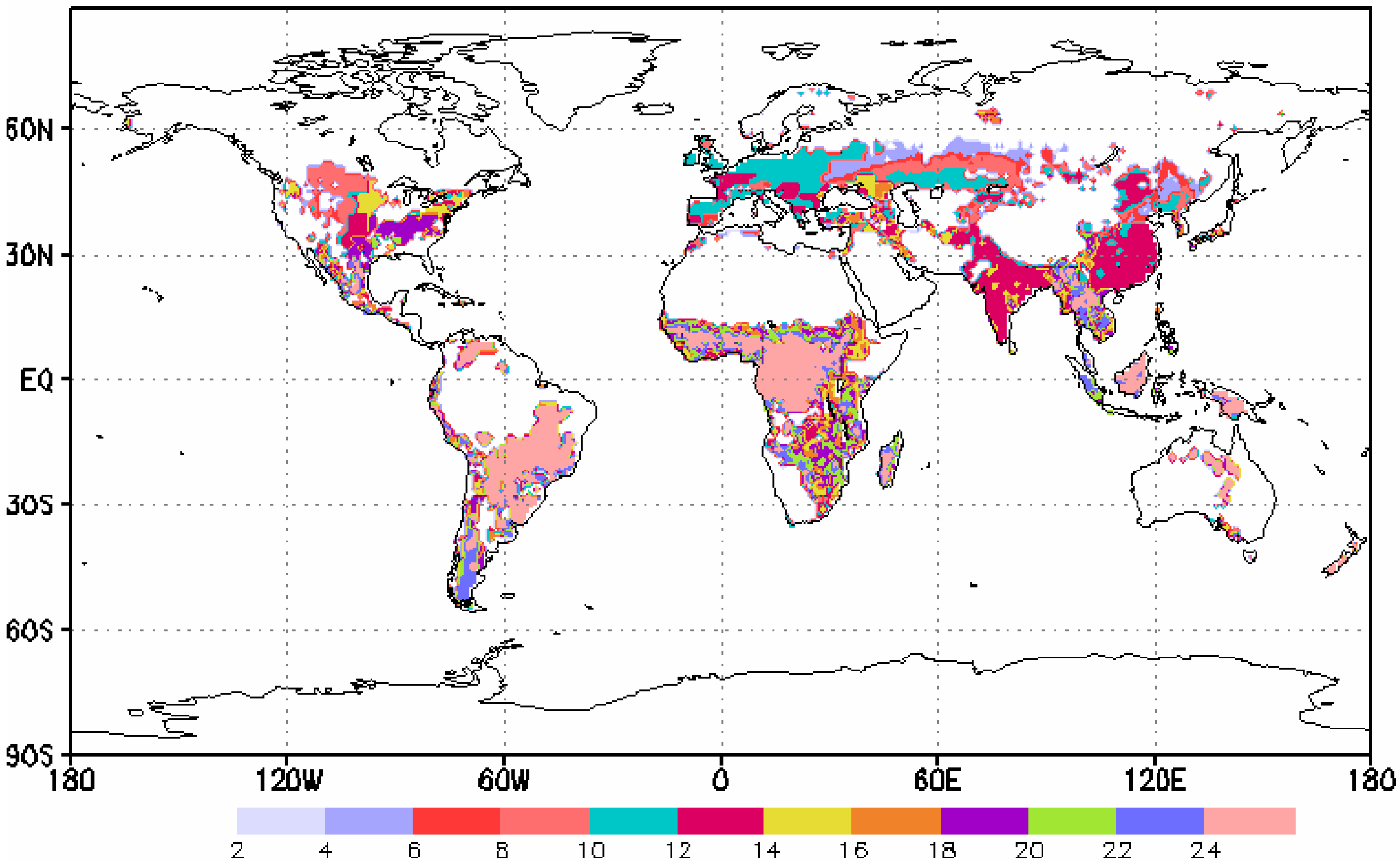
  Carbon accumulation with cropland management:
  - Influence of Agricultural Management on Soil Organic Carbon: A Compendium and Assessment of Canadian Studies (VandenBygaart et al., Agriculture and Agri-Food Canada)
  - Soil Carbon Sequestration by Tillage and Crop Rotation: A Global Data Analysis (West and Post, Oak Ridge National Laboratory)
  - Preliminary Estimates of the Potential for Carbon Mitigation in European Soils Through No-Till Farming (Smith et al., University of Aberdeen, United Kingdom)
  - Potential for Carbon Sequestration in European Soils: Preliminary Estimates for Five Scenarios Using Results from Long-Term Experiments (Smith et al., University of Aberdeen, United Kingdom)

  Carbon accumulation with grassland management:
  - Grassland Management and Conversion into Grassland: Effects on Soil Carbon (Conant et al., Colorado State University)

  Carbon loss following cultivation:
  - Changes in Soil Carbon Storage After Cultivation (Mann, Oak Ridge National Laboratory)

  Carbon accumulation following afforestation:
  - Changes in Soil Carbon Following Afforestation (Paul et al., Commonwealth Scientific and Industrial Research Organisation, Australia)

Spatial sequestraiton analyses: global

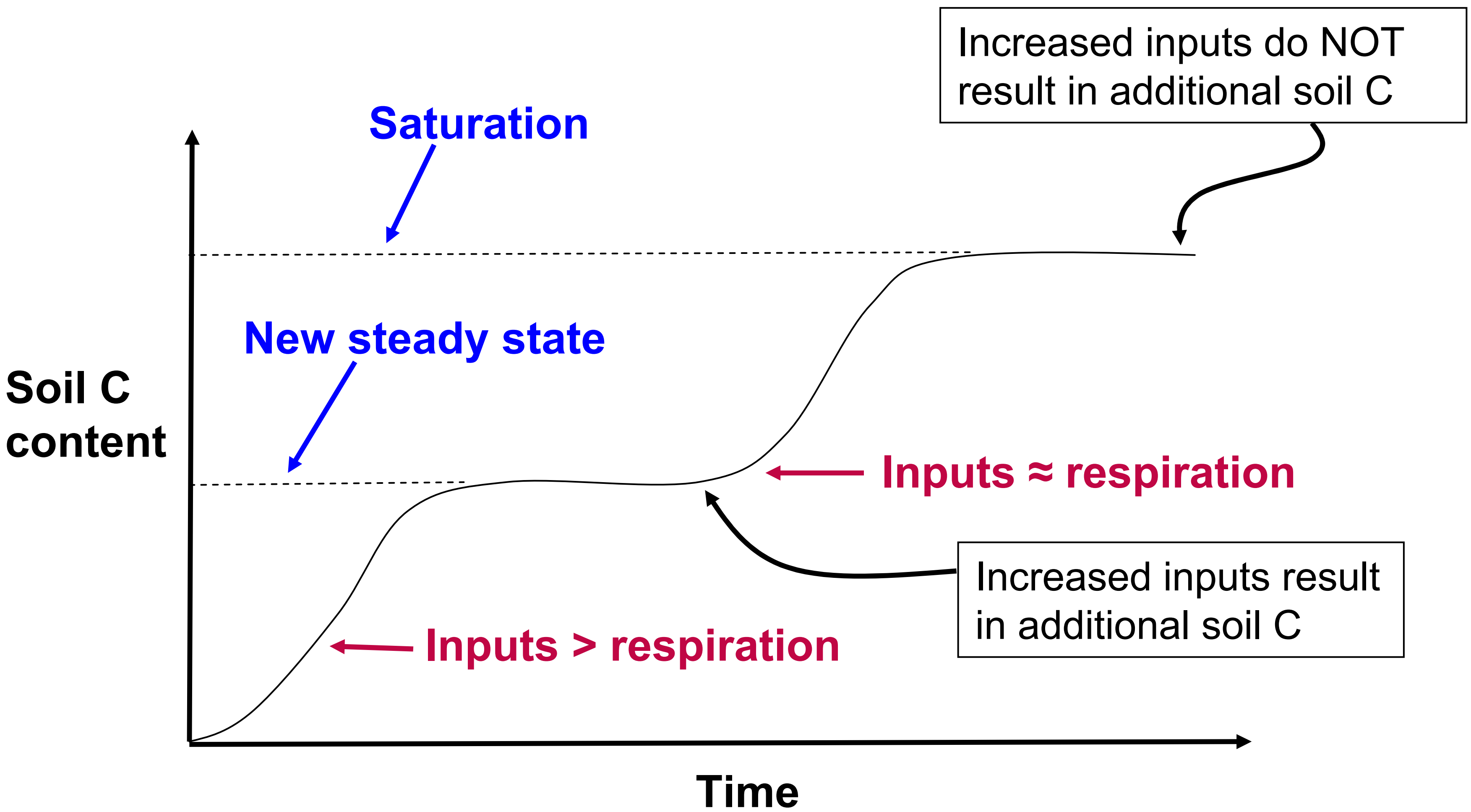


Percent change in soil carbon on agricultural lands following a change from conventional tillage to no-till

