Carbon Management in Agricultural Systems:
Integration of Field Measurements, Inventory Data, Remote Sensing, and Agricultural Economics

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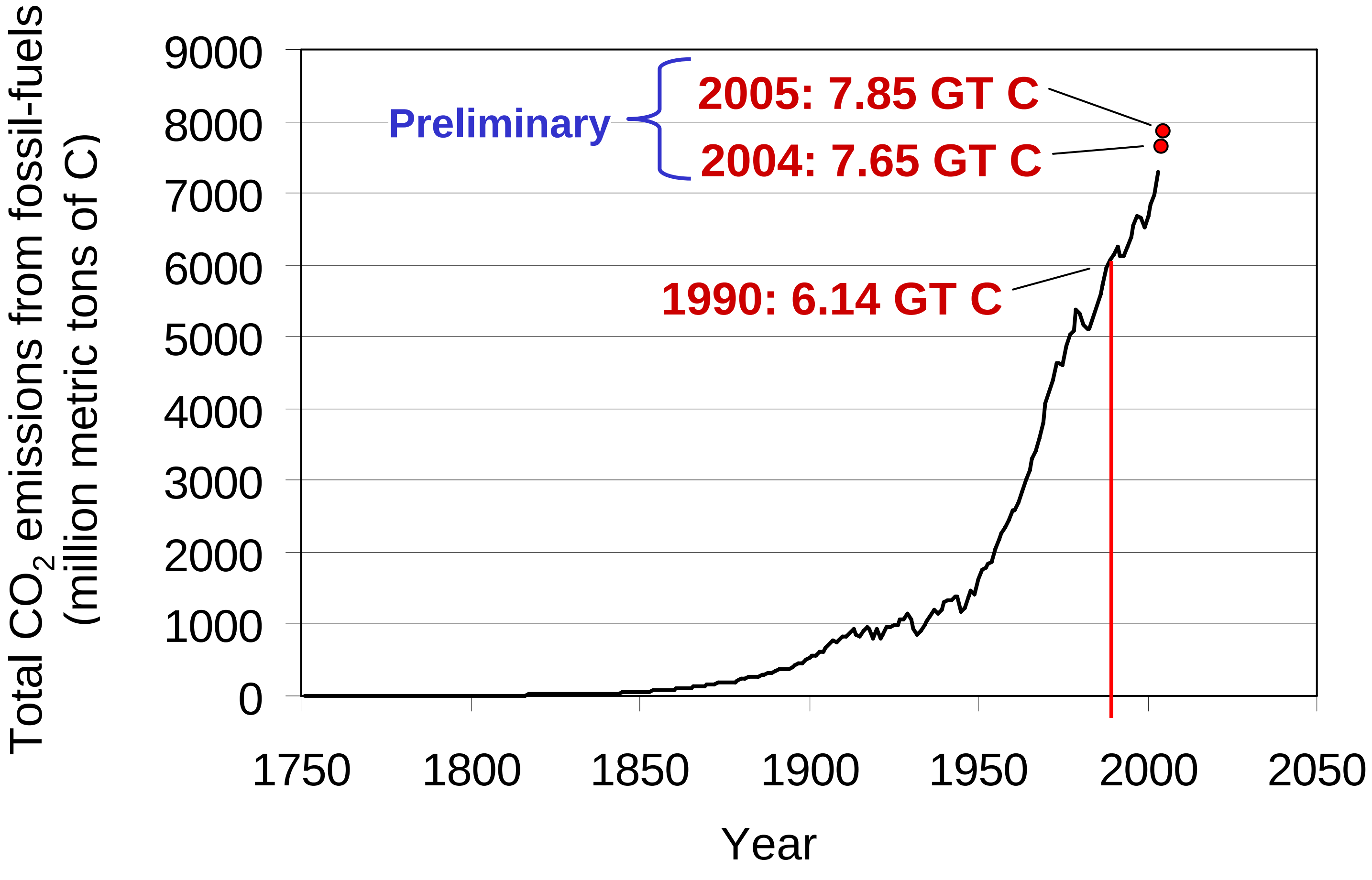
UT-BATTELLE

Status of Global CO_2 Emissions



Marland, G., T.A. Boden, R.J. Andres. 2006. Global, Regional, and National CO_2 Emissions. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, USA.

What is (Terrestrial) Carbon Management?

Definition

- Study of the flow of C in various forms through atmosphere, ocean, terrestrial biosphere, and lithosphere [IPCC 2001]
- Balance of carbon cycle at different geographic scales
- Bookkeeping to ensure that [carbon management] projects produce real and quantifiable environmental benefits [IPCC 2005]

Research activity

Carbon Cycle Science

↓

Carbon Budgets

↓

Carbon Accounting

↓

Carbon Management

Land Management →

What is (Terrestrial) Carbon Management?

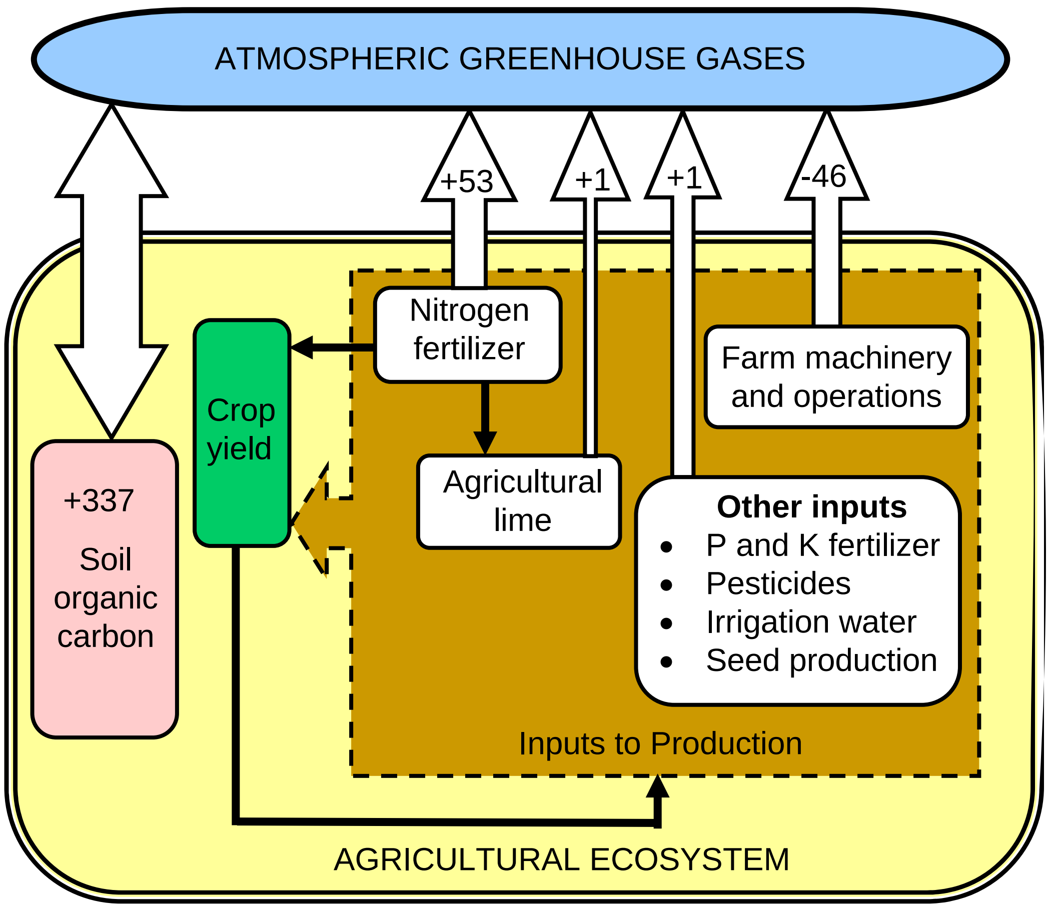
The management of resources (natural and synthetic) to reduce net C emissions to the atmosphere from terrestrial ecosystems, without adversely impacting ecosystem functions and services.

…or perhaps…

The management of resources (natural and synthetic) with respect to carbon.

What is the optimum management that maximizes yield AND carbon uptake or minimizes net C_{eq} emissions?

What is the net C_{eq} flux from different management systems?



Units in
kg C_{eq} ha^{-1} yr^{-1}

Figure represents a change from conventional tillage to no-till for average U.S. crops, circa 1995.
(Marland et al. 2003 Tellus 55B: 613-621. West and Marland 2002 Environ. Pollut. 116:439-444.)

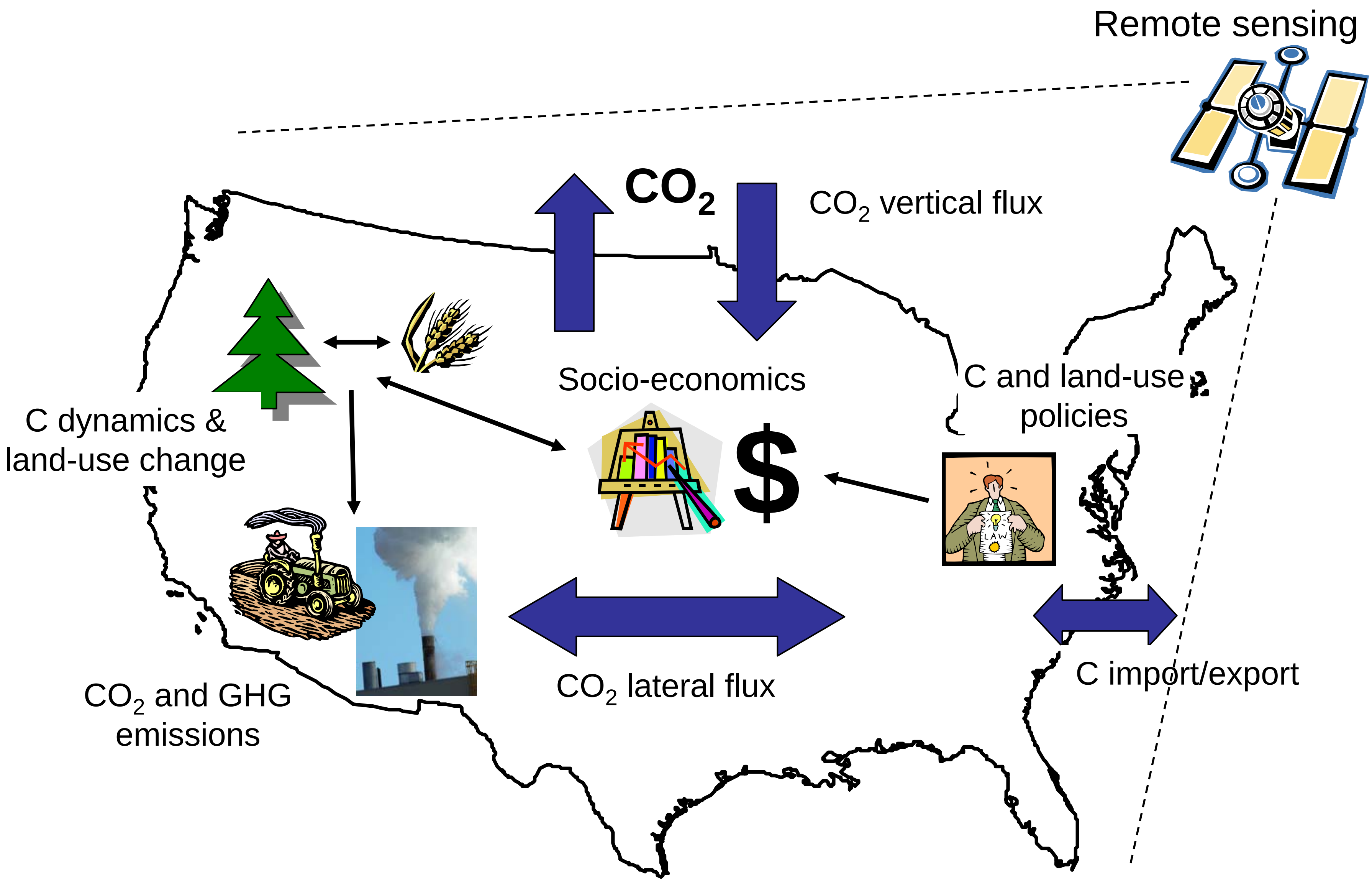
Current project

Spatially-Explicit Full Carbon and Greenhouse Gas Accounting at the Regional to National Scale: Estimating Net C-Equivalent Flux from US Agriculture