Preliminary results from A. Jain and X. Yang, Integrated Science Assessment Model

Estimates of sequestration potential

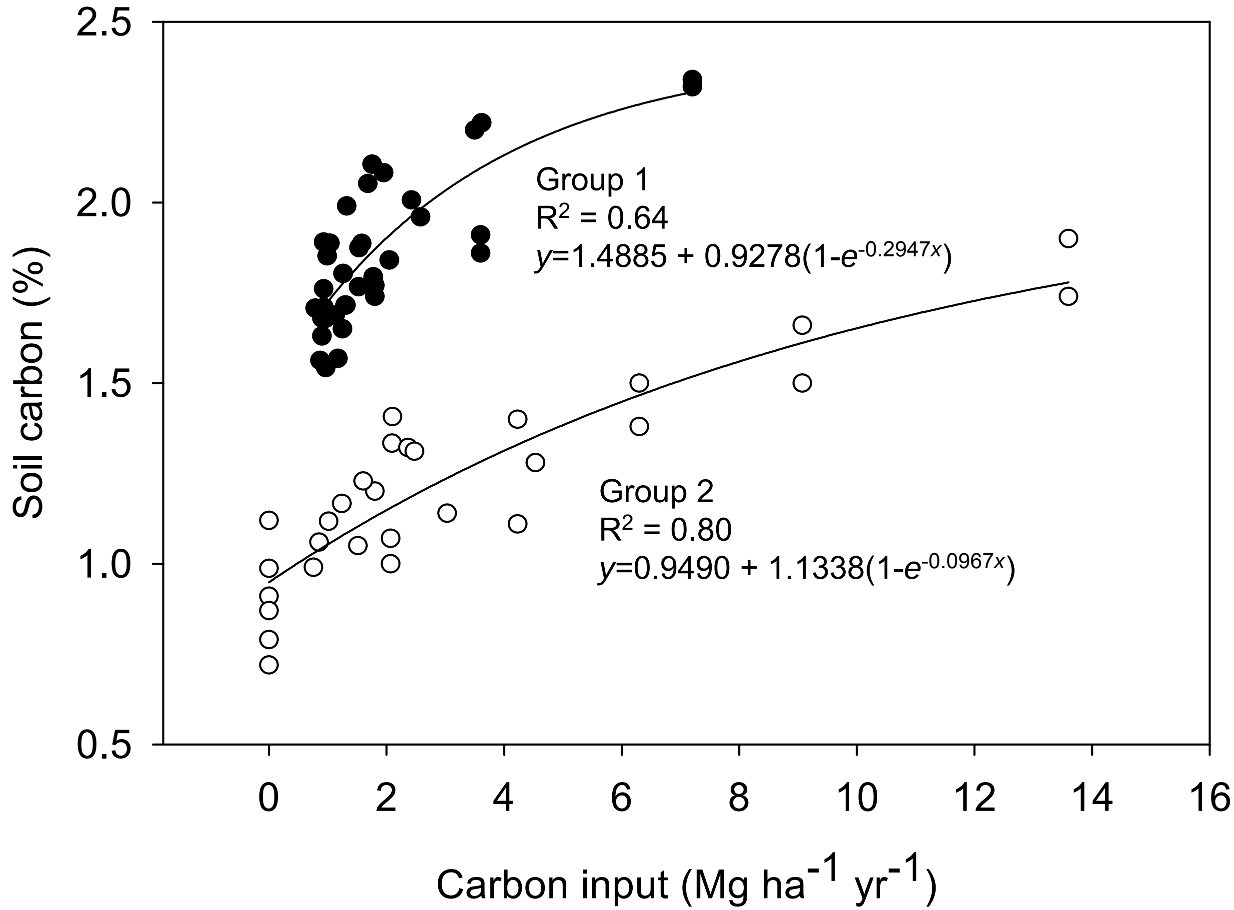
Soil C steady state as a function of C inputs and time



Revised from Johan Six, CASGMS Forum presentation (2004)

Estimates of sequestration potential

Soil carbon saturation – additional sequestration after initial steady state?



West, T.O. and J. Six (in preparation).

Soil C permanence – unknown

Results from intermittent tillage experiments

	Location	Change in total soil C	Change relative to previously seq. C
VandenBygaart and Kay (2004)	**Ontario, Canada; 22yr NT; (after 18 mo)**		
Sandy loam (HC)		0	0
Sandy loam (LC)		-10%	about -66%
Sandy clay loam		0	0
Silty clay loam		0	0
Pierce et al. (1994)	**East Lancing, MI; 6 yr NT; (after 4-5 yr)**		
1986 plot		+3.7%	
1987 plot		-2%	-16%
Kettler et al. (2000)	**Sidney, NE, 20yr NT (after 5 yr)**	0	0
Stockfish et al. (1999)	**Saxony, Germany, 20 yr NT (after 2 yr)**	-10%	-142%

Estimates of sequestration potential: Publications

Recent:

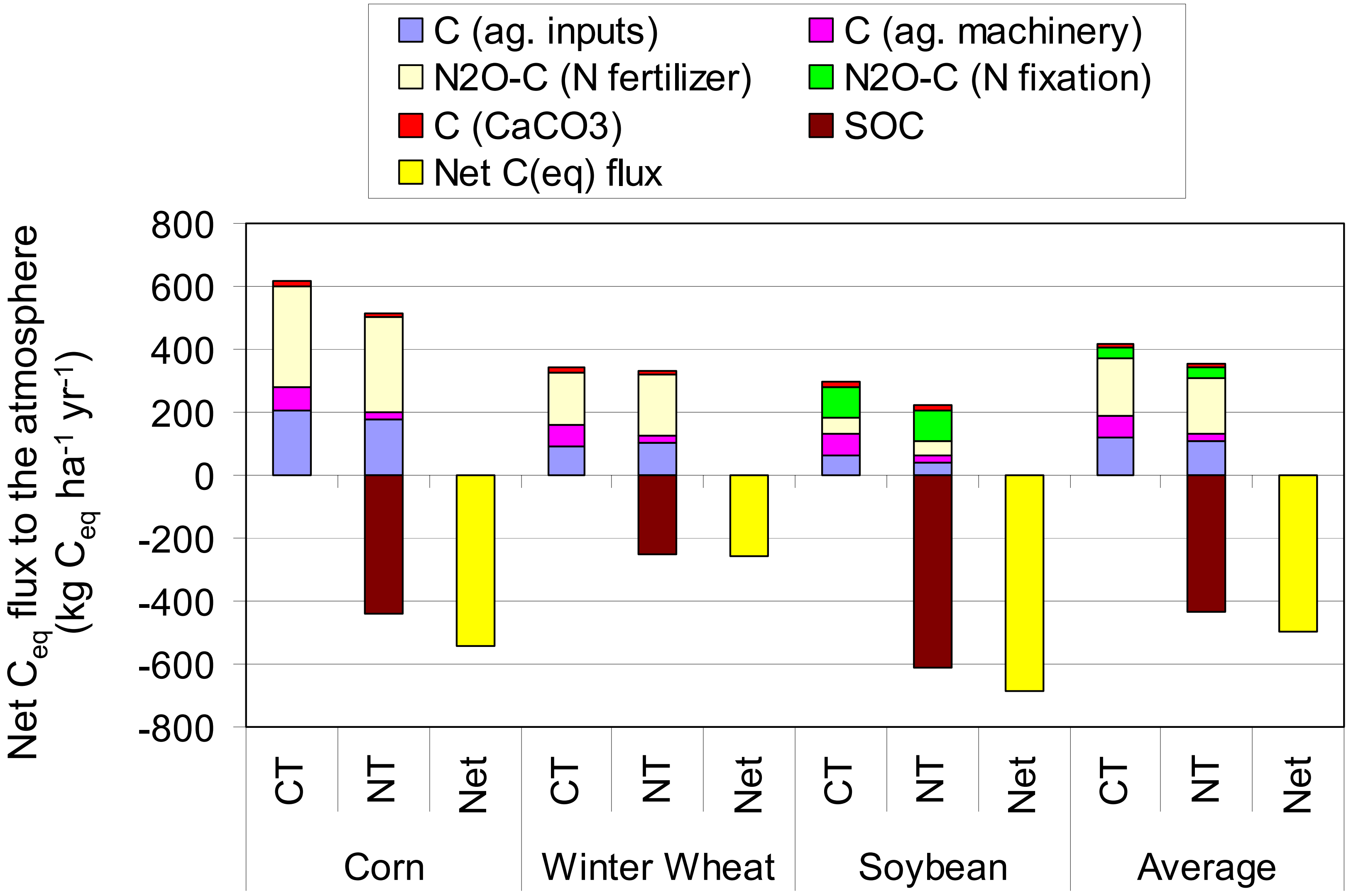
- Estimates of soil C change with cropland management (West and Post. 2002. SSSAJ 66:1930-1946)
- Development of carbon management response curves (West et al. 2004. Environmental Management 33:507-518)
- CSITE studies on processes and mechanisms of sequestration (Marland et al. 2004. Energy:1643-1650)

Future:

- Influence of sequestration duration and soil C saturation on soil C capacity (West and Six et al. *In preparation*)
- Sequestration potential in North America with potential climate change (West and Jain et al. *In preparation*)

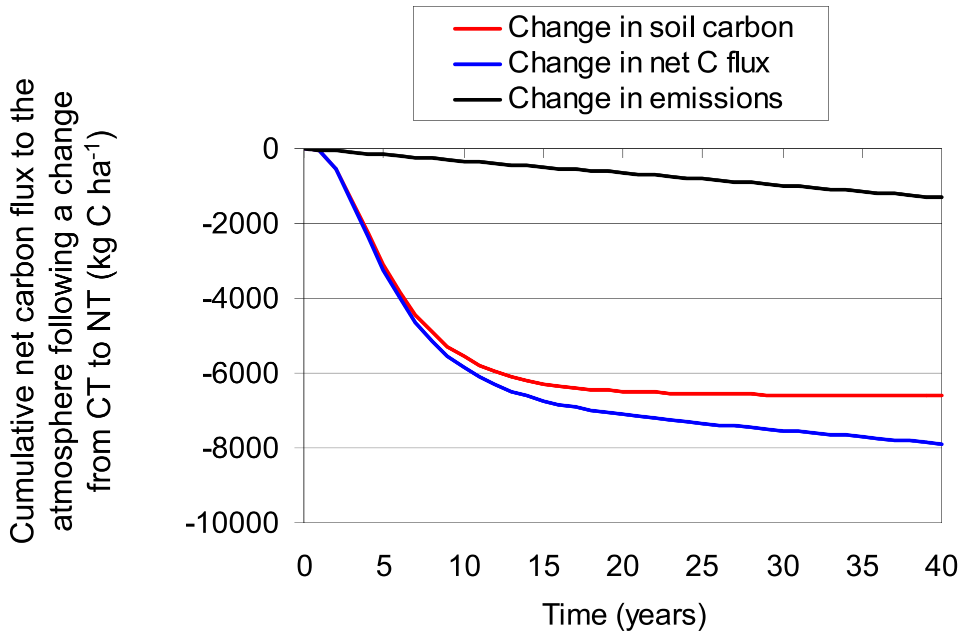
Net change in GHG emissions

Average GHG emissions, soil C seq., and net C_{eq} flux



Net change in GHG emissions

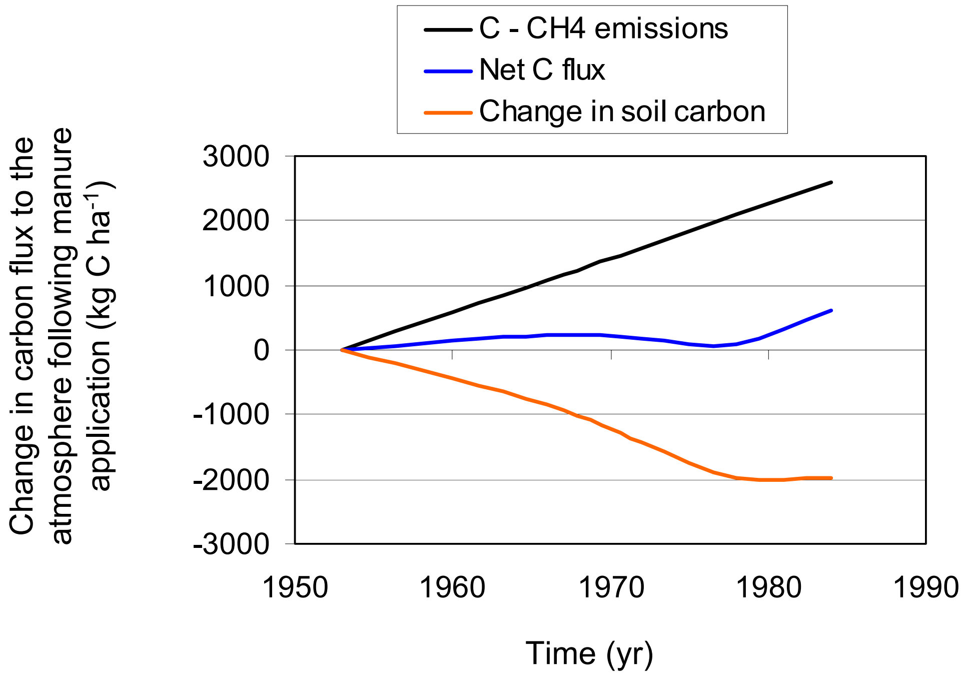
Changes in carbon storage vs. energy use and associated CO_2 emissions



Accounting for changes in CO_2 emissions results in additional savings of 33 kg C ha yr $^{-1}$ for a change from conventional tillage to no-till.

Net change in GHG emissions

Changes in carbon storage vs. greenhouse gas emissions

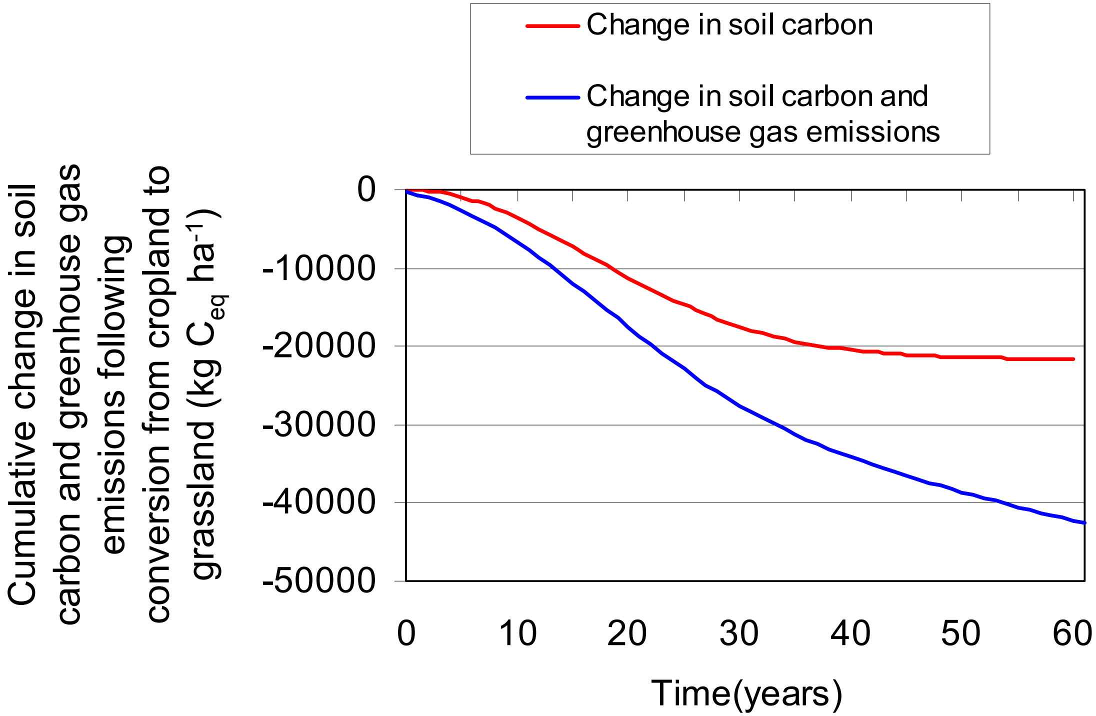


Carbon sequestered in soil as a result of manure application may be offset by CH_4 emissions if the manure management was changed from solid manure storage to liquid/slurry storage, as illustrated here. This illustration does not include decreases in CO_2 and N_2O emissions associated with the potential replacement of synthetic fertilizer with organic fertilizer.