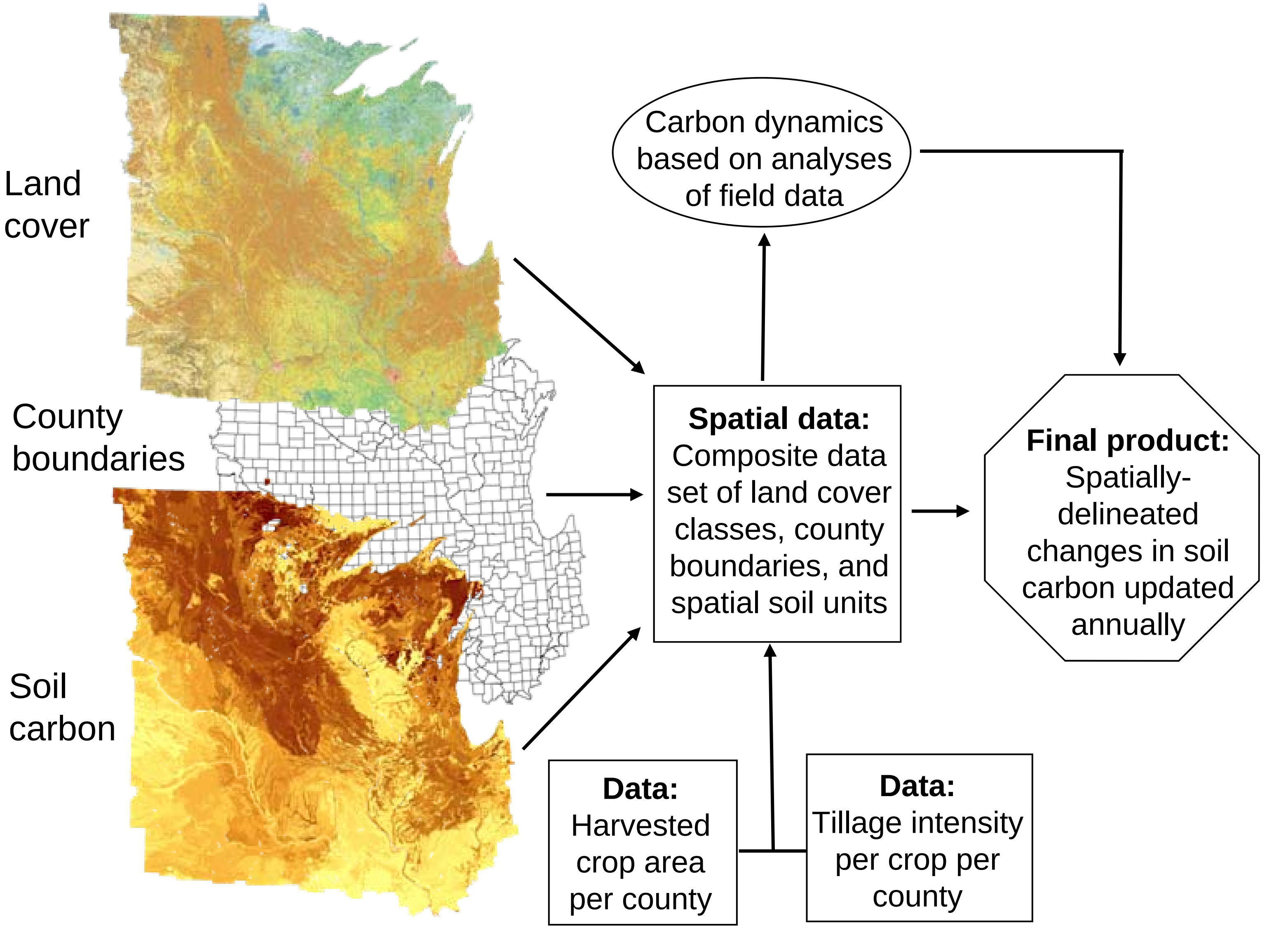
Project goals

- Estimate changes net C_{eq} flux at a high spatial resolution over large regions. Net C_{eq} flux includes:
  - soil carbon;
  - energy use associated with land management inputs;
  - on-site and off-site (upstream) emissions; and
- Incorporate socio-economics drivers associated with changes in land-use (e.g., financial decisions and perceptions of risk by land managers)
- A framework where R.S. products, inventory data, and field measurements can be easily revised or replaced on a regular basis.

Illustration of project components

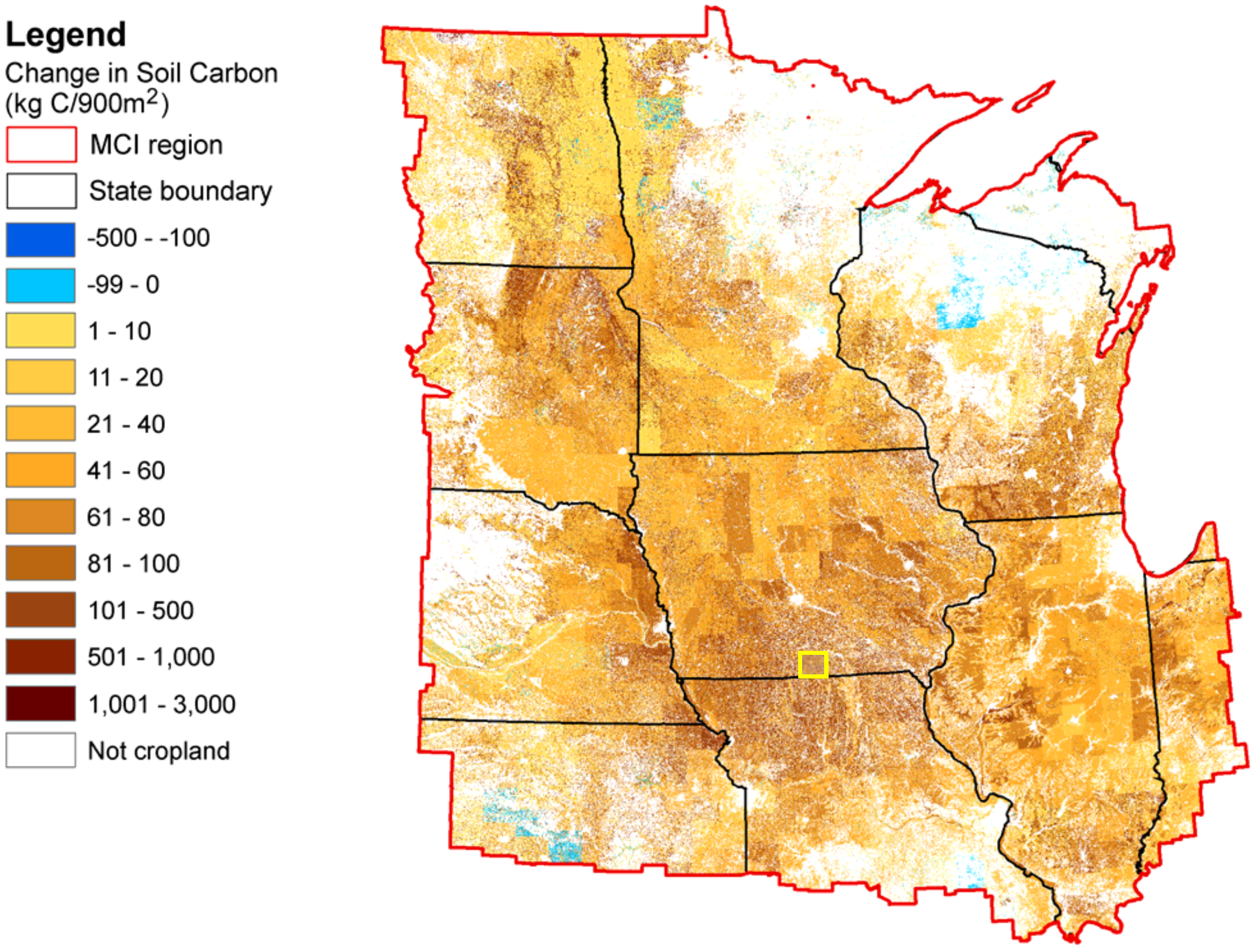


Completed framework for soil carbon accounting



Geographic area coincides with NACP Mid-Continent Intensive campaign

Cumulative change in soil carbon from 1991-2000 caused by changes in tillage intensity and crop rotations.



Magnified area is Wayne County, Iowa, representing a diverse set of cropping practices, tillage intensities, and soil types, and illustrating a range of soil carbon gain and loss at a 900m^2 resolution within a 10-year period.