Emissions of methane from manure management were estimated according to IPCC (1997). Soil carbon sequestration estimate from Norway experiment (Uhlen 1991)

Net change in GHG emissions

Changes in carbon storage vs. greenhouse gas emissions

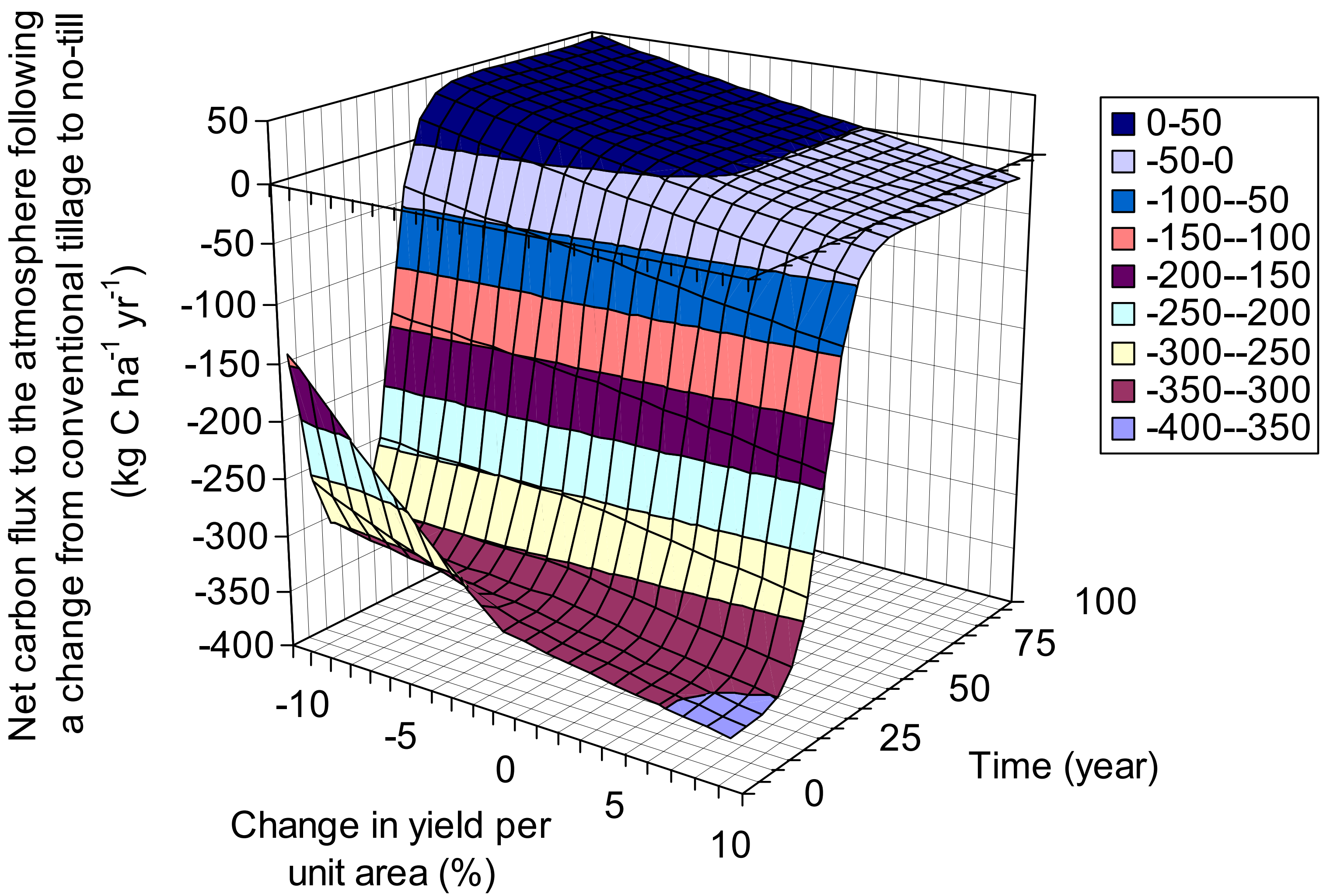


Accounting for the savings in greenhouse gas emissions, following conversion from cropland to grassland, can reduce net C flux to the atmosphere twice as much as considering soil C sequestration alone. This illustration assumes conversion from a corn/soybean rotation using average U.S. agricultural inputs.

Estimates of C sequestration based on data collection and analysis by Conant et al. (2001). Emissions estimates based on West and Marland (2002).

Net change in GHG emissions

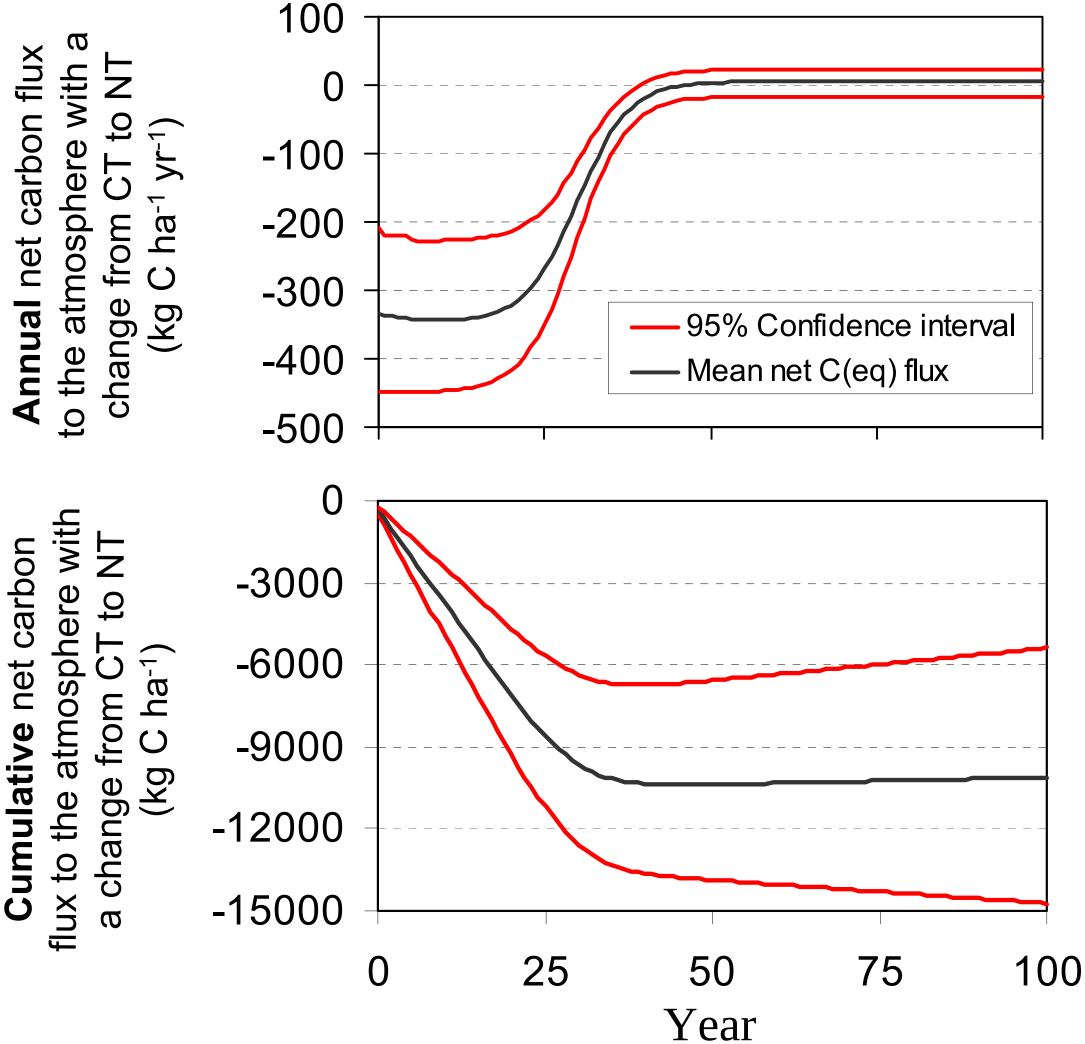
Net change in CO_2 emissions if changing agricultural practice leads to a change in agricultural productivity