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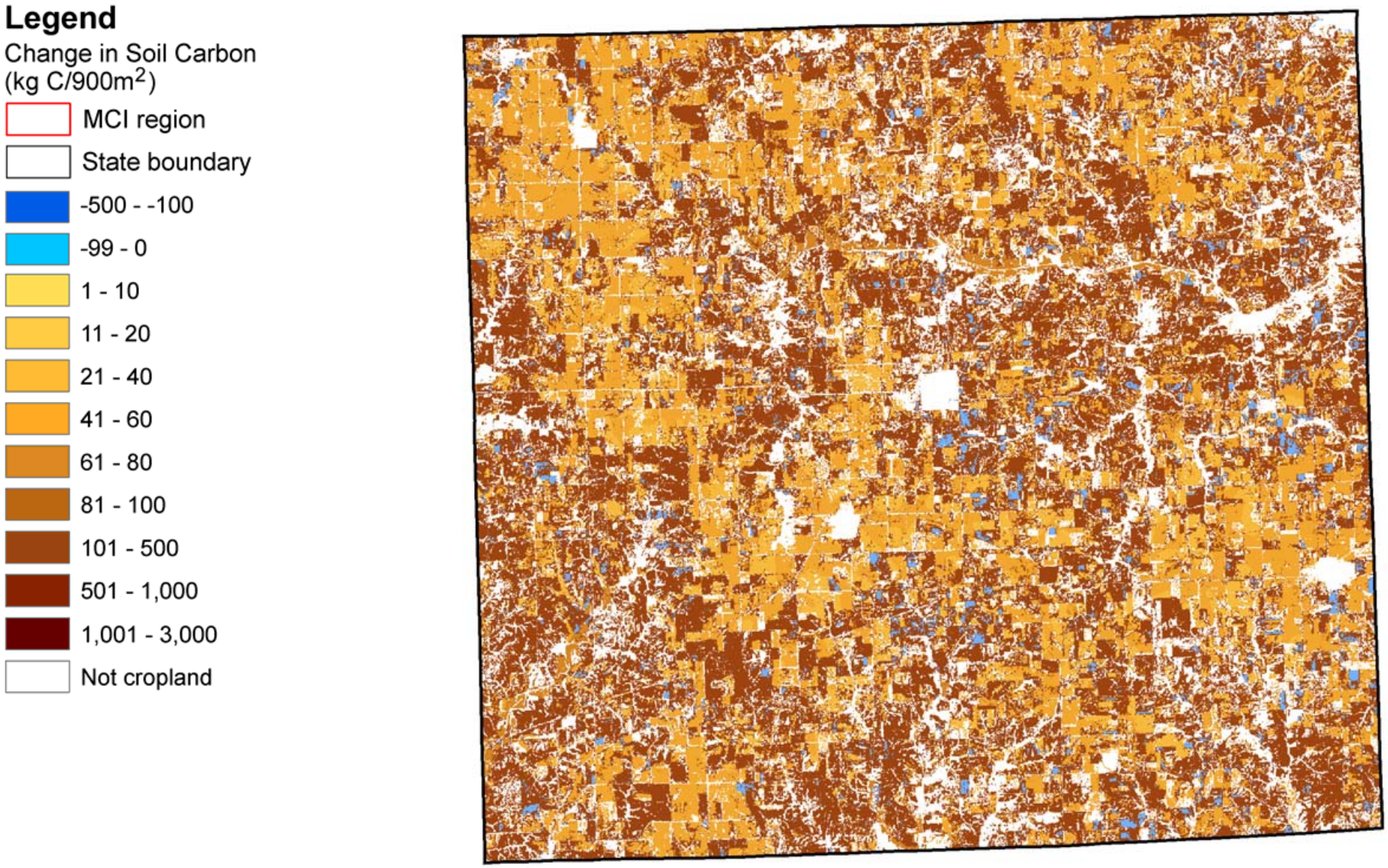
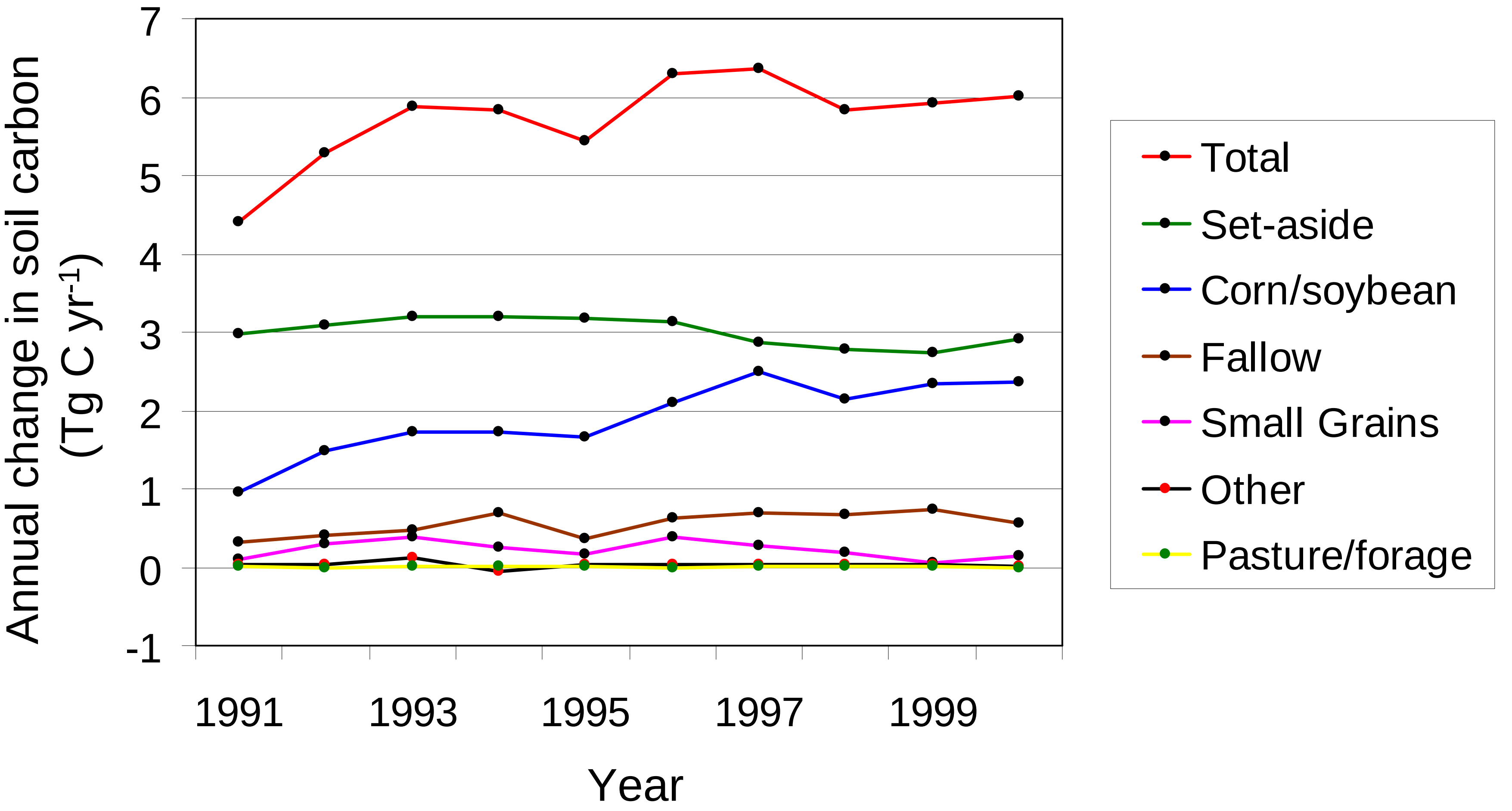


Magnified area is Wayne County, Iowa, representing a diverse set of cropping practices, tillage intensities, and soil types, and illustrating a range of soil carbon gain and loss at a 900m^2 resolution within a 10-year period.

Annual change in soil carbon from 1991-2000 in MCI region by crop



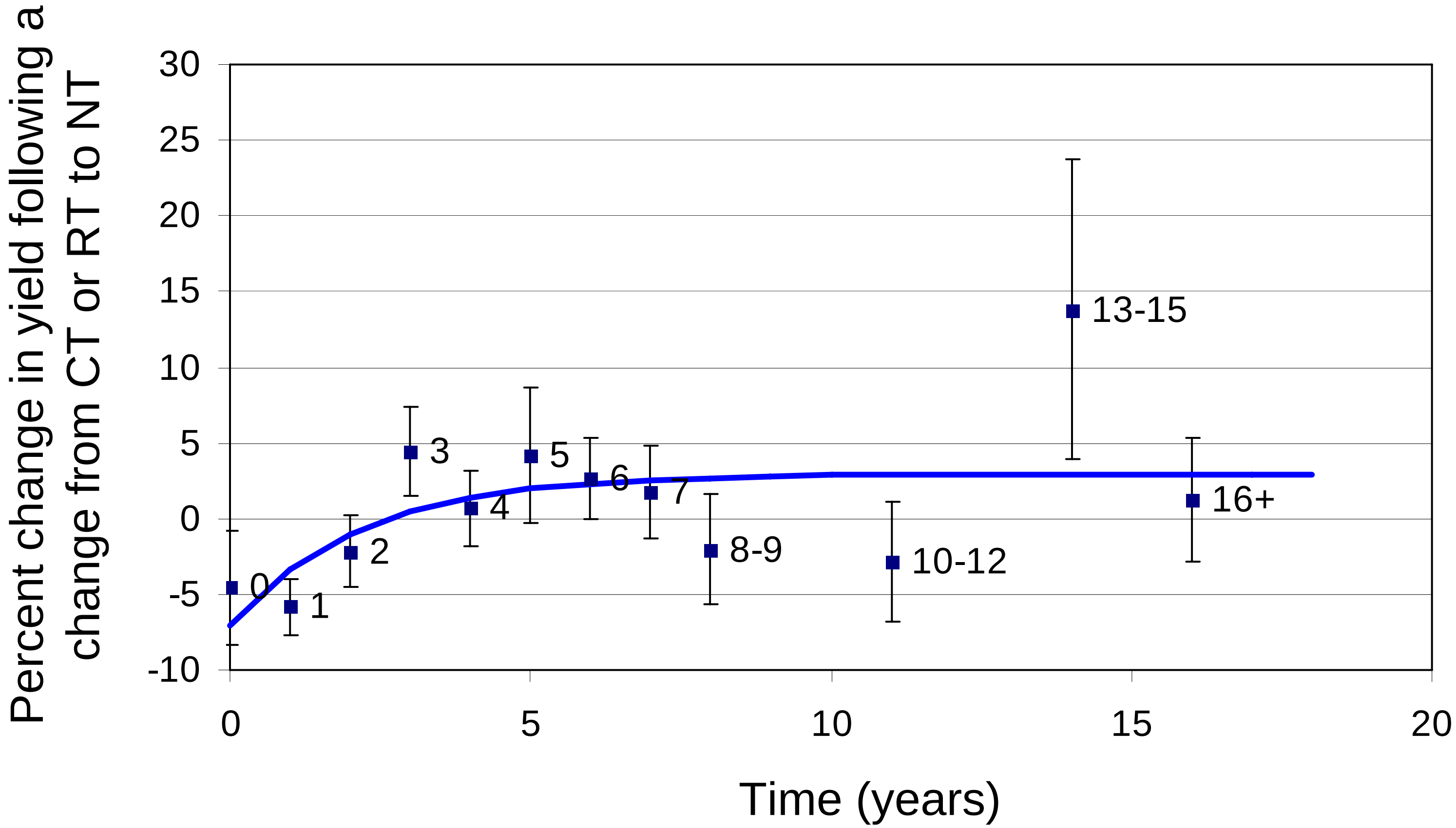
Teragram (Tg) = 1,000,000 Megagram (Mg) = 1 million metric tonne (MMT) = .001 Gigatone (GT)

Notes of interest on soil carbon component of overall C accounting framework

- Considers gain AND loss of soil carbon caused by movement back and forth between crop & tillage practices.
- Framework maintains integrity of NASS data throughout analysis at the sub-county level.
- Accumulation and loss rates based on percent of initial soil carbon and not on the carbon saturation potential of soils.
- Additional remote sensing products should be used and compared in our framework (e.g., MODIS, USDA - Cropland Data Layer, etc.).