Estimate of C sequestration including uncertainties in potential emissions and sequestration

- 337± 108 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 Ceq / kg N appplied
- 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)

Estimate of C sequestration including uncertainties in potential emissions and sequestration

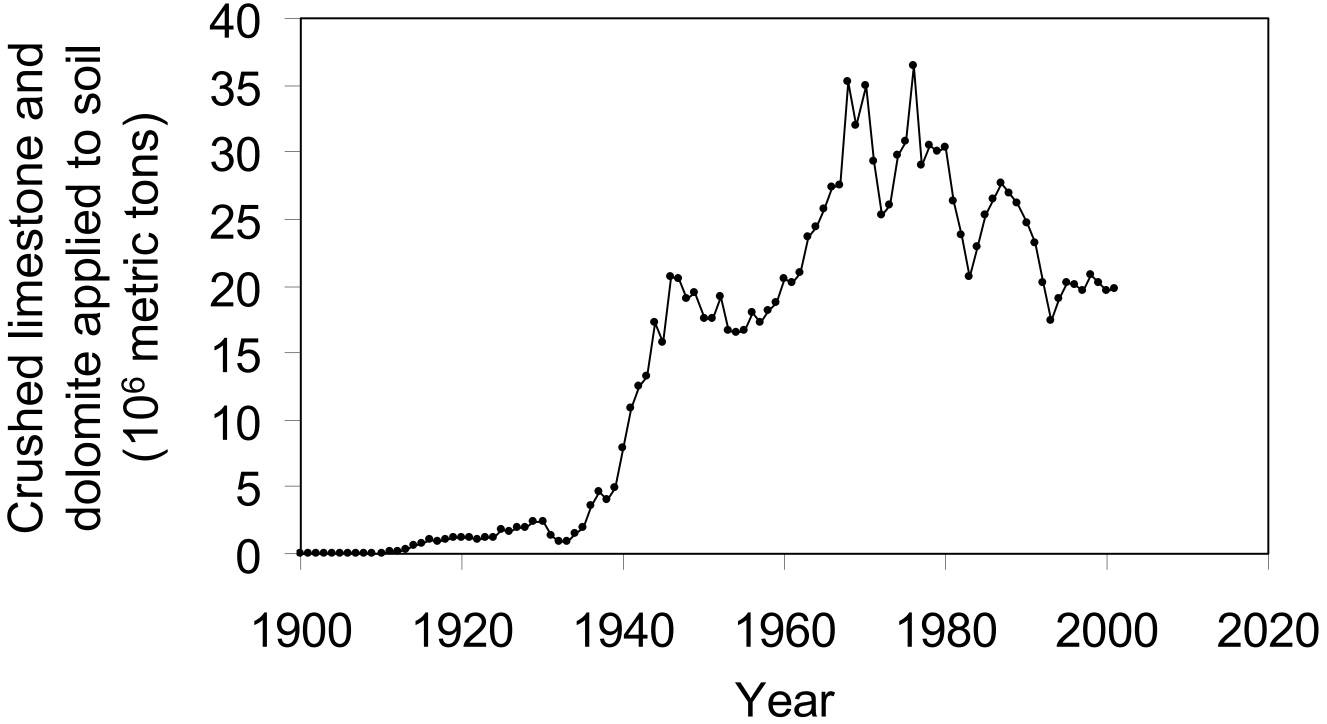


Marland et al. 2003. Tellus B 55:613-622

Net change in GHG emissions

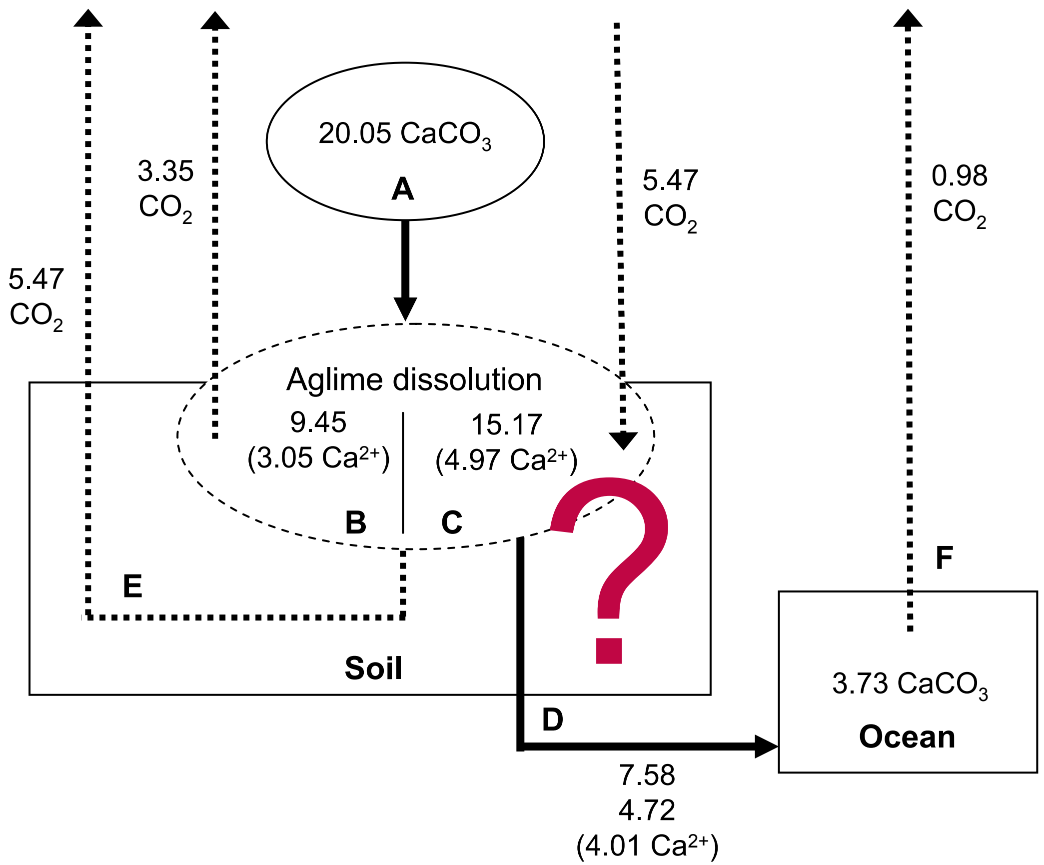
Ultimate fate of CO_2 from agricultural lime - Unknown

Historical use of agricultural lime



Net change in GHG emissions

Ultimate fate of CO_2 from agricultural lime - Unknown



~0.22 Mg net CO_2 emitted per Mg $CaCO_3$ applied (IPCC=0.46)

or

~50% of CO_2 in $CaCO_3$ is lost to the atmosphere (IPCC=100%)

+0.44 Mg CO_2 emitted per Mg $CaCO_3$ applied (IPCC. 1997. Revised Guidelines)
-0.18 to +0.30 Mg CO_2 emitted per Mg $CaCO_3$ applied (West and McBride, in review).
-44 to +44 (G.P. Robertson CASGMS Newsletter, Jan. 2004).

Net change in GHG emissions

Ultimate fate of CO_2 from agricultural lime - Unknown

Table 1. Net CO_2 emissions from applied agricultural lime

	CO_2 emissions per unit aglime (Mg C/Mg crushed stone)		Estimated U.S. CO_2 emissions from aglime (Tg CO_2 per year)[a]	
	Limestone	Dolomite	Based on 20 Tg aglime	Based on 30 Tg aglime
Houghton et al. (1997)	0.12	0.13	9.0[b]	13.4
This analysis	0.059	0.064	4.4	6.6

[a] Based on an approximate weighted average of 80% limestone and 20% dolomite.
[b] Represents current U.S. estimate used by EPA (2004).