Integration of carbon management with traditional management: carbon, yields, profit, and risks

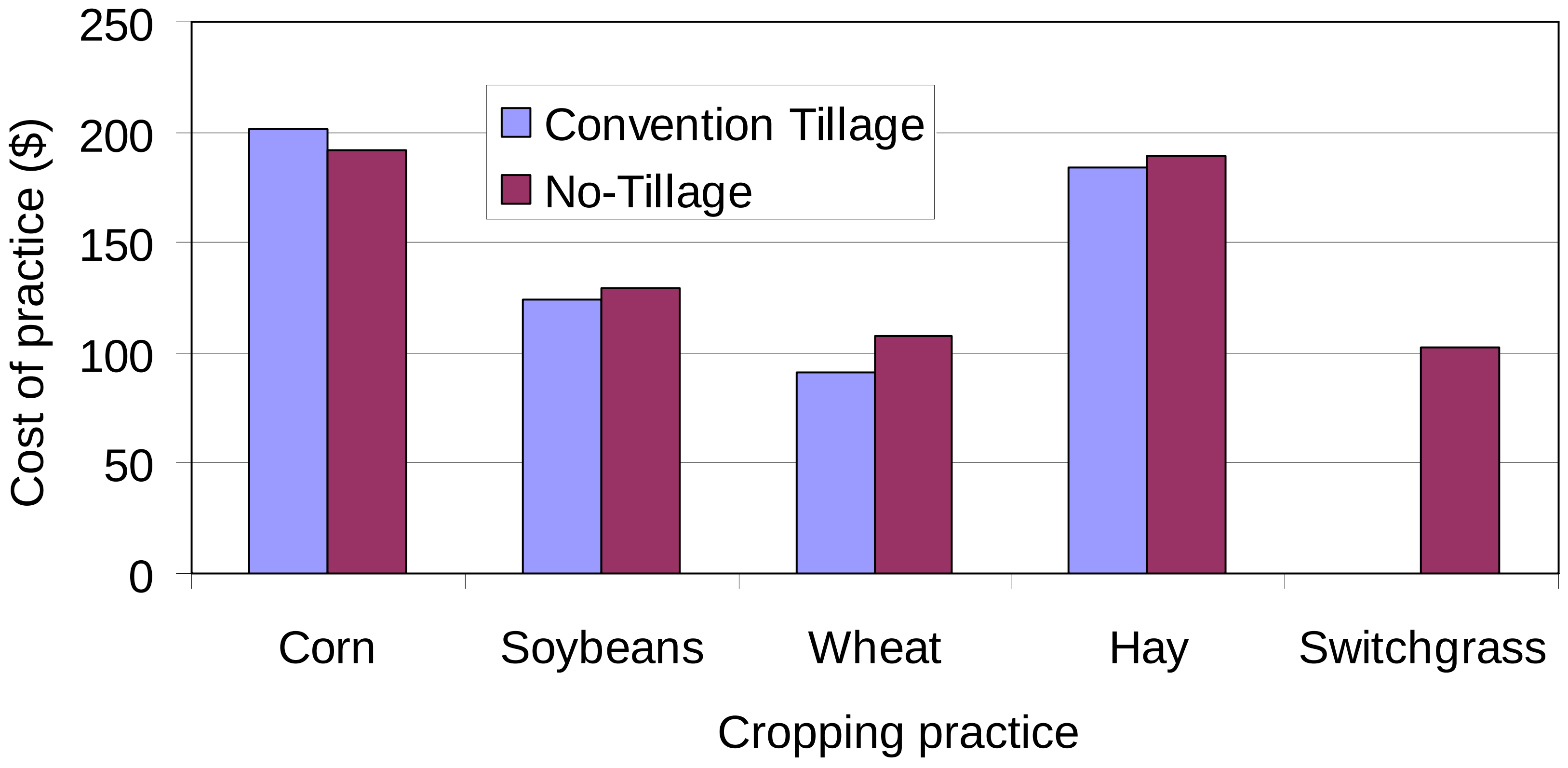
- Yield differences estimated from 4702 paired field experiments



These data help estimate yields following adoption of conservation tillage and help estimate risks associated with adoption.

Integration of carbon management with traditional management: carbon, yields, profit, and risks

- Cost differences between crop and tillage practices



Integration of carbon management with traditional management: carbon, yields, profit, and risks

- Energy and CO_2 emissions (on- and off-site) from agricultural management

Consists of:

- Direct Energy & CO_2
- Embodied Energy & CO_2, and
- Direct CO_2 and N_2O from agricultural lime and fertilizers

Currently includes:

- 777 combinations of crop & tillage management
- 403 active ingredients for pesticides
- 24 Operations with farm machinery
- 41 Fertilizer products

Completed in collaboration with Richard Nelson (Kansas State Univ.)

Carbon dioxide emissions from fertilizers and ag. lime

Table 3
Fossil fuel energy requirements and carbon dioxide emissions from production of fertilizer and agricultural lime

	N		P_2O_5		K_2O		$CaCO_3$	
	($GJ\ Mg^{-1}$)	($kg\ C\ Mg^{-1}$)	($GJ\ Mg^{-1}$)	($kg\ C\ Mg^{-1}$)	($GJ\ Mg^{-1}$)	($kg\ C\ Mg^{-1}$)	($GJ\ Mg^{-1}$)	($kg\ C\ Mg^{-1}$)
Production:[a]								
Natural gas	51.81	753.32	0.63	9.16	2.69	39.11	0.006	0.09
Electricity[b]	2.76	47.31	5.37	92.06	2.11	36.17	0.375	6.43
Distillate fuel	0.01	0.22	0.40	8.78	0.00	0.00	0.033	0.72
Steam[c]	0.91	13.23	-1.87	0.00	-	-	-	-
Coal	-	-	-	-	-	-	0.003	0.08
Gasoline	-	-	-	-	-	-	0.004	0.09
Production total	55.48	814.08	4.52	110.00	4.80	75.28	0.421	7.41
Post-production:[d]								
Distillate fuel	1.98	43.46	2.51	55.09	2.05	45.00	1.29	28.32
Fertilizer total[e]	**57.46**	**857.54**	**7.03**	**165.09**	**6.85**	**120.28**	**1.71**	**35.73**

[a] Production of N, P, and K include the extraction of nutrients and manufacture of fertilizer in 1987 (Bhat et al., 1994). Production of agricultural lime includes energy used in mining (United States Department of Commerce, 1992) and grinding (Mudahar and Hignett, 1987) limestone.

[b] Energy input from electricity is given as the primary energy input required for power generation and is based on 10.5 MJ $kwh(e)^{-1}$ (0.0105 GJ $kwh(e)^{-1}$).

[c] Demands for steam are assumed to be met by combustion of natural gas unless otherwise specified in the primary literature. In the production of phosphate fertilizers, some facilities produce a net excess of steam that is typically exported to other industries. This analysis does not include a CO_2 emissions credit for this excess steam (see text).

[d] Post-production consists of transportation of the mineral to the production facility, supply center, and the site of application. Energy used in transportation is 0.7 and 1.4 MJ Mg^{-1} km^{-1} by railroad and truck, respectively (Börjesson, 1996). Distance of transportation is assumed to be 800 and 160 km by railroad and truck, respectively (Mudahar and Hignet, 1982). Energy used in fertilizer application is included in later calculations (see Table 7).

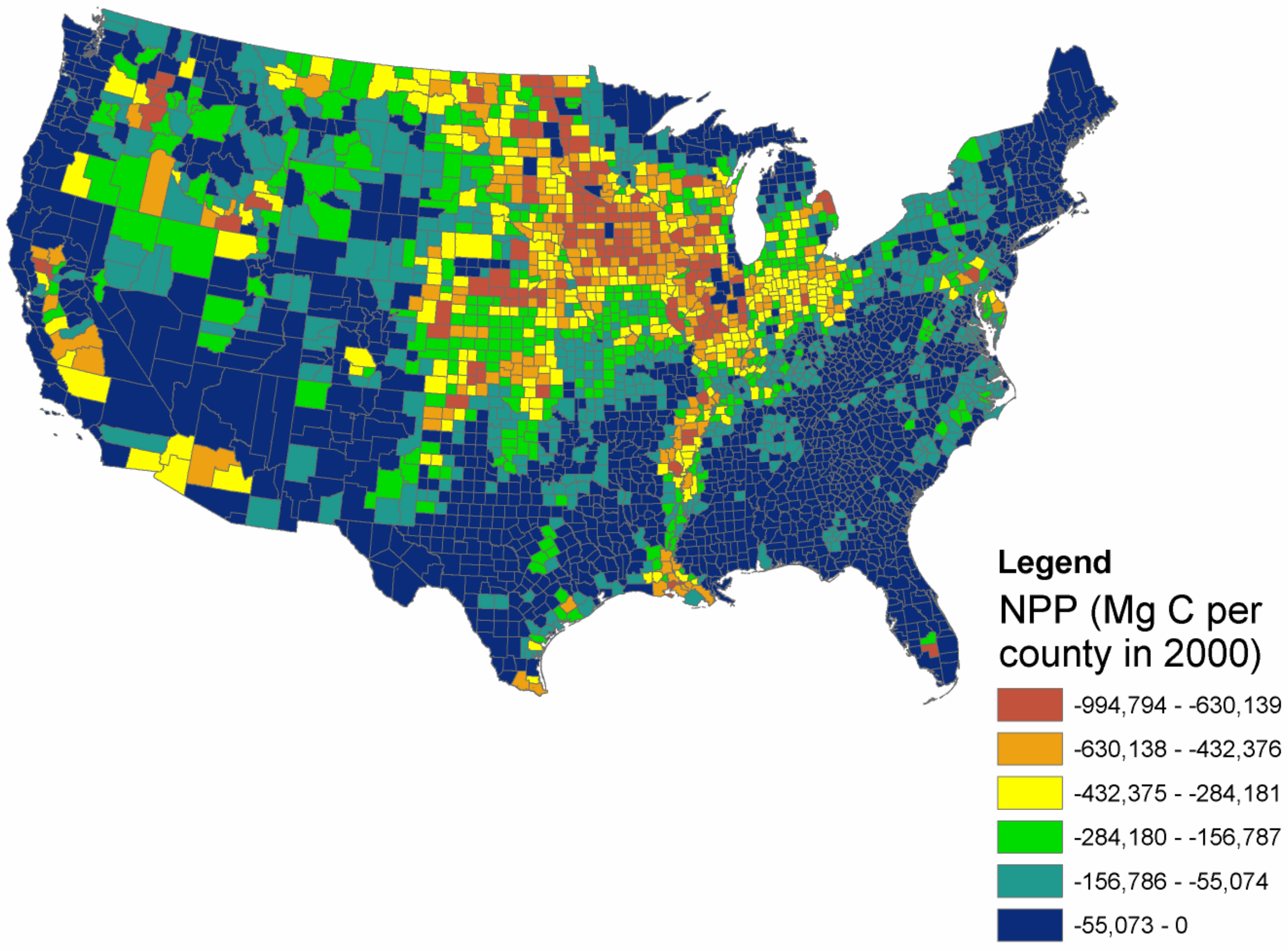
[e] Total values may not equal sums due to independent rounding.