Global Change Education Program

West and McBride (in review)

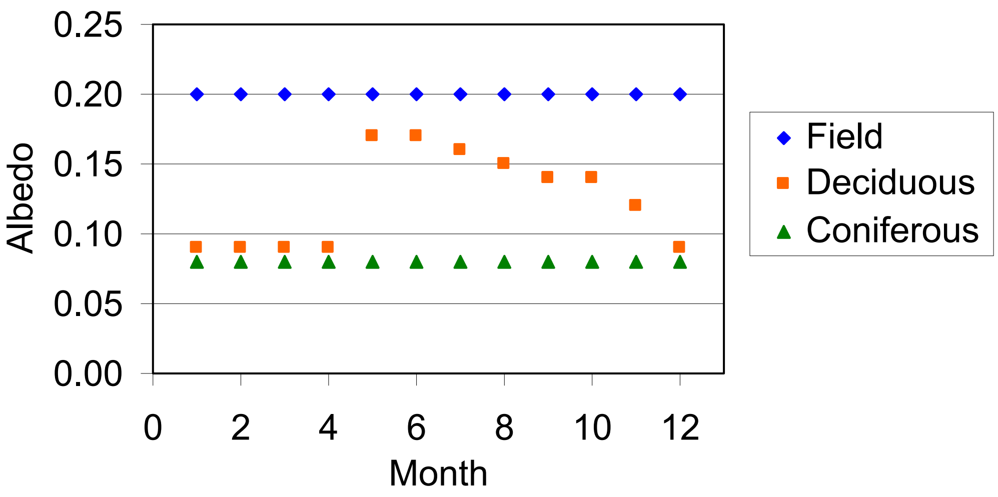
(switch to Gregg)

Net change in GHG emissions

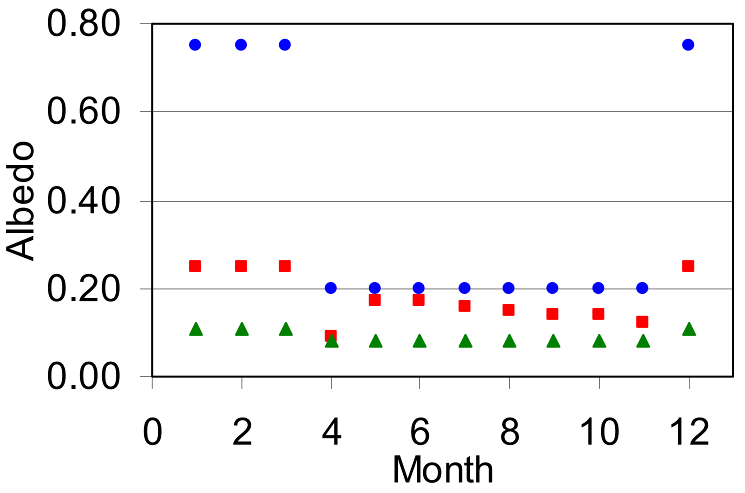
Representation of albedo in full C accounting

Land-use change
→ Change in albedo
→ Change in radiative forcing
→ Change in C (equivalent) emissions

Albedo with no snowcover



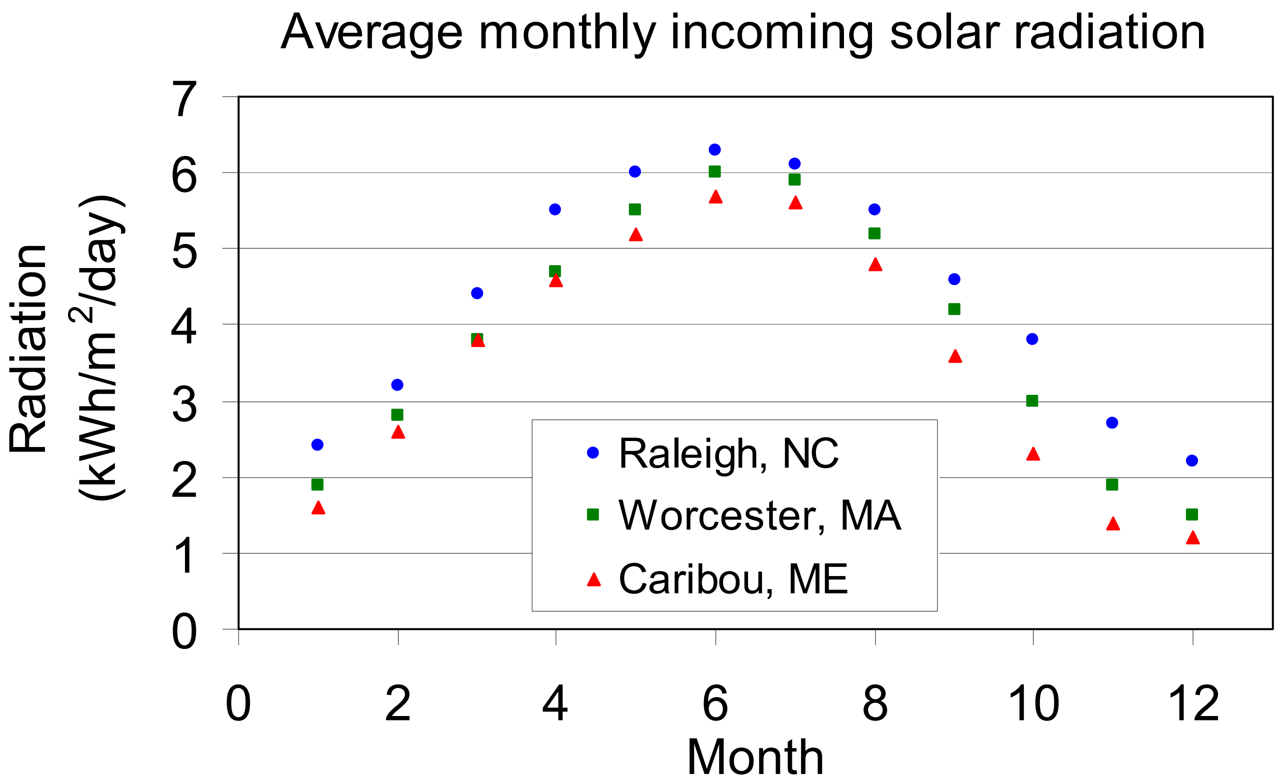
Albedo with 4 months snowcover



Marland, Kunda, Schlamadinger, Canella. (In preparation)