(West and Marland 2002, Agriculture, Ecosystems and Environment 91: 217-232)

Carbon management necessitates balancing the carbon budget for the production (and use) of natural resources.

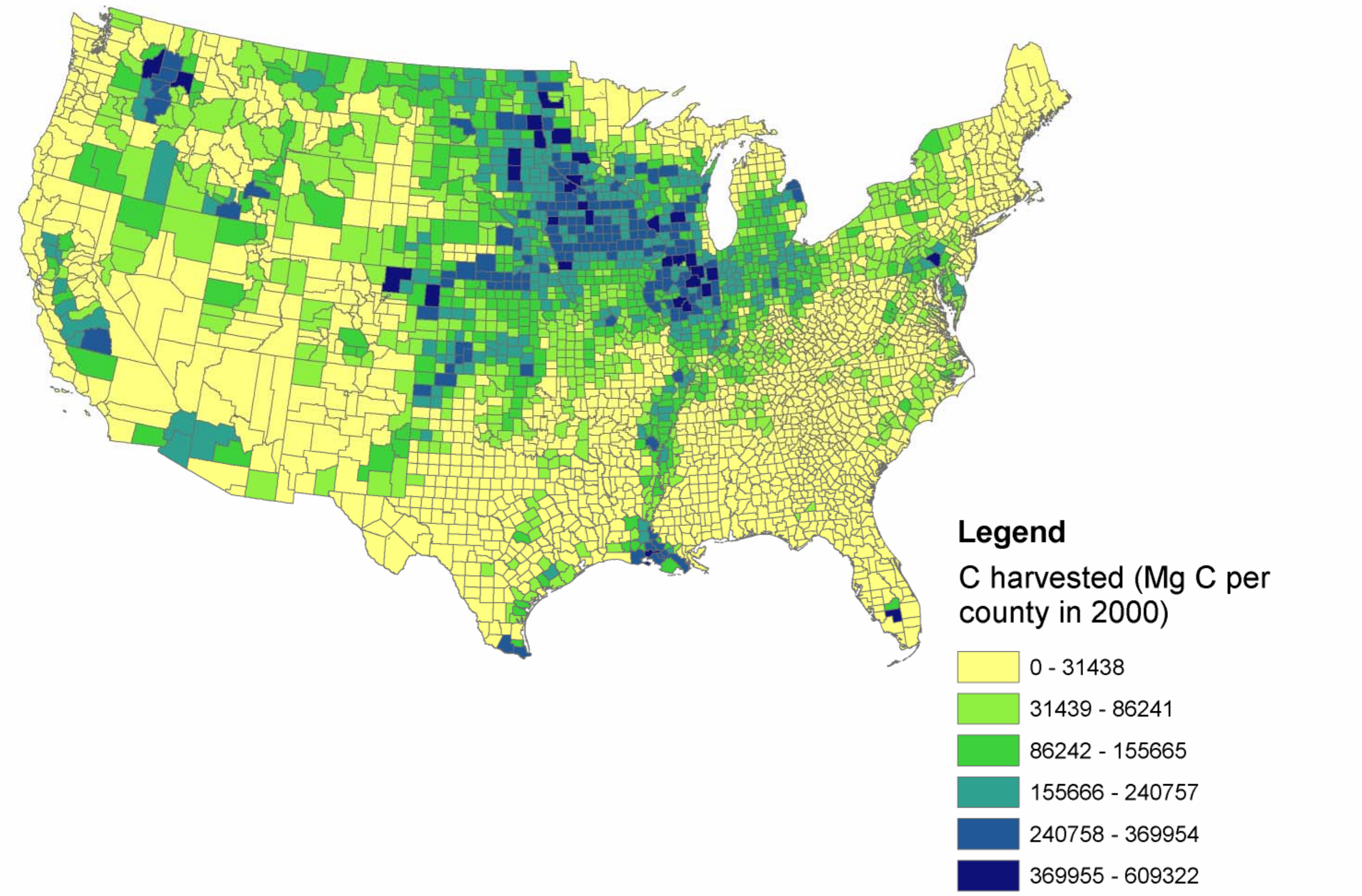
C uptake by agricultural crops in 2000

- -470,594,292 Mg C



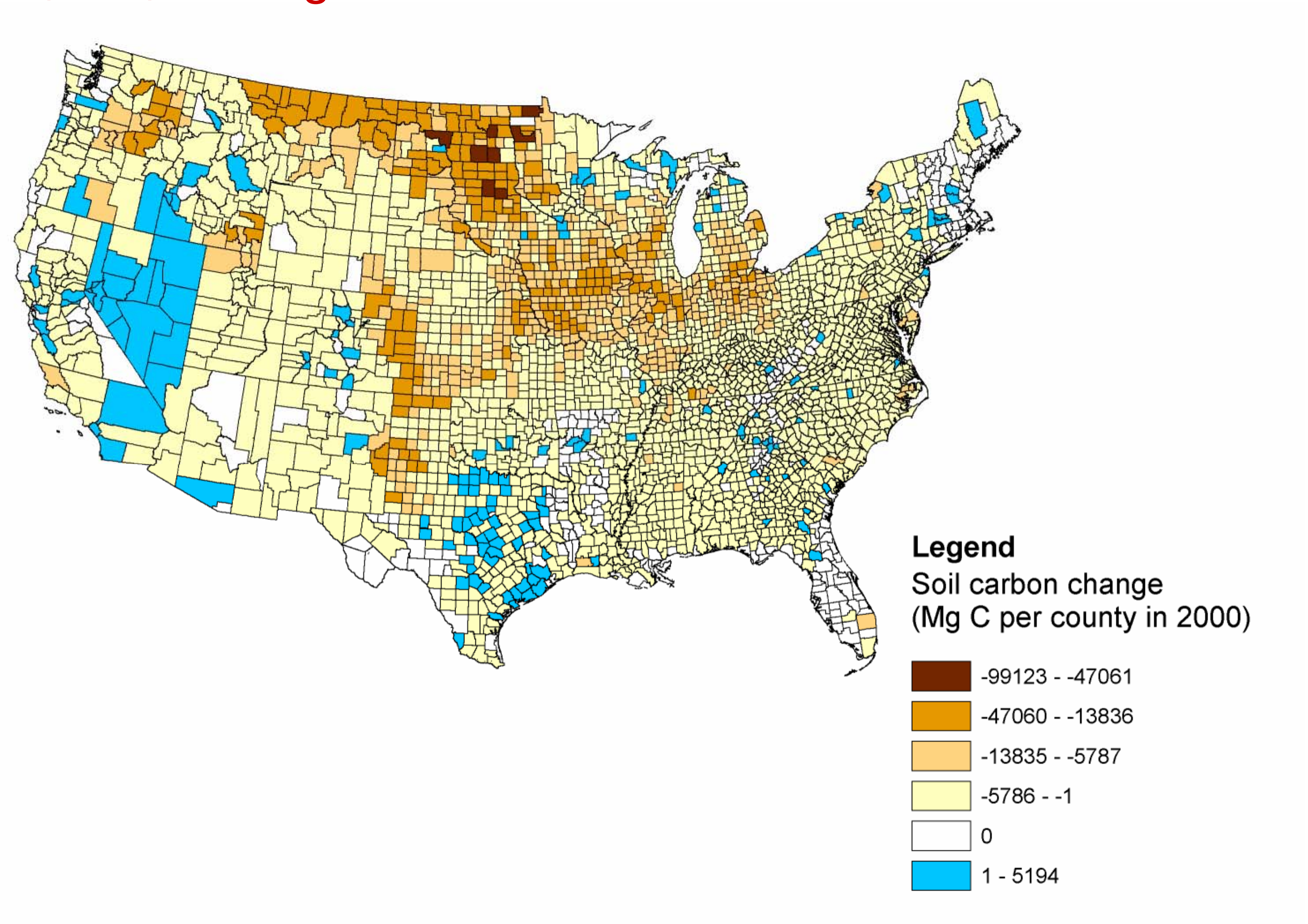
C removed from land (harvested) in 2000

- 206,500,893 Mg C



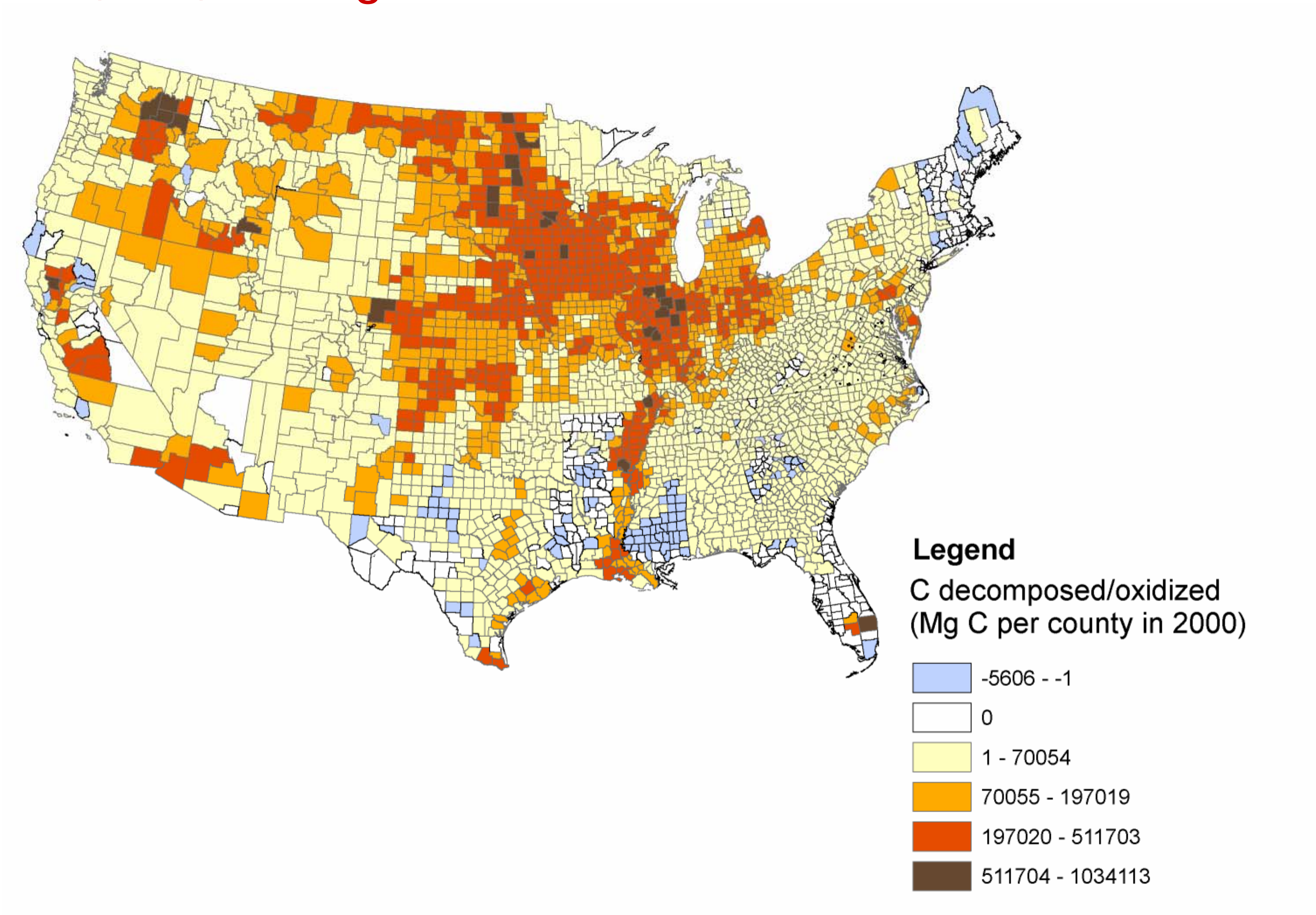
Soil carbon accumulation or loss in 2000

- -11,418,344 Mg C



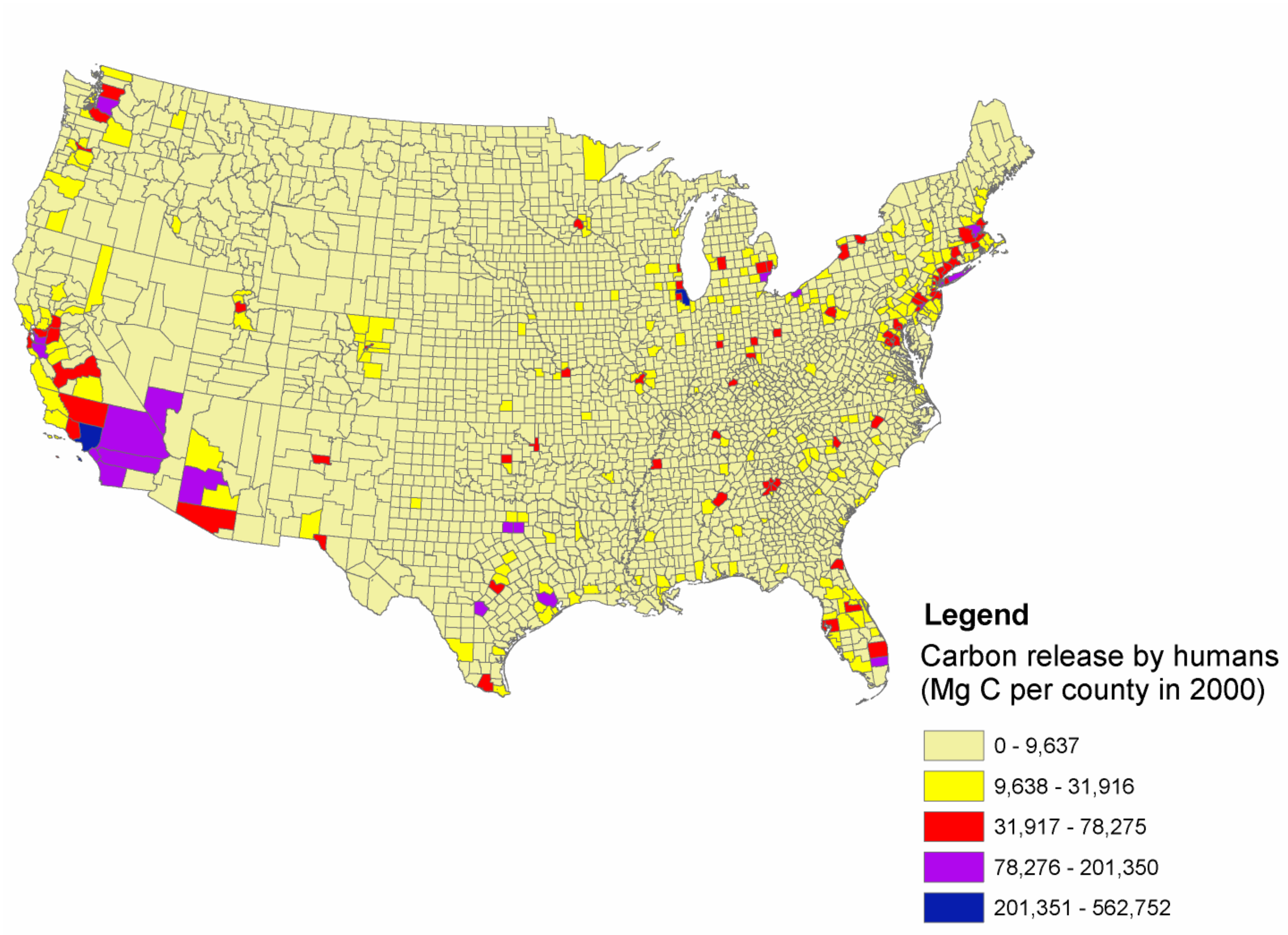
Soil carbon decomposed/oxidized on-site in 2000

- +252,675,055 Mg C



Release of carbon by HUMANS in 2000

- +16,532,596 Mg C

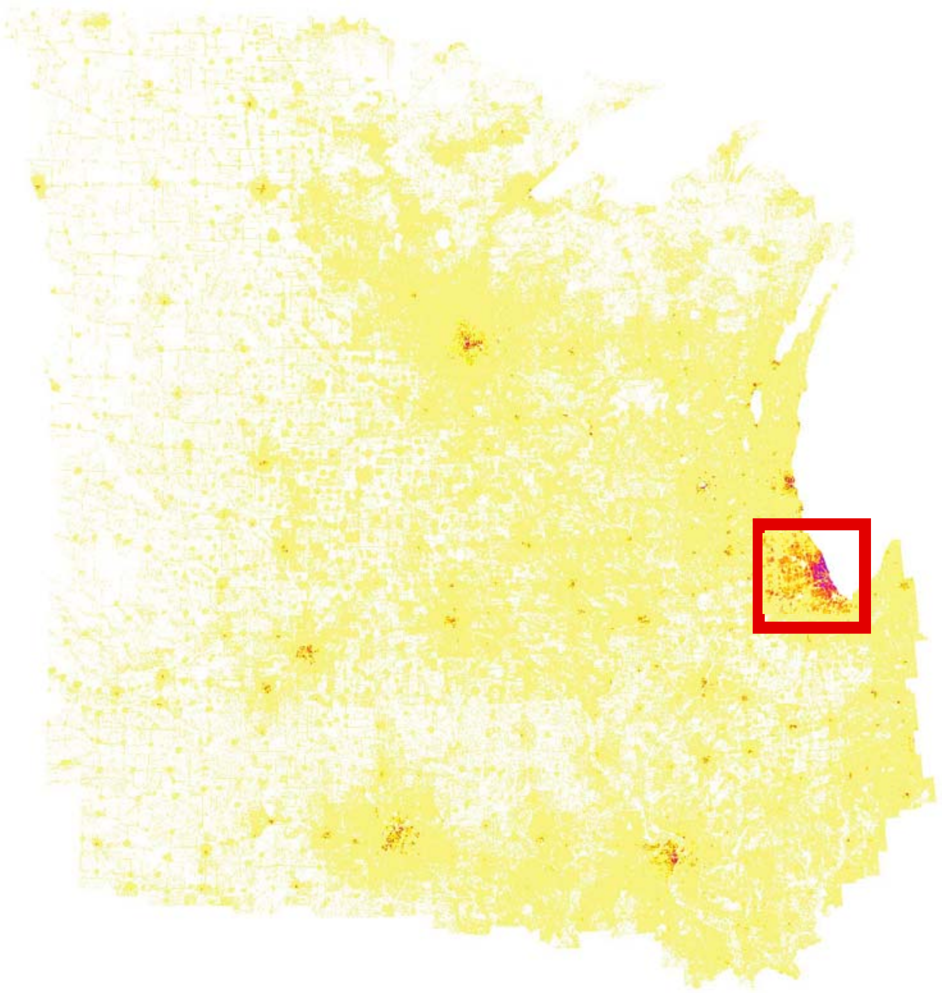


Carbon Emissions from Humans in 2000

Legend

Human C emissions (kg C) in 2000

- 0
- 1 - 6,384
- 6,385 - 13,440
- 13,441 - 22,064
- 22,065 - 32,368
- 32,369 - 45,024
- 45,025 - 61,600
- 61,601 - 83,440
- 83,441 - 113,008
- 113,009 - 154,000
- 154,001 - 211,904
- 211,905 - 288,848
- 288,849 - 398,384
- 398,385 - 561,008
- 561,009 - 1,050,448