Net change in GHG emissions

Representation of albedo in full C accounting



Net change in GHG emissions

Representation of albedo in full C accounting

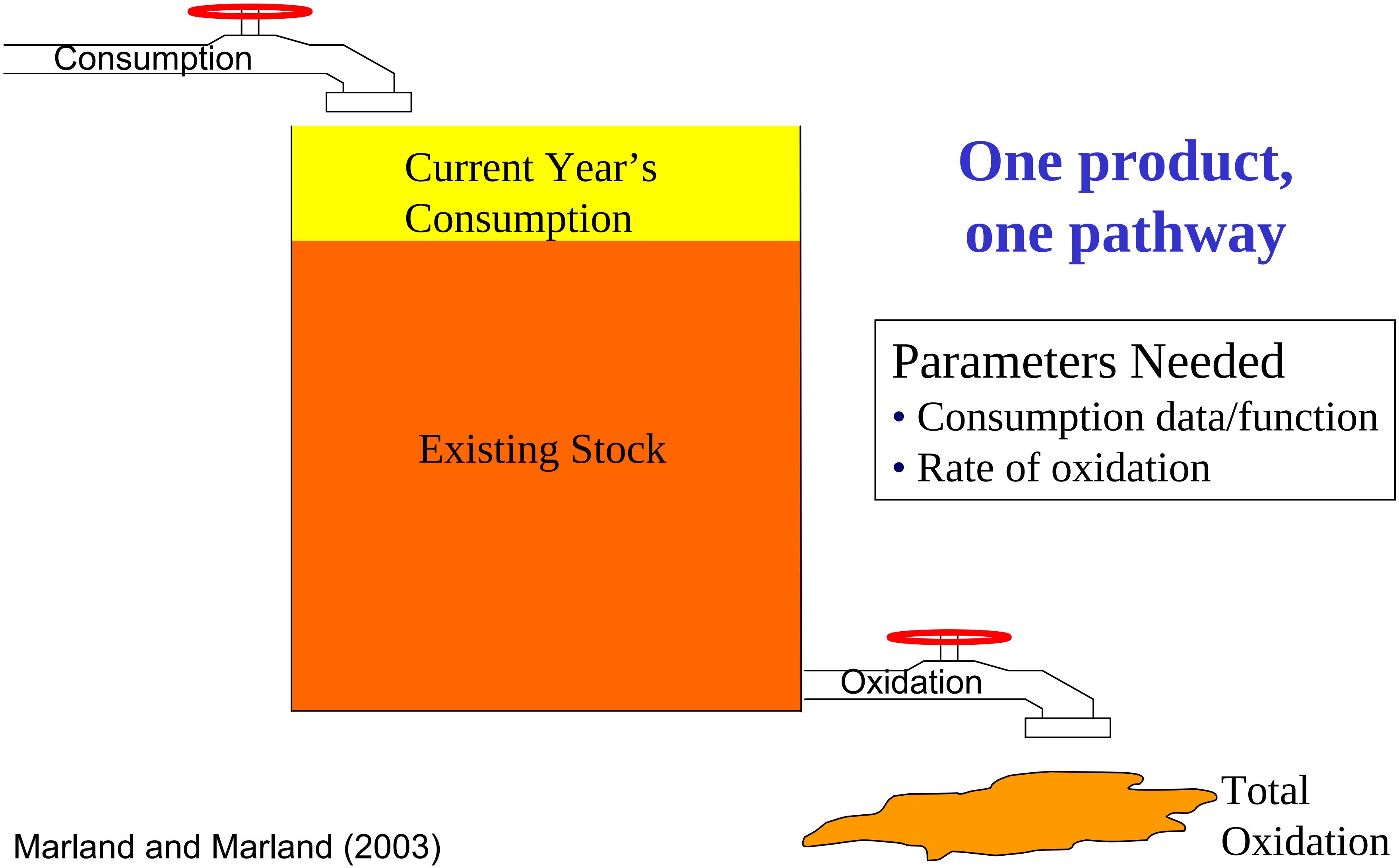
	W/m²	Mg C/ha
Field to deciduous forest		
No snow	12.33	72
Low snow	13.13	76
High snow	22.08	128
Field to coniferous forest		
No snow	21.94	128
Low snow	22.75	132
High snow	34.25	199

Deciduous (oak-hickory in western North Carolina) ≈ 97 Mg C/ha

Coniferous (spruce-fir in northern Maine) ≈ 47 Mg C/ha

Net change in GHG emissions

Treatment of long-term C containing products

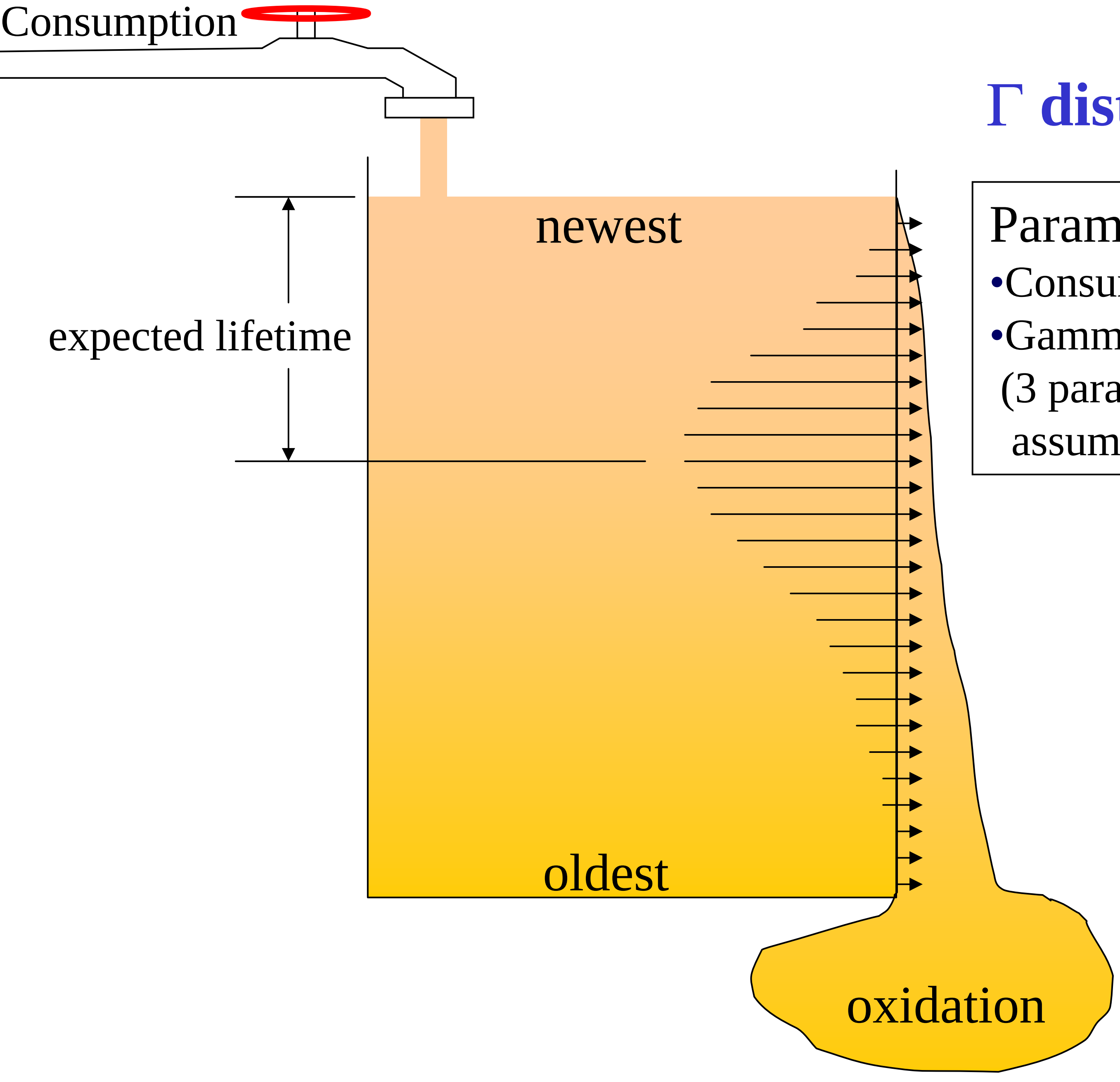


One product, one pathway

Parameters Needed
- Consumption data/function
- Rate of oxidation

Marland and Marland (2003)