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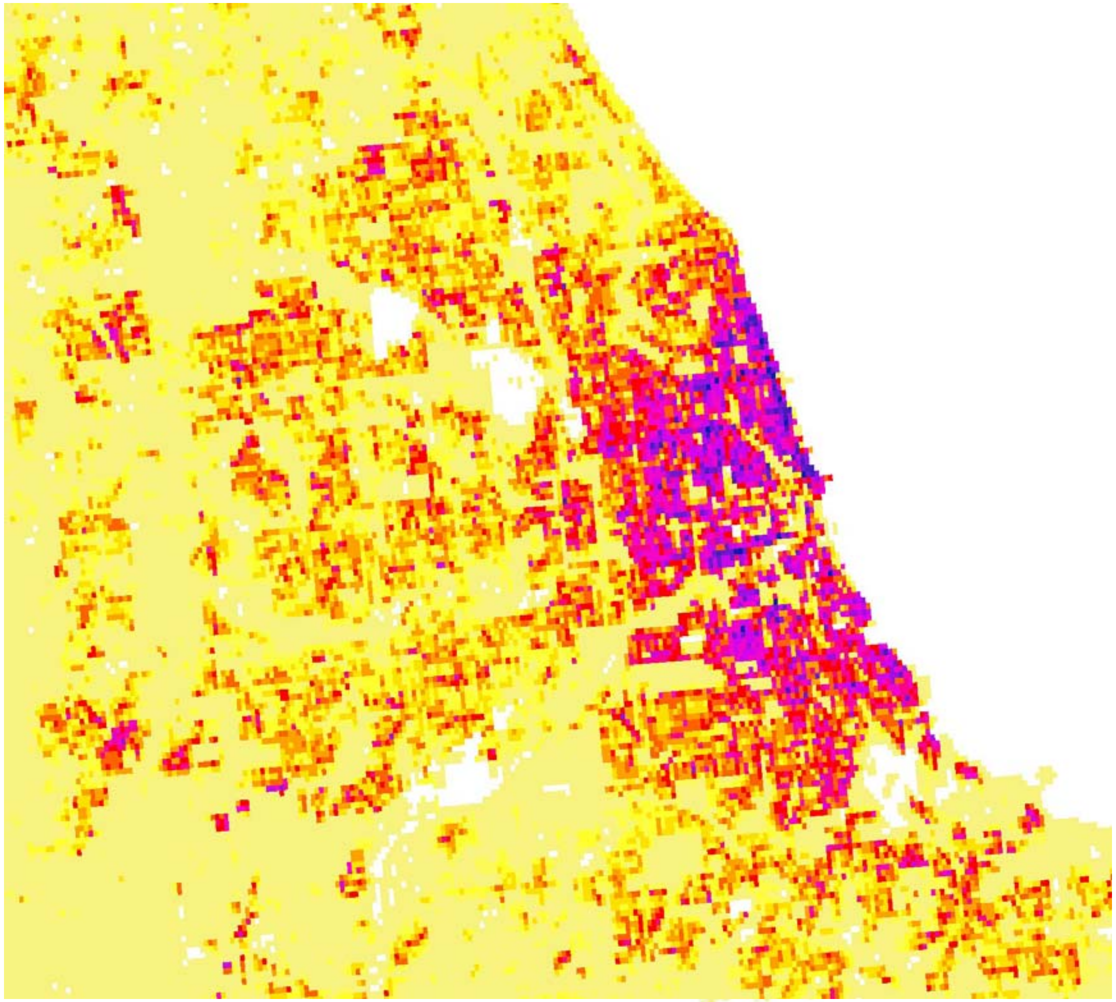
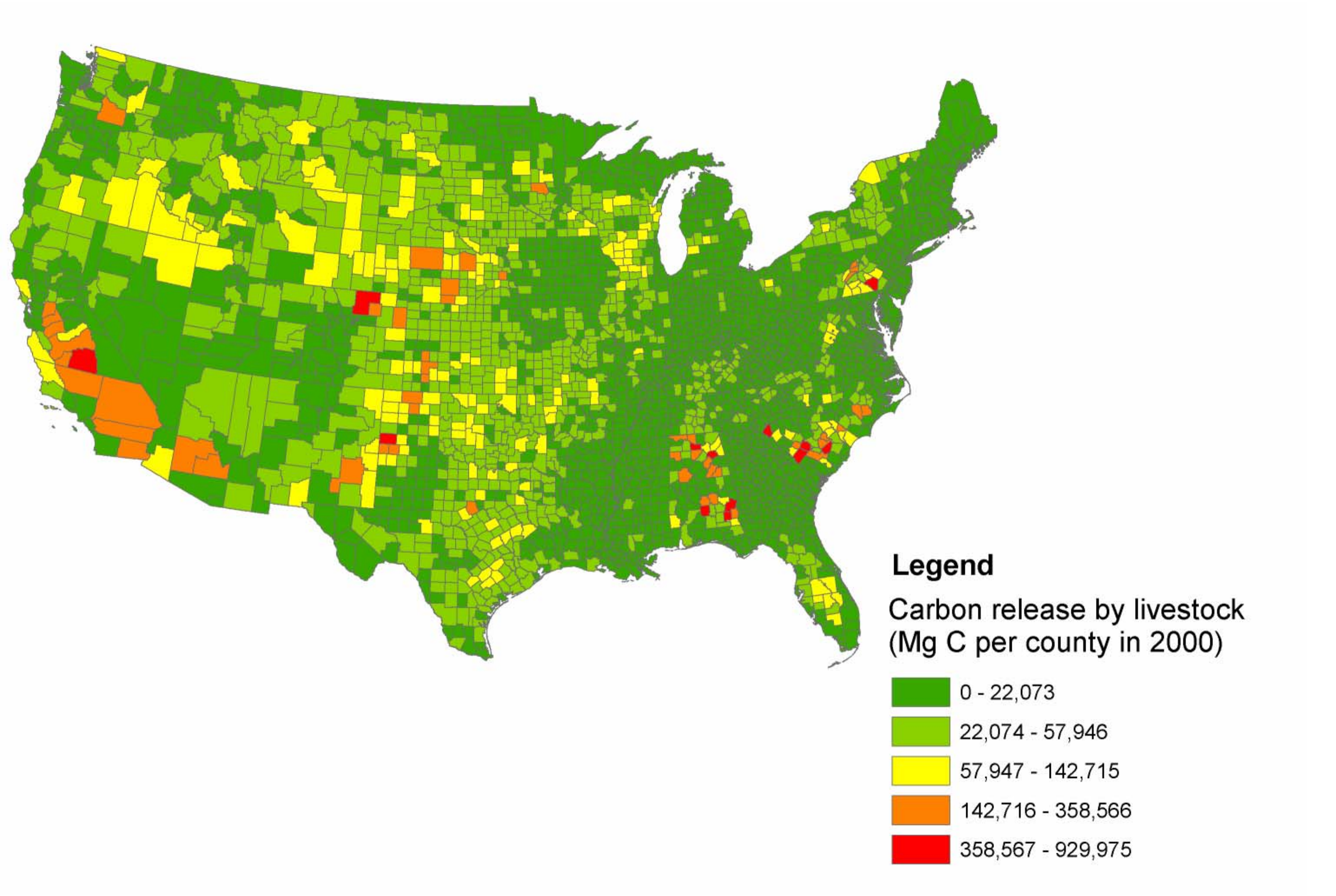
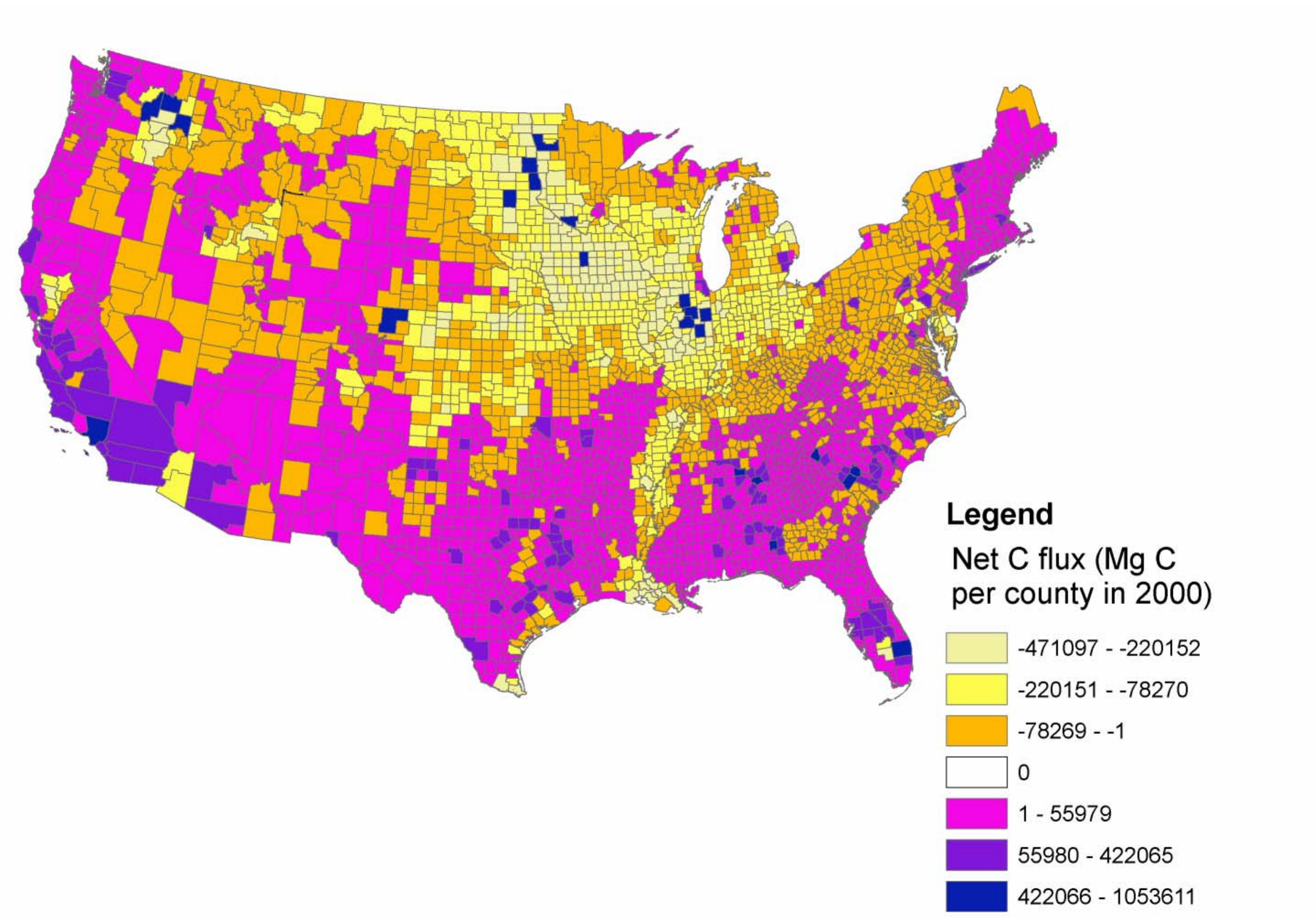