Γ distribution decay



Parameters Needed

- Consumption data/function
- Gamma decay function

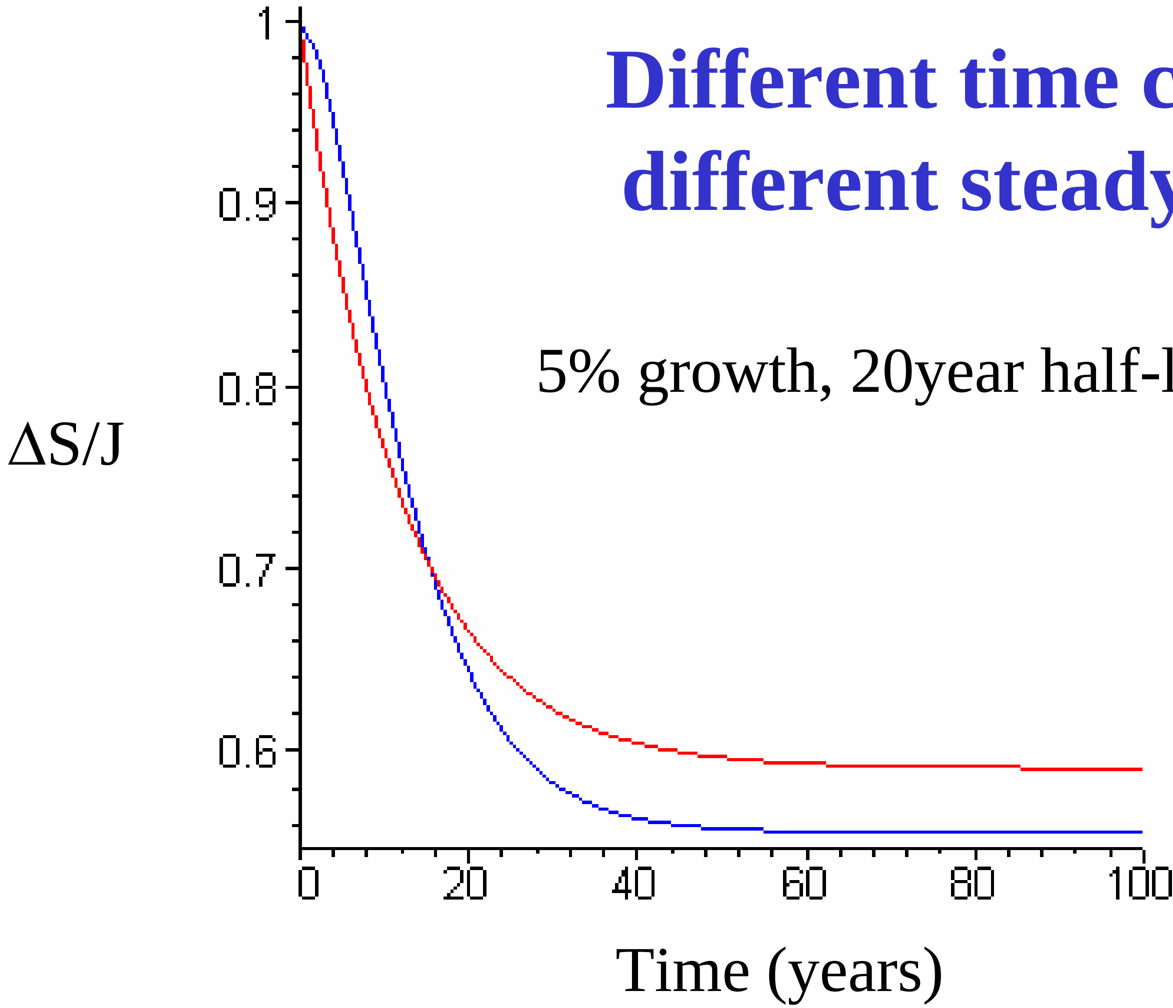
(3 parameter fit; 1 with a few assumptions)

Net change in GHG emissions

Treatment of long-term C containing products

Different time course, different steady state

5% growth, 20year half-life/mean life



Net change in GHG emissions: Publications

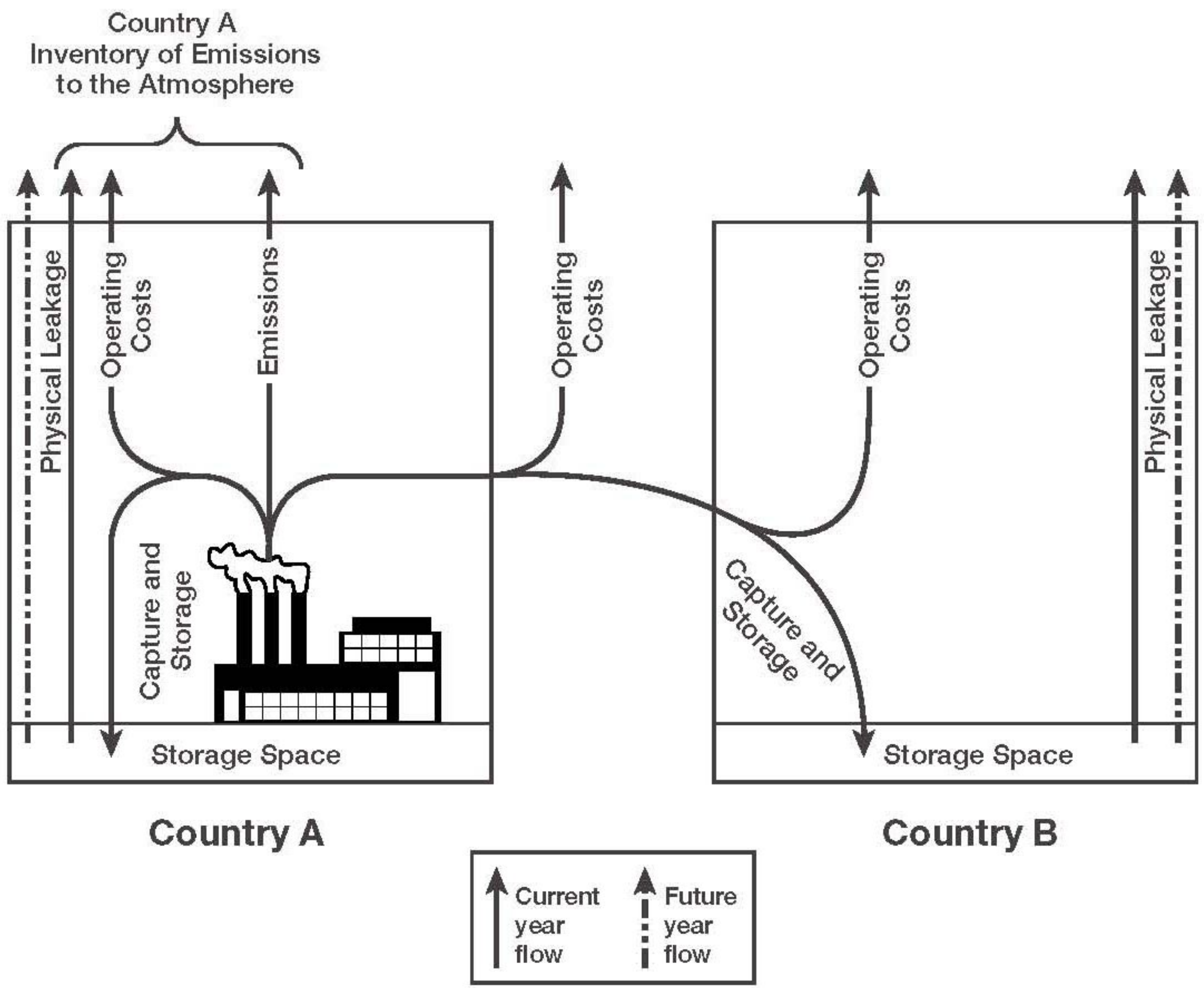
Recent:

- CO_2 emissions from ag. production inputs (West and Marland. 2002. Agric. Ecosyst. Environ.: 91:217-232.)
- Impact of C sequestration activities on land-use change (West and Marland. 2003. Biogeochemistry 6:73-83.)
- Sensitivity analysis of CO_2, N_2O, soil carbon, and land-use change (Marland et al. 2003. Tellus 55:613-622.)
- Treatment of long-term C containing products (Marland and Marland. 2003. ES&P 6:139-152)
- Climate impacts of land surface change and C management (Marland et al. 2003. Climate Policy 3:149-157)

Future:

- Ultimate fate of CO_2 following agricultural lime application (West and McBride. *In review*)

Accounting for sequestration



Carbon/GHG accounting issues: Publications

Recent:

- Accounting for permanence of sequestered C (Marland, Fruit, and Sedjo. 2001. ES&P 4:259-268)
- Net C accounting methodology (West and Marland. 2002. Environmental Pollution 16:439-444)
- Industry sector emissions reporting (West and Pena. 2002. ES&T 37:1057-1060)
- Development of carbon management response curves (West et al. 2004. Environmental Management 33:507-518)
- Methodological framework for research and analyses of terrestrial C sequestration (Post et al. 2004. Bioscience 54:895-908)

Summary & Significance

- Possibilities for C sequestration are generally known. Accurate sequestration potentials are necessary for our scientific understanding, for application in economic and biogeochemical models, and in policy development. We need spatial and temporal detail to truly understand sequestration potential.
- Full accounting has been addressed generally. We still need to increase representation of inputs and to increase spatial accuracy. We need to know that actions taken to mitigate climate change actually do mitigate climate change.
- Complimentary activities with support from NOAA, NASA, and NSF broaden our activities and impacts.

The End