Release of carbon by LIVESTOCK in 2000

- +80,635,900 Mg C

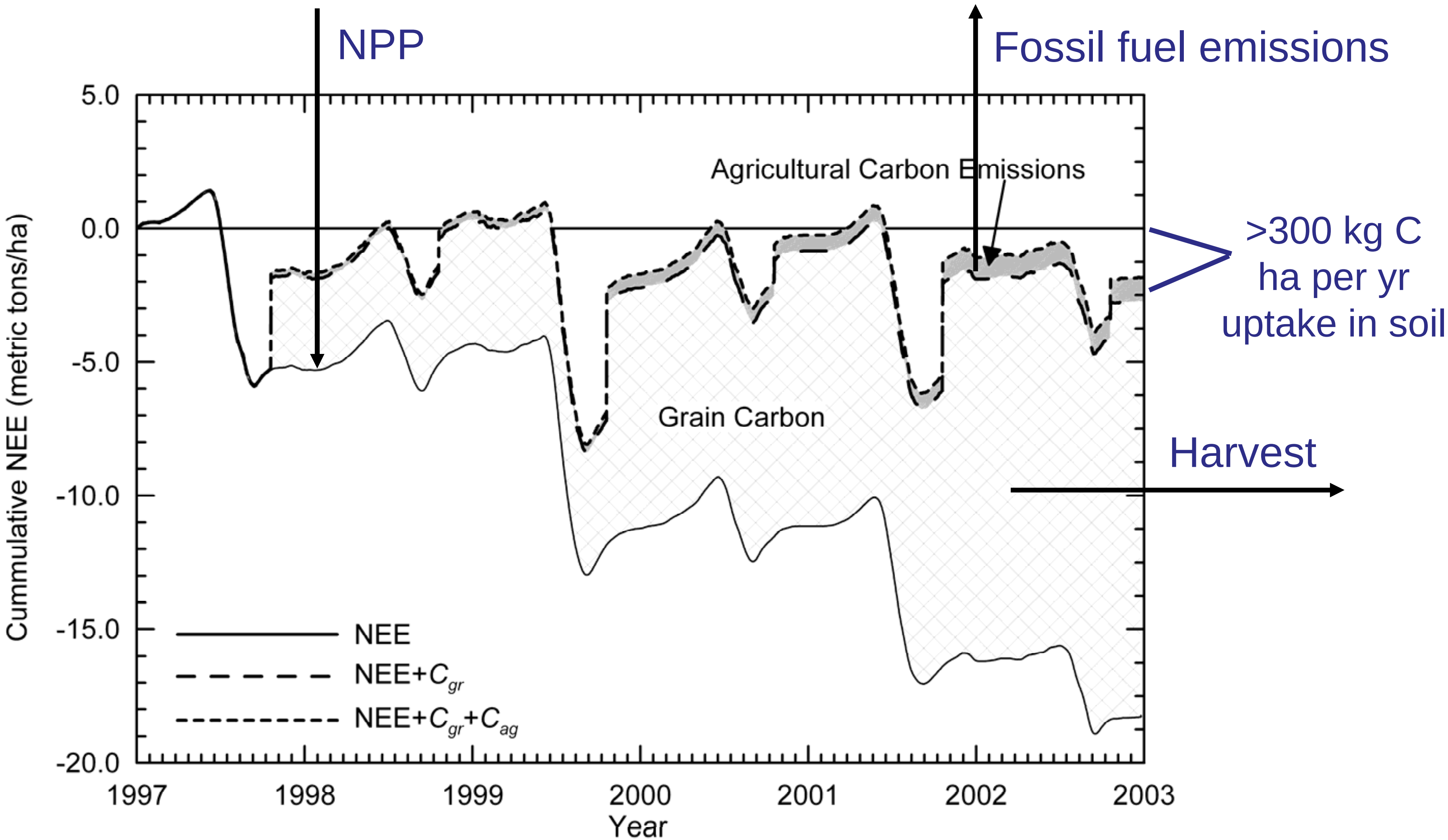


Net C flux from agric. production and use in 2000



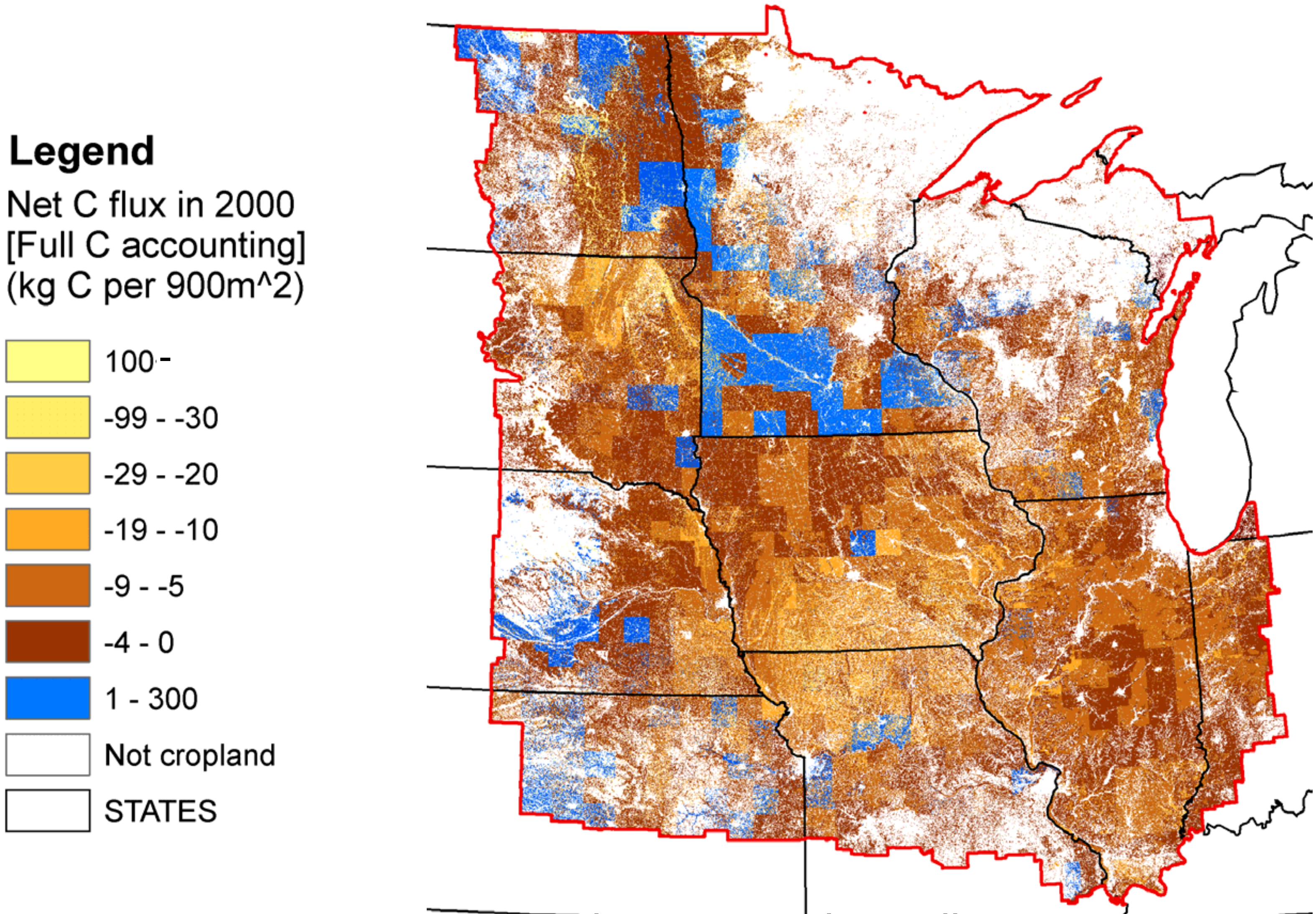
Note: US Ag. C budget not yet balanced

On-site C flux (NEE) and full C accounting (NBP) for a corn/soybean field, using eddy covariance measurements



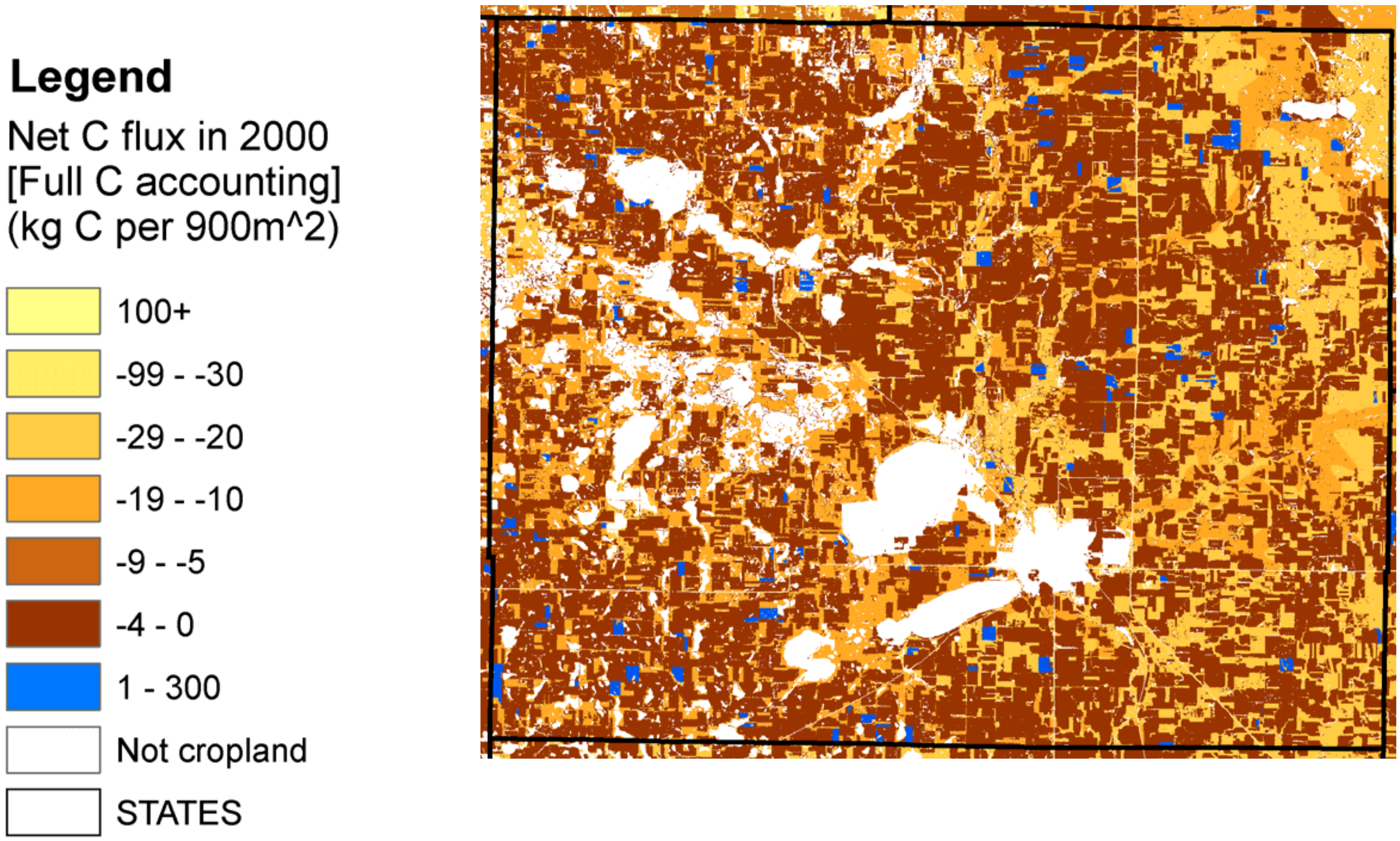
C.J. Bernacchi, S.E. Hollinger, and T. Meyers. 2005. Global Change Biology 11,1-6.

Full C accounting estimated at 30x30m resolution



Enhancement is Codington, SD

Full C accounting estimated at 30x30m resolution



Enhancement is Codington, SD

Suggested needs for carbon management research

- Consider R.S. products to help complete carbon budgets and full carbon accounting for other ecosystems (e.g., forests, wetlands, urban).
- Use remote sensing to increase spatial delineation of fluxes (e.g., better crop delineation)
- Understand sources/sinks of fluxes associated with land management, where they occur, what causes them, and how to manage them.
- Account for the interactions between changes in land-use AND land cover.

Project summary & conclusions

- Progress has been made in all project components (i.e., soils framework, costs, yields, GHG emissions, and risk/economic analyses.

- All components will be integrated with the POLYSYS agricultural economic model this year for final analyses and predictions of future regional carbon dynamics associated with carbon management on agricultural lands.

Project summary & conclusions (cont’d)

Potential collaborative activities include:

- use of different remote sensing products that spatially represent crops and land management (e.g., Cropland Data Layer)
- use of different biogeochemical modeling components
- comparison of final products with other relevant estimates based on socio-economics or top-down and bottom-up carbon modeling.

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